

The L^AT_EX3 Sources

The L^AT_EX3 Project*

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Abstract

This is the reference documentation for the `expl3` programming environment. The `expl3` modules set up an experimental naming scheme for L^AT_EX commands, which allow the L^AT_EX programmer to systematically name functions and variables, and specify the argument types of functions.

The T_EX and ϵ -T_EX primitives are all given a new name according to these conventions. However, in the main direct use of the primitives is not required or encouraged: the `expl3` modules define an independent low-level L^AT_EX3 programming language.

At present, the `expl3` modules are designed to be loaded on top of L^AT_EX 2 ϵ . In time, a L^AT_EX3 format will be produced based on this code. This allows the code to be used in L^AT_EX 2 ϵ packages *now* while a stand-alone L^AT_EX3 is developed.

While `expl3` is still experimental, the bundle is now regarded as broadly stable. The syntax conventions and functions provided are now ready for wider use. There may still be changes to some functions, but these will be minor when compared to the scope of `expl3`.

New modules will be added to the distributed version of `expl3` as they reach maturity.

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Part I

Introduction to `expl3` and this document

This document is intended to act as a comprehensive reference manual for the `expl3` language. A general guide to the L^AT_EX3 programming language is found in [expl3.pdf](#).

1 Naming functions and variables

L^AT_EX3 does not use `@` as a “letter” for defining internal macros. Instead, the symbols `_` and `:` are used in internal macro names to provide structure. The name of each *function* is divided into logical units using `_`, while `:` separates the *name* of the function from the *argument specifier* (“arg-spec”). This describes the arguments expected by the function. In most cases, each argument is represented by a single letter. The complete list of arg-spec letters for a function is referred to as the *signature* of the function.

Each function name starts with the *module* to which it belongs. Thus apart from a small number of very basic functions, all `expl3` function names contain at least one underscore to divide the module name from the descriptive name of the function. For example, all functions concerned with comma lists are in module `clist` and begin `\clist_`.

Every function must include an argument specifier. For functions which take no arguments, this will be blank and the function name will end `:`. Most functions take one or more arguments, and use the following argument specifiers:

- N and n** These mean *no manipulation*, of a single token for `N` and of a set of tokens given in braces for `n`. Both pass the argument through exactly as given. Usually, if you use a single token for an `n` argument, all will be well.
- c** This means *csname*, and indicates that the argument will be turned into a *csname* before being used. So `\foo:c {ArgumentOne}` will act in the same way as `\foo:N \ArgumentOne`.
- V and v** These mean *value of variable*. The `V` and `v` specifiers are used to get the content of a variable without needing to worry about the underlying T_EX structure containing the data. A `V` argument will be a single token (similar to `N`), for example `\foo:V \MyVariable`; on the other hand, using `v` a *csname* is constructed first, and then the value is recovered, for example `\foo:v {MyVariable}`.
- o** This means *expansion once*. In general, the `V` and `v` specifiers are favoured over `o` for recovering stored information. However, `o` is useful for correctly processing information with delimited arguments.
- x** The `x` specifier stands for *exhaustive expansion*: every token in the argument is fully expanded until only unexpandable ones remain. The T_EX `\edef` primitive carries out this type of expansion. Functions which feature an `x`-type argument are *not* expandable.
- e** The `e` specifier is in many respects identical to `x`, but with a very different implementation. Functions which feature an `e`-type argument may be expandable. The drawback is that `e` is extremely slow (often more than 200 times slower) in older engines, more precisely in non-LuaT_EX engines older than 2019.

- f** The **f** specifier stands for *full expansion*, and in contrast to **x** stops at the first non-expandable token (reading the argument from left to right) without trying to expand it. If this token is a *space token*, it is gobbled, and thus won't be part of the resulting argument. For example, when setting a token list variable (a macro used for storage), the sequence

```
\tl_set:Nn \l_my_a_tl { A }
\tl_set:Nn \l_my_b_tl { B }
\tl_set:Nf \l_my_a_tl { \l_my_a_tl \l_my_b_tl }
```

will leave `\l_my_a_tl` with the content `A\l_my_b_tl`, as `A` cannot be expanded and so terminates expansion before `\l_my_b_tl` is considered.

- T and F** For logic tests, there are the branch specifiers **T** (*true*) and **F** (*false*). Both specifiers treat the input in the same way as **n** (no change), but make the logic much easier to see.
- p** The letter **p** indicates *TeX parameters*. Normally this will be used for delimited functions as `expl3` provides better methods for creating simple sequential arguments.
- w** Finally, there is the **w** specifier for *weird* arguments. This covers everything else, but mainly applies to delimited values (where the argument must be terminated by some specified string).
- D** The **D** specifier means *do not use*. All of the *TeX* primitives are initially `\let` to a **D** name, and some are then given a second name. Only the kernel team should use anything with a **D** specifier!

Notice that the argument specifier describes how the argument is processed prior to being passed to the underlying function. For example, `\foo:c` will take its argument, convert it to a control sequence and pass it to `\foo:N`.

Variables are named in a similar manner to functions, but begin with a single letter to define the type of variable:

- c** Constant: global parameters whose value should not be changed.
- g** Parameters whose value should only be set globally.
- l** Parameters whose value should only be set locally.

Each variable name is then build up in a similar way to that of a function, typically starting with the module¹ name and then a descriptive part. Variables end with a short identifier to show the variable type:

clist Comma separated list.

dim "Rigid" lengths.

fp Floating-point values;

int Integer-valued count register.

¹The module names are not used in case of generic scratch registers defined in the data type modules, e.g., the **int** module contains some scratch variables called `\l_tmpa_int`, `\l_tmpb_int`, and so on. In such a case adding the module name up front to denote the module and in the back to indicate the type, as in `\l_int_tmpa_int` would be very unreadable.

muskip “Rubber” lengths for use in mathematics.

seq “Sequence”: a data-type used to implement lists (with access at both ends) and stacks.

skip “Rubber” lengths.

str String variables: contain character data.

tl Token list variables: placeholder for a token list.

Applying V-type or v-type expansion to variables of one of the above types is supported, while it is not supported for the following variable types:

bool Either true or false.

box Box register.

coffin A “box with handles” — a higher-level data type for carrying out **box** alignment operations.

flag Integer that can be incremented expandably.

farray Fixed-size array of floating point values.

intarray Fixed-size array of integers.

ior/iow An input or output stream, for reading from or writing to, respectively.

prop Property list: analogue of dictionary or associative arrays in other languages.

regex Regular expression.

1.1 Terminological inexactitude

A word of warning. In this document, and others referring to the `expl3` programming modules, we often refer to “variables” and “functions” as if they were actual constructs from a real programming language. In truth, `TeX` is a macro processor, and functions are simply macros that may or may not take arguments and expand to their replacement text. Many of the common variables are *also* macros, and if placed into the input stream will simply expand to their definition as well — a “function” with no arguments and a “token list variable” are almost the same.² On the other hand, some “variables” are actually registers that must be initialised and their values set and retrieved with specific functions.

The conventions of the `expl3` code are designed to clearly separate the ideas of “macros that contain data” and “macros that contain code”, and a consistent wrapper is applied to all forms of “data” whether they be macros or actually registers. This means that sometimes we will use phrases like “the function returns a value”, when actually we just mean “the macro expands to something”. Similarly, the term “execute” might be used in place of “expand” or it might refer to the more specific case of “processing in `TeX`’s stomach” (if you are familiar with the `TeXbook` parlance).

If in doubt, please ask; chances are we’ve been hasty in writing certain definitions and need to be told to tighten up our terminology.

²`TeX`nically, functions with no arguments are `\long` while token list variables are not.

2 Documentation conventions

This document is typeset with the experimental `l3doc` class; several conventions are used to help describe the features of the code. A number of conventions are used here to make the documentation clearer.

Each group of related functions is given in a box. For a function with a “user” name, this might read:

```
\ExplSyntaxOn
\ExplSyntaxOff
```

```
\ExplSyntaxOn ... \ExplSyntaxOff
```

The textual description of how the function works would appear here. The syntax of the function is shown in mono-spaced text to the right of the box. In this example, the function takes no arguments and so the name of the function is simply reprinted.

For programming functions, which use `_` and `:` in their name there are a few additional conventions: If two related functions are given with identical names but different argument specifiers, these are termed *variants* of each other, and the latter functions are printed in grey to show this more clearly. They will carry out the same function but will take different types of argument:

```
\seq_new:N
\seq_new:c
```

```
\seq_new:N <sequence>
```

When a number of variants are described, the arguments are usually illustrated only for the base function. Here, `<sequence>` indicates that `\seq_new:N` expects the name of a sequence. From the argument specifier, `\seq_new:c` also expects a sequence name, but as a name rather than as a control sequence. Each argument given in the illustration should be described in the following text.

Fully expandable functions Some functions are fully expandable, which allows them to be used within an `x`-type or `e`-type argument (in plain `TeX` terms, inside an `\edef` or `\expanded`), as well as within an `f`-type argument. These fully expandable functions are indicated in the documentation by a star:

```
\cs_to_str:N ☆
```

```
\cs_to_str:N <cs>
```

As with other functions, some text should follow which explains how the function works. Usually, only the star will indicate that the function is expandable. In this case, the function expects a `<cs>`, shorthand for a `<control sequence>`.

Restricted expandable functions A few functions are fully expandable but cannot be fully expanded within an `f`-type argument. In this case a hollow star is used to indicate this:

```
\seq_map_function:NN ☆
```

```
\seq_map_function:NN <seq> <function>
```

Conditional functions Conditional (`if`) functions are normally defined in three variants, with `T`, `F` and `TF` argument specifiers. This allows them to be used for different “true”/“false” branches, depending on which outcome the conditional is being used to test. To indicate this without repetition, this information is given in a shortened form:

<code>\sys_if_engine_xetex:<i><u>TF</u></i> *</code>	<code>\sys_if_engine_xetex:TF {\langle true code \rangle} {\langle false code \rangle}</code>
--	---

The underlining and italic of TF indicates that three functions are available:

- `\sys_if_engine_xetex:T`
- `\sys_if_engine_xetex:F`
- `\sys_if_engine_xetex:TF`

Usually, the illustration will use the TF variant, and so both $\langle true code \rangle$ and $\langle false code \rangle$ will be shown. The two variant forms T and F take only $\langle true code \rangle$ and $\langle false code \rangle$, respectively. Here, the star also shows that this function is expandable. With some minor exceptions, *all* conditional functions in the `expl3` modules should be defined in this way.

Variables, constants and so on are described in a similar manner:

<code>\l_tmpa_tl</code>	
-------------------------	--

A short piece of text will describe the variable: there is no syntax illustration in this case.

In some cases, the function is similar to one in $\text{\LaTeX} 2_{\epsilon}$ or plain \TeX . In these cases, the text will include an extra “ **\TeX hackers note**” section:

<code>\token_to_str:N *</code>	<code>\token_to_str:N \langle token \rangle</code>
--------------------------------	--

The normal description text.

\TeX hackers note: Detail for the experienced \TeX or $\text{\LaTeX} 2_{\epsilon}$ programmer. In this case, it would point out that this function is the \TeX primitive `\string`.

Changes to behaviour When new functions are added to `expl3`, the date of first inclusion is given in the documentation. Where the documented behaviour of a function changes after it is first introduced, the date of the update will also be given. This means that the programmer can be sure that any release of `expl3` after the date given will contain the function of interest with expected behaviour as described. Note that changes to code internals, including bug fixes, are not recorded in this way *unless* they impact on the expected behaviour.

3 Formal language conventions which apply generally

As this is a formal reference guide for $\text{\LaTeX} 3$ programming, the descriptions of functions are intended to be reasonably “complete”. However, there is also a need to avoid repetition. Formal ideas which apply to general classes of function are therefore summarised here.

For tests which have a TF argument specification, the test is evaluated to give a logically TRUE or FALSE result. Depending on this result, either the $\langle true code \rangle$ or the $\langle false code \rangle$ will be left in the input stream. In the case where the test is expandable, and a predicate (`_p`) variant is available, the logical value determined by the test is left in the input stream: this will typically be part of a larger logical construct.

4 \TeX concepts not supported by $\text{\LaTeX}3$

The \TeX concept of an “`\outer`” macro is *not supported* at all by $\text{\LaTeX}3$. As such, the functions provided here may break when used on top of $\text{\LaTeX}2_{\epsilon}$ if `\outer` tokens are used in the arguments.

Part II

The l3bootstrap package

Bootstrap code

1 Using the L^AT_EX3 modules

The modules documented in `source3` are designed to be used on top of L^AT_EX 2_ε and are loaded all as one with the usual `\usepackage{expl3}` or `\RequirePackage{expl3}` instructions. These modules will also form the basis of the L^AT_EX3 format, but work in this area is incomplete and not included in this documentation at present.

As the modules use a coding syntax different from standard L^AT_EX 2_ε it provides a few functions for setting it up.

`\ExplSyntaxOn`
`\ExplSyntaxOff`
 Updated: 2011-08-13

`\ExplSyntaxOn` *<code>* `\ExplSyntaxOff`

The `\ExplSyntaxOn` function switches to a category code régime in which spaces are ignored and in which the colon (:) and underscore (_) are treated as “letters”, thus allowing access to the names of code functions and variables. Within this environment, ~ is used to input a space. The `\ExplSyntaxOff` reverts to the document category code régime.

`\ProvidesExplPackage`
`\ProvidesExplClass`
`\ProvidesExplFile`
 Updated: 2017-03-19

`\RequirePackage{expl3}`
`\ProvidesExplPackage` *<package>* *<date>* *<version>* *<description>*

These functions act broadly in the same way as the corresponding L^AT_EX 2_ε kernel functions `\ProvidesPackage`, `\ProvidesClass` and `\ProvidesFile`. However, they also implicitly switch `\ExplSyntaxOn` for the remainder of the code with the file. At the end of the file, `\ExplSyntaxOff` will be called to reverse this. (This is the same concept as L^AT_EX 2_ε provides in turning on `\makeatletter` within package and class code.) The *<date>* should be given in the format *<year>/<month>/<day>*. If the *<version>* is given then it will be prefixed with v in the package identifier line.

`\GetIdInfo`
 Updated: 2012-06-04

`\RequirePackage{l3bootstrap}`
`\GetIdInfo` \$Id: *<SVN info field>* \$ *<description>*

Extracts all information from a SVN field. Spaces are not ignored in these fields. The information pieces are stored in separate control sequences with `\ExplFileName` for the part of the file name leading up to the period, `\ExplFileDate` for date, `\ExplFileVersion` for version and `\ExplFileDescription` for the description.

To summarize: Every single package using this syntax should identify itself using one of the above methods. Special care is taken so that every package or class file loaded with `\RequirePackage` or similar are loaded with usual L^AT_EX 2_ε category codes and the L^AT_EX3 category code scheme is reloaded when needed afterwards. See implementation for details. If you use the `\GetIdInfo` command you can use the information when loading a package with

```
\ProvidesExplPackage{\ExplFileName}
  {\ExplFileDate}{\ExplFileVersion}{\ExplFileDescription}
```

Part III

The l3names package

Namespace for primitives

1 Setting up the L^AT_EX3 programming language

This module is at the core of the L^AT_EX3 programming language. It performs the following tasks:

- defines new names for all T_EX primitives;
- switches to the category code régime for programming;
- provides support settings for building the code as a T_EX format.

This module is entirely dedicated to primitives, which should not be used directly within L^AT_EX3 code (outside of “kernel-level” code). As such, the primitives are not documented here: *The T_EXbook*, *T_EX by Topic* and the manuals for pdfT_EX, X_YT_EX, LuaT_EX, pT_EX and upT_EX should be consulted for details of the primitives. These are named `\tex_⟨name⟩:D`, typically based on the primitive’s *⟨name⟩* in pdfT_EX and omitting a leading `pdf` when the primitive is not related to pdf output.

Part IV

The l3basics package

Basic definitions

As the name suggest this package holds some basic definitions which are needed by most or all other packages in this set.

Here we describe those functions that are used all over the place. With that we mean functions dealing with the construction and testing of control sequences. Furthermore the basic parts of conditional processing are covered; conditional processing dealing with specific data types is described in the modules specific for the respective data types.

1 No operation functions

`\prg_do_nothing: *`

`\prg_do_nothing:`

An expandable function which does nothing at all: leaves nothing in the input stream after a single expansion.

`\scan_stop:`

`\scan_stop:`

A non-expandable function which does nothing. Does not vanish on expansion but produces no typeset output.

2 Grouping material

`\group_begin:`

`\group_begin:`**`\group_end:`**

`\group_end:`

These functions begin and end a group for definition purposes. Assignments are local to groups unless carried out in a global manner. (A small number of exceptions to this rule will be noted as necessary elsewhere in this document.) Each `\group_begin:` must be matched by a `\group_end:`, although this does not have to occur within the same function. Indeed, it is often necessary to start a group within one function and finish it within another, for example when seeking to use non-standard category codes.

`\group_insert_after:N`

`\group_insert_after:N` $\langle token \rangle$

Adds $\langle token \rangle$ to the list of $\langle tokens \rangle$ to be inserted when the current group level ends. The list of $\langle tokens \rangle$ to be inserted is empty at the beginning of a group: multiple applications of `\group_insert_after:N` may be used to build the inserted list one $\langle token \rangle$ at a time. The current group level may be closed by a `\group_end:` function or by a token with category code 2 (close-group), namely a `}` if standard category codes apply.

3 Control sequences and functions

As \TeX is a macro language, creating new functions means creating macros. At point of use, a function is replaced by the replacement text (“code”) in which each parameter in the code ($\#1$, $\#2$, *etc.*) is replaced the appropriate arguments absorbed by the function. In the following, *code* is therefore used as a shorthand for “replacement text”.

Functions which are not “protected” are fully expanded inside an \mathbf{x} expansion. In contrast, “protected” functions are not expanded within \mathbf{x} expansions.

3.1 Defining functions

Functions can be created with no requirement that they are declared first (in contrast to variables, which must always be declared). Declaring a function before setting up the code means that the name chosen is checked and an error raised if it is already in use. The name of a function can be checked at the point of definition using the `\cs_new...` functions: this is recommended for all functions which are defined for the first time.

There are three ways to define new functions. All classes define a function to expand to the substitution text. Within the substitution text the actual parameters are substituted for the formal parameters ($\#1$, $\#2$, ...).

new Create a new function with the **new** scope, such as `\cs_new:Npn`. The definition is global and results in an error if it is already defined.

set Create a new function with the **set** scope, such as `\cs_set:Npn`. The definition is restricted to the current \TeX group and does not result in an error if the function is already defined.

gset Create a new function with the **gset** scope, such as `\cs_gset:Npn`. The definition is global and does not result in an error if the function is already defined.

Within each set of scope there are different ways to define a function. The differences depend on restrictions on the actual parameters and the expandability of the resulting function.

nopar Create a new function with the **nopar** restriction, such as `\cs_set_nopar:Npn`. The parameter may not contain `\par` tokens.

protected Create a new function with the **protected** restriction, such as `\cs_set_protected:Npn`. The parameter may contain `\par` tokens but the function will not expand within an \mathbf{x} -type or \mathbf{e} -type expansion.

Finally, the functions in Subsections 3.2 and 3.3 are primarily meant to define *base functions* only. Base functions can only have the following argument specifiers:

N and n No manipulation.

T and F Functionally equivalent to **n** (you are actually encouraged to use the family of `\prg_new_conditional:` functions described in Section 1).

p and w These are special cases.

The `\cs_new:` functions below (and friends) do not stop you from using other argument specifiers in your function names, but they do not handle expansion for you. You should define the base function and then use `\cs_generate_variant:Nn` to generate custom variants as described in Section 2.

3.2 Defining new functions using parameter text

<code>\cs_new:Npn</code>	<code>\cs_new:Npn <function> <parameters> {<code>}</code>
<code>\cs_new:cpn</code>	Creates <code><function></code> to expand to <code><code></code> as replacement text. Within the <code><code></code> , the
<code>\cs_new:Npx</code>	<code><parameters></code> (<code>#1</code> , <code>#2</code> , <i>etc.</i>) will be replaced by those absorbed by the function. The
<code>\cs_new:cpx</code>	definition is global and an error results if the <code><function></code> is already defined.

<code>\cs_new_nopar:Npn</code>	<code>\cs_new_nopar:Npn <function> <parameters> {<code>}</code>
<code>\cs_new_nopar:cpn</code>	Creates <code><function></code> to expand to <code><code></code> as replacement text. Within the <code><code></code> , the
<code>\cs_new_nopar:Npx</code>	<code><parameters></code> (<code>#1</code> , <code>#2</code> , <i>etc.</i>) will be replaced by those absorbed by the function. When the
<code>\cs_new_nopar:cpx</code>	<code><function></code> is used the <code><parameters></code> absorbed cannot contain <code>\par</code> tokens. The definition

is global and an error results if the `<function>` is already defined.

<code>\cs_new_protected:Npn</code>	<code>\cs_new_protected:Npn <function> <parameters> {<code>}</code>
<code>\cs_new_protected:cpn</code>	Creates <code><function></code> to expand to <code><code></code> as replacement text. Within the <code><code></code> , the
<code>\cs_new_protected:Npx</code>	<code><parameters></code> (<code>#1</code> , <code>#2</code> , <i>etc.</i>) will be replaced by those absorbed by the function. The
<code>\cs_new_protected:cpx</code>	<code><function></code> will not expand within an x-type argument. The definition is global and an

error results if the `<function>` is already defined.

<code>\cs_new_protected_nopar:Npn</code>	<code>\cs_new_protected_nopar:Npn <function> <parameters> {<code>}</code>
<code>\cs_new_protected_nopar:cpn</code>	
<code>\cs_new_protected_nopar:Npx</code>	
<code>\cs_new_protected_nopar:cpx</code>	

Creates `<function>` to expand to `<code>` as replacement text. Within the `<code>`, the `<parameters>` (`#1`, `#2`, *etc.*) will be replaced by those absorbed by the function. When the `<function>` is used the `<parameters>` absorbed cannot contain `\par` tokens. The `<function>` will not expand within an x-type or e-type argument. The definition is global and an error results if the `<function>` is already defined.

<code>\cs_set:Npn</code>	<code>\cs_set:Npn <function> <parameters> {<code>}</code>
<code>\cs_set:cpn</code>	Sets <code><function></code> to expand to <code><code></code> as replacement text. Within the <code><code></code> , the
<code>\cs_set:Npx</code>	<code><parameters></code> (<code>#1</code> , <code>#2</code> , <i>etc.</i>) will be replaced by those absorbed by the function. The
<code>\cs_set:cpx</code>	assignment of a meaning to the <code><function></code> is restricted to the current \TeX group level.

<code>\cs_set_nopar:Npn</code>	<code>\cs_set_nopar:Npn <function> <parameters> {<code>}</code>
<code>\cs_set_nopar:cpn</code>	Sets <code><function></code> to expand to <code><code></code> as replacement text. Within the <code><code></code> , the
<code>\cs_set_nopar:Npx</code>	<code><parameters></code> (<code>#1</code> , <code>#2</code> , <i>etc.</i>) will be replaced by those absorbed by the function. When the
<code>\cs_set_nopar:cpx</code>	<code><function></code> is used the <code><parameters></code> absorbed cannot contain <code>\par</code> tokens. The assignment

of a meaning to the `<function>` is restricted to the current \TeX group level.

<code>\cs_set_protected:Npn</code>	<code>\cs_set_protected:Npn <function> <parameters> {<code>}</code>
<code>\cs_set_protected:cpn</code>	Sets <code><function></code> to expand to <code><code></code> as replacement text. Within the <code><code></code> , the
<code>\cs_set_protected:Npx</code>	<code><parameters></code> (<code>#1</code> , <code>#2</code> , <i>etc.</i>) will be replaced by those absorbed by the function. The
<code>\cs_set_protected:cpx</code>	assignment of a meaning to the <code><function></code> is restricted to the current \TeX group level.

The `<function>` will not expand within an x-type or e-type argument.

<code>\cs_set_protected_nopar:Npn</code>	<code>\cs_set_protected_nopar:Npn <function> <parameters> {<code>}</code>
<code>\cs_set_protected_nopar:cpn</code>	
<code>\cs_set_protected_nopar:Npx</code>	
<code>\cs_set_protected_nopar:cpx</code>	

Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain `\par` tokens. The assignment of a meaning to the $\langle function \rangle$ is restricted to the current \TeX group level. The $\langle function \rangle$ will not expand within an **x**-type or **e**-type argument.

<code>\cs_gset:Npn</code>	<code>\cs_gset:Npn <function> <parameters> {<code>}</code>
<code>\cs_gset:cpn</code>	
<code>\cs_gset:Npx</code>	
<code>\cs_gset:cpx</code>	

Globally sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. The assignment of a meaning to the $\langle function \rangle$ is *not* restricted to the current \TeX group level: the assignment is global.

<code>\cs_gset_nopar:Npn</code>	<code>\cs_gset_nopar:Npn <function> <parameters> {<code>}</code>
<code>\cs_gset_nopar:cpn</code>	
<code>\cs_gset_nopar:Npx</code>	
<code>\cs_gset_nopar:cpx</code>	

Globally sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain `\par` tokens. The assignment of a meaning to the $\langle function \rangle$ is *not* restricted to the current \TeX group level: the assignment is global.

<code>\cs_gset_protected:Npn</code>	<code>\cs_gset_protected:Npn <function> <parameters> {<code>}</code>
<code>\cs_gset_protected:cpn</code>	
<code>\cs_gset_protected:Npx</code>	
<code>\cs_gset_protected:cpx</code>	

Globally sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. The assignment of a meaning to the $\langle function \rangle$ is *not* restricted to the current \TeX group level: the assignment is global. The $\langle function \rangle$ will not expand within an **x**-type or **e**-type argument.

<code>\cs_gset_protected_nopar:Npn</code>	<code>\cs_gset_protected_nopar:Npn <function> <parameters> {<code>}</code>
<code>\cs_gset_protected_nopar:cpn</code>	
<code>\cs_gset_protected_nopar:Npx</code>	
<code>\cs_gset_protected_nopar:cpx</code>	

Globally sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain `\par` tokens. The assignment of a meaning to the $\langle function \rangle$ is *not* restricted to the current \TeX group level: the assignment is global. The $\langle function \rangle$ will not expand within an **x**-type argument.

3.3 Defining new functions using the signature

<code>\cs_new:Nn</code>	<code>\cs_new:Nn <function> {<code>}</code>
<code>\cs_new:(cn Nx cx)</code>	

Creates $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. The definition is global and an error results if the $\langle function \rangle$ is already defined.

<hr/> <code>\cs_new_nopar:Nn</code> <code>\cs_new_nopar:(cn Nx cx)</code> <hr/>	<code>\cs_new_nopar:Nn <function> {<code>}</code> <p>Creates $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, <i>etc.</i>) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain <code>\par</code> tokens. The definition is global and an error results if the $\langle function \rangle$ is already defined.</p>
<hr/> <code>\cs_new_protected:Nn</code> <code>\cs_new_protected:(cn Nx cx)</code> <hr/>	<code>\cs_new_protected:Nn <function> {<code>}</code> <p>Creates $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, <i>etc.</i>) will be replaced by those absorbed by the function. The $\langle function \rangle$ will not expand within an x-type argument. The definition is global and an error results if the $\langle function \rangle$ is already defined.</p>
<hr/> <code>\cs_new_protected_nopar:Nn</code> <code>\cs_new_protected_nopar:(cn Nx cx)</code> <hr/>	<code>\cs_new_protected_nopar:Nn <function> {<code>}</code> <p>Creates $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, <i>etc.</i>) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain <code>\par</code> tokens. The $\langle function \rangle$ will not expand within an x-type or e-type argument. The definition is global and an error results if the $\langle function \rangle$ is already defined.</p>
<hr/> <code>\cs_set:Nn</code> <code>\cs_set:(cn Nx cx)</code> <hr/>	<code>\cs_set:Nn <function> {<code>}</code> <p>Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, <i>etc.</i>) will be replaced by those absorbed by the function. The assignment of a meaning to the $\langle function \rangle$ is restricted to the current \TeX group level.</p>
<hr/> <code>\cs_set_nopar:Nn</code> <code>\cs_set_nopar:(cn Nx cx)</code> <hr/>	<code>\cs_set_nopar:Nn <function> {<code>}</code> <p>Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, <i>etc.</i>) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain <code>\par</code> tokens. The assignment of a meaning to the $\langle function \rangle$ is restricted to the current \TeX group level.</p>
<hr/> <code>\cs_set_protected:Nn</code> <code>\cs_set_protected:(cn Nx cx)</code> <hr/>	<code>\cs_set_protected:Nn <function> {<code>}</code> <p>Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, <i>etc.</i>) will be replaced by those absorbed by the function. The $\langle function \rangle$ will not expand within an x-type argument. The assignment of a meaning to the $\langle function \rangle$ is restricted to the current \TeX group level.</p>

<code>\cs_set_protected_nopar:Nn</code>	<code>\cs_set_protected_nopar:Nn <function> {<code>}</code>
<code>\cs_set_protected_nopar:(cn Nx cx)</code>	

Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain `\par` tokens. The $\langle function \rangle$ will not expand within an *x*-type or *e*-type argument. The assignment of a meaning to the $\langle function \rangle$ is restricted to the current T_EX group level.

<code>\cs_gset:Nn</code>	<code>\cs_gset:Nn <function> {<code>}</code>
<code>\cs_gset:(cn Nx cx)</code>	

Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. The assignment of a meaning to the $\langle function \rangle$ is global.

<code>\cs_gset_nopar:Nn</code>	<code>\cs_gset_nopar:Nn <function> {<code>}</code>
<code>\cs_gset_nopar:(cn Nx cx)</code>	

Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain `\par` tokens. The assignment of a meaning to the $\langle function \rangle$ is global.

<code>\cs_gset_protected:Nn</code>	<code>\cs_gset_protected:Nn <function> {<code>}</code>
<code>\cs_gset_protected:(cn Nx cx)</code>	

Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. The $\langle function \rangle$ will not expand within an *x*-type argument. The assignment of a meaning to the $\langle function \rangle$ is global.

<code>\cs_gset_protected_nopar:Nn</code>	<code>\cs_gset_protected_nopar:Nn <function> {<code>}</code>
<code>\cs_gset_protected_nopar:(cn Nx cx)</code>	

Sets $\langle function \rangle$ to expand to $\langle code \rangle$ as replacement text. Within the $\langle code \rangle$, the number of $\langle parameters \rangle$ is detected automatically from the function signature. These $\langle parameters \rangle$ ($\#1$, $\#2$, *etc.*) will be replaced by those absorbed by the function. When the $\langle function \rangle$ is used the $\langle parameters \rangle$ absorbed cannot contain `\par` tokens. The $\langle function \rangle$ will not expand within an *x*-type or *e*-type argument. The assignment of a meaning to the $\langle function \rangle$ is global.

<code>\cs_generate_from_arg_count:NNnn</code>	<code>\cs_generate_from_arg_count:NNnn <function> <creator> {<number>}</code>
<code>\cs_generate_from_arg_count:(cNnn Ncnn)</code>	<code>{<code>}</code>

Updated: 2012-01-14

Uses the $\langle creator \rangle$ function (which should have signature Npn , for example `\cs_new:Npn`) to define a $\langle function \rangle$ which takes $\langle number \rangle$ arguments and has $\langle code \rangle$ as replacement text. The $\langle number \rangle$ of arguments is an integer expression, evaluated as detailed for `\int_eval:n`.

3.4 Copying control sequences

Control sequences (not just functions as defined above) can be set to have the same meaning using the functions described here. Making two control sequences equivalent means that the second control sequence is a *copy* of the first (rather than a pointer to it). Thus the old and new control sequence are not tied together: changes to one are not reflected in the other.

In the following text “cs” is used as an abbreviation for “control sequence”.

`\cs_new_eq:NN`
`\cs_new_eq:(Nc|cN|cc)`

`\cs_new_eq:NN` $\langle cs_1 \rangle$ $\langle cs_2 \rangle$
`\cs_new_eq:NN` $\langle cs_1 \rangle$ $\langle token \rangle$

Globally creates $\langle control\ sequence_1 \rangle$ and sets it to have the same meaning as $\langle control\ sequence_2 \rangle$ or $\langle token \rangle$. The second control sequence may subsequently be altered without affecting the copy.

`\cs_set_eq:NN`
`\cs_set_eq:(Nc|cN|cc)`

`\cs_set_eq:NN` $\langle cs_1 \rangle$ $\langle cs_2 \rangle$
`\cs_set_eq:NN` $\langle cs_1 \rangle$ $\langle token \rangle$

Sets $\langle control\ sequence_1 \rangle$ to have the same meaning as $\langle control\ sequence_2 \rangle$ (or $\langle token \rangle$). The second control sequence may subsequently be altered without affecting the copy. The assignment of a meaning to the $\langle control\ sequence_1 \rangle$ is restricted to the current \TeX group level.

`\cs_gset_eq:NN`
`\cs_gset_eq:(Nc|cN|cc)`

`\cs_gset_eq:NN` $\langle cs_1 \rangle$ $\langle cs_2 \rangle$
`\cs_gset_eq:NN` $\langle cs_1 \rangle$ $\langle token \rangle$

Globally sets $\langle control\ sequence_1 \rangle$ to have the same meaning as $\langle control\ sequence_2 \rangle$ (or $\langle token \rangle$). The second control sequence may subsequently be altered without affecting the copy. The assignment of a meaning to the $\langle control\ sequence_1 \rangle$ is *not* restricted to the current \TeX group level: the assignment is global.

3.5 Deleting control sequences

There are occasions where control sequences need to be deleted. This is handled in a very simple manner.

`\cs_undefine:N`
`\cs_undefine:c`

`\cs_undefine:N` $\langle control\ sequence \rangle$

Sets $\langle control\ sequence \rangle$ to be globally undefined.

Updated: 2011-09-15

3.6 Showing control sequences

`\cs_meaning:N` ★
`\cs_meaning:c` ★

`\cs_meaning:N` $\langle control\ sequence \rangle$

This function expands to the *meaning* of the $\langle control\ sequence \rangle$ control sequence. For a macro, this includes the $\langle replacement\ text \rangle$.

Updated: 2011-12-22

\TeX hackers note: This is \TeX ’s `\meaning` primitive. For tokens that are not control sequences, it is more logical to use `\token_to_meaning:N`. The `c` variant correctly reports undefined arguments.

`\cs_show:N`
`\cs_show:c`

Updated: 2017-02-14

`\cs_show:N` $\langle control\ sequence \rangle$
Displays the definition of the $\langle control\ sequence \rangle$ on the terminal.

T_EXhackers note: This is similar to the T_EX primitive `\show`, wrapped to a fixed number of characters per line.

`\cs_log:N`
`\cs_log:c`

New: 2014-08-22
Updated: 2017-02-14

`\cs_log:N` $\langle control\ sequence \rangle$
Writes the definition of the $\langle control\ sequence \rangle$ in the log file. See also `\cs_show:N` which displays the result in the terminal.

3.7 Converting to and from control sequences

`\use:c` ★

`\use:c` $\{ \langle control\ sequence\ name \rangle \}$

Expands the $\langle control\ sequence\ name \rangle$ until only characters remain, and then converts this into a control sequence. This process requires two expansions. As in other `c`-type arguments the $\langle control\ sequence\ name \rangle$ must, when fully expanded, consist of character tokens, typically a mixture of category code 10 (space), 11 (letter) and 12 (other).

T_EXhackers note: Protected macros that appear in a `c`-type argument are expanded despite being protected; `\exp_not:n` also has no effect. An internal error occurs if non-characters or active characters remain after full expansion, as the conversion to a control sequence is not possible.

As an example of the `\use:c` function, both

`\use:c { a b c }`

and

```
\tl_new:N \l_my_tl
\tl_set:Nn \l_my_tl { a b c }
\use:c { \tl_use:N \l_my_tl }
```

would be equivalent to

`\abc`

after two expansions of `\use:c`.

`\cs_if_exist_use:N` ★
`\cs_if_exist_use:c` ★
`\cs_if_exist_use:NTF` ★
`\cs_if_exist_use:cTF` ★

New: 2012-11-10

`\cs_if_exist_use:N` $\langle control\ sequence \rangle$
`\cs_if_exist_use:NTF` $\langle control\ sequence \rangle$ $\{ \langle true\ code \rangle \}$ $\{ \langle false\ code \rangle \}$

Tests whether the $\langle control\ sequence \rangle$ is currently defined according to the conditional `\cs_if_exist:NTF` (whether as a function or another control sequence type), and if it is inserts the $\langle control\ sequence \rangle$ into the input stream followed by the $\langle true\ code \rangle$. Otherwise the $\langle false\ code \rangle$ is used.

<code>\cs:w</code>	★	<code>\cs:w</code> \langle <i>control sequence name</i> \rangle <code>\cs_end:</code>
<code>\cs_end:</code>	★	

Converts the given \langle *control sequence name* \rangle into a single control sequence token. This process requires one expansion. The content for \langle *control sequence name* \rangle may be literal material or from other expandable functions. The \langle *control sequence name* \rangle must, when fully expanded, consist of character tokens which are not active: typically of category code 10 (space), 11 (letter) or 12 (other), or a mixture of these.

T_EXhackers note: These are the T_EX primitives `\csname` and `\endcsname`.

As an example of the `\cs:w` and `\cs_end:` functions, both

`\cs:w a b c \cs_end:`

and

```
\tl_new:N \l_my_tl
\tl_set:Nn \l_my_tl { a b c }
\cs:w \tl_use:N \l_my_tl \cs_end:
```

would be equivalent to

`\abc`

after one expansion of `\cs:w`.

<code>\cs_to_str:N</code>	★	<code>\cs_to_str:N</code> \langle <i>control sequence</i> \rangle
---------------------------	---	---

Converts the given \langle *control sequence* \rangle into a series of characters with category code 12 (other), except spaces, of category code 10. The result does *not* include the current escape token, contrarily to `\token_to_str:N`. Full expansion of this function requires exactly 2 expansion steps, and so an x-type or e-type expansion, or two o-type expansions are required to convert the \langle *control sequence* \rangle to a sequence of characters in the input stream. In most cases, an f-expansion is correct as well, but this loses a space at the start of the result.

4 Analysing control sequences

<code>\cs_split_function:N</code>	★	<code>\cs_split_function:N</code> \langle <i>function</i> \rangle
-----------------------------------	---	---

New: 2018-04-06

Splits the \langle *function* \rangle into the \langle *name* \rangle (*i.e.* the part before the colon) and the \langle *signature* \rangle (*i.e.* after the colon). This information is then placed in the input stream in three parts: the \langle *name* \rangle , the \langle *signature* \rangle and a logic token indicating if a colon was found (to differentiate variables from function names). The \langle *name* \rangle does not include the escape character, and both the \langle *name* \rangle and \langle *signature* \rangle are made up of tokens with category code 12 (other).

The next three functions decompose T_EX macros into their constituent parts: if the \langle *token* \rangle passed is not a macro then no decomposition can occur. In the latter case, all three functions leave `\scan_stop:` in the input stream.

\cs_prefix_spec:N ★

New: 2019-02-27

\cs_prefix_spec:N $\langle token \rangle$

If the $\langle token \rangle$ is a macro, this function leaves the applicable TeX prefixes in input stream as a string of tokens of category code 12 (with spaces having category code 10). Thus for example

```
\cs_set:Npn \next:nn #1#2 { x #1~y #2 }
\cs_prefix_spec:N \next:nn
```

leaves `\long` in the input stream. If the $\langle token \rangle$ is not a macro then `\scan_stop:` is left in the input stream.

TeXhackers note: The prefix can be empty, `\long`, `\protected` or `\protected\long` with backslash replaced by the current escape character.

\cs_argument_spec:N ★

New: 2019-02-27

\cs_argument_spec:N $\langle token \rangle$

If the $\langle token \rangle$ is a macro, this function leaves the primitive TeX argument specification in input stream as a string of character tokens of category code 12 (with spaces having category code 10). Thus for example

```
\cs_set:Npn \next:nn #1#2 { x #1 y #2 }
\cs_argument_spec:N \next:nn
```

leaves `#1#2` in the input stream. If the $\langle token \rangle$ is not a macro then `\scan_stop:` is left in the input stream.

TeXhackers note: If the argument specification contains the string `->`, then the function produces incorrect results.

\cs_replacement_spec:N ★

New: 2019-02-27

\cs_replacement_spec:N $\langle token \rangle$

If the $\langle token \rangle$ is a macro, this function leaves the replacement text in input stream as a string of character tokens of category code 12 (with spaces having category code 10). Thus for example

```
\cs_set:Npn \next:nn #1#2 { x #1~y #2 }
\cs_replacement_spec:N \next:nn
```

leaves `x#1~y#2` in the input stream. If the $\langle token \rangle$ is not a macro then `\scan_stop:` is left in the input stream.

TeXhackers note: If the argument specification contains the string `->`, then the function produces incorrect results.

5 Using or removing tokens and arguments

Tokens in the input can be read and used or read and discarded. If one or more tokens are wrapped in braces then when absorbing them the outer set is removed. At the same time, the category code of each token is set when the token is read by a function (if it

is read more than once, the category code is determined by the situation in force when first function absorbs the token).

<code>\use:n</code>	*	<code>\use:n</code>	<code>{\langle group_1 \rangle}</code>
<code>\use:nn</code>	*	<code>\use:nn</code>	<code>{\langle group_1 \rangle} {\langle group_2 \rangle}</code>
<code>\use:nnn</code>	*	<code>\use:nnn</code>	<code>{\langle group_1 \rangle} {\langle group_2 \rangle} {\langle group_3 \rangle}</code>
<code>\use:nnnn</code>	*	<code>\use:nnnn</code>	<code>{\langle group_1 \rangle} {\langle group_2 \rangle} {\langle group_3 \rangle} {\langle group_4 \rangle}</code>

As illustrated, these functions absorb between one and four arguments, as indicated by the argument specifier. The braces surrounding each argument are removed and the remaining tokens are left in the input stream. The category code of these tokens is also fixed by this process (if it has not already been by some other absorption). All of these functions require only a single expansion to operate, so that one expansion of

`\use:nn { abc } { { def } }`

results in the input stream containing

`abc { def }`

i.e. only the outer braces are removed.

T_EXhackers note: The `\use:n` function is equivalent to L^AT_EX 2_ε's `\@firstofone`.

<code>\use_i:nn</code>	*	<code>\use_i:nn</code>	<code>{\langle arg_1 \rangle} {\langle arg_2 \rangle}</code>
<code>\use_ii:nn</code>	*		

These functions absorb two arguments from the input stream. The function `\use_i:nn` discards the second argument, and leaves the content of the first argument in the input stream. `\use_ii:nn` discards the first argument and leaves the content of the second argument in the input stream. The category code of these tokens is also fixed (if it has not already been by some other absorption). A single expansion is needed for the functions to take effect.

T_EXhackers note: These are equivalent to L^AT_EX 2_ε's `\@firstoftwo` and `\@secondoftwo`.

<code>\use_i:nnn</code>	*	<code>\use_i:nnn</code>	<code>{\langle arg_1 \rangle} {\langle arg_2 \rangle} {\langle arg_3 \rangle}</code>
<code>\use_ii:nnn</code>	*		
<code>\use_iii:nnn</code>	*		

These functions absorb three arguments from the input stream. The function `\use_i:nnn` discards the second and third arguments, and leaves the content of the first argument in the input stream. `\use_ii:nnn` and `\use_iii:nnn` work similarly, leaving the content of second or third arguments in the input stream, respectively. The category code of these tokens is also fixed (if it has not already been by some other absorption). A single expansion is needed for the functions to take effect.

<code>\use_i:nnnn</code>	*	<code>\use_i:nnnn</code>	<code>{\langle arg_1 \rangle} {\langle arg_2 \rangle} {\langle arg_3 \rangle} {\langle arg_4 \rangle}</code>
<code>\use_ii:nnnn</code>	*		
<code>\use_iii:nnnn</code>	*		
<code>\use_iv:nnnn</code>	*		

These functions absorb four arguments from the input stream. The function `\use_i:nnnn` discards the second, third and fourth arguments, and leaves the content of the first argument in the input stream. `\use_ii:nnnn`, `\use_iii:nnnn` and `\use_iv:nnnn` work similarly, leaving the content of second, third or fourth arguments in the input stream, respectively. The category code of these tokens is also fixed (if it has not already been by some other absorption). A single expansion is needed for the functions to take effect.

<code>\use_i_ii:nnn</code>	★	<code>\use_i_ii:nnn {\langle arg_1 \rangle} {\langle arg_2 \rangle} {\langle arg_3 \rangle}</code>
----------------------------	---	--

This function absorbs three arguments and leaves the content of the first and second in the input stream. The category code of these tokens is also fixed (if it has not already been by some other absorption). A single expansion is needed for the function to take effect. An example:

```
\use_i_ii:nnn { abc } { { def } } { ghi }
```

results in the input stream containing

```
abc { def }
```

i.e. the outer braces are removed and the third group is removed.

<code>\use_ii_i:nn</code>	★	<code>\use_ii_i:nnn {\langle arg_1 \rangle} {\langle arg_2 \rangle}</code>
---------------------------	---	--

New: 2019-06-02

This function absorbs two arguments and leaves the content of the second and first in the input stream. The category code of these tokens is also fixed (if it has not already been by some other absorption). A single expansion is needed for the function to take effect.

<code>\use_none:n</code>	★	<code>\use_none:n {\langle group_1 \rangle}</code>
--------------------------	---	--

<code>\use_none:nn</code>	★
---------------------------	---

<code>\use_none:nnn</code>	★
----------------------------	---

<code>\use_none:nnnn</code>	★
-----------------------------	---

<code>\use_none:nnnnn</code>	★
------------------------------	---

<code>\use_none:nnnnnn</code>	★
-------------------------------	---

<code>\use_none:nnnnnnn</code>	★
--------------------------------	---

<code>\use_none:nnnnnnnn</code>	★
---------------------------------	---

<code>\use_none:nnnnnnnnn</code>	★
----------------------------------	---

These functions absorb between one and nine groups from the input stream, leaving nothing on the resulting input stream. These functions work after a single expansion. One or more of the `n` arguments may be an unbraced single token (*i.e.* an `N` argument).

TeXhackers note: These are equivalent to L^AT_EX 2_ε's `\@gobble`, `\@gobbletwo`, *etc.*

<code>\use:e</code>	★	<code>\use:e {\langle expandable tokens \rangle}</code>
---------------------	---	---

New: 2018-06-18

Fully expands the `\langle token list \rangle` in an `x`-type manner, *but* the function remains fully expandable, and parameter character (usually `#`) need not be doubled.

TeXhackers note: `\use:e` is a wrapper around the primitive `\expanded` where it is available: it requires two expansions to complete its action. When `\expanded` is not available this function is very slow.

<code>\use:x</code>		<code>\use:x {\langle expandable tokens \rangle}</code>
---------------------	--	---

Updated: 2011-12-31

Fully expands the `\langle expandable tokens \rangle` and inserts the result into the input stream at the current location. Any hash characters (`#`) in the argument must be doubled.

5.1 Selecting tokens from delimited arguments

A different kind of function for selecting tokens from the token stream are those that use delimited arguments.

<code>\use_none_delimit_by_q_nil:w</code>	<code>*</code>	<code>\use_none_delimit_by_q_nil:w <balanced text> \q_nil</code>
<code>\use_none_delimit_by_q_stop:w</code>	<code>*</code>	<code>\use_none_delimit_by_q_stop:w <balanced text> \q_stop</code>
<code>\use_none_delimit_by_q_recursion_stop:w</code>	<code>*</code>	<code>\use_none_delimit_by_q_recursion_stop:w <balanced text></code>

Absorb the *<balanced text>* form the input stream delimited by the marker given in the function name, leaving nothing in the input stream.

<code>\use_i_delimit_by_q_nil:nw</code>	<code>*</code>	<code>\use_i_delimit_by_q_nil:nw {<inserted tokens>} <balanced text></code>
<code>\use_i_delimit_by_q_stop:nw</code>	<code>*</code>	<code>\q_nil</code>
<code>\use_i_delimit_by_q_recursion_stop:nw</code>	<code>*</code>	<code>\use_i_delimit_by_q_stop:nw {<inserted tokens>} <balanced text> \q_stop</code>
		<code>\use_i_delimit_by_q_recursion_stop:nw {<inserted tokens>}</code>
		<code><balanced text> \q_recursion_stop</code>

Absorb the *<balanced text>* form the input stream delimited by the marker given in the function name, leaving *<inserted tokens>* in the input stream for further processing.

6 Predicates and conditionals

L^AT_EX3 has three concepts for conditional flow processing:

Branching conditionals Functions that carry out a test and then execute, depending on its result, either the code supplied as the *<true code>* or the *<false code>*. These arguments are denoted with T and F, respectively. An example would be

`\cs_if_free:cTF {abc} {<true code>} {<false code>}`

a function that turns the first argument into a control sequence (since it's marked as c) then checks whether this control sequence is still free and then depending on the result carries out the code in the second argument (true case) or in the third argument (false case).

These type of functions are known as “conditionals”; whenever a TF function is defined it is usually accompanied by T and F functions as well. These are provided for convenience when the branch only needs to go a single way. Package writers are free to choose which types to define but the kernel definitions always provide all three versions.

Important to note is that these branching conditionals with *<true code>* and/or *<false code>* are always defined in a way that the code of the chosen alternative can operate on following tokens in the input stream.

These conditional functions may or may not be fully expandable, but if they are expandable they are accompanied by a “predicate” for the same test as described below.

Predicates “Predicates” are functions that return a special type of boolean value which can be tested by the boolean expression parser. All functions of this type are expandable and have names that end with `_p` in the description part. For example,

`\cs_if_free_p:N`

would be a predicate function for the same type of test as the conditional described above. It would return “true” if its argument (a single token denoted by N) is still free for definition. It would be used in constructions like

```

\bool_if:nTF {
  \cs_if_free_p:N \l_tmpz_tl || \cs_if_free_p:N \g_tmpz_tl
} {\true code} {\false code}

```

For each predicate defined, a “branching conditional” also exists that behaves like a conditional described above.

Primitive conditionals There is a third variety of conditional, which is the original concept used in plain \TeX and $\text{\LaTeX 2}_{\epsilon}$. Their use is discouraged in `expl3` (although still used in low-level definitions) because they are more fragile and in many cases require more expansion control (hence more code) than the two types of conditionals described above.

```

\c_true_bool
\c_false_bool

```

Constants that represent `true` and `false`, respectively. Used to implement predicates.

6.1 Tests on control sequences

```

\cs_if_eq_p:NN * \cs_if_eq_p:NN <cs1> <cs2>
\cs_if_eq:NNTF * \cs_if_eq:NNTF <cs1> <cs2> {\true code} {\false code}

```

Compares the definition of two *<control sequences>* and is logically `true` if they are the same, *i.e.* if they have exactly the same definition when examined with `\cs_show:N`.

```

\cs_if_exist_p:N * \cs_if_exist_p:N <control sequence>
\cs_if_exist_p:c * \cs_if_exist:NNTF <control sequence> {\true code} {\false code}
\cs_if_exist:NNTF *
\cs_if_exist:cTF *

```

Tests whether the *<control sequence>* is currently defined (whether as a function or another control sequence type). Any definition of *<control sequence>* other than `\relax` evaluates as `true`.

```

\cs_if_free_p:N * \cs_if_free_p:N <control sequence>
\cs_if_free_p:c * \cs_if_free:NNTF <control sequence> {\true code} {\false code}
\cs_if_free:NNTF *
\cs_if_free:cTF *

```

Tests whether the *<control sequence>* is currently free to be defined. This test is `false` if the *<control sequence>* currently exists (as defined by `\cs_if_exist:N`).

6.2 Primitive conditionals

The ϵ - \TeX engine itself provides many different conditionals. Some expand whatever comes after them and others don’t. Hence the names for these underlying functions often contains a `:w` part but higher level functions are often available. See for instance `\int_compare_p:nNn` which is a wrapper for `\if_int_compare:w`.

Certain conditionals deal with specific data types like boxes and fonts and are described there. The ones described below are either the universal conditionals or deal with control sequences. We prefix primitive conditionals with `\if_`.

<code>\if_true:</code>	★	<code>\if_true: <true code> \else: <false code> \fi:</code>
<code>\if_false:</code>	★	<code>\if_false: <true code> \else: <false code> \fi:</code>
<code>\else:</code>	★	<code>\reverse_if:N <primitive conditional></code>
<code>\fi:</code>	★	<code>\if_true:</code> always executes <i><true code></i> , while <code>\if_false:</code> always executes <i><false code></i> .
<code>\reverse_if:N</code>	★	<code>\reverse_if:N</code> reverses any two-way primitive conditional. <code>\else:</code> and <code>\fi:</code> delimit the branches of the conditional. The function <code>\or:</code> is documented in <code>l3int</code> and used in case switches.

TeXhackers note: These are equivalent to their corresponding TeX primitive conditionals; `\reverse_if:N` is ε -TeX's `\unless`.

<code>\if_meaning:w</code>	★	<code>\if_meaning:w <arg₁₂</code>
----------------------------	---	---

`\if_meaning:w` executes *<true code>* when *<arg_{1 and *<arg_{2 are the same, otherwise it executes *<false code>*. *<arg_{1 and *<arg_{2 could be functions, variables, tokens; in all cases the *unexpanded* definitions are compared.}*}*}*}*

TeXhackers note: This is TeX's `\ifx`.

<code>\if:w</code>	★	<code>\if:w <token₁₂</code>
<code>\if_charcode:w</code>	★	<code>\if_catcode:w <token₁₂</code>
<code>\if_catcode:w</code>	★	These conditionals expand any following tokens until two unexpandable tokens are left. If you wish to prevent this expansion, prefix the token in question with <code>\exp_not:N</code> . <code>\if_catcode:w</code> tests if the category codes of the two tokens are the same whereas <code>\if:w</code> tests if the character codes are identical. <code>\if_charcode:w</code> is an alternative name for <code>\if:w</code> .

<code>\if_cs_exist:N</code>	★	<code>\if_cs_exist:N <cs> <true code> \else: <false code> \fi:</code>
<code>\if_cs_exist:w</code>	★	<code>\if_cs_exist:w <tokens> \cs_end: <true code> \else: <false code> \fi:</code>

Check if *<cs>* appears in the hash table or if the control sequence that can be formed from *<tokens>* appears in the hash table. The latter function does not turn the control sequence in question into `\scan_stop:!` This can be useful when dealing with control sequences which cannot be entered as a single token.

<code>\if_mode_horizontal:</code>	★	<code>\if_mode_horizontal: <true code> \else: <false code> \fi:</code>
<code>\if_mode_vertical:</code>	★	Execute <i><true code></i> if currently in horizontal mode, otherwise execute <i><false code></i> . Similar for the other functions.
<code>\if_mode_math:</code>	★	
<code>\if_mode_inner:</code>	★	

Part V

The l3expan package

Argument expansion

This module provides generic methods for expanding T_EX arguments in a systematic manner. The functions in this module all have prefix `exp`.

Not all possible variations are implemented for every base function. Instead only those that are used within the L^AT_EX3 kernel or otherwise seem to be of general interest are implemented. Consult the module description to find out which functions are actually defined. The next section explains how to define missing variants.

1 Defining new variants

The definition of variant forms for base functions may be necessary when writing new functions or when applying a kernel function in a situation that we haven't thought of before.

Internally preprocessing of arguments is done with functions of the form `\exp_....`. They all look alike, an example would be `\exp_args:NNo`. This function has three arguments, the first and the second are a single tokens, while the third argument should be given in braces. Applying `\exp_args:NNo` expands the content of third argument once before any expansion of the first and second arguments. If `\seq_gpush:No` was not defined it could be coded in the following way:

```
\exp_args:NNo \seq_gpush:Nn
  \g_file_name_stack
  { \l_tmpa_tl }
```

In other words, the first argument to `\exp_args:NNo` is the base function and the other arguments are preprocessed and then passed to this base function. In the example the first argument to the base function should be a single token which is left unchanged while the second argument is expanded once. From this example we can also see how the variants are defined. They just expand into the appropriate `\exp_` function followed by the desired base function, *e.g.*

```
\cs_generate_variant:Nn \seq_gpush:Nn { No }
```

results in the definition of `\seq_gpush:No`

```
\cs_new:Npn \seq_gpush:No { \exp_args:NNo \seq_gpush:Nn }
```

Providing variants in this way in style files is safe as the `\cs_generate_variant:Nn` function will only create new definitions if there is not already one available. Therefore adding such definition to later releases of the kernel will not make such style files obsolete.

The steps above may be automated by using the function `\cs_generate_variant:Nn`, described next.

2 Methods for defining variants

We recall the set of available argument specifiers.

- `N` is used for single-token arguments while `c` constructs a control sequence from its name and passes it to a parent function as an `N`-type argument.
- Many argument types extract or expand some tokens and provide it as an `n`-type argument, namely a braced multiple-token argument: `V` extracts the value of a variable, `v` extracts the value from the name of a variable, `n` uses the argument as it is, `o` expands once, `f` expands fully the front of the token list, `e` and `x` expand fully all tokens (differences are explained later).
- A few odd argument types remain: `T` and `F` for conditional processing, otherwise identical to `n`-type arguments, `p` for the parameter text in definitions, `w` for arguments with a specific syntax, and `D` to denote primitives that should not be used directly.

`\cs_generate_variant:Nn`
`\cs_generate_variant:cn`

Updated: 2017-11-28

`\cs_generate_variant:Nn` \langle parent control sequence \rangle $\{$ \langle variant argument specifiers \rangle $\}$

This function is used to define argument-specifier variants of the \langle parent control sequence \rangle for L^AT_EX3 code-level macros. The \langle parent control sequence \rangle is first separated into the \langle base name \rangle and \langle original argument specifier \rangle . The comma-separated list of \langle variant argument specifiers \rangle is then used to define variants of the \langle original argument specifier \rangle if these are not already defined. For each \langle variant \rangle given, a function is created that expands its arguments as detailed and passes them to the \langle parent control sequence \rangle . So for example

```
\cs_set:Npn \foo:Nn #1#2 { code here }
\cs_generate_variant:Nn \foo:Nn { c }
```

creates a new function `\foo:cn` which expands its first argument into a control sequence name and passes the result to `\foo:Nn`. Similarly

```
\cs_generate_variant:Nn \foo:Nn { NV , cV }
```

generates the functions `\foo:NV` and `\foo:cV` in the same way. The `\cs_generate_variant:Nn` function can only be applied if the \langle parent control sequence \rangle is already defined. If the \langle parent control sequence \rangle is protected or if the \langle variant \rangle involves any `x` argument, then the \langle variant control sequence \rangle is also protected. The \langle variant \rangle is created globally, as is any `\exp_args:N` \langle variant \rangle function needed to carry out the expansion.

Only `n` and `N` arguments can be changed to other types. The only allowed changes are

- `c` variant of an `N` parent;
- `o`, `V`, `v`, `f`, `e`, or `x` variant of an `n` parent;
- `N`, `n`, `T`, `F`, or `p` argument unchanged.

This means the \langle parent \rangle of a \langle variant \rangle form is always unambiguous, even in cases where both an `n`-type parent and an `N`-type parent exist, such as for `\tl_count:n` and `\tl_count:N`.

For backward compatibility it is currently possible to make `n`, `o`, `V`, `v`, `f`, `e`, or `x`-type variants of an `N`-type argument or `N` or `c`-type variants of an `n`-type argument. Both are deprecated. The first because passing more than one token to an `N`-type argument will typically break the parent function's code. The second because programmers who use that most often want to access the value of a variable given its name, hence should use a `V`-type or `v`-type variant instead of `c`-type. In those cases, using the lower-level `\exp_args:No` or `\exp_args:Nc` functions explicitly is preferred to defining confusing variants.

3 Introducing the variants

The `V` type returns the value of a register, which can be one of `tl`, `clist`, `int`, `skip`, `dim`, `muskip`, or built-in T_EX registers. The `v` type is the same except it first creates a control sequence out of its argument before returning the value.

In general, the programmer should not need to be concerned with expansion control. When simply using the content of a variable, functions with a `V` specifier should be used. For those referred to by \langle cs \rangle name, the `v` specifier is available for the same purpose. Only

when specific expansion steps are needed, such as when using delimited arguments, should the lower-level functions with `o` specifiers be employed.

The `e` type expands all tokens fully, starting from the first. More precisely the expansion is identical to that of T_EX’s `\message` (in particular `#` needs not be doubled). It was added in May 2018. In recent enough engines (starting around 2019) it relies on the primitive `\expanded` hence is fast. In older engines it is very much slower. As a result it should only be used in performance critical code if typical users will have a recent installation of the T_EX ecosystem.

The `x` type expands all tokens fully, starting from the first. In contrast to `e`, all macro parameter characters `#` must be doubled, and omitting this leads to low-level errors. In addition this type of expansion is not expandable, namely functions that have `x` in their signature do not themselves expand when appearing inside `x` or `e` expansion.

The `f` type is so special that it deserves an example. It is typically used in contexts where only expandable commands are allowed. Then `x`-expansion cannot be used, and `f`-expansion provides an alternative that expands the front of the token list as much as can be done in such contexts. For instance, say that we want to evaluate the integer expression $3 + 4$ and pass the result 7 as an argument to an expandable function `\example:n`. For this, one should define a variant using `\cs_generate_variant:Nn \example:n { f }`, then do

```
\example:f { \int_eval:n { 3 + 4 } }
```

Note that `x`-expansion would also expand `\int_eval:n` fully to its result 7, but the variant `\example:x` cannot be expandable. Note also that `o`-expansion would not expand `\int_eval:n` fully to its result since that function requires several expansions. Besides the fact that `x`-expansion is protected rather than expandable, another difference between `f`-expansion and `x`-expansion is that `f`-expansion expands tokens from the beginning and stops as soon as a non-expandable token is encountered, while `x`-expansion continues expanding further tokens. Thus, for instance

```
\example:f { \int_eval:n { 1 + 2 } , \int_eval:n { 3 + 4 } }
```

results in the call

```
\example:n { 3 , \int_eval:n { 3 + 4 } }
```

while using `\example:x` or `\example:e` instead results in

```
\example:n { 3 , 7 }
```

at the cost of being protected (for `x` type) or very much slower in old engines (for `e` type). If you use `f` type expansion in conditional processing then you should stick to using TF type functions only as the expansion does not finish any `\if... \fi`: itself!

It is important to note that both `f`- and `o`-type expansion are concerned with the expansion of tokens from left to right in their arguments. In particular, `o`-type expansion applies to the first *token* in the argument it receives: it is conceptually similar to

```
\exp_after:wN <base function> \exp_after:wN { <argument> }
```

At the same time, `f`-type expansion stops at the *first* non-expandable token. This means for example that both

```
\tl_set:No \l_tmpa_tl { { \g_tmpb_tl } }
```

and

```
\tl_set:Nf \l_tmpa_tl { { \g_tmpb_tl } }
```

leave `\g_tmpb_tl` unchanged: `{` is the first token in the argument and is non-expandable. It is usually best to keep the following in mind when using variant forms.

- Variants with `x`-type arguments (that are fully expanded before being passed to the `n`-type base function) are never expandable even when the base function is. Such variants cannot work correctly in arguments that are themselves subject to expansion. Consider using `f` or `e` expansion.
- In contrast, `e` expansion (full expansion, almost like `x` except for the treatment of `#`) does not prevent variants from being expandable (if the base function is). The drawback is that `e` expansion is very much slower in old engines (before 2019). Consider using `f` expansion if that type of expansion is sufficient to perform the required expansion, or `x` expansion if the variant will not itself need to be expandable.
- Finally `f` expansion only expands the front of the token list, stopping at the first non-expandable token. This may fail to fully expand the argument.

When speed is essential (for functions that do very little work and whose variants are used numerous times in a document) the following considerations apply because internal functions for argument expansion come in two flavours, some faster than others.

- Arguments that might need expansion should come first in the list of arguments.
- Arguments that should consist of single tokens `N`, `c`, `V`, or `v` should come first among these.
- Arguments that appear after the first multi-token argument `n`, `f`, `e`, or `o` require slightly slower special processing to be expanded. Therefore it is best to use the optimized functions, namely those that contain only `N`, `c`, `V`, and `v`, and, in the last position, `o`, `f`, `e`, with possible trailing `N` or `n` or `T` or `F`, which are not expanded. Any `x`-type argument causes slightly slower processing.

4 Manipulating the first argument

These functions are described in detail: expansion of multiple tokens follows the same rules but is described in a shorter fashion.

```
\exp_args:Nc ★ \exp_args:Nc <function> {<tokens>}  
\exp_args:cc ★
```

This function absorbs two arguments (the `<function>` name and the `<tokens>`). The `<tokens>` are expanded until only characters remain, and are then turned into a control sequence. The result is inserted into the input stream *after* reinsertion of the `<function>`. Thus the `<function>` may take more than one argument: all others are left unchanged.

The `:cc` variant constructs the `<function>` name in the same manner as described for the `<tokens>`.

T_EXhackers note: Protected macros that appear in a `c`-type argument are expanded despite being protected; `\exp_not:n` also has no effect. An internal error occurs if non-characters or active characters remain after full expansion, as the conversion to a control sequence is not possible.

`\exp_args:No` ★ `\exp_args:No` $\langle function \rangle$ $\{\langle tokens \rangle\}$...

This function absorbs two arguments (the $\langle function \rangle$ name and the $\langle tokens \rangle$). The $\langle tokens \rangle$ are expanded once, and the result is inserted in braces into the input stream *after* reinsertion of the $\langle function \rangle$. Thus the $\langle function \rangle$ may take more than one argument: all others are left unchanged.

`\exp_args:Nv` ★ `\exp_args:Nv` $\langle function \rangle$ $\langle variable \rangle$

This function absorbs two arguments (the names of the $\langle function \rangle$ and the $\langle variable \rangle$). The content of the $\langle variable \rangle$ are recovered and placed inside braces into the input stream *after* reinsertion of the $\langle function \rangle$. Thus the $\langle function \rangle$ may take more than one argument: all others are left unchanged.

`\exp_args:Nv` ★ `\exp_args:Nv` $\langle function \rangle$ $\{\langle tokens \rangle\}$

This function absorbs two arguments (the $\langle function \rangle$ name and the $\langle tokens \rangle$). The $\langle tokens \rangle$ are expanded until only characters remain, and are then turned into a control sequence. This control sequence should be the name of a $\langle variable \rangle$. The content of the $\langle variable \rangle$ are recovered and placed inside braces into the input stream *after* reinsertion of the $\langle function \rangle$. Thus the $\langle function \rangle$ may take more than one argument: all others are left unchanged.

TeXhackers note: Protected macros that appear in a v-type argument are expanded despite being protected; `\exp_not:n` also has no effect. An internal error occurs if non-characters or active characters remain after full expansion, as the conversion to a control sequence is not possible.

`\exp_args:Ne` ★ `\exp_args:Ne` $\langle function \rangle$ $\{\langle tokens \rangle\}$

New: 2018-05-15

This function absorbs two arguments (the $\langle function \rangle$ name and the $\langle tokens \rangle$) and exhaustively expands the $\langle tokens \rangle$. The result is inserted in braces into the input stream *after* reinsertion of the $\langle function \rangle$. Thus the $\langle function \rangle$ may take more than one argument: all others are left unchanged.

TeXhackers note: This relies on the `\expanded` primitive when available (in LuaTeX and starting around 2019 in other engines). Otherwise it uses some fall-back code that is very much slower. As a result it should only be used in performance-critical code if typical users have a recent installation of the TeX ecosystem.

`\exp_args:Nf` ★ `\exp_args:Nf` $\langle function \rangle$ $\{\langle tokens \rangle\}$

This function absorbs two arguments (the $\langle function \rangle$ name and the $\langle tokens \rangle$). The $\langle tokens \rangle$ are fully expanded until the first non-expandable token is found (if that is a space it is removed), and the result is inserted in braces into the input stream *after* reinsertion of the $\langle function \rangle$. Thus the $\langle function \rangle$ may take more than one argument: all others are left unchanged.

<code>\exp_args:Nx</code>	<code>\exp_args:Nx</code>	$\langle function \rangle$	$\{\langle tokens \rangle\}$
---------------------------	---------------------------	----------------------------	------------------------------

This function absorbs two arguments (the $\langle function \rangle$ name and the $\langle tokens \rangle$) and exhaustively expands the $\langle tokens \rangle$. The result is inserted in braces into the input stream *after* reinsertion of the $\langle function \rangle$. Thus the $\langle function \rangle$ may take more than one argument: all others are left unchanged.

5 Manipulating two arguments

<code>\exp_args:NNc</code>	\star	<code>\exp_args:NNc</code>	$\langle token_1 \rangle$	$\langle token_2 \rangle$	$\{\langle tokens \rangle\}$
----------------------------	---------	----------------------------	---------------------------	---------------------------	------------------------------

<code>\exp_args:NNo</code>	\star	These optimized functions absorb three arguments and expand the second and third as detailed by their argument specifier. The first argument of the function is then the next item on the input stream, followed by the expansion of the second and third arguments.
<code>\exp_args:NNV</code>	\star	
<code>\exp_args:NNv</code>	\star	
<code>\exp_args:NNe</code>	\star	
<code>\exp_args:NNf</code>	\star	
<code>\exp_args:Ncc</code>	\star	

<code>\exp_args:Nco</code>	\star
<code>\exp_args:NcV</code>	\star
<code>\exp_args:Ncv</code>	\star
<code>\exp_args:Ncf</code>	\star
<code>\exp_args:NVV</code>	\star

Updated: 2018-05-15

<code>\exp_args:Nnc</code>	\star	<code>\exp_args:Noo</code>	$\langle token \rangle$	$\{\langle tokens_1 \rangle\}$	$\{\langle tokens_2 \rangle\}$
----------------------------	---------	----------------------------	-------------------------	--------------------------------	--------------------------------

<code>\exp_args:Nno</code>	\star	These functions absorb three arguments and expand the second and third as detailed by their argument specifier. The first argument of the function is then the next item on the input stream, followed by the expansion of the second and third arguments. These functions need slower processing.
<code>\exp_args:NnV</code>	\star	
<code>\exp_args:Nnv</code>	\star	
<code>\exp_args:Nne</code>	\star	
<code>\exp_args:Nnf</code>	\star	
<code>\exp_args:Noc</code>	\star	

<code>\exp_args:Noo</code>	\star
<code>\exp_args:Nof</code>	\star
<code>\exp_args:NVo</code>	\star
<code>\exp_args:Nfo</code>	\star
<code>\exp_args:Nff</code>	\star

Updated: 2018-05-15

<code>\exp_args:NNx</code>	\star	<code>\exp_args:NNx</code>	$\langle token_1 \rangle$	$\langle token_2 \rangle$	$\{\langle tokens \rangle\}$
----------------------------	---------	----------------------------	---------------------------	---------------------------	------------------------------

<code>\exp_args:Ncx</code>	\star	These functions absorb three arguments and expand the second and third as detailed by their argument specifier. The first argument of the function is then the next item on the input stream, followed by the expansion of the second and third arguments. These functions are not expandable due to their x-type argument.
<code>\exp_args:Nnx</code>	\star	
<code>\exp_args:Nox</code>	\star	
<code>\exp_args:Nxo</code>	\star	
<code>\exp_args:Nxx</code>	\star	

6 Manipulating three arguments

<code>\exp_args:NNNo</code>	*	<code>\exp_args:NNNo</code>	$\langle token_1 \rangle$	$\langle token_2 \rangle$	$\langle token_3 \rangle$	$\{\langle tokens \rangle\}$
<code>\exp_args:NNNV</code>	*	These optimized functions absorb four arguments and expand the second, third and fourth as detailed by their argument specifier. The first argument of the function is then the next item on the input stream, followed by the expansion of the second argument, <i>etc.</i>				
<code>\exp_args:NNNv</code>	*					
<code>\exp_args:Nccc</code>	*					
<code>\exp_args:NcNc</code>	*					
<code>\exp_args:NcNo</code>	*					
<code>\exp_args:Ncco</code>	*					

<code>\exp_args:NNcf</code>	*	<code>\exp_args:NNoo</code>	$\langle token_1 \rangle$	$\langle token_2 \rangle$	$\{\langle token_3 \rangle\}$	$\{\langle tokens \rangle\}$
<code>\exp_args:NNno</code>	*	These functions absorb four arguments and expand the second, third and fourth as detailed by their argument specifier. The first argument of the function is then the next item on the input stream, followed by the expansion of the second argument, <i>etc.</i> These functions need slower processing.				
<code>\exp_args:NNnV</code>	*					
<code>\exp_args:NNoo</code>	*					
<code>\exp_args:NNVV</code>	*					
<code>\exp_args:Ncno</code>	*					
<code>\exp_args:NcnV</code>	*					
<code>\exp_args:Ncoo</code>	*					
<code>\exp_args:NcVV</code>	*					
<code>\exp_args:Nnnc</code>	*					
<code>\exp_args:Nnno</code>	*					
<code>\exp_args:Nnnf</code>	*					
<code>\exp_args:Nnff</code>	*					
<code>\exp_args:Nooo</code>	*					
<code>\exp_args:Noof</code>	*					
<code>\exp_args:Nffo</code>	*					

<code>\exp_args:NNNx</code>	<code>\exp_args:NNnx</code>	$\langle token_1 \rangle$	$\langle token_2 \rangle$	$\{\langle tokens_1 \rangle\}$	$\{\langle tokens_2 \rangle\}$
<code>\exp_args:NNox</code>	These functions absorb four arguments and expand the second, third and fourth as detailed by their argument specifier. The first argument of the function is then the next item on the input stream, followed by the expansion of the second argument, <i>etc.</i>				
<code>\exp_args:Nccx</code>					
<code>\exp_args:Ncnx</code>					
<code>\exp_args:NNnx</code>					
<code>\exp_args:Nnox</code>					
<code>\exp_args:Noox</code>					

New: 2015-08-12

7 Unbraced expansion

<code>\exp_last_unbraced:No</code>	★	<code>\exp_last_unbraced:Nno</code> $\langle token \rangle$ $\{\langle tokens_1 \rangle\}$ $\{\langle tokens_2 \rangle\}$
<code>\exp_last_unbraced:(NV Nv Nf)</code>	★	
<code>\exp_last_unbraced:Ne</code>	★	
<code>\exp_last_unbraced:NNo</code>	★	
<code>\exp_last_unbraced:(NNV NNf Nco NcV)</code>	★	
<code>\exp_last_unbraced:Nno</code>	★	
<code>\exp_last_unbraced:(Noo Nfo)</code>	★	
<code>\exp_last_unbraced:NNNo</code>	★	
<code>\exp_last_unbraced:(NNNV NNNf)</code>	★	
<code>\exp_last_unbraced:NnNo</code>	★	
<code>\exp_last_unbraced:NNNNo</code>	★	
<code>\exp_last_unbraced:NNNNf</code>	★	

Updated: 2018-05-15

These functions absorb the number of arguments given by their specification, carry out the expansion indicated and leave the results in the input stream, with the last argument not surrounded by the usual braces. Of these, the `:Nno`, `:Noo`, `:Nfo` and `:NnNo` variants need slower processing.

T_EXhackers note: As an optimization, the last argument is unbraced by some of those functions before expansion. This can cause problems if the argument is empty: for instance, `\exp_last_unbraced:Nf \foo_bar:w { } \q_stop` leads to an infinite loop, as the quark is f-expanded.

<code>\exp_last_unbraced:Nx</code>	<code>\exp_last_unbraced:Nx</code> $\langle function \rangle$ $\{\langle tokens \rangle\}$
------------------------------------	--

This function fully expands the $\langle tokens \rangle$ and leaves the result in the input stream after reinsertion of the $\langle function \rangle$. This function is not expandable.

<code>\exp_last_two_unbraced:Noo</code> ★	<code>\exp_last_two_unbraced:Noo</code> $\langle token \rangle$ $\{\langle tokens_1 \rangle\}$ $\{\langle tokens_2 \rangle\}$
---	---

This function absorbs three arguments and expands the second and third once. The first argument of the function is then the next item on the input stream, followed by the expansion of the second and third arguments, which are not wrapped in braces. This function needs special (slower) processing.

<code>\exp_after:wN</code> ★	<code>\exp_after:wN</code> $\langle token_1 \rangle$ $\langle token_2 \rangle$
------------------------------	--

Carries out a single expansion of $\langle token_2 \rangle$ (which may consume arguments) prior to the expansion of $\langle token_1 \rangle$. If $\langle token_2 \rangle$ has no expansion (for example, if it is a character) then it is left unchanged. It is important to notice that $\langle token_1 \rangle$ may be *any* single token, including group-opening and -closing tokens (`{` or `}` assuming normal T_EX category codes). Unless specifically required this should be avoided: expansion should be carried out using an appropriate argument specifier variant or the appropriate `\exp_arg:N` function.

T_EXhackers note: This is the T_EX primitive `\expandafter` renamed.

8 Preventing expansion

Despite the fact that the following functions are all about preventing expansion, they're designed to be used in an expandable context and hence are all marked as being 'expandable' since they themselves disappear after the expansion has completed.

<hr/> <hr/> <code>\exp_not:N</code> *	<code>\exp_not:N</code> $\langle token \rangle$
	Prevents expansion of the $\langle token \rangle$ in a context where it would otherwise be expanded, for example an x -type argument or the first token in an o or e or f argument.
	TeXhackers note: This is the TeX <code>\noexpand</code> primitive. It only prevents expansion. At the beginning of an f -type argument, a space $\langle token \rangle$ is removed even if it appears as <code>\exp_not:N \c_space_token</code> . In an x -expanding definition (<code>\cs_new:Npx</code>), a macro parameter introduces an argument even if it appears as <code>\exp_not:N # 1</code> . This differs from <code>\exp_not:n</code> .
<hr/> <hr/> <code>\exp_not:c</code> *	<code>\exp_not:c</code> $\{\langle tokens \rangle\}$
	Expands the $\langle tokens \rangle$ until only characters remain, and then converts this into a control sequence. Further expansion of this control sequence is then inhibited using <code>\exp_not:N</code> .
	TeXhackers note: Protected macros that appear in a c -type argument are expanded despite being protected; <code>\exp_not:n</code> also has no effect. An internal error occurs if non-characters or active characters remain after full expansion, as the conversion to a control sequence is not possible.
<hr/> <hr/> <code>\exp_not:n</code> *	<code>\exp_not:n</code> $\{\langle tokens \rangle\}$
	Prevents expansion of the $\langle tokens \rangle$ in an e or x -type argument. In all other cases the $\langle tokens \rangle$ continue to be expanded, for example in the input stream or in other types of arguments such as c , f , v . The argument of <code>\exp_not:n</code> <i>must</i> be surrounded by braces.
	TeXhackers note: This is the ε -TeX <code>\unexpanded</code> primitive. In an x -expanding definition (<code>\cs_new:Npx</code>), <code>\exp_not:n {\#1}</code> is equivalent to <code>##1</code> rather than to <code>#1</code> , namely it inserts the two characters <code>#</code> and <code>1</code> . In an e -type argument <code>\exp_not:n {\#}</code> is equivalent to <code>#</code> , namely it inserts the character <code>#</code> .
<hr/> <hr/> <code>\exp_not:o</code> *	<code>\exp_not:o</code> $\{\langle tokens \rangle\}$
	Expands the $\langle tokens \rangle$ once, then prevents any further expansion in x -type or e -type arguments using <code>\exp_not:n</code> .
<hr/> <hr/> <code>\exp_not:v</code> *	<code>\exp_not:v</code> $\langle variable \rangle$
	Recovers the content of the $\langle variable \rangle$, then prevents expansion of this material in x -type or e -type arguments using <code>\exp_not:n</code> .

<hr/> <hr/>	<code>\exp_not:v *</code>	<code>\exp_not:v {<tokens>}</code>	Expands the <i><tokens></i> until only characters remains, and then converts this into a control sequence which should be a <i><variable></i> name. The content of the <i><variable></i> is recovered, and further expansion in <i>x</i> -type or <i>e</i> -type arguments is prevented using <code>\exp_not:n</code> .
<hr/> <hr/>	<code>\exp_not:e *</code>	<code>\exp_not:e {<tokens>}</code>	Expands <i><tokens></i> exhaustively, then protects the result of the expansion (including any tokens which were not expanded) from further expansion in <i>e</i> or <i>x</i> -type arguments using <code>\exp_not:n</code> . This is very rarely useful but is provided for consistency.
<hr/> <hr/>	<code>\exp_not:f *</code>	<code>\exp_not:f {<tokens>}</code>	Expands <i><tokens></i> fully until the first unexpandable token is found (if it is a space it is removed). Expansion then stops, and the result of the expansion (including any tokens which were not expanded) is protected from further expansion in <i>x</i> -type or <i>e</i> -type arguments using <code>\exp_not:n</code> .
<hr/> <hr/>	<code>\exp_stop_f: *</code>	<code>\foo_bar:f { <tokens> \exp_stop_f: <more tokens> }</code>	This function terminates an <i>f</i> -type expansion. Thus if a function <code>\foo_bar:f</code> starts an <i>f</i> -type expansion and all of <i><tokens></i> are expandable <code>\exp_stop_f:</code> terminates the expansion of tokens even if <i><more tokens></i> are also expandable. The function itself is an implicit space token. Inside an <i>x</i> -type expansion, it retains its form, but when typeset it produces the underlying space (␣).

Updated: 2011-06-03

9 Controlled expansion

The `expl3` language makes all efforts to hide the complexity of `TeX` expansion from the programmer by providing concepts that evaluate/expand arguments of functions prior to calling the “base” functions. Thus, instead of using many `\expandafter` calls and other trickery it is usually a matter of choosing the right variant of a function to achieve a desired result.

Of course, deep down `TeX` is using expansion as always and there are cases where a programmer needs to control that expansion directly; typical situations are basic data manipulation tools. This section documents the functions for that level. These commands are used throughout the kernel code, but we hope that outside the kernel there will be little need to resort to them. Instead the argument manipulation methods document above should usually be sufficient.

While `\exp_after:wN` expands one token (out of order) it is sometimes necessary to expand several tokens in one go. The next set of commands provide this functionality. Be aware that it is absolutely required that the programmer has full control over the tokens to be expanded, i.e., it is not possible to use these functions to expand unknown input as part of *<expandable-tokens>* as that will break badly if unexpandable tokens are encountered in that place!

<code>\exp:w</code>	★	<code>\exp:w <expandable tokens> \exp_end:</code>
<code>\exp_end:</code>	★	Expands <code><expandable-tokens></code> until reaching <code>\exp_end:</code> at which point expansion stops. The full expansion of <code><expandable tokens></code> has to be empty. If any token in <code><expandable tokens></code> or any token generated by expanding the tokens therein is not expandable the expansion will end prematurely and as a result <code>\exp_end:</code> will be misinterpreted later on. ³
New: 2015-08-23		

In typical use cases the `\exp_end:` is hidden somewhere in the replacement text of `<expandable-tokens>` rather than being on the same expansion level than `\exp:w`, e.g., you may see code such as

```
\exp:w \@@_case:NnTF #1 {#2} { } { }
```

where somewhere during the expansion of `\@@_case:NnTF` the `\exp_end:` gets generated.

T_EXhackers note: The current implementation uses `\romannumeral` hence ignores space tokens and explicit signs + and - in the expansion of the `<expandable tokens>`, but this should not be relied upon.

<code>\exp:w</code>	★	<code>\exp:w <expandable-tokens> \exp_end_continue_f:w <further-tokens></code>
<code>\exp_end_continue_f:w</code>	★	Expands <code><expandable-tokens></code> until reaching <code>\exp_end_continue_f:w</code> at which point expansion continues as an f-type expansion expanding <code><further-tokens></code> until an unexpandable token is encountered (or the f-type expansion is explicitly terminated by <code>\exp_stop_f:</code>). As with all f-type expansions a space ending the expansion gets removed. The full expansion of <code><expandable-tokens></code> has to be empty. If any token in <code><expandable-tokens></code> or any token generated by expanding the tokens therein is not expandable the expansion will end prematurely and as a result <code>\exp_end_continue_f:w</code> will be misinterpreted later on. ⁴
New: 2015-08-23		

The full expansion of `<expandable-tokens>` has to be empty. If any token in `<expandable-tokens>` or any token generated by expanding the tokens therein is not expandable the expansion will end prematurely and as a result `\exp_end_continue_f:w` will be misinterpreted later on.⁴

In typical use cases `<expandable-tokens>` contains no tokens at all, e.g., you will see code such as

```
\exp_after:wN { \exp:w \exp_end_continue_f:w #2 }
```

where the `\exp_after:wN` triggers an f-expansion of the tokens in #2. For technical reasons this has to happen using two tokens (if they would be hidden inside another command `\exp_after:wN` would only expand the command but not trigger any additional f-expansion).

You might wonder why there are two different approaches available, after all the effect of

```
\exp:w <expandable-tokens> \exp_end:
```

can be alternatively achieved through an f-type expansion by using `\exp_stop_f:`, i.e.

```
\exp:w \exp_end_continue_f:w <expandable-tokens> \exp_stop_f:
```

The reason is simply that the first approach is slightly faster (one less token to parse and less expansion internally) so in places where such performance really matters and where we want to explicitly stop the expansion at a defined point the first form is preferable.

³Due to the implementation you might get the character in position 0 in the current font (typically “”) in the output without any error message!

⁴In this particular case you may get a character into the output as well as an error message.

<code>\exp:w</code>	★
<code>\exp_end_continue_f:nw</code>	★

New: 2015-08-23

`\exp:w` *<expandable-tokens>* `\exp_end_continue_f:nw` *<further-tokens>*

The difference to `\exp_end_continue_f:w` is that we first we pick up an argument which is then returned to the input stream. If *<further-tokens>* starts with space tokens then these space tokens are removed while searching for the argument. If it starts with a brace group then the braces are removed. Thus such spaces or braces will not terminate the f-type expansion.

10 Internal functions

`\::n` `\cs_new:Npn \exp_args:Ncof { \::c \::o \::f \::: }`

`\::N` Internal forms for the base expansion types. These names do *not* conform to the general \LaTeX 3 approach as this makes them more readily visible in the log and so forth. They should not be used outside this module.

`\::c`
`\::o`
`\::e`
`\::f`
`\::x`
`\::v`
`\::V`
`\:::`

`\::o_unbraced` `\cs_new:Npn \exp_last_unbraced:Nno { \::n \::o_unbraced \::: }`

`\::e_unbraced` Internal forms for the expansion types which leave the terminal argument unbraced. These names do *not* conform to the general \LaTeX 3 approach as this makes them more readily visible in the log and so forth. They should not be used outside this module.

`\::f_unbraced`
`\::x_unbraced`
`\::v_unbraced`
`\::V_unbraced`

Part VI

The l3tl package

Token lists

T_EX works with tokens, and L^AT_EX3 therefore provides a number of functions to deal with lists of tokens. Token lists may be present directly in the argument to a function:

```
\foo:n { a collection of \tokens }
```

or may be stored in a so-called “token list variable”, which have the suffix `tl`: a token list variable can also be used as the argument to a function, for example

```
\foo:N \l_some_tl
```

In both cases, functions are available to test and manipulate the lists of tokens, and these have the module prefix `tl`. In many cases, functions which can be applied to token list variables are paired with similar functions for application to explicit lists of tokens: the two “views” of a token list are therefore collected together here.

A token list (explicit, or stored in a variable) can be seen either as a list of “items”, or a list of “tokens”. An item is whatever `\use:n` would grab as its argument: a single non-space token or a brace group, with optional leading explicit space characters (each item is thus itself a token list). A token is either a normal `N` argument, or `␣`, `{`, or `}` (assuming normal T_EX category codes). Thus for example

```
{ Hello } ~ world
```

contains six items (Hello, w, o, r, l and d), but thirteen tokens (`{`, H, e, l, l, o, `}`, `␣`, w, o, r, l and d). Functions which act on items are often faster than their analogue acting directly on tokens.

1 Creating and initialising token list variables

<code>\tl_new:N</code>	<code>\tl_new:N <tl var></code>
<code>\tl_new:c</code>	

Creates a new `<tl var>` or raises an error if the name is already taken. The declaration is global. The `<tl var>` is initially empty.

<code>\tl_const:Nn</code>	<code>\tl_const:Nn <tl var> {<token list>}</code>
<code>\tl_const:(Nx cn cx)</code>	

Creates a new constant `<tl var>` or raises an error if the name is already taken. The value of the `<tl var>` is set globally to the `<token list>`.

<code>\tl_clear:N</code>	<code>\tl_clear:N <tl var></code>
<code>\tl_clear:c</code>	
<code>\tl_gclear:N</code>	
<code>\tl_gclear:c</code>	

Clears all entries from the `<tl var>`.

<hr/>	
<code>\tl_clear_new:N</code>	<code>\tl_clear_new:N <tl var></code>
<code>\tl_clear_new:c</code>	
<code>\tl_gclear_new:N</code>	Ensures that the $\langle tl\ var\rangle$ exists globally by applying <code>\tl_new:N</code> if necessary, then applies
<code>\tl_gclear_new:c</code>	<code>\tl_(g)clear:N</code> to leave the $\langle tl\ var\rangle$ empty.
<hr/>	
<code>\tl_set_eq:NN</code>	<code>\tl_set_eq:NN <tl var_1> <tl var_2></code>
<code>\tl_set_eq:(cN Nc cc)</code>	Sets the content of $\langle tl\ var_1\rangle$ equal to that of $\langle tl\ var_2\rangle$.
<code>\tl_gset_eq:NN</code>	
<code>\tl_gset_eq:(cN Nc cc)</code>	
<hr/>	
<code>\tl_concat:NNN</code>	<code>\tl_concat:NNN <tl var_1> <tl var_2> <tl var_3></code>
<code>\tl_concat:ccc</code>	
<code>\tl_gconcat:NNN</code>	Concatenates the content of $\langle tl\ var_2\rangle$ and $\langle tl\ var_3\rangle$ together and saves the result in
<code>\tl_gconcat:ccc</code>	$\langle tl\ var_1\rangle$. The $\langle tl\ var_2\rangle$ is placed at the left side of the new token list.
<hr/>	
New: 2012-05-18	
<hr/>	
<code>\tl_if_exist_p:N *</code>	<code>\tl_if_exist_p:N <tl var></code>
<code>\tl_if_exist_p:c *</code>	<code>\tl_if_exist:NTF <tl var> {\true code} {\false code}</code>
<code>\tl_if_exist:N\overline{TF} *</code>	
<code>\tl_if_exist:c\overline{TF} *</code>	Tests whether the $\langle tl\ var\rangle$ is currently defined. This does not check that the $\langle tl\ var\rangle$ really is a token list variable.
<hr/>	
New: 2012-03-03	
<hr/>	

2 Adding data to token list variables

<hr/>	
<code>\tl_set:Nn</code>	<code>\tl_set:Nn <tl var> {\tokens}</code>
<code>\tl_set:(NV Nv No Nf Nx cn cV cv co cf cx)</code>	
<code>\tl_gset:Nn</code>	
<code>\tl_gset:(NV Nv No Nf Nx cn cV cv co cf cx)</code>	
<hr/>	
Sets $\langle tl\ var\rangle$ to contain $\langle tokens\rangle$, removing any previous content from the variable.	
<hr/>	
<code>\tl_put_left:Nn</code>	<code>\tl_put_left:Nn <tl var> {\tokens}</code>
<code>\tl_put_left:(NV No Nx cn cV co cx)</code>	
<code>\tl_gput_left:Nn</code>	
<code>\tl_gput_left:(NV No Nx cn cV co cx)</code>	
<hr/>	
Appends $\langle tokens\rangle$ to the left side of the current content of $\langle tl\ var\rangle$.	
<hr/>	
<code>\tl_put_right:Nn</code>	<code>\tl_put_right:Nn <tl var> {\tokens}</code>
<code>\tl_put_right:(NV No Nx cn cV co cx)</code>	
<code>\tl_gput_right:Nn</code>	
<code>\tl_gput_right:(NV No Nx cn cV co cx)</code>	
<hr/>	
Appends $\langle tokens\rangle$ to the right side of the current content of $\langle tl\ var\rangle$.	

3 Modifying token list variables

```
\tl_replace_once:Nnn
\tl_replace_once:cnn
\tl_greplace_once:Nnn
\tl_greplace_once:cnn
```

Updated: 2011-08-11

```
\tl_replace_once:Nnn <tl var> {{<old tokens>}} {{<new tokens>}}
```

Replaces the first (leftmost) occurrence of *<old tokens>* in the *<tl var>* with *<new tokens>*. *<Old tokens>* cannot contain `{`, `}` or `#` (more precisely, explicit character tokens with category code 1 (begin-group) or 2 (end-group), and tokens with category code 6).

```
\tl_replace_all:Nnn
\tl_replace_all:cnn
\tl_greplace_all:Nnn
\tl_greplace_all:cnn
```

Updated: 2011-08-11

```
\tl_replace_all:Nnn <tl var> {{<old tokens>}} {{<new tokens>}}
```

Replaces all occurrences of *<old tokens>* in the *<tl var>* with *<new tokens>*. *<Old tokens>* cannot contain `{`, `}` or `#` (more precisely, explicit character tokens with category code 1 (begin-group) or 2 (end-group), and tokens with category code 6). As this function operates from left to right, the pattern *<old tokens>* may remain after the replacement (see `\tl_remove_all:Nn` for an example).

```
\tl_remove_once:Nn
\tl_remove_once:cn
\tl_gremove_once:Nn
\tl_gremove_once:cn
```

Updated: 2011-08-11

```
\tl_remove_once:Nn <tl var> {{<tokens>}}
```

Removes the first (leftmost) occurrence of *<tokens>* from the *<tl var>*. *<Tokens>* cannot contain `{`, `}` or `#` (more precisely, explicit character tokens with category code 1 (begin-group) or 2 (end-group), and tokens with category code 6).

```
\tl_remove_all:Nn
\tl_remove_all:cn
\tl_gremove_all:Nn
\tl_gremove_all:cn
```

Updated: 2011-08-11

```
\tl_remove_all:Nn <tl var> {{<tokens>}}
```

Removes all occurrences of *<tokens>* from the *<tl var>*. *<Tokens>* cannot contain `{`, `}` or `#` (more precisely, explicit character tokens with category code 1 (begin-group) or 2 (end-group), and tokens with category code 6). As this function operates from left to right, the pattern *<tokens>* may remain after the removal, for instance,

```
\tl_set:Nn \l_tmpa_tl {abbccd} \tl_remove_all:Nn \l_tmpa_tl {bc}
```

results in `\l_tmpa_tl` containing `abcd`.

4 Reassigning token list category codes

These functions allow the rescanning of tokens: re-apply T_EX's tokenization process to apply category codes different from those in force when the tokens were absorbed. Whilst this functionality is supported, it is often preferable to find alternative approaches to achieving outcomes rather than rescanning tokens (for example construction of token lists token-by-token with intervening category code changes or using `\char_generate:nn`).

<code>\tl_set_rescan:Nnn</code>	<code>\tl_set_rescan:Nnn <tl var> {<setup>} {<tokens>}</code>
<code>\tl_set_rescan:(Nno Nnx cnn cno cnx)</code>	
<code>\tl_gset_rescan:Nnn</code>	
<code>\tl_gset_rescan:(Nno Nnx cnn cno cnx)</code>	

Updated: 2015-08-11

Sets $\langle tl\ var \rangle$ to contain $\langle tokens \rangle$, applying the category code régime specified in the $\langle setup \rangle$ before carrying out the assignment. (Category codes applied to tokens not explicitly covered by the $\langle setup \rangle$ are those in force at the point of use of `\tl_set_rescan:Nnn`.) This allows the $\langle tl\ var \rangle$ to contain material with category codes other than those that apply when $\langle tokens \rangle$ are absorbed. The $\langle setup \rangle$ is run within a group and may contain any valid input, although only changes in category codes are relevant. See also `\tl_rescan:nn`.

T_EXhackers note: The $\langle tokens \rangle$ are first turned into a string (using `\tl_to_str:n`). If the string contains one or more characters with character code `\newlinechar` (set equal to `\endlinechar` unless that is equal to 32, before the user $\langle setup \rangle$), then it is split into lines at these characters, then read as if reading multiple lines from a file, ignoring spaces (catcode 10) at the beginning and spaces and tabs (character code 32 or 9) at the end of every line. Otherwise, spaces (and tabs) are retained at both ends of the single-line string, as if it appeared in the middle of a line read from a file.

<code>\tl_rescan:nn</code>	<code>\tl_rescan:nn {<setup>} {<tokens>}</code>
----------------------------	---

Updated: 2015-08-11

Rescans $\langle tokens \rangle$ applying the category code régime specified in the $\langle setup \rangle$, and leaves the resulting tokens in the input stream. (Category codes applied to tokens not explicitly covered by the $\langle setup \rangle$ are those in force at the point of use of `\tl_rescan:nn`.) The $\langle setup \rangle$ is run within a group and may contain any valid input, although only changes in category codes are relevant. See also `\tl_set_rescan:Nnn`, which is more robust than using `\tl_set:Nn` in the $\langle tokens \rangle$ argument of `\tl_rescan:nn`.

T_EXhackers note: The $\langle tokens \rangle$ are first turned into a string (using `\tl_to_str:n`). If the string contains one or more characters with character code `\newlinechar` (set equal to `\endlinechar` unless that is equal to 32, before the user $\langle setup \rangle$), then it is split into lines at these characters, then read as if reading multiple lines from a file, ignoring spaces (catcode 10) at the beginning and spaces and tabs (character code 32 or 9) at the end of every line. Otherwise, spaces (and tabs) are retained at both ends of the single-line string, as if it appeared in the middle of a line read from a file.

5 Token list conditionals

<code>\tl_if_blank_p:n</code>	★	<code>\tl_if_blank_p:n {<token list>}</code>
<code>\tl_if_blank_p:(V o)</code>	★	<code>\tl_if_blank:nTF {<token list>} {<true code>} {<false code>}</code>
<code>\tl_if_blank:nTF</code>	★	
<code>\tl_if_blank:(V o)TF</code>	★	

Tests if the $\langle token\ list \rangle$ consists only of blank spaces (*i.e.* contains no item). The test is **true** if $\langle token\ list \rangle$ is zero or more explicit space characters (explicit tokens with character code 32 and category code 10), and is **false** otherwise.

<code>\tl_if_empty_p:N</code>	★	<code>\tl_if_empty_p:N <tl var></code>
<code>\tl_if_empty_p:c</code>	★	<code>\tl_if_empty:NTF <tl var> {<true code>} {<false code>}</code>
<code>\tl_if_empty:nTF</code>	★	Tests if the <i><token list variable></i> is entirely empty (<i>i.e.</i> contains no tokens at all).
<code>\tl_if_empty:cTF</code>	★	

<code>\tl_if_empty_p:n</code>	★	<code>\tl_if_empty_p:n {<token list>}</code>
<code>\tl_if_empty_p:(V o)</code>	★	<code>\tl_if_empty:nTF {<token list>} {<true code>} {<false code>}</code>
<code>\tl_if_empty:nTF</code>	★	Tests if the <i><token list></i> is entirely empty (<i>i.e.</i> contains no tokens at all).
<code>\tl_if_empty:(V o)TF</code>	★	

New: 2012-05-24
Updated: 2012-06-05

<code>\tl_if_eq_p:NN</code>	★	<code>\tl_if_eq_p:NN <tl var₁> <tl var₂></code>
<code>\tl_if_eq_p:(Nc cN cc)</code>	★	<code>\tl_if_eq:NNTF <tl var₁> <tl var₂> {<true code>} {<false code>}</code>
<code>\tl_if_eq:NNTF</code>	★	Compares the content of two <i><token list variables></i> and is logically true if the two contain the same list of tokens (<i>i.e.</i> identical in both the list of characters they contain and the category codes of those characters). Thus for example
<code>\tl_if_eq:(Nc cN cc)TF</code>	★	

```

\tl_set:Nn \l_tmpa_tl { abc }
\tl_set:Nx \l_tmpb_tl { \tl_to_str:n { abc } }
\tl_if_eq:NNTF \l_tmpa_tl \l_tmpb_tl { true } { false }

```

yields **false**.

<code>\tl_if_eq:nnTF</code>	★	<code>\tl_if_eq:nnTF {<token list₁>} {<token list₂>} {<true code>} {<false code>}</code>
-----------------------------	---	--

Tests if *<token list₁>* and *<token list₂>* contain the same list of tokens, both in respect of character codes and category codes.

<code>\tl_if_in:NnTF</code>	★	<code>\tl_if_in:NnTF <tl var> {<token list>} {<true code>} {<false code>}</code>
<code>\tl_if_in:cnTF</code>	★	Tests if the <i><token list></i> is found in the content of the <i><tl var></i> . The <i><token list></i> cannot contain the tokens <code>{</code> , <code>}</code> or <code>#</code> (more precisely, explicit character tokens with category code 1 (begin-group) or 2 (end-group), and tokens with category code 6).

<code>\tl_if_in:nnTF</code>	★	<code>\tl_if_in:nnTF {<token list₁>} {<token list₂>} {<true code>} {<false code>}</code>
<code>\tl_if_in:(Vn on no)TF</code>	★	Tests if <i><token list₂></i> is found inside <i><token list₁></i> . The <i><token list₂></i> cannot contain the tokens <code>{</code> , <code>}</code> or <code>#</code> (more precisely, explicit character tokens with category code 1 (begin-group) or 2 (end-group), and tokens with category code 6).

<code>\tl_if_noval_p:n</code>	★	<code>\tl_if_noval_p:n {<token list>}</code>
<code>\tl_if_noval_p:nTF</code>	★	<code>\tl_if_noval_p:nTF {<token list>} {<true code>} {<false code>}</code>

New: 2017-11-14

Tests if the *<token list>* is exactly equal to the special `\c_noval_p_tl` marker. This function is intended to allow construction of flexible document interface structures in which missing optional arguments are detected.

<code>\tl_if_single_p:N</code> ★ <code>\tl_if_single_p:c</code> ★ <code>\tl_if_single:N\underline{TF}</code> ★ <code>\tl_if_single:c\underline{TF}</code> ★	<code>\tl_if_single_p:N</code> <tl var> <code>\tl_if_single:N\underline{TF}</code> <tl var> {<true code>} {<false code>}
--	--

Updated: 2011-08-13

Tests if the content of the <tl var> consists of a single item, *i.e.* is a single normal token (neither an explicit space character nor a begin-group character) or a single brace group, surrounded by optional spaces on both sides. In other words, such a token list has token count 1 according to `\tl_count:N`.

<code>\tl_if_single_p:n</code> ★ <code>\tl_if_single:n\underline{TF}</code> ★	<code>\tl_if_single_p:n</code> {<token list>} <code>\tl_if_single:n\underline{TF}</code> {<token list>} {<true code>} {<false code>}
---	--

Updated: 2011-08-13

Tests if the <token list> has exactly one item, *i.e.* is a single normal token (neither an explicit space character nor a begin-group character) or a single brace group, surrounded by optional spaces on both sides. In other words, such a token list has token count 1 according to `\tl_count:n`.

<code>\tl_if_single_token_p:n</code> ★ <code>\tl_if_single_token:n\underline{TF}</code> ★	<code>\tl_if_single_token_p:n</code> {<token list>} <code>\tl_if_single_token:n\underline{TF}</code> {<token list>} {<true code>} {<false code>}
---	--

Tests if the token list consists of exactly one token, *i.e.* is either a single space character or a single “normal” token. Token groups ({...}) are not single tokens.

<code>\tl_case:Nn</code> ★ <code>\tl_case:cn</code> ★ <code>\tl_case:Nn\underline{TF}</code> ★ <code>\tl_case:cn\underline{TF}</code> ★	<code>\tl_case:Nn\underline{TF}</code> <test token list variable> { <token list variable case ₁ > {<code case ₁ >} <token list variable case ₂ > {<code case ₂ >} ... <token list variable case _n > {<code case _n >} } {<true code>} {<false code>}
--	--

New: 2013-07-24

This function compares the <test token list variable> in turn with each of the <token list variable cases>. If the two are equal (as described for `\tl_if_eq:N \underline{TF}`) then the associated <code> is left in the input stream and other cases are discarded. If any of the cases are matched, the <true code> is also inserted into the input stream (after the code for the appropriate case), while if none match then the <false code> is inserted. The function `\tl_case:Nn`, which does nothing if there is no match, is also available.

6 Mapping to token lists

<code>\tl_map_function:NN</code> ☆ <code>\tl_map_function:cN</code> ☆	<code>\tl_map_function:NN</code> <tl var> <function>
--	--

Updated: 2012-06-29

Applies <function> to every <item> in the <tl var>. The <function> receives one argument for each iteration. This may be a number of tokens if the <item> was stored within braces. Hence the <function> should anticipate receiving n-type arguments. See also `\tl_map_function:nN`.

<code>\tl_map_function:nN</code> ☆	<code>\tl_map_function:nN</code> {<token list>} <function>
------------------------------------	--

Updated: 2012-06-29

Applies <function> to every <item> in the <token list>, The <function> receives one argument for each iteration. This may be a number of tokens if the <item> was stored within braces. Hence the <function> should anticipate receiving n-type arguments. See also `\tl_map_function:NN`.

<hr/> <code>\tl_map_inline:Nn</code> <hr/>	<code>\tl_map_inline:Nn <tl var> {<inline function>}</code>
<code>\tl_map_inline:cn</code> <hr/>	Applies the <i><inline function></i> to every <i><item></i> stored within the <i><tl var></i> . The <i><inline function></i> should consist of code which receives the <i><item></i> as <i>#1</i> . See also <code>\tl_map_function:Nn</code> .
Updated: 2012-06-29 <hr/>	
<hr/> <code>\tl_map_inline:nn</code> <hr/>	<code>\tl_map_inline:nn {<token list>} {<inline function>}</code>
<code>\tl_map_inline:nn</code> <hr/>	Applies the <i><inline function></i> to every <i><item></i> stored within the <i><token list></i> . The <i><inline function></i> should consist of code which receives the <i><item></i> as <i>#1</i> . See also <code>\tl_map_function:nn</code> .
Updated: 2012-06-29 <hr/>	
<hr/> <code>\tl_map_variable:NNn</code> <hr/>	<code>\tl_map_variable:NNn <tl var> <variable> {<code>}</code>
<code>\tl_map_variable:cNn</code> <hr/>	Stores each <i><item></i> of the <i><tl var></i> in turn in the (token list) <i><variable></i> and applies the <i><code></i> . The <i><code></i> will usually make use of the <i><variable></i> , but this is not enforced. The assignments to the <i><variable></i> are local. See also <code>\tl_map_inline:Nn</code> .
Updated: 2012-06-29 <hr/>	
<hr/> <code>\tl_map_variable:nNn</code> <hr/>	<code>\tl_map_variable:nNn {<token list>} <variable> {<code>}</code>
<code>\tl_map_variable:nNn</code> <hr/>	Stores each <i><item></i> of the <i><token list></i> in turn in the (token list) <i><variable></i> and applies the <i><code></i> . The <i><code></i> will usually make use of the <i><variable></i> , but this is not enforced. The assignments to the <i><variable></i> are local. See also <code>\tl_map_inline:nn</code> .
Updated: 2012-06-29 <hr/>	
<hr/> <code>\tl_map_break: ☆</code> <hr/>	<code>\tl_map_break:</code>
<code>\tl_map_break: ☆</code> <hr/>	Used to terminate a <code>\tl_map...</code> function before all entries in the <i><token list variable></i> have been processed. This normally takes place within a conditional statement, for example
Updated: 2012-06-29 <hr/>	
	<pre> \tl_map_inline:Nn \l_my_tl { \str_if_eq:nnT { #1 } { bingo } { \tl_map_break: } % Do something useful } </pre>
	See also <code>\tl_map_break:n</code> . Use outside of a <code>\tl_map...</code> scenario leads to low level \TeX errors.
	\TeXhackers note: When the mapping is broken, additional tokens may be inserted before the <i><tokens></i> are inserted into the input stream. This depends on the design of the mapping function.

`\tl_map_break:n` ☆

Updated: 2012-06-29

`\tl_map_break:n` {<code>}

Used to terminate a `\tl_map...` function before all entries in the <token list variable> have been processed, inserting the <code> after the mapping has ended. This normally takes place within a conditional statement, for example

```
\tl_map_inline:Nn \l_my_tl
{
  \str_if_eq:nnT { #1 } { bingo }
  { \tl_map_break:n { <code> } }
  % Do something useful
}
```

Use outside of a `\tl_map...` scenario leads to low level TeX errors.

TeXhackers note: When the mapping is broken, additional tokens may be inserted before the <code> is inserted into the input stream. This depends on the design of the mapping function.

7 Using token lists

`\tl_to_str:n` ★

`\tl_to_str:V` ★

`\tl_to_str:n` {<token list>}

Converts the <token list> to a <string>, leaving the resulting character tokens in the input stream. A <string> is a series of tokens with category code 12 (other) with the exception of spaces, which retain category code 10 (space). This function requires only a single expansion. Its argument *must* be braced.

TeXhackers note: This is the ε -TeX primitive `\detokenize`. Converting a <token list> to a <string> yields a concatenation of the string representations of every token in the <token list>. The string representation of a control sequence is

- an escape character, whose character code is given by the internal parameter `\escapechar`, absent if the `\escapechar` is negative or greater than the largest character code;
- the control sequence name, as defined by `\cs_to_str:N`;
- a space, unless the control sequence name is a single character whose category at the time of expansion of `\tl_to_str:n` is not “letter”.

The string representation of an explicit character token is that character, doubled in the case of (explicit) macro parameter characters (normally #). In particular, the string representation of a token list may depend on the category codes in effect when it is evaluated, and the value of the `\escapechar`: for instance `\tl_to_str:n {\a}` normally produces the three character “backslash”, “lower-case a”, “space”, but it may also produce a single “lower-case a” if the escape character is negative and `a` is currently not a letter.

`\tl_to_str:N` ★

`\tl_to_str:c` ★

`\tl_to_str:N` <tl var>

Converts the content of the <tl var> into a series of characters with category code 12 (other) with the exception of spaces, which retain category code 10 (space). This <string> is then left in the input stream. For low-level details, see the notes given for `\tl_to_str:n`.

<code>\tl_use:N</code>	★	<code>\tl_use:N <tl var></code>
------------------------	---	---------------------------------------

<code>\tl_use:c</code>	★
------------------------	---

Recovers the content of a $\langle tl\ var \rangle$ and places it directly in the input stream. An error is raised if the variable does not exist or if it is invalid. Note that it is possible to use a $\langle tl\ var \rangle$ directly without an accessor function.

8 Working with the content of token lists

<code>\tl_count:n</code>	★	<code>\tl_count:n {\tokens}</code>
--------------------------	---	------------------------------------

<code>\tl_count:(V o)</code>	★
------------------------------	---

New: 2012-05-13

Counts the number of $\langle items \rangle$ in $\langle tokens \rangle$ and leaves this information in the input stream. Unbraced tokens count as one element as do each token group $\{\dots\}$. This process ignores any unprotected spaces within $\langle tokens \rangle$. See also `\tl_count:N`. This function requires three expansions, giving an $\langle integer\ denotation \rangle$.

<code>\tl_count:N</code>	★	<code>\tl_count:N <tl var></code>
--------------------------	---	---

<code>\tl_count:c</code>	★
--------------------------	---

New: 2012-05-13

Counts the number of token groups in the $\langle tl\ var \rangle$ and leaves this information in the input stream. Unbraced tokens count as one element as do each token group $\{\dots\}$. This process ignores any unprotected spaces within the $\langle tl\ var \rangle$. See also `\tl_count:n`. This function requires three expansions, giving an $\langle integer\ denotation \rangle$.

<code>\tl_count_tokens:n</code>	★	<code>\tl_count_tokens:n {\tokens}</code>
---------------------------------	---	---

New: 2019-02-25

Counts the number of \TeX tokens in the $\langle tokens \rangle$ and leaves this information in the input stream. Every token, including spaces and braces, contributes one to the total; thus for instance, the token count of `a~{bc}` is 6.

<code>\tl_reverse:n</code>	★	<code>\tl_reverse:n {\token list}</code>
----------------------------	---	--

<code>\tl_reverse:(V o)</code>	★
--------------------------------	---

Updated: 2012-01-08

Reverses the order of the $\langle items \rangle$ in the $\langle token\ list \rangle$, so that $\langle item_1 \rangle \langle item_2 \rangle \langle item_3 \rangle \dots \langle item_n \rangle$ becomes $\langle item_n \rangle \dots \langle item_3 \rangle \langle item_2 \rangle \langle item_1 \rangle$. This process preserves unprotected space within the $\langle token\ list \rangle$. Tokens are not reversed within braced token groups, which keep their outer set of braces. In situations where performance is important, consider `\tl_reverse_items:n`. See also `\tl_reverse:N`.

\TeX hackers note: The result is returned within `\unexpanded`, which means that the token list does not expand further when appearing in an `x`-type argument expansion.

<code>\tl_reverse:N</code>		<code>\tl_reverse:N <tl var></code>
----------------------------	--	---

<code>\tl_reverse:c</code>	
----------------------------	--

<code>\tl_greverse:N</code>	
-----------------------------	--

<code>\tl_greverse:c</code>	
-----------------------------	--

Updated: 2012-01-08

Reverses the order of the $\langle items \rangle$ stored in $\langle tl\ var \rangle$, so that $\langle item_1 \rangle \langle item_2 \rangle \langle item_3 \rangle \dots \langle item_n \rangle$ becomes $\langle item_n \rangle \dots \langle item_3 \rangle \langle item_2 \rangle \langle item_1 \rangle$. This process preserves unprotected spaces within the $\langle token\ list\ variable \rangle$. Braced token groups are copied without reversing the order of tokens, but keep the outer set of braces. See also `\tl_reverse:n`, and, for improved performance, `\tl_reverse_items:n`.

<hr/> <code>\tl_reverse_items:n</code> ★ <hr/>	<code>\tl_reverse_items:n</code> $\{\langle token\ list\rangle\}$
<hr/> New: 2012-01-08 <hr/>	Reverses the order of the $\langle items\rangle$ stored in $\langle tl\ var\rangle$, so that $\{\langle item_1\rangle\}\{\langle item_2\rangle\}\{\langle item_3\rangle\}\dots\{\langle item_n\rangle\}$ becomes $\{\langle item_n\rangle\}\dots\{\langle item_3\rangle\}\{\langle item_2\rangle\}\{\langle item_1\rangle\}$. This process removes any unprotected space within the $\langle token\ list\rangle$. Braced token groups are copied without reversing the order of tokens, and keep the outer set of braces. Items which are initially not braced are copied with braces in the result. In cases where preserving spaces is important, consider the slower function <code>\tl_reverse:n</code> .

TeXhackers note: The result is returned within `\unexpanded`, which means that the token list does not expand further when appearing in an **x**-type argument expansion.

<hr/> <code>\tl_trim_spaces:n</code> ★ <code>\tl_trim_spaces:o</code> ★ <hr/>	<code>\tl_trim_spaces:n</code> $\{\langle token\ list\rangle\}$
<hr/> New: 2011-07-09 Updated: 2012-06-25 <hr/>	Removes any leading and trailing explicit space characters (explicit tokens with character code 32 and category code 10) from the $\langle token\ list\rangle$ and leaves the result in the input stream.

TeXhackers note: The result is returned within `\unexpanded`, which means that the token list does not expand further when appearing in an **x**-type argument expansion.

<hr/> <code>\tl_trim_spaces_apply:nN</code> ★ <code>\tl_trim_spaces_apply:oN</code> ★ <hr/>	<code>\tl_trim_spaces_apply:nN</code> $\{\langle token\ list\rangle\}$ $\langle function\rangle$
<hr/> New: 2018-04-12 <hr/>	Removes any leading and trailing explicit space characters (explicit tokens with character code 32 and category code 10) from the $\langle token\ list\rangle$ and passes the result to the $\langle function\rangle$ as an n -type argument.

<hr/> <code>\tl_trim_spaces:N</code> <code>\tl_trim_spaces:c</code> <code>\tl_gtrim_spaces:N</code> <code>\tl_gtrim_spaces:c</code> <hr/>	<code>\tl_trim_spaces:N</code> $\langle tl\ var\rangle$
<hr/> New: 2011-07-09 <hr/>	Removes any leading and trailing explicit space characters (explicit tokens with character code 32 and category code 10) from the content of the $\langle tl\ var\rangle$. Note that this therefore <i>resets</i> the content of the variable.

<hr/> <code>\tl_sort:Nn</code> <code>\tl_sort:cn</code> <code>\tl_gsort:Nn</code> <code>\tl_gsort:cn</code> <hr/>	<code>\tl_sort:Nn</code> $\langle tl\ var\rangle$ $\{\langle comparison\ code\rangle\}$
<hr/> New: 2017-02-06 <hr/>	Sorts the items in the $\langle tl\ var\rangle$ according to the $\langle comparison\ code\rangle$, and assigns the result to $\langle tl\ var\rangle$. The details of sorting comparison are described in Section 1.

<hr/> <code>\tl_sort:nN</code> ★ <hr/>	<code>\tl_sort:nN</code> $\{\langle token\ list\rangle\}$ $\langle conditional\rangle$
<hr/> New: 2017-02-06 <hr/>	Sorts the items in the $\langle token\ list\rangle$, using the $\langle conditional\rangle$ to compare items, and leaves the result in the input stream. The $\langle conditional\rangle$ should have signature <code>:nnTF</code> , and return true if the two items being compared should be left in the same order, and false if the items should be swapped. The details of sorting comparison are described in Section 1.

TeXhackers note: The result is returned within `\exp_not:n`, which means that the token list does not expand further when appearing in an **x**-type or **e**-type argument expansion.

9 The first token from a token list

Functions which deal with either only the very first item (balanced text or single normal token) in a token list, or the remaining tokens.

<code>\tl_head:N</code>	★	<code>\tl_head:n {⟨token list⟩}</code>
<code>\tl_head:n</code>	★	
<code>\tl_head:(V v f)</code>	★	Leaves in the input stream the first <i>⟨item⟩</i> in the <i>⟨token list⟩</i> , discarding the rest of the <i>⟨token list⟩</i> . All leading explicit space characters (explicit tokens with character code 32 and category code 10) are discarded; for example
Updated: 2012-09-09		

`\tl_head:n { abc }`

and

`\tl_head:n { ~ abc }`

both leave `a` in the input stream. If the “head” is a brace group, rather than a single token, the braces are removed, and so

`\tl_head:n { ~ { ~ ab } c }`

yields `▯ab`. A blank *⟨token list⟩* (see `\tl_if_blank:nTF`) results in `\tl_head:n` leaving nothing in the input stream.

TeXhackers note: The result is returned within `\exp_not:n`, which means that the token list does not expand further when appearing in an *x*-type argument expansion.

<code>\tl_head:w</code>	★	<code>\tl_head:w ⟨token list⟩ { } \q_stop</code>
Leaves in the input stream the first <i>⟨item⟩</i> in the <i>⟨token list⟩</i> , discarding the rest of the <i>⟨token list⟩</i> . All leading explicit space characters (explicit tokens with character code 32 and category code 10) are discarded. A blank <i>⟨token list⟩</i> (which consists only of space characters) results in a low-level TeX error, which may be avoided by the inclusion of an empty group in the input (as shown), without the need for an explicit test. Alternatively, <code>\tl_if_blank:nF</code> may be used to avoid using the function with a “blank” argument. This function requires only a single expansion, and thus is suitable for use within an <i>o</i> -type expansion. In general, <code>\tl_head:n</code> should be preferred if the number of expansions is not critical.		

<code>\tl_tail:N</code>	★	<code>\tl_tail:n {⟨token list⟩}</code>
-------------------------	---	--

<code>\tl_tail:n</code>	★
-------------------------	---

<code>\tl_tail:(V v f)</code>	★
-------------------------------	---

Updated: 2012-09-01

Discards all leading explicit space characters (explicit tokens with character code 32 and category code 10) and the first *⟨item⟩* in the *⟨token list⟩*, and leaves the remaining tokens in the input stream. Thus for example

`\tl_tail:n { a ~ {bc} d }`

and

`\tl_tail:n { ~ a ~ {bc} d }`

both leave `␣{bc}d` in the input stream. A blank *⟨token list⟩* (see `\tl_if_blank:nTF`) results in `\tl_tail:n` leaving nothing in the input stream.

TeXhackers note: The result is returned within `\exp_not:n`, which means that the token list does not expand further when appearing in an *x*-type argument expansion.

<code>\tl_if_head_eq_catcode_p:nN</code>	★	<code>\tl_if_head_eq_catcode_p:nN {⟨token list⟩} ⟨test token⟩</code>
--	---	--

<code>\tl_if_head_eq_catcode:nNTF</code>	★	<code>\tl_if_head_eq_catcode:nNTF {⟨token list⟩} ⟨test token⟩</code>
--	---	--

`{⟨true code⟩} {⟨false code⟩}`

Updated: 2012-07-09

Tests if the first *⟨token⟩* in the *⟨token list⟩* has the same category code as the *⟨test token⟩*. In the case where the *⟨token list⟩* is empty, the test is always **false**.

<code>\tl_if_head_eq_charcode_p:nN</code>	★	<code>\tl_if_head_eq_charcode_p:nN {⟨token list⟩} ⟨test token⟩</code>
---	---	---

<code>\tl_if_head_eq_charcode_p:fN</code>	★	<code>\tl_if_head_eq_charcode:nNTF {⟨token list⟩} ⟨test token⟩</code>
---	---	---

<code>\tl_if_head_eq_charcode:nNTF</code>	★	<code>{⟨true code⟩} {⟨false code⟩}</code>
---	---	---

<code>\tl_if_head_eq_charcode:fNTF</code>	★
---	---

Updated: 2012-07-09

Tests if the first *⟨token⟩* in the *⟨token list⟩* has the same character code as the *⟨test token⟩*. In the case where the *⟨token list⟩* is empty, the test is always **false**.

<code>\tl_if_head_eq_meaning_p:nN</code>	★	<code>\tl_if_head_eq_meaning_p:nN {⟨token list⟩} ⟨test token⟩</code>
--	---	--

<code>\tl_if_head_eq_meaning:nNTF</code>	★	<code>\tl_if_head_eq_meaning:nNTF {⟨token list⟩} ⟨test token⟩</code>
--	---	--

`{⟨true code⟩} {⟨false code⟩}`

Updated: 2012-07-09

Tests if the first *⟨token⟩* in the *⟨token list⟩* has the same meaning as the *⟨test token⟩*. In the case where *⟨token list⟩* is empty, the test is always **false**.

<code>\tl_if_head_is_group_p:n</code>	★	<code>\tl_if_head_is_group_p:n {⟨token list⟩}</code>
---------------------------------------	---	--

<code>\tl_if_head_is_group:nTF</code>	★	<code>\tl_if_head_is_group:nTF {⟨token list⟩} {⟨true code⟩} {⟨false code⟩}</code>
---------------------------------------	---	---

New: 2012-07-08

Tests if the first *⟨token⟩* in the *⟨token list⟩* is an explicit begin-group character (with category code 1 and any character code), in other words, if the *⟨token list⟩* starts with a brace group. In particular, the test is **false** if the *⟨token list⟩* starts with an implicit token such as `\c_group_begin_token`, or if it is empty. This function is useful to implement actions on token lists on a token by token basis.

<code>\tl_if_head_is_N_type_p:n</code>	<code>★</code>	<code>\tl_if_head_is_N_type_p:n {⟨token list⟩}</code>
<code>\tl_if_head_is_N_type:nTF</code>	<code>★</code>	<code>\tl_if_head_is_N_type:nTF {⟨token list⟩} {⟨true code⟩} {⟨false code⟩}</code>

New: 2012-07-08

Tests if the first *⟨token⟩* in the *⟨token list⟩* is a normal N-type argument. In other words, it is neither an explicit space character (explicit token with character code 32 and category code 10) nor an explicit begin-group character (with category code 1 and any character code). An empty argument yields **false**, as it does not have a “normal” first token. This function is useful to implement actions on token lists on a token by token basis.

<code>\tl_if_head_is_space_p:n</code>	<code>★</code>	<code>\tl_if_head_is_space_p:n {⟨token list⟩}</code>
<code>\tl_if_head_is_space:nTF</code>	<code>★</code>	<code>\tl_if_head_is_space:nTF {⟨token list⟩} {⟨true code⟩} {⟨false code⟩}</code>

Updated: 2012-07-08

Tests if the first *⟨token⟩* in the *⟨token list⟩* is an explicit space character (explicit token with character code 12 and category code 10). In particular, the test is **false** if the *⟨token list⟩* starts with an implicit token such as `\c_space_token`, or if it is empty. This function is useful to implement actions on token lists on a token by token basis.

10 Using a single item

<code>\tl_item:nn</code>	<code>★</code>	<code>\tl_item:nn {⟨token list⟩} {⟨integer expression⟩}</code>
<code>\tl_item:Nn</code>	<code>★</code>	
<code>\tl_item:cn</code>	<code>★</code>	

New: 2014-07-17

Indexing items in the *⟨token list⟩* from 1 on the left, this function evaluates the *⟨integer expression⟩* and leaves the appropriate item from the *⟨token list⟩* in the input stream. If the *⟨integer expression⟩* is negative, indexing occurs from the right of the token list, starting at -1 for the right-most item. If the index is out of bounds, then the function expands to nothing.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the *⟨item⟩* does not expand further when appearing in an x-type argument expansion.

<code>\tl_rand_item:N</code>	<code>★</code>	<code>\tl_rand_item:N ⟨tl var⟩</code>
<code>\tl_rand_item:c</code>	<code>★</code>	<code>\tl_rand_item:n {⟨token list⟩}</code>
<code>\tl_rand_item:n</code>	<code>★</code>	

New: 2016-12-06

Selects a pseudo-random item of the *⟨token list⟩*. If the *⟨token list⟩* is blank, the result is empty. This is not available in older versions of Xe_{La}TeX.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the *⟨item⟩* does not expand further when appearing in an x-type argument expansion.

<code>\tl_range:Nnn *</code> <code>\tl_range:nnn *</code>	<code>\tl_range:Nnn <tl var> {<start index>} {<end index>}</code> <code>\tl_range:nnn {<token list>} {<start index>} {<end index>}</code>
--	--

New: 2017-02-17
Updated: 2017-07-15

Leaves in the input stream the items from the $\langle start\ index \rangle$ to the $\langle end\ index \rangle$ inclusive. Spaces and braces are preserved between the items returned (but never at either end of the list).

Here $\langle start\ index \rangle$ and $\langle end\ index \rangle$ should be integer denotations. For describing in detail the functions' behavior, let m and n be the start and end index respectively. If either is 0, the result is empty. A positive index means 'start counting from the left end', a negative index means 'start counting from the right end'. Let l be the count of the token list.

The *actual start point* is determined as $M = m$ if $m > 0$ and as $M = l + m + 1$ if $m < 0$. Similarly the *actual end point* is $N = n$ if $n > 0$ and $N = l + n + 1$ if $n < 0$. If $M > N$, the result is empty. Otherwise it consists of all items from position M to position N inclusive; for the purpose of this rule, we can imagine that the token list extends at infinity on either side, with void items at positions s for $s \leq 0$ or $s > l$.

Spaces in between items in the actual range are preserved. Spaces at either end of the token list will be removed anyway (think to the token list being passed to `\tl_trim_spaces:n` to begin with).

Thus, with $l = 7$ as in the examples below, all of the following are equivalent and result in the whole token list

```
\tl_range:nnn { abcd~{e{}}fg } { 1 } { 7 }
\tl_range:nnn { abcd~{e{}}fg } { 1 } { 12 }
\tl_range:nnn { abcd~{e{}}fg } { -7 } { 7 }
\tl_range:nnn { abcd~{e{}}fg } { -12 } { 7 }
```

Here are some more interesting examples. The calls

```
\iow_term:x { \tl_range:nnn { abcd~{e{}}fg } { 2 } { 5 } }
\tl_range:nnn { abcd~{e{}}fg } { 2 } { -3 } }
\tl_range:nnn { abcd~{e{}}fg } { -6 } { 5 } }
\tl_range:nnn { abcd~{e{}}fg } { -6 } { -3 } }
```

are all equivalent and will print `bcd{e{}}` on the terminal; similarly

```
\iow_term:x { \tl_range:nnn { abcd~{e{}}fg } { 2 } { 5 } }
\tl_range:nnn { abcd~{e{}}fg } { 2 } { -3 } }
\tl_range:nnn { abcd~{e{}}fg } { -6 } { 5 } }
\tl_range:nnn { abcd~{e{}}fg } { -6 } { -3 } }
```

are all equivalent and will print `bcd {e{}}` on the terminal (note the space in the middle). To the contrary,

```
\tl_range:nnn { abcd~{e{}}f } { 2 } { 4 }
```

will discard the space after 'd'.

If we want to get the items from the third to the last, the call is `\tl_range:nnn { <tl> } { 3 } { -`. Similarly, for discarding the last item, we can do `\tl_range:nnn { <tl> } { 1 } { -2 }`.

The behavior of `\tl_range:Nnn` is exactly the same, acting on the contents of the `tl` variable.

For improved performance, see `\tl_range_braced:nnn` and `\tl_range_unbraced:nnn`.

T_EXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the $\langle item \rangle$ does not expand further when appearing in an `x`-type argument expansion.

11 Viewing token lists

`\tl_show:N`
`\tl_show:c`

Updated: 2015-08-01

`\tl_show:N <tl var>`

Displays the content of the `<tl var>` on the terminal.

TeXhackers note: This is similar to the TeX primitive `\show`, wrapped to a fixed number of characters per line.

`\tl_show:n`

Updated: 2015-08-07

`\tl_show:n <{token list}>`

Displays the `<token list>` on the terminal.

TeXhackers note: This is similar to the ϵ -TeX primitive `\showtokens`, wrapped to a fixed number of characters per line.

`\tl_log:N`
`\tl_log:c`

New: 2014-08-22
Updated: 2015-08-01

`\tl_log:N <tl var>`

Writes the content of the `<tl var>` in the log file. See also `\tl_show:N` which displays the result in the terminal.

`\tl_log:n`

New: 2014-08-22
Updated: 2015-08-07

`\tl_log:n <{token list}>`

Writes the `<token list>` in the log file. See also `\tl_show:n` which displays the result in the terminal.

12 Constant token lists

`\c_empty_tl`

Constant that is always empty.

`\c_novalue_tl`

New: 2017-11-14

A marker for the absence of an argument. This constant `tl` can safely be typeset (*cf.* `\q_nil`), with the result being `-NoValue-`. It is important to note that `\c_novalue_tl` is constructed such that it will *not* match the simple text input `-NoValue-`, *i.e.* that

```
\tl_if_eq:NnTF \c_novalue_tl { -NoValue- }
```

is logically **false**. The `\c_novalue_tl` marker is intended for use in creating document-level interfaces, where it serves as an indicator that an (optional) argument was omitted. In particular, it is distinct from a simple empty `tl`.

`\c_space_tl`

An explicit space character contained in a token list (compare this with `\c_space_token`). For use where an explicit space is required.

13 Scratch token lists

<code>\l_tmpa_tl</code>	Scratch token lists for local assignment. These are never used by the kernel code, and so are safe for use with any <code>L^AT_EX3</code> -defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\l_tmpb_tl</code>	

<code>\g_tmpa_tl</code>	Scratch token lists for global assignment. These are never used by the kernel code, and so are safe for use with any <code>L^AT_EX3</code> -defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\g_tmpb_tl</code>	

Part VII

The l3str package: Strings

TeX associates each character with a category code: as such, there is no concept of a “string” as commonly understood in many other programming languages. However, there are places where we wish to manipulate token lists while in some sense “ignoring” category codes: this is done by treating token lists as strings in a TeX sense.

A TeX string (and thus an expl3 string) is a series of characters which have category code 12 (“other”) with the exception of space characters which have category code 10 (“space”). Thus at a technical level, a TeX string is a token list with the appropriate category codes. In this documentation, these are simply referred to as strings.

String variables are simply specialised token lists, but by convention should be named with the suffix `...str`. Such variables should contain characters with category code 12 (other), except spaces, which have category code 10 (blank space). All the functions in this module which accept a token list argument first convert it to a string using `\tl_to_str:n` for internal processing, and do not treat a token list or the corresponding string representation differently.

As a string is a subset of the more general token list, it is sometimes unclear when one should be used over the other. Use a string variable for data that isn’t primarily intended for typesetting and for which a level of protection from unwanted expansion is suitable. This data type simplifies comparison of variables since there are no concerns about expansion of their contents.

The functions `\cs_to_str:N`, `\tl_to_str:n`, `\tl_to_str:N` and `\token_to_str:N` (and variants) generate strings from the appropriate input: these are documented in `l3basics`, `l3tl` and `l3token`, respectively.

Most expandable functions in this module come in three flavours:

- `\str_...:N`, which expect a token list or string variable as their argument;
- `\str_...:n`, taking any token list (or string) as an argument;
- `\str_..._ignore_spaces:n`, which ignores any space encountered during the operation: these functions are typically faster than those which take care of escaping spaces appropriately.

1 Building strings

`\str_new:N``\str_new:c`

`New: 2015-09-18`

`\str_new:N <str var>`

Creates a new `<str var>` or raises an error if the name is already taken. The declaration is global. The `<str var>` is initially empty.

`\str_const:Nn``\str_const:(NV|Nx|cn|cV|cx)`

`New: 2015-09-18``Updated: 2018-07-28`

`\str_const:Nn <str var> {<token list>}`

Creates a new constant `<str var>` or raises an error if the name is already taken. The value of the `<str var>` is set globally to the `<token list>`, converted to a string.

<code>\str_clear:N</code>	<code>\str_clear:N <str var></code>
<code>\str_clear:c</code>	
<code>\str_gclear:N</code>	Clears the content of the $\langle str var \rangle$.
<code>\str_gclear:c</code>	
<hr/>	
New: 2015-09-18	

<code>\str_clear_new:N</code>	<code>\str_clear_new:N <str var></code>
<code>\str_clear_new:c</code>	
	Ensures that the $\langle str var \rangle$ exists globally by applying <code>\str_new:N</code> if necessary, then applies <code>\str_(g)clear:N</code> to leave the $\langle str var \rangle$ empty.
<hr/>	
New: 2015-09-18	

<code>\str_set_eq:NN</code>	<code>\str_set_eq:NN <str var₁> <str var₂></code>
<code>\str_set_eq:(cN Nc cc)</code>	
<code>\str_gset_eq:NN</code>	Sets the content of $\langle str var_1 \rangle$ equal to that of $\langle str var_2 \rangle$.
<code>\str_gset_eq:(cN Nc cc)</code>	
<hr/>	
New: 2015-09-18	

<code>\str_concat:NNN</code>	<code>\str_concat:NNN <str var₁> <str var₂> <str var₃></code>
<code>\str_concat:ccc</code>	
<code>\str_gconcat:NNN</code>	Concatenates the content of $\langle str var_2 \rangle$ and $\langle str var_3 \rangle$ together and saves the result in $\langle str var_1 \rangle$. The $\langle str var_2 \rangle$ is placed at the left side of the new string variable. The $\langle str var_2 \rangle$ and $\langle str var_3 \rangle$ must indeed be strings, as this function does not convert their contents to a string.
<code>\str_gconcat:ccc</code>	
<hr/>	
New: 2017-10-08	

2 Adding data to string variables

<code>\str_set:Nn</code>	<code>\str_set:Nn <str var> {<token list>}</code>
<code>\str_set:(NV Nx cn cV cx)</code>	
<code>\str_gset:Nn</code>	Converts the $\langle token list \rangle$ to a $\langle string \rangle$, and stores the result in $\langle str var \rangle$.
<code>\str_gset:(NV Nx cn cV cx)</code>	
<hr/>	
New: 2015-09-18	
Updated: 2018-07-28	

<code>\str_put_left:Nn</code>	<code>\str_put_left:Nn <str var> {<token list>}</code>
<code>\str_put_left:(NV Nx cn cV cx)</code>	
<code>\str_gput_left:Nn</code>	
<code>\str_gput_left:(NV Nx cn cV cx)</code>	
<hr/>	
New: 2015-09-18	
Updated: 2018-07-28	

Converts the $\langle token list \rangle$ to a $\langle string \rangle$, and prepends the result to $\langle str var \rangle$. The current contents of the $\langle str var \rangle$ are not automatically converted to a string.

<code>\str_put_right:Nn</code>	<code>\str_put_right:Nn <str var> {(token list)}</code>
<code>\str_put_right:(NV Nx cn cV cx)</code>	
<code>\str_gput_right:Nn</code>	
<code>\str_gput_right:(NV Nx cn cV cx)</code>	

New: 2015-09-18

Updated: 2018-07-28

Converts the $\langle token list \rangle$ to a $\langle string \rangle$, and appends the result to $\langle str var \rangle$. The current contents of the $\langle str var \rangle$ are not automatically converted to a string.

3 Modifying string variables

<code>\str_replace_once:Nnn</code>	<code>\str_replace_once:Nnn <str var> {(old)} {(new)}</code>
<code>\str_replace_once:cnn</code>	
<code>\str_greplace_once:Nnn</code>	
<code>\str_greplace_once:cnn</code>	

New: 2017-10-08

<code>\str_replace_all:Nnn</code>	<code>\str_replace_all:Nnn <str var> {(old)} {(new)}</code>
<code>\str_replace_all:cnn</code>	
<code>\str_greplace_all:Nnn</code>	
<code>\str_greplace_all:cnn</code>	

New: 2017-10-08

<code>\str_remove_once:Nn</code>	<code>\str_remove_once:Nn <str var> {(token list)}</code>
<code>\str_remove_once:cn</code>	
<code>\str_gremove_once:Nn</code>	
<code>\str_gremove_once:cn</code>	

New: 2017-10-08

<code>\str_remove_all:Nn</code>	<code>\str_remove_all:Nn <str var> {(token list)}</code>
<code>\str_remove_all:cn</code>	
<code>\str_gremove_all:Nn</code>	
<code>\str_gremove_all:cn</code>	

New: 2017-10-08

```
\str_set:Nn \l_tmpa_str {abbccd} \str_remove_all:Nn \l_tmpa_str
{bc}
```

results in `\l_tmpa_str` containing `abcd`.

4 String conditionals

<code>\str_if_exist_p:N</code> *	<code>\str_if_exist_p:N <str var></code>
<code>\str_if_exist_p:c</code> *	<code>\str_if_exist:NTF <str var> {<true code>} {<false code>}</code>
<code>\str_if_exist:N\underline{TF}</code> *	Tests whether the <i><str var></i> is currently defined. This does not check that the <i><str var></i> really is a string.
<code>\str_if_exist:c\underline{TF}</code> *	

New: 2015-09-18

<code>\str_if_empty_p:N</code> *	<code>\str_if_empty_p:N <str var></code>
<code>\str_if_empty_p:c</code> *	<code>\str_if_empty:NTF <str var> {<true code>} {<false code>}</code>
<code>\str_if_empty:N\underline{TF}</code> *	Tests if the <i><string variable></i> is entirely empty (<i>i.e.</i> contains no characters at all).
<code>\str_if_empty:c\underline{TF}</code> *	

New: 2015-09-18

<code>\str_if_eq_p:NN</code> *	<code>\str_if_eq_p:NN <str var₁> <str var₂></code>
<code>\str_if_eq_p:(Nc cN cc)</code> *	<code>\str_if_eq:NTF <str var₁> <str var₂> {<true code>} {<false code>}</code>
<code>\str_if_eq:NN\underline{TF}</code> *	Compares the content of two <i><str variables></i> and is logically true if the two contain the same characters in the same order.
<code>\str_if_eq:(Nc cN cc)\underline{TF}</code> *	

New: 2015-09-18

<code>\str_if_eq_p:nn</code> *	<code>\str_if_eq_p:nn {<tl₁>} {<tl₂>}</code>
<code>\str_if_eq_p:(Vn on no nV VV vn nv)</code> *	<code>\str_if_eq:nnTF {<tl₁>} {<tl₂>} {<true code>} {<false code>}</code>
<code>\str_if_eq:nn\underline{TF}</code> *	
<code>\str_if_eq:(Vn on no nV VV vn nv)\underline{TF}</code> *	
<code>\str_if_eq_p:ee</code> *	
<code>\str_if_eq:ee\underline{TF}</code> *	

Updated: 2018-06-18

Compares the two *<token lists>* on a character by character basis (namely after converting them to strings), and is **true** if the two *<strings>* contain the same characters in the same order. Thus for example

`\str_if_eq_p:no { abc } { \tl_to_str:n { abc } }`

is logically **true**.

<code>\str_if_in:Nn\underline{TF}</code>	<code>\str_if_in:NnTF <str var> {<token list>} {<true code>} {<false code>}</code>
<code>\str_if_in:cn\underline{TF}</code>	Converts the <i><token list></i> to a <i><string></i> and tests if that <i><string></i> is found in the content of the <i><str var></i> .

New: 2017-10-08

<code>\str_if_in:nn\underline{TF}</code>	<code>\str_if_in:nnTF <tl₁> {<tl₂>} {<true code>} {<false code>}</code>
	Converts both <i><token lists></i> to <i><strings></i> and tests whether <i><string_{2 is found inside <i><string_{1.}</i>}</i>

New: 2017-10-08

<code>\str_case:nn</code>	★	<code>\str_case:nnTF {⟨test string⟩}</code>
<code>\str_case:(on nV nv)</code>	★	{
<code>\str_case:nnTF</code>	★	{⟨string case ₁ ⟩} {⟨code case ₁ ⟩}
<code>\str_case:(on nV nv)TF</code>	★	{⟨string case ₂ ⟩} {⟨code case ₂ ⟩}
		...
		{⟨string case _n ⟩} {⟨code case _n ⟩}
		}
		{⟨true code⟩}
		{⟨false code⟩}

New: 2013-07-24
Updated: 2015-02-28

Compares the *⟨test string⟩* in turn with each of the *⟨string cases⟩* (all token lists are converted to strings). If the two are equal (as described for `\str_if_eq:nnTF`) then the associated *⟨code⟩* is left in the input stream and other cases are discarded. If any of the cases are matched, the *⟨true code⟩* is also inserted into the input stream (after the code for the appropriate case), while if none match then the *⟨false code⟩* is inserted. The function `\str_case:nn`, which does nothing if there is no match, is also available.

<code>\str_case_e:nn</code>	★	<code>\str_case_e:nnTF {⟨test string⟩}</code>
<code>\str_case_e:nnTF</code>	★	{
		{⟨string case ₁ ⟩} {⟨code case ₁ ⟩}
		{⟨string case ₂ ⟩} {⟨code case ₂ ⟩}
		...
		{⟨string case _n ⟩} {⟨code case _n ⟩}
		}
		{⟨true code⟩}
		{⟨false code⟩}

New: 2018-06-19

Compares the full expansion of the *⟨test string⟩* in turn with the full expansion of the *⟨string cases⟩* (all token lists are converted to strings). If the two full expansions are equal (as described for `\str_if_eq:nnTF`) then the associated *⟨code⟩* is left in the input stream and other cases are discarded. If any of the cases are matched, the *⟨true code⟩* is also inserted into the input stream (after the code for the appropriate case), while if none match then the *⟨false code⟩* is inserted. The function `\str_case_e:nn`, which does nothing if there is no match, is also available. The *⟨test string⟩* is expanded in each comparison, and must always yield the same result: for example, random numbers must not be used within this string.

5 Mapping to strings

<code>\str_map_function:NN</code>	☆	<code>\str_map_function:NN ⟨str var⟩ ⟨function⟩</code>
<code>\str_map_function:cN</code>	☆	Applies <i>⟨function⟩</i> to every <i>⟨character⟩</i> in the <i>⟨str var⟩</i> including spaces. See also <code>\str_map_function:nN</code> .
		New: 2017-11-14
<code>\str_map_function:nN</code>	☆	<code>\str_map_function:nN {⟨token list⟩} ⟨function⟩</code>
		Converts the <i>⟨token list⟩</i> to a <i>⟨string⟩</i> then applies <i>⟨function⟩</i> to every <i>⟨character⟩</i> in the <i>⟨string⟩</i> including spaces. See also <code>\str_map_function:NN</code> .
		New: 2017-11-14

<hr/> <code>\str_map_inline:Nn</code> <code>\str_map_inline:cn</code> <hr/> New: 2017-11-14	<code>\str_map_inline:Nn <str var> {<inline function>}</code> Applies the <i><inline function></i> to every <i><character></i> in the <i><str var></i> including spaces. The <i><inline function></i> should consist of code which receives the <i><character></i> as #1. See also <code>\str_map_function:NN</code> .
<hr/> <code>\str_map_inline:nn</code> <hr/> New: 2017-11-14	<code>\str_map_inline:nn {<token list>} {<inline function>}</code> Converts the <i><token list></i> to a <i><string></i> then applies the <i><inline function></i> to every <i><character></i> in the <i><string></i> including spaces. The <i><inline function></i> should consist of code which receives the <i><character></i> as #1. See also <code>\str_map_function:NN</code> .
<hr/> <code>\str_map_variable:NNn</code> <code>\str_map_variable:cNn</code> <hr/> New: 2017-11-14	<code>\str_map_variable:NNn <str var> <variable> {<code>}</code> Stores each <i><character></i> of the <i><string></i> (including spaces) in turn in the (string or token list) <i><variable></i> and applies the <i><code></i> . The <i><code></i> will usually make use of the <i><variable></i> , but this is not enforced. The assignments to the <i><variable></i> are local. See also <code>\str_map_inline:Nn</code> .
<hr/> <code>\str_map_variable:nNn</code> <hr/> New: 2017-11-14	<code>\str_map_variable:nNn {<token list>} <variable> {<code>}</code> Converts the <i><token list></i> to a <i><string></i> then stores each <i><character></i> in the <i><string></i> (including spaces) in turn in the (string or token list) <i><variable></i> and applies the <i><code></i> . The <i><code></i> will usually make use of the <i><variable></i> , but this is not enforced. The assignments to the <i><variable></i> are local. See also <code>\str_map_inline:Nn</code> .
<hr/> <code>\str_map_break: ☆</code> <hr/> New: 2017-10-08	<code>\str_map_break:</code> Used to terminate a <code>\str_map...</code> function before all characters in the <i><string></i> have been processed. This normally takes place within a conditional statement, for example <pre> \str_map_inline:Nn \l_my_str { \str_if_eq:nnT { #1 } { bingo } { \str_map_break: } % Do something useful } </pre> <p>See also <code>\str_map_break:n</code>. Use outside of a <code>\str_map...</code> scenario leads to low level \TeX errors.</p>

\TeX hackers note: When the mapping is broken, additional tokens may be inserted before continuing with the code that follows the loop. This depends on the design of the mapping function.

`\str_map_break:n` ☆

New: 2017-10-08

`\str_map_break:n` {*<code>*}

Used to terminate a `\str_map...` function before all characters in the *<string>* have been processed, inserting the *<code>* after the mapping has ended. This normally takes place within a conditional statement, for example

```
\str_map_inline:Nn \l_my_str
{
  \str_if_eq:nnT { #1 } { bingo }
  { \str_map_break:n { <code> } }
  % Do something useful
}
```

Use outside of a `\str_map...` scenario leads to low level TeX errors.

TeXhackers note: When the mapping is broken, additional tokens may be inserted before the *<code>* is inserted into the input stream. This depends on the design of the mapping function.

6 Working with the content of strings

`\str_use:N` ★

`\str_use:c` ★

New: 2015-09-18

`\str_use:N` *<str var>*

Recovers the content of a *<str var>* and places it directly in the input stream. An error is raised if the variable does not exist or if it is invalid. Note that it is possible to use a *<str>* directly without an accessor function.

`\str_count:N`

`\str_count:c`

`\str_count:n`

`\str_count_ignore_spaces:n` ★

New: 2015-09-18

Leaves in the input stream the number of characters in the string representation of *<token list>*, as an integer denotation. The functions differ in their treatment of spaces. In the case of `\str_count:N` and `\str_count:n`, all characters including spaces are counted. The `\str_count_ignore_spaces:n` function leaves the number of non-space characters in the input stream.

`\str_count_spaces:N` ★

`\str_count_spaces:c` ★

`\str_count_spaces:n` ★

New: 2015-09-18

`\str_count_spaces:n` {*<token list>*}

Leaves in the input stream the number of space characters in the string representation of *<token list>*, as an integer denotation. Of course, this function has no `_ignore_spaces` variant.

<code>\str_head:N</code>	★	<code>\str_head:n {⟨token list⟩}</code>
<code>\str_head:c</code>	★	
<code>\str_head:n</code>	★	
<code>\str_head_ignore_spaces:n</code>	★	

New: 2015-09-18

Converts the $\langle token\ list \rangle$ into a $\langle string \rangle$. The first character in the $\langle string \rangle$ is then left in the input stream, with category code “other”. The functions differ if the first character is a space: `\str_head:N` and `\str_head:n` return a space token with category code 10 (blank space), while the `\str_head_ignore_spaces:n` function ignores this space character and leaves the first non-space character in the input stream. If the $\langle string \rangle$ is empty (or only contains spaces in the case of the `_ignore_spaces` function), then nothing is left on the input stream.

<code>\str_tail:N</code>	★	<code>\str_tail:n {⟨token list⟩}</code>
<code>\str_tail:c</code>	★	
<code>\str_tail:n</code>	★	
<code>\str_tail_ignore_spaces:n</code>	★	

New: 2015-09-18

Converts the $\langle token\ list \rangle$ to a $\langle string \rangle$, removes the first character, and leaves the remaining characters (if any) in the input stream, with category codes 12 and 10 (for spaces). The functions differ in the case where the first character is a space: `\str_tail:N` and `\str_tail:n` only trim that space, while `\str_tail_ignore_spaces:n` removes the first non-space character and any space before it. If the $\langle token\ list \rangle$ is empty (or blank in the case of the `_ignore_spaces` variant), then nothing is left on the input stream.

<code>\str_item:Nn</code>	★	<code>\str_item:nn {⟨token list⟩} {⟨integer expression⟩}</code>
<code>\str_item:nn</code>	★	
<code>\str_item_ignore_spaces:nn</code>	★	

New: 2015-09-18

Converts the $\langle token\ list \rangle$ to a $\langle string \rangle$, and leaves in the input stream the character in position $\langle integer\ expression \rangle$ of the $\langle string \rangle$, starting at 1 for the first (left-most) character. In the case of `\str_item:Nn` and `\str_item:nn`, all characters including spaces are taken into account. The `\str_item_ignore_spaces:nn` function skips spaces when counting characters. If the $\langle integer\ expression \rangle$ is negative, characters are counted from the end of the $\langle string \rangle$. Hence, -1 is the right-most character, *etc.*

<code>\str_range:Nnn</code>	<code>*</code>	<code>\str_range:nnn {⟨token list⟩} {⟨start index⟩} {⟨end index⟩}</code>
<code>\str_range:cnn</code>	<code>*</code>	
<code>\str_range:nnn</code>	<code>*</code>	
<code>\str_range_ignore_spaces:nnn</code>	<code>*</code>	

New: 2015-09-18

Converts the $\langle token\ list \rangle$ to a $\langle string \rangle$, and leaves in the input stream the characters from the $\langle start\ index \rangle$ to the $\langle end\ index \rangle$ inclusive. Spaces are preserved and counted as items (contrast this with `\tl_range:nnn` where spaces are not counted as items and are possibly discarded from the output).

Here $\langle start\ index \rangle$ and $\langle end\ index \rangle$ should be integer denotations. For describing in detail the functions' behavior, let m and n be the start and end index respectively. If either is 0, the result is empty. A positive index means 'start counting from the left end', a negative index means 'start counting from the right end'. Let l be the count of the token list.

The *actual start point* is determined as $M = m$ if $m > 0$ and as $M = l + m + 1$ if $m < 0$. Similarly the *actual end point* is $N = n$ if $n > 0$ and $N = l + n + 1$ if $n < 0$. If $M > N$, the result is empty. Otherwise it consists of all items from position M to position N inclusive; for the purpose of this rule, we can imagine that the token list extends at infinity on either side, with void items at positions s for $s \leq 0$ or $s > l$. For instance,

```
\iow_term:x { \str_range:nnn { abcdef } { 2 } { 5 } }
\iow_term:x { \str_range:nnn { abcdef } { -4 } { -1 } }
\iow_term:x { \str_range:nnn { abcdef } { -2 } { -1 } }
\iow_term:x { \str_range:nnn { abcdef } { 0 } { -1 } }
```

prints bcde, cdef, ef, and an empty line to the terminal. The $\langle start\ index \rangle$ must always be smaller than or equal to the $\langle end\ index \rangle$: if this is not the case then no output is generated. Thus

```
\iow_term:x { \str_range:nnn { abcdef } { 5 } { 2 } }
\iow_term:x { \str_range:nnn { abcdef } { -1 } { -4 } }
```

both yield empty strings.

The behavior of `\str_range_ignore_spaces:nnn` is similar, but spaces are removed before starting the job. The input

```
\iow_term:x { \str_range:nnn { abcdefg } { 2 } { 5 } }
\iow_term:x { \str_range:nnn { abcdefg } { 2 } { -3 } }
\iow_term:x { \str_range:nnn { abcdefg } { -6 } { 5 } }
\iow_term:x { \str_range:nnn { abcdefg } { -6 } { -3 } }

\iow_term:x { \str_range:nnn { abc~efg } { 2 } { 5 } }
\iow_term:x { \str_range:nnn { abc~efg } { 2 } { -3 } }
\iow_term:x { \str_range:nnn { abc~efg } { -6 } { 5 } }
\iow_term:x { \str_range:nnn { abc~efg } { -6 } { -3 } }

\iow_term:x { \str_range_ignore_spaces:nnn { abcdefg } { 2 } { 5 } }
\iow_term:x { \str_range_ignore_spaces:nnn { abcdefg } { 2 } { -3 } }
\iow_term:x { \str_range_ignore_spaces:nnn { abcdefg } { -6 } { 5 } }
\iow_term:x { \str_range_ignore_spaces:nnn { abcdefg } { -6 } { -3 } }

\iow_term:x { \str_range_ignore_spaces:nnn { abcd~efg } { 2 } { 5 } }
\iow_term:x { \str_range_ignore_spaces:nnn { abcd~efg } { 2 } { -3 } }
\iow_term:x { \str_range_ignore_spaces:nnn { abcd~efg } { -6 } { 5 } }
\iow_term:x { \str_range_ignore_spaces:nnn { abcd~efg } { -6 } { -3 } }
```

will print four instances of bcde, four instances of bc e and eight instances of bcde.

7 String manipulation

```

\str_lower_case:n * \str_lower_case:n {\tokens}
\str_lower_case:f * \str_upper_case:n {\tokens}
\str_upper_case:n *
\str_upper_case:f *

```

New: 2015-03-01

Converts the input $\langle tokens \rangle$ to their string representation, as described for `\tl_to_str:n`, and then to the lower or upper case representation using a one-to-one mapping as described by the Unicode Consortium file `UnicodeData.txt`.

These functions are intended for case changing programmatic data in places where upper/lower case distinctions are meaningful. One example would be automatically generating a function name from user input where some case changing is needed. In this situation the input is programmatic, not textual, case does have meaning and a language-independent one-to-one mapping is appropriate. For example

```

\cs_new_protected:Npn \myfunc:nn #1#2
{
  \cs_set_protected:cpn
  {
    user
    \str_upper_case:f { \tl_head:n {#1} }
    \str_lower_case:f { \tl_tail:n {#1} }
  }
  { #2 }
}

```

would be used to generate a function with an auto-generated name consisting of the upper case equivalent of the supplied name followed by the lower case equivalent of the rest of the input.

These functions should *not* be used for

- Caseless comparisons: use `\str_fold_case:n` for this situation (case folding is distinct from lower casing).
- Case changing text for typesetting: see the `\tl_lower_case:n(n)`, `\tl_upper_case:n(n)` and `\tl_mixed_case:n(n)` functions which correctly deal with context-dependence and other factors appropriate to text case changing.

TeXhackers note: As with all `expl3` functions, the input supported by `\str_fold_case:n` is *engine-native* characters which are or interoperate with UTF-8. As such, when used with pdfTeX *only* the Latin alphabet characters A–Z are case-folded (*i.e.* the ASCII range which coincides with UTF-8). Full UTF-8 support is available with both XeTeX and LuaTeX.

```
\str_fold_case:n ★
\str_fold_case:V ★
```

New: 2014-06-19
Updated: 2016-03-07

```
\str_fold_case:n {(tokens)}
```

Converts the input $\langle tokens \rangle$ to their string representation, as described for `\tl_to_str:n`, and then folds the case of the resulting $\langle string \rangle$ to remove case information. The result of this process is left in the input stream.

String folding is a process used for material such as identifiers rather than for “text”. The folding provided by `\str_fold_case:n` follows the mappings provided by the [Unicode Consortium](#), who [state](#):

Case folding is primarily used for caseless comparison of text, such as identifiers in a computer program, rather than actual text transformation. Case folding in Unicode is based on the lowercase mapping, but includes additional changes to the source text to help make it language-insensitive and consistent. As a result, case-folded text should be used solely for internal processing and generally should not be stored or displayed to the end user.

The folding approach implemented by `\str_fold_case:n` follows the “full” scheme defined by the Unicode Consortium (*e.g.* SSfolds to SS). As case-folding is a language-insensitive process, there is no special treatment of Turkic input (*i.e.* I always folds to i and not to ı).

TeXhackers note: As with all `expl3` functions, the input supported by `\str_fold_case:n` is *engine-native* characters which are or interoperate with UTF-8. As such, when used with pdfTeX *only* the Latin alphabet characters A–Z are case-folded (*i.e.* the ASCII range which coincides with UTF-8). Full UTF-8 support is available with both XeTeX and LuaTeX, subject only to the fact that XeTeX in particular has issues with characters of code above hexadecimal 0xFFFF when interacting with `\tl_to_str:n`.

8 Viewing strings

```
\str_show:N
\str_show:c
\str_show:n
```

New: 2015-09-18

```
\str_show:N <str var>
```

Displays the content of the $\langle str var \rangle$ on the terminal.

```
\str_log:N
\str_log:c
\str_log:n
```

New: 2019-02-15

```
\str_log:N <str var>
```

Writes the content of the $\langle str var \rangle$ in the log file.

9 Constant token lists

<code>\c_ampersand_str</code>	Constant strings, containing a single character token, with category code 12.
<code>\c_atsign_str</code>	
<code>\c_backslash_str</code>	
<code>\c_left_brace_str</code>	
<code>\c_right_brace_str</code>	
<code>\c_circumflex_str</code>	
<code>\c_colon_str</code>	
<code>\c_dollar_str</code>	
<code>\c_hash_str</code>	
<code>\c_percent_str</code>	
<code>\c_tilde_str</code>	
<code>\c_underscore_str</code>	

New: 2015-09-19

10 Scratch strings

<code>\l_tmpa_str</code>	Scratch strings for local assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\l_tmpb_str</code>	

<code>\g_tmpa_str</code>	Scratch strings for global assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\g_tmpb_str</code>	

Part VIII

The `l3str-convert` package: string encoding conversions

1 Encoding and escaping schemes

Traditionally, string encodings only specify how strings of characters should be stored as bytes. However, the resulting lists of bytes are often to be used in contexts where only a restricted subset of bytes are permitted (*e.g.*, PDF string objects, URLs). Hence, storing a string of characters is done in two steps.

- The code points (“character codes”) are expressed as bytes following a given “encoding”. This can be UTF-16, ISO 8859-1, *etc.* See Table 1 for a list of supported encodings.⁵
- Bytes are translated to \TeX tokens through a given “escaping”. Those are defined for the most part by the pdf file format. See Table 2 for a list of escaping methods supported.⁶

2 Conversion functions

`\str_set_convert:Nnnn`
`\str_gset_convert:Nnnn`

`\str_set_convert:Nnnn <str var> {<string>} {<name 1>} {<name 2>}`

This function converts the $\langle string \rangle$ from the encoding given by $\langle name 1 \rangle$ to the encoding given by $\langle name 2 \rangle$, and stores the result in the $\langle str var \rangle$. Each $\langle name \rangle$ can have the form $\langle encoding \rangle$ or $\langle encoding \rangle / \langle escaping \rangle$, where the possible values of $\langle encoding \rangle$ and $\langle escaping \rangle$ are given in Tables 1 and 2, respectively. The default escaping is to input and output bytes directly. The special case of an empty $\langle name \rangle$ indicates the use of “native” strings, 8-bit for pdf \TeX , and Unicode strings for the other two engines.

For example,

`\str_set_convert:Nnnn \l_foo_str { Hello! } { } { utf16/hex }`

results in the variable `\l_foo_str` holding the string `FEFF00480065006C006C006F0021`. This is obtained by converting each character in the (native) string `Hello!` to the UTF-16 encoding, and expressing each byte as a pair of hexadecimal digits. Note the presence of a (big-endian) byte order mark “FEFF”, which can be avoided by specifying the encoding `utf16be/hex`.

An error is raised if the $\langle string \rangle$ is not valid according to the $\langle escaping 1 \rangle$ and $\langle encoding 1 \rangle$, or if it cannot be reencoded in the $\langle encoding 2 \rangle$ and $\langle escaping 2 \rangle$ (for instance, if a character does not exist in the $\langle encoding 2 \rangle$). Erroneous input is replaced by the Unicode replacement character “FFFD”, and characters which cannot be reencoded are replaced by either the replacement character “FFFD if it exists in the $\langle encoding 2 \rangle$, or an encoding-specific replacement character, or the question mark character.

⁵Encodings and escapings will be added as they are requested.

Table 1: Supported encodings. Non-alphanumeric characters are ignored, and capital letters are lower-cased before searching for the encoding in this list.

<i>⟨Encoding⟩</i>	description
<code>utf8</code>	UTF-8
<code>utf16</code>	UTF-16, with byte-order mark
<code>utf16be</code>	UTF-16, big-endian
<code>utf16le</code>	UTF-16, little-endian
<code>utf32</code>	UTF-32, with byte-order mark
<code>utf32be</code>	UTF-32, big-endian
<code>utf32le</code>	UTF-32, little-endian
<code>iso88591, latin1</code>	ISO 8859-1
<code>iso88592, latin2</code>	ISO 8859-2
<code>iso88593, latin3</code>	ISO 8859-3
<code>iso88594, latin4</code>	ISO 8859-4
<code>iso88595</code>	ISO 8859-5
<code>iso88596</code>	ISO 8859-6
<code>iso88597</code>	ISO 8859-7
<code>iso88598</code>	ISO 8859-8
<code>iso88599, latin5</code>	ISO 8859-9
<code>iso885910, latin6</code>	ISO 8859-10
<code>iso885911</code>	ISO 8859-11
<code>iso885913, latin7</code>	ISO 8859-13
<code>iso885914, latin8</code>	ISO 8859-14
<code>iso885915, latin9</code>	ISO 8859-15
<code>iso885916, latin10</code>	ISO 8859-16
<code>clist</code>	comma-list of integers
<i>⟨empty⟩</i>	native (Unicode) string

Table 2: Supported escapings. Non-alphanumeric characters are ignored, and capital letters are lower-cased before searching for the escaping in this list.

<i>⟨Escaping⟩</i>	description
<code>bytes</code> , or <code>empty</code>	arbitrary bytes
<code>hex</code> , <code>hexadecimal</code>	byte = two hexadecimal digits
<code>name</code>	see <code>\pdfescapename</code>
<code>string</code>	see <code>\pdfescapestring</code>
<code>url</code>	encoding used in URLs

<code>\str_set_convert:NnnnTF</code> <code>\str_gset_convert:NnnnTF</code>	<code>\str_set_convert:NnnnTF <str var> {<string>} {<name 1>} {<name 2>} {<true code>} {<false code>}</code>
---	--

As `\str_set_convert:Nnnn`, converts the $\langle string \rangle$ from the encoding given by $\langle name 1 \rangle$ to the encoding given by $\langle name 2 \rangle$, and assigns the result to $\langle str var \rangle$. Contrarily to `\str_set_convert:Nnnn`, the conditional variant does not raise errors in case the $\langle string \rangle$ is not valid according to the $\langle name 1 \rangle$ encoding, or cannot be expressed in the $\langle name 2 \rangle$ encoding. Instead, the $\langle false code \rangle$ is performed.

3 Creating 8-bit mappings

<code>\str_declare_eight_bit_encoding:nnn</code>	<code>\str_declare_eight_bit_encoding:nnn {<name>} {<mapping>} {<missing>}</code>
--	---

Declares the encoding $\langle name \rangle$ to map bytes to Unicode characters according to the $\langle mapping \rangle$, and map those bytes which are not mentioned in the $\langle mapping \rangle$ either to the replacement character (if they appear in $\langle missing \rangle$), or to themselves.

4 Possibilities, and things to do

Encoding/escaping-related tasks.

- In XeTeX/LuaTeX, would it be better to use the `^^^~....` approach to build a string from a given list of character codes? Namely, within a group, assign 0-9a-f and all characters we want to category “other”, then assign `^` the category superscript, and use `\scantokens`.
- Change `\str_set_convert:Nnnn` to expand its last two arguments.
- Describe the internal format in the code comments. Refuse code points in ["D800,"DFFF] in the internal representation?
- Add documentation about each encoding and escaping method, and add examples.
- The `hex` unescaping should raise an error for odd-token count strings.
- Decide what bytes should be escaped in the `url` escaping. Perhaps `!'()*~./0123456789_` are safe, and all other characters should be escaped?
- Automate generation of 8-bit mapping files.
- Change the framework for 8-bit encodings: for decoding from 8-bit to Unicode, use 256 integer registers; for encoding, use a tree-box.
- More encodings (see Heiko’s `stringenc`). CESU?
- More escapings: ASCII85, shell escapes, lua escapes, *etc.*?

Part IX

The l3quark package

Quarks

Two special types of constants in L^AT_EX3 are “quarks” and “scan marks”. By convention all constants of type quark start out with `\q_`, and scan marks start with `\s_`.

1 Quarks

Quarks are control sequences that expand to themselves and should therefore *never* be executed directly in the code. This would result in an endless loop!

They are meant to be used as delimiter in weird functions, the most common use case being the ‘stop token’ (*i.e.* `\q_stop`). For example, when writing a macro to parse a user-defined date

```
\date_parse:n {19/June/1981}
```

one might write a command such as

```
\cs_new:Npn \date_parse:n #1 { \date_parse_aux:w #1 \q_stop }
\cs_new:Npn \date_parse_aux:w #1 / #2 / #3 \q_stop
{ <do something with the date> }
```

Quarks are sometimes also used as error return values for functions that receive erroneous input. For example, in the function `\prop_get:NnN` to retrieve a value stored in some key of a property list, if the key does not exist then the return value is the quark `\q_no_value`. As mentioned above, such quarks are extremely fragile and it is imperative when using such functions that code is carefully written to check for pathological cases to avoid leakage of a quark into an uncontrolled environment.

Quarks also permit the following ingenious trick when parsing tokens: when you pick up a token in a temporary variable and you want to know whether you have picked up a particular quark, all you have to do is compare the temporary variable to the quark using `\tl_if_eq:NNTF`. A set of special quark testing functions is set up below. All the quark testing functions are expandable although the ones testing only single tokens are much faster. An example of the quark testing functions and their use in recursion can be seen in the implementation of `\clist_map_function:NN`.

2 Defining quarks

`\quark_new:N`

`\quark_new:N <quark>`

Creates a new `<quark>` which expands only to `<quark>`. The `<quark>` is defined globally, and an error message is raised if the name was already taken.

`\q_stop`

Used as a marker for delimited arguments, such as

```
\cs_set:Npn \tmp:w #1#2 \q_stop {#1}
```

<u><u>\q_mark</u></u>	Used as a marker for delimited arguments when <code>\q_stop</code> is already in use.
<u><u>\q_nil</u></u>	Quark to mark a null value in structured variables or functions. Used as an end delimiter when this may itself need to be tested (in contrast to <code>\q_stop</code> , which is only ever used as a delimiter).
<u><u>\q_no_value</u></u>	A canonical value for a missing value, when one is requested from a data structure. This is therefore used as a “return” value by functions such as <code>\prop_get:NnN</code> if there is no data to return.

3 Quark tests

The method used to define quarks means that the single token (N) tests are faster than the multi-token (n) tests. The latter should therefore only be used when the argument can definitely take more than a single token.

<u><u>\quark_if_nil_p:N</u></u> *	<u><u>\quark_if_nil:N</u></u> <i><token></i>
<u><u>\quark_if_nil:NTF</u></u> *	<u><u>\quark_if_nil:N</u></u> <i><token></i> <i>{<true code>}</i> <i>{<false code>}</i>
	Tests if the <i><token></i> is equal to <code>\q_nil</code> .
<u><u>\quark_if_nil_p:n</u></u> *	<u><u>\quark_if_nil_p:n</u></u> <i>{<token list>}</i>
<u><u>\quark_if_nil_p:(o V)</u></u> *	<u><u>\quark_if_nil:nTF</u></u> <i>{<token list>}</i> <i>{<true code>}</i> <i>{<false code>}</i>
<u><u>\quark_if_nil:nTF</u></u> *	Tests if the <i><token list></i> contains only <code>\q_nil</code> (distinct from <i><token list></i> being empty or
<u><u>\quark_if_nil:(o V)TF</u></u> *	containing <code>\q_nil</code> plus one or more other tokens).
<u><u>\quark_if_no_value_p:N</u></u> *	<u><u>\quark_if_no_value_p:N</u></u> <i><token></i>
<u><u>\quark_if_no_value_p:c</u></u> *	<u><u>\quark_if_no_value:N</u></u> <i><token></i> <i>{<true code>}</i> <i>{<false code>}</i>
<u><u>\quark_if_no_value:N</u></u> *	Tests if the <i><token></i> is equal to <code>\q_no_value</code> .
<u><u>\quark_if_no_value:cTF</u></u> *	
<u><u>\quark_if_no_value_p:n</u></u> *	<u><u>\quark_if_no_value_p:n</u></u> <i>{<token list>}</i>
<u><u>\quark_if_no_value:nTF</u></u> *	<u><u>\quark_if_no_value:nTF</u></u> <i>{<token list>}</i> <i>{<true code>}</i> <i>{<false code>}</i>
	Tests if the <i><token list></i> contains only <code>\q_no_value</code> (distinct from <i><token list></i> being empty or containing <code>\q_no_value</code> plus one or more other tokens).

4 Recursion

This module provides a uniform interface to intercepting and terminating loops as when one is doing tail recursion. The building blocks follow below and an example is shown in Section 5.

<u><u>\q_recursion_tail</u></u>	This quark is appended to the data structure in question and appears as a real element there. This means it gets any list separators around it.
---------------------------------	---

<hr/> <hr/> <code>\q_recursion_stop</code>	This quark is added <i>after</i> the data structure. Its purpose is to make it possible to terminate the recursion at any point easily.
<hr/> <hr/> <code>\quark_if_recursion_tail_stop:N</code>	<code>\quark_if_recursion_tail_stop:N <token></code> Tests if <i><token></i> contains only the marker <code>\q_recursion_tail</code> , and if so uses <code>\use_none_delimit_by_q_recursion_stop:w</code> to terminate the recursion that this belongs to. The recursion input must include the marker tokens <code>\q_recursion_tail</code> and <code>\q_recursion_stop</code> as the last two items.
<hr/> <hr/> <code>\quark_if_recursion_tail_stop:n</code> <code>\quark_if_recursion_tail_stop:o</code>	<code>\quark_if_recursion_tail_stop:n <{token list}></code> Updated: 2011-09-06 Tests if the <i><token list></i> contains only <code>\q_recursion_tail</code> , and if so uses <code>\use_none_delimit_by_q_recursion_stop:w</code> to terminate the recursion that this belongs to. The recursion input must include the marker tokens <code>\q_recursion_tail</code> and <code>\q_recursion_stop</code> as the last two items.
<hr/> <hr/> <code>\quark_if_recursion_tail_stop_do:Nn</code>	<code>\quark_if_recursion_tail_stop_do:Nn <token> <{insertion}></code> Tests if <i><token></i> contains only the marker <code>\q_recursion_tail</code> , and if so uses <code>\use_i_delimit_by_q_recursion_stop:w</code> to terminate the recursion that this belongs to. The recursion input must include the marker tokens <code>\q_recursion_tail</code> and <code>\q_recursion_stop</code> as the last two items. The <i><insertion></i> code is then added to the input stream after the recursion has ended.
<hr/> <hr/> <code>\quark_if_recursion_tail_stop_do:nn</code> <code>\quark_if_recursion_tail_stop_do:on</code>	<code>\quark_if_recursion_tail_stop_do:nn <{token list}> <{insertion}></code> Updated: 2011-09-06 Tests if the <i><token list></i> contains only <code>\q_recursion_tail</code> , and if so uses <code>\use_i_delimit_by_q_recursion_stop:w</code> to terminate the recursion that this belongs to. The recursion input must include the marker tokens <code>\q_recursion_tail</code> and <code>\q_recursion_stop</code> as the last two items. The <i><insertion></i> code is then added to the input stream after the recursion has ended.
<hr/> <hr/> <code>\quark_if_recursion_tail_break:NN</code> <code>\quark_if_recursion_tail_break:nN</code>	<code>\quark_if_recursion_tail_break:nN <{token list}> \<type>_map_break:</code> New: 2018-04-10 Tests if <i><token list></i> contains only <code>\q_recursion_tail</code> , and if so terminates the recursion using <code>\<type>_map_break:.</code> The recursion end should be marked by <code>\prg_break_point:Nn \<type>_map_break:.</code>

5 An example of recursion with quarks

Quarks are mainly used internally in the `expl3` code to define recursion functions such as `\tl_map_inline:nn` and so on. Here is a small example to demonstrate how to

use quarks in this fashion. We shall define a command called `\my_map_dbl:nn` which takes a token list and applies an operation to every *pair* of tokens. For example, `\my_map_dbl:nn {abcd} {[--#1--#2--]~}` would produce “[-a-b-] [-c-d-]”. Using quarks to define such functions simplifies their logic and ensures robustness in many cases.

Here’s the definition of `\my_map_dbl:nn`. First of all, define the function that does the processing based on the inline function argument `#2`. Then initiate the recursion using an internal function. The token list `#1` is terminated using `\q_recursion_tail`, with delimiters according to the type of recursion (here a pair of `\q_recursion_tail`), concluding with `\q_recursion_stop`. These quarks are used to mark the end of the token list being operated upon.

```
\cs_new:Npn \my_map_dbl:nn #1#2
{
  \cs_set:Npn \__my_map_dbl_fn:nn ##1 ##2 {#2}
  \__my_map_dbl:nn #1 \q_recursion_tail \q_recursion_tail
  \q_recursion_stop
}
```

The definition of the internal recursion function follows. First check if either of the input tokens are the termination quarks. Then, if not, apply the inline function to the two arguments.

```
\cs_new:Nn \__my_map_dbl:nn
{
  \quark_if_recursion_tail_stop:n {#1}
  \quark_if_recursion_tail_stop:n {#2}
  \__my_map_dbl_fn:nn {#1} {#2}
}
```

Finally, recurse:

```
\__my_map_dbl:nn
}
```

Note that contrarily to L^AT_EX3 built-in mapping functions, this mapping function cannot be nested, since the second map would overwrite the definition of `__my_map_dbl_fn:nn`.

6 Scan marks

Scan marks are control sequences set equal to `\scan_stop:`, hence never expand in an expansion context and are (largely) invisible if they are encountered in a typesetting context.

Like quarks, they can be used as delimiters in weird functions and are often safer to use for this purpose. Since they are harmless when executed by T_EX in non-expandable contexts, they can be used to mark the end of a set of instructions. This allows to skip to that point if the end of the instructions should not be performed (see l3regex).

`\scan_new:N`

New: 2018-04-01

`\scan_new:N` *<scan mark>*

Creates a new *<scan mark>* which is set equal to `\scan_stop:`. The *<scan mark>* is defined globally, and an error message is raised if the name was already taken by another scan mark.

<hr/> <code>\s_stop</code> <hr/>	Used at the end of a set of instructions, as a marker that can be jumped to using <code>\use_</code>
<hr/> <small>New: 2018-04-01</small> <hr/>	<code>none_delimit_by_s_stop:w</code> .

<hr/> <code>\use_none_delimit_by_s_stop:w</code> <hr/>	<code>\use_none_delimit_by_s_stop:w</code> <i><tokens></i> <code>\s_stop</code>
---	---

New: 2018-04-01

Removes the *<tokens>* and `\s_stop` from the input stream. This leads to a low-level T_EX error if `\s_stop` is absent.

Part X

The l3seq package

Sequences and stacks

L^AT_EX3 implements a “sequence” data type, which contain an ordered list of entries which may contain any *balanced text*. It is possible to map functions to sequences such that the function is applied to every item in the sequence.

Sequences are also used to implement stack functions in L^AT_EX3. This is achieved using a number of dedicated stack functions.

1 Creating and initialising sequences

<code>\seq_new:N</code>	<code>\seq_new:N <sequence></code>
<code>\seq_new:c</code>	

Creates a new *<sequence>* or raises an error if the name is already taken. The declaration is global. The *<sequence>* initially contains no items.

<code>\seq_clear:N</code>	<code>\seq_clear:N <sequence></code>
<code>\seq_clear:c</code>	
<code>\seq_gclear:N</code>	
<code>\seq_gclear:c</code>	

Clears all items from the *<sequence>*.

<code>\seq_clear_new:N</code>	<code>\seq_clear_new:N <sequence></code>
<code>\seq_clear_new:c</code>	
<code>\seq_gclear_new:N</code>	
<code>\seq_gclear_new:c</code>	

Ensures that the *<sequence>* exists globally by applying `\seq_new:N` if necessary, then applies `\seq_(g)clear:N` to leave the *<sequence>* empty.

<code>\seq_set_eq:NN</code>	<code>\seq_set_eq:NN <sequence₁> <sequence₂></code>
<code>\seq_set_eq:(cN Nc cc)</code>	
<code>\seq_gset_eq:NN</code>	
<code>\seq_gset_eq:(cN Nc cc)</code>	

Sets the content of *<sequence₁>* equal to that of *<sequence₂>*.

<code>\seq_set_from_clist:NN</code>	<code>\seq_set_from_clist:NN <sequence> <comma-list></code>
<code>\seq_set_from_clist:(cN Nc cc)</code>	
<code>\seq_set_from_clist:Nn</code>	
<code>\seq_set_from_clist:cn</code>	
<code>\seq_gset_from_clist:NN</code>	
<code>\seq_gset_from_clist:(cN Nc cc)</code>	
<code>\seq_gset_from_clist:Nn</code>	
<code>\seq_gset_from_clist:cn</code>	

New: 2014-07-17

Converts the data in the *<comma list>* into a *<sequence>*: the original *<comma list>* is unchanged.

`\seq_set_split:Nnn`
`\seq_set_split:NnV`
`\seq_gset_split:Nnn`
`\seq_gset_split:NnV`

New: 2011-08-15
 Updated: 2012-07-02

`\seq_set_split:Nnn` $\langle sequence \rangle$ $\{\langle delimiter \rangle\}$ $\{\langle token list \rangle\}$

Splits the $\langle token list \rangle$ into $\langle items \rangle$ separated by $\langle delimiter \rangle$, and assigns the result to the $\langle sequence \rangle$. Spaces on both sides of each $\langle item \rangle$ are ignored, then one set of outer braces is removed (if any); this space trimming behaviour is identical to that of `l3clist` functions. Empty $\langle items \rangle$ are preserved by `\seq_set_split:Nnn`, and can be removed afterwards using `\seq_remove_all:Nn` $\langle sequence \rangle$ $\{\langle \rangle\}$. The $\langle delimiter \rangle$ may not contain `{`, `}` or `#` (assuming \TeX 's normal category code régime). If the $\langle delimiter \rangle$ is empty, the $\langle token list \rangle$ is split into $\langle items \rangle$ as a $\langle token list \rangle$.

`\seq_concat:NNN`
`\seq_concat:ccc`
`\seq_gconcat:NNN`
`\seq_gconcat:ccc`

`\seq_concat:NNN` $\langle sequence_1 \rangle$ $\langle sequence_2 \rangle$ $\langle sequence_3 \rangle$

Concatenates the content of $\langle sequence_2 \rangle$ and $\langle sequence_3 \rangle$ together and saves the result in $\langle sequence_1 \rangle$. The items in $\langle sequence_2 \rangle$ are placed at the left side of the new sequence.

`\seq_if_exist_p:N` \star
`\seq_if_exist_p:c` \star
`\seq_if_exist:NTF` \star
`\seq_if_exist:cTF` \star

New: 2012-03-03

`\seq_if_exist_p:N` $\langle sequence \rangle$

`\seq_if_exist:NTF` $\langle sequence \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$

Tests whether the $\langle sequence \rangle$ is currently defined. This does not check that the $\langle sequence \rangle$ really is a sequence variable.

2 Appending data to sequences

`\seq_put_left:Nn`
`\seq_put_left:(NV|Nv|No|Nx|cn|cV|cv|co|cx)`
`\seq_gput_left:Nn`
`\seq_gput_left:(NV|Nv|No|Nx|cn|cV|cv|co|cx)`

`\seq_put_left:Nn` $\langle sequence \rangle$ $\{\langle item \rangle\}$

Appends the $\langle item \rangle$ to the left of the $\langle sequence \rangle$.

`\seq_put_right:Nn`
`\seq_put_right:(NV|Nv|No|Nx|cn|cV|cv|co|cx)`
`\seq_gput_right:Nn`
`\seq_gput_right:(NV|Nv|No|Nx|cn|cV|cv|co|cx)`

`\seq_put_right:Nn` $\langle sequence \rangle$ $\{\langle item \rangle\}$

Appends the $\langle item \rangle$ to the right of the $\langle sequence \rangle$.

3 Recovering items from sequences

Items can be recovered from either the left or the right of sequences. For implementation reasons, the actions at the left of the sequence are faster than those acting on the right. These functions all assign the recovered material locally, *i.e.* setting the $\langle token list variable \rangle$ used with `\tl_set:Nn` and *never* `\tl_gset:Nn`.

`\seq_get_left:NN`
`\seq_get_left:cN`

Updated: 2012-05-14

`\seq_get_left:NN` $\langle sequence \rangle$ $\langle token list variable \rangle$

Stores the left-most item from a $\langle sequence \rangle$ in the $\langle token list variable \rangle$ without removing it from the $\langle sequence \rangle$. The $\langle token list variable \rangle$ is assigned locally. If $\langle sequence \rangle$ is empty the $\langle token list variable \rangle$ is set to the special marker `\q_no_value`.

<code>\seq_get_right:NN</code> <code>\seq_get_right:cn</code> <hr/> Updated: 2012-05-19	<code>\seq_get_right:NN</code> $\langle sequence \rangle$ $\langle token list variable \rangle$ Stores the right-most item from a $\langle sequence \rangle$ in the $\langle token list variable \rangle$ without removing it from the $\langle sequence \rangle$. The $\langle token list variable \rangle$ is assigned locally. If $\langle sequence \rangle$ is empty the $\langle token list variable \rangle$ is set to the special marker <code>\q_no_value</code> .
---	--

<code>\seq_pop_left:NN</code> <code>\seq_pop_left:cn</code> <hr/> Updated: 2012-05-14	<code>\seq_pop_left:NN</code> $\langle sequence \rangle$ $\langle token list variable \rangle$ Pops the left-most item from a $\langle sequence \rangle$ into the $\langle token list variable \rangle$, <i>i.e.</i> removes the item from the sequence and stores it in the $\langle token list variable \rangle$. Both of the variables are assigned locally. If $\langle sequence \rangle$ is empty the $\langle token list variable \rangle$ is set to the special marker <code>\q_no_value</code> .
---	---

<code>\seq_gpop_left:NN</code> <code>\seq_gpop_left:cn</code> <hr/> Updated: 2012-05-14	<code>\seq_gpop_left:NN</code> $\langle sequence \rangle$ $\langle token list variable \rangle$ Pops the left-most item from a $\langle sequence \rangle$ into the $\langle token list variable \rangle$, <i>i.e.</i> removes the item from the sequence and stores it in the $\langle token list variable \rangle$. The $\langle sequence \rangle$ is modified globally, while the assignment of the $\langle token list variable \rangle$ is local. If $\langle sequence \rangle$ is empty the $\langle token list variable \rangle$ is set to the special marker <code>\q_no_value</code> .
---	---

<code>\seq_pop_right:NN</code> <code>\seq_pop_right:cn</code> <hr/> Updated: 2012-05-19	<code>\seq_pop_right:NN</code> $\langle sequence \rangle$ $\langle token list variable \rangle$ Pops the right-most item from a $\langle sequence \rangle$ into the $\langle token list variable \rangle$, <i>i.e.</i> removes the item from the sequence and stores it in the $\langle token list variable \rangle$. Both of the variables are assigned locally. If $\langle sequence \rangle$ is empty the $\langle token list variable \rangle$ is set to the special marker <code>\q_no_value</code> .
---	---

<code>\seq_gpop_right:NN</code> <code>\seq_gpop_right:cn</code> <hr/> Updated: 2012-05-19	<code>\seq_gpop_right:NN</code> $\langle sequence \rangle$ $\langle token list variable \rangle$ Pops the right-most item from a $\langle sequence \rangle$ into the $\langle token list variable \rangle$, <i>i.e.</i> removes the item from the sequence and stores it in the $\langle token list variable \rangle$. The $\langle sequence \rangle$ is modified globally, while the assignment of the $\langle token list variable \rangle$ is local. If $\langle sequence \rangle$ is empty the $\langle token list variable \rangle$ is set to the special marker <code>\q_no_value</code> .
---	---

<code>\seq_item:Nn *</code> <code>\seq_item:cn *</code> <hr/> New: 2014-07-17	<code>\seq_item:Nn</code> $\langle sequence \rangle$ $\{\langle integer expression \rangle\}$ Indexing items in the $\langle sequence \rangle$ from 1 at the top (left), this function evaluates the $\langle integer expression \rangle$ and leaves the appropriate item from the sequence in the input stream. If the $\langle integer expression \rangle$ is negative, indexing occurs from the bottom (right) of the sequence. If the $\langle integer expression \rangle$ is larger than the number of items in the $\langle sequence \rangle$ (as calculated by <code>\seq_count:N</code>) then the function expands to nothing.
---	--

T_EXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the $\langle item \rangle$ does not expand further when appearing in an x-type argument expansion.

<code>\seq_rand_item:N *</code> <code>\seq_rand_item:c *</code> <hr/> New: 2016-12-06	<code>\seq_rand_item:N</code> $\langle seq var \rangle$ Selects a pseudo-random item of the $\langle sequence \rangle$. If the $\langle sequence \rangle$ is empty the result is empty. This is not available in older versions of X _Ǝ T _E X.
---	---

T_EXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the $\langle item \rangle$ does not expand further when appearing in an x-type argument expansion.

4 Recovering values from sequences with branching

The functions in this section combine tests for non-empty sequences with recovery of an item from the sequence. They offer increased readability and performance over separate testing and recovery phases.

`\seq_get_left:NNTF`
`\seq_get_left:cNTF`

New: 2012-05-14
Updated: 2012-05-19

`\seq_get_left:NNTF` $\langle sequence \rangle$ $\langle token list variable \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$

If the $\langle sequence \rangle$ is empty, leaves the $\langle false code \rangle$ in the input stream. The value of the $\langle token list variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, stores the left-most item from the $\langle sequence \rangle$ in the $\langle token list variable \rangle$ without removing it from the $\langle sequence \rangle$, then leaves the $\langle true code \rangle$ in the input stream. The $\langle token list variable \rangle$ is assigned locally.

`\seq_get_right:NNTF`
`\seq_get_right:cNTF`

New: 2012-05-19

`\seq_get_right:NNTF` $\langle sequence \rangle$ $\langle token list variable \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$

If the $\langle sequence \rangle$ is empty, leaves the $\langle false code \rangle$ in the input stream. The value of the $\langle token list variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, stores the right-most item from the $\langle sequence \rangle$ in the $\langle token list variable \rangle$ without removing it from the $\langle sequence \rangle$, then leaves the $\langle true code \rangle$ in the input stream. The $\langle token list variable \rangle$ is assigned locally.

`\seq_pop_left:NNTF`
`\seq_pop_left:cNTF`

New: 2012-05-14
Updated: 2012-05-19

`\seq_pop_left:NNTF` $\langle sequence \rangle$ $\langle token list variable \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$

If the $\langle sequence \rangle$ is empty, leaves the $\langle false code \rangle$ in the input stream. The value of the $\langle token list variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, pops the left-most item from the $\langle sequence \rangle$ in the $\langle token list variable \rangle$, *i.e.* removes the item from the $\langle sequence \rangle$, then leaves the $\langle true code \rangle$ in the input stream. Both the $\langle sequence \rangle$ and the $\langle token list variable \rangle$ are assigned locally.

`\seq_gpop_left:NNTF`
`\seq_gpop_left:cNTF`

New: 2012-05-14
Updated: 2012-05-19

`\seq_gpop_left:NNTF` $\langle sequence \rangle$ $\langle token list variable \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$

If the $\langle sequence \rangle$ is empty, leaves the $\langle false code \rangle$ in the input stream. The value of the $\langle token list variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, pops the left-most item from the $\langle sequence \rangle$ in the $\langle token list variable \rangle$, *i.e.* removes the item from the $\langle sequence \rangle$, then leaves the $\langle true code \rangle$ in the input stream. The $\langle sequence \rangle$ is modified globally, while the $\langle token list variable \rangle$ is assigned locally.

`\seq_pop_right:NNTF`
`\seq_pop_right:cNTF`

New: 2012-05-19

`\seq_pop_right:NNTF` $\langle sequence \rangle$ $\langle token list variable \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$

If the $\langle sequence \rangle$ is empty, leaves the $\langle false code \rangle$ in the input stream. The value of the $\langle token list variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, pops the right-most item from the $\langle sequence \rangle$ in the $\langle token list variable \rangle$, *i.e.* removes the item from the $\langle sequence \rangle$, then leaves the $\langle true code \rangle$ in the input stream. Both the $\langle sequence \rangle$ and the $\langle token list variable \rangle$ are assigned locally.

```
\seq_gpop_right:NNTF
\seq_gpop_right:cNTF
```

New: 2012-05-19

```
\seq_gpop_right:NNTF <sequence> <token list variable> {<true code>} {<false code>}
```

If the $\langle sequence \rangle$ is empty, leaves the $\langle false code \rangle$ in the input stream. The value of the $\langle token list variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, pops the right-most item from the $\langle sequence \rangle$ in the $\langle token list variable \rangle$, i.e. removes the item from the $\langle sequence \rangle$, then leaves the $\langle true code \rangle$ in the input stream. The $\langle sequence \rangle$ is modified globally, while the $\langle token list variable \rangle$ is assigned locally.

5 Modifying sequences

While sequences are normally used as ordered lists, it may be necessary to modify the content. The functions here may be used to update sequences, while retaining the order of the unaffected entries.

```
\seq_remove_duplicates:N
\seq_remove_duplicates:c
\seq_gremove_duplicates:N
\seq_gremove_duplicates:c
```

```
\seq_remove_duplicates:N <sequence>
```

Removes duplicate items from the $\langle sequence \rangle$, leaving the left most copy of each item in the $\langle sequence \rangle$. The $\langle item \rangle$ comparison takes place on a token basis, as for `\tl_if_eq:nnTF`.

TpXhackers note: This function iterates through every item in the $\langle sequence \rangle$ and does a comparison with the $\langle items \rangle$ already checked. It is therefore relatively slow with large sequences.

```
\seq_remove_all:Nn
\seq_remove_all:cn
\seq_gremove_all:Nn
\seq_gremove_all:cn
```

```
\seq_remove_all:Nn <sequence> {<item>}
```

Removes every occurrence of $\langle item \rangle$ from the $\langle sequence \rangle$. The $\langle item \rangle$ comparison takes place on a token basis, as for `\tl_if_eq:nnTF`.

```
\seq_reverse:N
\seq_reverse:c
\seq_greverse:N
\seq_greverse:c
```

New: 2014-07-18

```
\seq_reverse:N <sequence>
```

Reverses the order of the items stored in the $\langle sequence \rangle$.

```
\seq_sort:Nn
\seq_sort:cn
\seq_gsort:Nn
\seq_gsort:cn
```

New: 2017-02-06

```
\seq_sort:Nn <sequence> {<comparison code>}
```

Sorts the items in the $\langle sequence \rangle$ according to the $\langle comparison code \rangle$, and assigns the result to $\langle sequence \rangle$. The details of sorting comparison are described in [Section 1](#).

6 Sequence conditionals

```
\seq_if_empty_p:N *
\seq_if_empty_p:c *
\seq_if_empty:NNTF *
\seq_if_empty:cNTF *
```

```
\seq_if_empty_p:N <sequence>
```

```
\seq_if_empty:NNTF <sequence> {<true code>} {<false code>}
```

Tests if the $\langle sequence \rangle$ is empty (containing no items).

<code>\seq_if_in:NnTF</code>	<code>\seq_if_in:NnTF <sequence> {(item)} {(true code)} {(false code)}</code>
<code>\seq_if_in:(NV Nv No Nx cn cV cv co cx)TF</code>	

Tests if the $\langle item \rangle$ is present in the $\langle sequence \rangle$.

7 Mapping to sequences

<code>\seq_map_function:NN</code> ☆	<code>\seq_map_function:NN <sequence> <function></code>
-------------------------------------	---

<code>\seq_map_function:cN</code> ☆

Updated: 2012-06-29

Applies $\langle function \rangle$ to every $\langle item \rangle$ stored in the $\langle sequence \rangle$. The $\langle function \rangle$ will receive one argument for each iteration. The $\langle items \rangle$ are returned from left to right. The function `\seq_map_inline:Nn` is faster than `\seq_map_function:NN` for sequences with more than about 10 items.

<code>\seq_map_inline:Nn</code>	<code>\seq_map_inline:Nn <sequence> {(inline function)}</code>
---------------------------------	--

<code>\seq_map_inline:cn</code>

Updated: 2012-06-29

Applies $\langle inline function \rangle$ to every $\langle item \rangle$ stored within the $\langle sequence \rangle$. The $\langle inline function \rangle$ should consist of code which will receive the $\langle item \rangle$ as #1. The $\langle items \rangle$ are returned from left to right.

<code>\seq_map_variable:NNn</code>	<code>\seq_map_variable:NNn <sequence> <variable> {(code)}</code>
<code>\seq_map_variable:(Ncn cNn ccn)</code>	

Updated: 2012-06-29

Stores each $\langle item \rangle$ of the $\langle sequence \rangle$ in turn in the (token list) $\langle variable \rangle$ and applies the $\langle code \rangle$. The $\langle code \rangle$ will usually make use of the $\langle variable \rangle$, but this is not enforced. The assignments to the $\langle variable \rangle$ are local. The $\langle items \rangle$ are returned from left to right.

<code>\seq_map_break:</code> ☆	<code>\seq_map_break:</code>
--------------------------------	------------------------------

Updated: 2012-06-29

Used to terminate a `\seq_map...` function before all entries in the $\langle sequence \rangle$ have been processed. This normally takes place within a conditional statement, for example

```
\seq_map_inline:Nn \l_my_seq
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \seq_map_break: }
  {
    % Do something useful
  }
}
```

Use outside of a `\seq_map...` scenario leads to low level T_EX errors.

T_EXhackers note: When the mapping is broken, additional tokens may be inserted before further items are taken from the input stream. This depends on the design of the mapping function.

`\seq_map_break:n` ☆

Updated: 2012-06-29

`\seq_map_break:n {<code>}`

Used to terminate a `\seq_map...` function before all entries in the *<sequence>* have been processed, inserting the *<code>* after the mapping has ended. This normally takes place within a conditional statement, for example

```
\seq_map_inline:Nn \l_my_seq
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \seq_map_break:n { <code> } }
  {
    % Do something useful
  }
}
```

Use outside of a `\seq_map...` scenario leads to low level TeX errors.

TeXhackers note: When the mapping is broken, additional tokens may be inserted before the *<code>* is inserted into the input stream. This depends on the design of the mapping function.

`\seq_count:N` ★

`\seq_count:c` ★

New: 2012-07-13

`\seq_count:N <sequence>`

Leaves the number of items in the *<sequence>* in the input stream as an *<integer denotation>*. The total number of items in a *<sequence>* includes those which are empty and duplicates, *i.e.* every item in a *<sequence>* is unique.

8 Using the content of sequences directly

`\seq_use:Nnnn` ★

`\seq_use:cnnn` ★

New: 2013-05-26

`\seq_use:Nnnn <seq var> {<separator between two>}`

`{<separator between more than two>} {<separator between final two>}`

Places the contents of the *<seq var>* in the input stream, with the appropriate *<separator>* between the items. Namely, if the sequence has more than two items, the *<separator between more than two>* is placed between each pair of items except the last, for which the *<separator between final two>* is used. If the sequence has exactly two items, then they are placed in the input stream separated by the *<separator between two>*. If the sequence has a single item, it is placed in the input stream, and an empty sequence produces no output. An error is raised if the variable does not exist or if it is invalid.

For example,

```
\seq_set_split:Nnn \l_tmpa_seq { | } { a | b | c | {de} | f }
\seq_use:Nnnn \l_tmpa_seq { ~and~ } { ,~ } { ,~and~ }
```

inserts “a, b, c, de, and f” in the input stream. The first separator argument is not used in this case because the sequence has more than 2 items.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the *<items>* do not expand further when appearing in an x-type argument expansion.

`\seq_use:Nn` ★

`\seq_use:cn` ★

New: 2013-05-26

`\seq_use:Nn` $\langle seq\ var \rangle$ $\{\langle separator \rangle\}$

Places the contents of the $\langle seq\ var \rangle$ in the input stream, with the $\langle separator \rangle$ between the items. If the sequence has a single item, it is placed in the input stream with no $\langle separator \rangle$, and an empty sequence produces no output. An error is raised if the variable does not exist or if it is invalid.

For example,

```
\seq_set_split:Nnn \l_tmpa_seq { | } { a | b | c | {de} | f }
\seq_use:Nn \l_tmpa_seq { ~and~ }
```

inserts “a and b and c and de and f” in the input stream.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the $\langle items \rangle$ do not expand further when appearing in an `x`-type argument expansion.

9 Sequences as stacks

Sequences can be used as stacks, where data is pushed to and popped from the top of the sequence. (The left of a sequence is the top, for performance reasons.) The stack functions for sequences are not intended to be mixed with the general ordered data functions detailed in the previous section: a sequence should either be used as an ordered data type or as a stack, but not in both ways.

`\seq_get:NN`

`\seq_get:cn`

Updated: 2012-05-14

`\seq_get:NN` $\langle sequence \rangle$ $\langle token\ list\ variable \rangle$

Reads the top item from a $\langle sequence \rangle$ into the $\langle token\ list\ variable \rangle$ without removing it from the $\langle sequence \rangle$. The $\langle token\ list\ variable \rangle$ is assigned locally. If $\langle sequence \rangle$ is empty the $\langle token\ list\ variable \rangle$ is set to the special marker `\q_no_value`.

`\seq_pop:NN`

`\seq_pop:cn`

Updated: 2012-05-14

`\seq_pop:NN` $\langle sequence \rangle$ $\langle token\ list\ variable \rangle$

Pops the top item from a $\langle sequence \rangle$ into the $\langle token\ list\ variable \rangle$. Both of the variables are assigned locally. If $\langle sequence \rangle$ is empty the $\langle token\ list\ variable \rangle$ is set to the special marker `\q_no_value`.

`\seq_gpop:NN`

`\seq_gpop:cn`

Updated: 2012-05-14

`\seq_gpop:NN` $\langle sequence \rangle$ $\langle token\ list\ variable \rangle$

Pops the top item from a $\langle sequence \rangle$ into the $\langle token\ list\ variable \rangle$. The $\langle sequence \rangle$ is modified globally, while the $\langle token\ list\ variable \rangle$ is assigned locally. If $\langle sequence \rangle$ is empty the $\langle token\ list\ variable \rangle$ is set to the special marker `\q_no_value`.

`\seq_get:NNTF`

`\seq_get:cNTF`

New: 2012-05-14

Updated: 2012-05-19

`\seq_get:NNTF` $\langle sequence \rangle$ $\langle token\ list\ variable \rangle$ $\{\langle true\ code \rangle\}$ $\{\langle false\ code \rangle\}$

If the $\langle sequence \rangle$ is empty, leaves the $\langle false\ code \rangle$ in the input stream. The value of the $\langle token\ list\ variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle sequence \rangle$ is non-empty, stores the top item from a $\langle sequence \rangle$ in the $\langle token\ list\ variable \rangle$ without removing it from the $\langle sequence \rangle$. The $\langle token\ list\ variable \rangle$ is assigned locally.

`\seq_pop:NNTF`
`\seq_pop:cNTF`

New: 2012-05-14
Updated: 2012-05-19

`\seq_pop:NNTF <sequence> <token list variable> {\true code} {\false code}`

If the `<sequence>` is empty, leaves the `<false code>` in the input stream. The value of the `<token list variable>` is not defined in this case and should not be relied upon. If the `<sequence>` is non-empty, pops the top item from the `<sequence>` in the `<token list variable>`, *i.e.* removes the item from the `<sequence>`. Both the `<sequence>` and the `<token list variable>` are assigned locally.

`\seq_gpop:NNTF`
`\seq_gpop:cNTF`

New: 2012-05-14
Updated: 2012-05-19

`\seq_gpop:NNTF <sequence> <token list variable> {\true code} {\false code}`

If the `<sequence>` is empty, leaves the `<false code>` in the input stream. The value of the `<token list variable>` is not defined in this case and should not be relied upon. If the `<sequence>` is non-empty, pops the top item from the `<sequence>` in the `<token list variable>`, *i.e.* removes the item from the `<sequence>`. The `<sequence>` is modified globally, while the `<token list variable>` is assigned locally.

`\seq_push:Nn`
`\seq_push:(NV|Nv|No|Nx|cn|cV|cv|co|cx)`
`\seq_gpush:Nn`
`\seq_gpush:(NV|Nv|No|Nx|cn|cV|cv|co|cx)`

`\seq_push:Nn <sequence> {\item}`

Adds the `{\item}` to the top of the `<sequence>`.

10 Sequences as sets

Sequences can also be used as sets, such that all of their items are distinct. Usage of sequences as sets is not currently widespread, hence no specific set function is provided. Instead, it is explained here how common set operations can be performed by combining several functions described in earlier sections. When using sequences to implement sets, one should be careful not to rely on the order of items in the sequence representing the set.

Sets should not contain several occurrences of a given item. To make sure that a `<sequence variable>` only has distinct items, use `\seq_remove_duplicates:N <sequence variable>`. This function is relatively slow, and to avoid performance issues one should only use it when necessary.

Some operations on a set `<seq var>` are straightforward. For instance, `\seq_count:N <seq var>` expands to the number of items, while `\seq_if_in:NnTF <seq var> {\item}` tests if the `<item>` is in the set.

Adding an `<item>` to a set `<seq var>` can be done by appending it to the `<seq var>` if it is not already in the `<seq var>`:

```
\seq_if_in:NnF <seq var> {\item}
{ \seq_put_right:Nn <seq var> {\item} }
```

Removing an `<item>` from a set `<seq var>` can be done using `\seq_remove_all:Nn`,

```
\seq_remove_all:Nn <seq var> {\item}
```

The intersection of two sets `<seq var1 and <seq var2 can be stored into <seq var3 by collecting items of <seq var1 which are in <seq var2.`

```

\seq_clear:N <seq var3>
\seq_map_inline:Nn <seq var1>
{
\seq_if_in:NnT <seq var2> {#1}
{ \seq_put_right:Nn <seq var3> {#1} }
}

```

The code as written here only works if $\langle seq\ var_3 \rangle$ is different from the other two sequence variables. To cover all cases, items should first be collected in a sequence $\backslash l_ \langle pkg \rangle_internal_seq$, then $\langle seq\ var_3 \rangle$ should be set equal to this internal sequence. The same remark applies to other set functions.

The union of two sets $\langle seq\ var_1 \rangle$ and $\langle seq\ var_2 \rangle$ can be stored into $\langle seq\ var_3 \rangle$ through

```

\seq_concat:NNN <seq var3> <seq var1> <seq var2>
\seq_remove_duplicates:N <seq var3>

```

or by adding items to (a copy of) $\langle seq\ var_1 \rangle$ one by one

```

\seq_set_eq:NN <seq var3> <seq var1>
\seq_map_inline:Nn <seq var2>
{
\seq_if_in:NnF <seq var3> {#1}
{ \seq_put_right:Nn <seq var3> {#1} }
}

```

The second approach is faster than the first when the $\langle seq\ var_2 \rangle$ is short compared to $\langle seq\ var_1 \rangle$.

The difference of two sets $\langle seq\ var_1 \rangle$ and $\langle seq\ var_2 \rangle$ can be stored into $\langle seq\ var_3 \rangle$ by removing items of the $\langle seq\ var_2 \rangle$ from (a copy of) the $\langle seq\ var_1 \rangle$ one by one.

```

\seq_set_eq:NN <seq var3> <seq var1>
\seq_map_inline:Nn <seq var2>
{ \seq_remove_all:Nn <seq var3> {#1} }

```

The symmetric difference of two sets $\langle seq\ var_1 \rangle$ and $\langle seq\ var_2 \rangle$ can be stored into $\langle seq\ var_3 \rangle$ by computing the difference between $\langle seq\ var_1 \rangle$ and $\langle seq\ var_2 \rangle$ and storing the result as $\backslash l_ \langle pkg \rangle_internal_seq$, then the difference between $\langle seq\ var_2 \rangle$ and $\langle seq\ var_1 \rangle$, and finally concatenating the two differences to get the symmetric differences.

```

\seq_set_eq:NN \l\_ \langle pkg \rangle\_internal\_seq <seq var1>
\seq_map_inline:Nn <seq var2>
{ \seq_remove_all:Nn \l\_ \langle pkg \rangle\_internal\_seq {#1} }
\seq_set_eq:NN <seq var3> <seq var2>
\seq_map_inline:Nn <seq var1>
{ \seq_remove_all:Nn <seq var3> {#1} }
\seq_concat:NNN <seq var3> <seq var3> \l\_ \langle pkg \rangle\_internal\_seq

```

11 Constant and scratch sequences

$\backslash c_empty_seq$ Constant that is always empty.

New: 2012-07-02

`\l_tmpa_seq`
`\l_tmpb_seq`

New: 2012-04-26

Scratch sequences for local assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

`\g_tmpa_seq`
`\g_tmpb_seq`

New: 2012-04-26

Scratch sequences for global assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

12 Viewing sequences

`\seq_show:N`
`\seq_show:c`

Updated: 2015-08-01

`\seq_show:N` $\langle sequence \rangle$
Displays the entries in the $\langle sequence \rangle$ in the terminal.

`\seq_log:N`
`\seq_log:c`

New: 2014-08-12
Updated: 2015-08-01

`\seq_log:N` $\langle sequence \rangle$
Writes the entries in the $\langle sequence \rangle$ in the log file.

Part XI

The l3int package

Integers

Calculation and comparison of integer values can be carried out using literal numbers, `int` registers, constants and integers stored in token list variables. The standard operators `+`, `-`, `/` and `*` and parentheses can be used within such expressions to carry arithmetic operations. This module carries out these functions on *integer expressions* (“`intexpr`”).

1 Integer expressions

`\int_eval:n *` `\int_eval:n {(integer expression)}`

Evaluates the *integer expression* and leaves the result in the input stream as an integer denotation: for positive results an explicit sequence of decimal digits not starting with 0, for negative results - followed by such a sequence, and 0 for zero. The *integer expression* should consist, after expansion, of +, -, *, /, (,) and of course integer operands. The result is calculated by applying standard mathematical rules with the following peculiarities:

- / denotes division rounded to the closest integer with ties rounded away from zero;
- there is an error and the overall expression evaluates to zero whenever the absolute value of any intermediate result exceeds $2^{31} - 1$, except in the case of scaling operations $a*b/c$, for which $a*b$ may be arbitrarily large;
- parentheses may not appear after unary + or -, namely placing +(or -(at the start of an expression or after +, -, *, / or (leads to an error.

Each integer operand can be either an integer variable (with no need for `\int_use:N`) or an integer denotation. For example both

```
\int_eval:n { 5 + 4 * 3 - ( 3 + 4 * 5 ) }
```

and

```
\tl_new:N \l_my_tl
\tl_set:Nn \l_my_tl { 5 }
\int_new:N \l_my_int
\int_set:Nn \l_my_int { 4 }
\int_eval:n { \l_my_tl + \l_my_int * 3 - ( 3 + 4 * 5 ) }
```

evaluate to -6 because `\l_my_tl` expands to the integer denotation 5. As the *integer expression* is fully expanded from left to right during evaluation, fully expandable and restricted-expandable functions can both be used, and `\exp_not:n` and its variants have no effect while `\exp_not:N` may incorrectly interrupt the expression.

T_EXhackers note: Exactly two expansions are needed to evaluate `\int_eval:n`. The result is *not* an *internal integer*, and therefore requires suitable termination if used in a T_EX-style integer assignment.

As all T_EX integers, integer operands can also be dimension or skip variables, converted to integers in `sp`, or octal numbers given as ' followed by digits other than 8 and 9, or hexadecimal numbers given as " followed by digits or upper case letters from A to F, or the character code of some character or one-character control sequence, given as 'char'.

<hr/> \int_eval:w ★ <hr/>	\int_eval:w $\langle integer\ expression \rangle$
New: 2018-03-30	Evaluates the $\langle integer\ expression \rangle$ as described for \int_eval:n . The end of the expression is the first token encountered that cannot form part of such an expression. If that token is \scan_stop : it is removed, otherwise not. Spaces do <i>not</i> terminate the expression. However, spaces terminate explicit integers, and this may terminate the expression: for instance, \int_eval:w 1_+1_9 expands to 29 since the digit 9 is not part of the expression.
<hr/> \int_abs:n ★ <hr/>	\int_abs:n $\{\langle integer\ expression \rangle\}$
Updated: 2012-09-26	Evaluates the $\langle integer\ expression \rangle$ as described for \int_eval:n and leaves the absolute value of the result in the input stream as an $\langle integer\ denotation \rangle$ after two expansions.
<hr/> \int_div_round:nn ★ <hr/>	\int_div_round:nn $\{\langle intexpr_1 \rangle\} \{\langle intexpr_2 \rangle\}$
Updated: 2012-09-26	Evaluates the two $\langle integer\ expressions \rangle$ as described earlier, then divides the first value by the second, and rounds the result to the closest integer. Ties are rounded away from zero. Note that this is identical to using / directly in an $\langle integer\ expression \rangle$. The result is left in the input stream as an $\langle integer\ denotation \rangle$ after two expansions.
<hr/> \int_div_truncate:nn ★ <hr/>	\int_div_truncate:nn $\{\langle intexpr_1 \rangle\} \{\langle intexpr_2 \rangle\}$
Updated: 2012-02-09	Evaluates the two $\langle integer\ expressions \rangle$ as described earlier, then divides the first value by the second, and rounds the result towards zero. Note that division using / rounds to the closest integer instead. The result is left in the input stream as an $\langle integer\ denotation \rangle$ after two expansions.
<hr/> \int_max:nn ★ \int_min:nn ★ <hr/>	\int_max:nn $\{\langle intexpr_1 \rangle\} \{\langle intexpr_2 \rangle\}$ \int_min:nn $\{\langle intexpr_1 \rangle\} \{\langle intexpr_2 \rangle\}$
Updated: 2012-09-26	Evaluates the $\langle integer\ expressions \rangle$ as described for \int_eval:n and leaves either the larger or smaller value in the input stream as an $\langle integer\ denotation \rangle$ after two expansions.
<hr/> \int_mod:nn ★ <hr/>	\int_mod:nn $\{\langle intexpr_1 \rangle\} \{\langle intexpr_2 \rangle\}$
Updated: 2012-09-26	Evaluates the two $\langle integer\ expressions \rangle$ as described earlier, then calculates the integer remainder of dividing the first expression by the second. This is obtained by subtracting \int_div_truncate:nn $\{\langle intexpr_1 \rangle\} \{\langle intexpr_2 \rangle\}$ times $\langle intexpr_2 \rangle$ from $\langle intexpr_1 \rangle$. Thus, the result has the same sign as $\langle intexpr_1 \rangle$ and its absolute value is strictly less than that of $\langle intexpr_2 \rangle$. The result is left in the input stream as an $\langle integer\ denotation \rangle$ after two expansions.

2 Creating and initialising integers

<hr/> \int_new:N \int_new:c <hr/>	\int_new:N $\langle integer \rangle$
	Creates a new $\langle integer \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle integer \rangle$ is initially equal to 0.

<code>\int_const:Nn</code>	<code>\int_const:Nn <integer> {<integer expression>}</code>
<code>\int_const:cn</code>	Creates a new constant <i><integer></i> or raises an error if the name is already taken. The value of the <i><integer></i> is set globally to the <i><integer expression></i> .
Updated: 2011-10-22	

<code>\int_zero:N</code>	<code>\int_zero:N <integer></code>
<code>\int_zero:c</code>	Sets <i><integer></i> to 0.
<code>\int_gzero:N</code>	
<code>\int_gzero:c</code>	

<code>\int_zero_new:N</code>	<code>\int_zero_new:N <integer></code>
<code>\int_zero_new:c</code>	Ensures that the <i><integer></i> exists globally by applying <code>\int_new:N</code> if necessary, then applies <code>\int_(g)zero:N</code> to leave the <i><integer></i> set to zero.
<code>\int_gzero_new:N</code>	
<code>\int_gzero_new:c</code>	
New: 2011-12-13	

<code>\int_set_eq:NN</code>	<code>\int_set_eq:NN <integer₁₂</code>
<code>\int_set_eq:(cN Nc cc)</code>	Sets the content of <i><integer_{1 equal to that of <i><integer_{2.}</i>}</i>
<code>\int_gset_eq:NN</code>	
<code>\int_gset_eq:(cN Nc cc)</code>	

<code>\int_if_exist_p:N *</code>	<code>\int_if_exist_p:N <int></code>
<code>\int_if_exist_p:c *</code>	<code>\int_if_exist:NTF <int> {<true code>} {<false code>}</code>
<code>\int_if_exist:NTF *</code>	Tests whether the <i><int></i> is currently defined. This does not check that the <i><int></i> really is an integer variable.
<code>\int_if_exist:cTF *</code>	
New: 2012-03-03	

3 Setting and incrementing integers

<code>\int_add:Nn</code>	<code>\int_add:Nn <integer> {<integer expression>}</code>
<code>\int_add:cn</code>	Adds the result of the <i><integer expression></i> to the current content of the <i><integer></i> .
<code>\int_gadd:Nn</code>	
<code>\int_gadd:cn</code>	
Updated: 2011-10-22	

<code>\int_decr:N</code>	<code>\int_decr:N <integer></code>
<code>\int_decr:c</code>	Decreases the value stored in <i><integer></i> by 1.
<code>\int_gdecr:N</code>	
<code>\int_gdecr:c</code>	

<code>\int_incr:N</code>	<code>\int_incr:N <integer></code>
<code>\int_incr:c</code>	Increases the value stored in <i><integer></i> by 1.
<code>\int_gincr:N</code>	
<code>\int_gincr:c</code>	

<code>\int_set:Nn</code>	<code>\int_set:Nn <integer> {<integer expression>}</code>
<code>\int_set:cn</code>	
<code>\int_gset:Nn</code>	Sets <i><integer></i> to the value of <i><integer expression></i> , which must evaluate to an integer (as described for <code>\int_eval:n</code>).
<code>\int_gset:cn</code>	

Updated: 2011-10-22

<code>\int_sub:Nn</code>	<code>\int_sub:Nn <integer> {<integer expression>}</code>
<code>\int_sub:cn</code>	
<code>\int_gsub:Nn</code>	Subtracts the result of the <i><integer expression></i> from the current content of the <i><integer></i> .
<code>\int_gsub:cn</code>	

Updated: 2011-10-22

4 Using integers

<code>\int_use:N</code> *	<code>\int_use:N <integer></code>
<code>\int_use:c</code> *	
	Recovers the content of an <i><integer></i> and places it directly in the input stream. An error is raised if the variable does not exist or if it is invalid. Can be omitted in places where an <i><integer></i> is required (such as in the first and third arguments of <code>\int_compare:nNnTF</code>).

Updated: 2011-10-22

TeXhackers note: `\int_use:N` is the TeX primitive `\the`: this is one of several L^AT_EX3 names for this primitive.

5 Integer expression conditionals

<code>\int_compare_p:nNn</code> *	<code>\int_compare_p:nNn {<intexpr₁>} <relation> {<intexpr₂>}</code>
<code>\int_compare:nNnTF</code> *	<code>\int_compare:nNnTF {<intexpr₁>} <relation> {<intexpr₂>} {<true code>} {<false code>}</code>

This function first evaluates each of the *<integer expressions>* as described for `\int_eval:n`. The two results are then compared using the *<relation>*:

Equal	=
Greater than	>
Less than	<

This function is less flexible than `\int_compare:nTF` but around 5 times faster.

```

\int_compare_p:n * \int_compare_p:n
\int_compare:nTF * {
    <intexpr1> <relation1>
    ...
    <intexprN> <relationN>
    <intexprN+1>
}
\int_compare:nTF
{
    <intexpr1> <relation1>
    ...
    <intexprN> <relationN>
    <intexprN+1>
}
{<true code>} {<false code>}

```

Updated: 2013-01-13

This function evaluates the *<integer expressions>* as described for `\int_eval:n` and compares consecutive result using the corresponding *<relation>*, namely it compares *<intexpr₁>* and *<intexpr₂>* using the *<relation₁>*, then *<intexpr₂>* and *<intexpr₃>* using the *<relation₂>*, until finally comparing *<intexpr_N>* and *<intexpr_{N+1}>* using the *<relation_N>*. The test yields **true** if all comparisons are **true**. Each *<integer expression>* is evaluated only once, and the evaluation is lazy, in the sense that if one comparison is **false**, then no other *<integer expression>* is evaluated and no other comparison is performed. The *<relations>* can be any of the following:

Equal	= or ==
Greater than or equal to	>=
Greater than	>
Less than or equal to	<=
Less than	<
Not equal	!=

This function is more flexible than `\int_compare:nNnTF` but around 5 times slower.

<code>\int_case:nn</code> *	<code>\int_case:nnTF</code> { <i>test integer expression</i> }
<code>\int_case:nnTF</code> *	{
	{ <i>intexpr case₁</i> } { <i>code case₁</i> }
	{ <i>intexpr case₂</i> } { <i>code case₂</i> }
	...
	{ <i>intexpr case_n</i> } { <i>code case_n</i> }
	}
	{ <i>true code</i> }
	{ <i>false code</i> }

New: 2013-07-24

This function evaluates the *test integer expression* and compares this in turn to each of the *integer expression cases*. If the two are equal then the associated *code* is left in the input stream and other cases are discarded. If any of the cases are matched, the *true code* is also inserted into the input stream (after the code for the appropriate case), while if none match then the *false code* is inserted. The function `\int_case:nn`, which does nothing if there is no match, is also available. For example

```
\int_case:nnF
{ 2 * 5 }
{
  { 5 }      { Small }
  { 4 + 6 }   { Medium }
  { -2 * 10 } { Negative }
}
{ No idea! }
```

leaves “Medium” in the input stream.

<code>\int_if_even_p:n</code> *	<code>\int_if_odd_p:n</code> { <i>integer expression</i> }
<code>\int_if_even:nTF</code> *	<code>\int_if_odd:nTF</code> { <i>integer expression</i> }
<code>\int_if_odd_p:n</code> *	{ <i>true code</i> } { <i>false code</i> }
<code>\int_if_odd:nTF</code> *	

This function first evaluates the *integer expression* as described for `\int_eval:n`. It then evaluates if this is odd or even, as appropriate.

6 Integer expression loops

<code>\int_do_until:nNnn</code> ☆	<code>\int_do_until:nNnn</code> { <i>intexpr₁</i> } <i>relation</i> { <i>intexpr₂</i> } { <i>code</i> }
-----------------------------------	---

Places the *code* in the input stream for T_EX to process, and then evaluates the relationship between the two *integer expressions* as described for `\int_compare:nNnTF`. If the test is **false** then the *code* is inserted into the input stream again and a loop occurs until the *relation* is **true**.

<code>\int_do_while:nNnn</code> ☆	<code>\int_do_while:nNnn</code> { <i>intexpr₁</i> } <i>relation</i> { <i>intexpr₂</i> } { <i>code</i> }
-----------------------------------	---

Places the *code* in the input stream for T_EX to process, and then evaluates the relationship between the two *integer expressions* as described for `\int_compare:nNnTF`. If the test is **true** then the *code* is inserted into the input stream again and a loop occurs until the *relation* is **false**.

<hr/> <code>\int_until_do:nNnn</code> ☆ <hr/>	<code>\int_until_do:nNnn {⟨intexpr₁⟩} ⟨relation⟩ {⟨intexpr₂⟩} {⟨code⟩}</code> Evaluates the relationship between the two <i>⟨integer expressions⟩</i> as described for <code>\int_compare:nNnTF</code> , and then places the <i>⟨code⟩</i> in the input stream if the <i>⟨relation⟩</i> is false . After the <i>⟨code⟩</i> has been processed by T _E X the test is repeated, and a loop occurs until the test is true .
<hr/> <code>\int_while_do:nNnn</code> ☆ <hr/>	<code>\int_while_do:nNnn {⟨intexpr₁⟩} ⟨relation⟩ {⟨intexpr₂⟩} {⟨code⟩}</code> Evaluates the relationship between the two <i>⟨integer expressions⟩</i> as described for <code>\int_compare:nNnTF</code> , and then places the <i>⟨code⟩</i> in the input stream if the <i>⟨relation⟩</i> is true . After the <i>⟨code⟩</i> has been processed by T _E X the test is repeated, and a loop occurs until the test is false .
<hr/> <code>\int_do_until:nn</code> ☆ <hr/> Updated: 2013-01-13 <hr/>	<code>\int_do_until:nn {⟨integer relation⟩} {⟨code⟩}</code> Places the <i>⟨code⟩</i> in the input stream for T _E X to process, and then evaluates the <i>⟨integer relation⟩</i> as described for <code>\int_compare:nTF</code> . If the test is false then the <i>⟨code⟩</i> is inserted into the input stream again and a loop occurs until the <i>⟨relation⟩</i> is true .
<hr/> <code>\int_do_while:nn</code> ☆ <hr/> Updated: 2013-01-13 <hr/>	<code>\int_do_while:nn {⟨integer relation⟩} {⟨code⟩}</code> Places the <i>⟨code⟩</i> in the input stream for T _E X to process, and then evaluates the <i>⟨integer relation⟩</i> as described for <code>\int_compare:nTF</code> . If the test is true then the <i>⟨code⟩</i> is inserted into the input stream again and a loop occurs until the <i>⟨relation⟩</i> is false .
<hr/> <code>\int_until_do:nn</code> ☆ <hr/> Updated: 2013-01-13 <hr/>	<code>\int_until_do:nn {⟨integer relation⟩} {⟨code⟩}</code> Evaluates the <i>⟨integer relation⟩</i> as described for <code>\int_compare:nTF</code> , and then places the <i>⟨code⟩</i> in the input stream if the <i>⟨relation⟩</i> is false . After the <i>⟨code⟩</i> has been processed by T _E X the test is repeated, and a loop occurs until the test is true .
<hr/> <code>\int_while_do:nn</code> ☆ <hr/> Updated: 2013-01-13 <hr/>	<code>\int_while_do:nn {⟨integer relation⟩} {⟨code⟩}</code> Evaluates the <i>⟨integer relation⟩</i> as described for <code>\int_compare:nTF</code> , and then places the <i>⟨code⟩</i> in the input stream if the <i>⟨relation⟩</i> is true . After the <i>⟨code⟩</i> has been processed by T _E X the test is repeated, and a loop occurs until the test is false .

7 Integer step functions

<code>\int_step_function:nN</code>	☆	<code>\int_step_function:nN {⟨final value⟩} ⟨function⟩</code>
<code>\int_step_function:nnN</code>	☆	<code>\int_step_function:nnN {⟨initial value⟩} {⟨final value⟩} ⟨function⟩</code>
<code>\int_step_function:nnnN</code>	☆	<code>\int_step_function:nnnN {⟨initial value⟩} {⟨step⟩} {⟨final value⟩} ⟨function⟩</code>

New: 2012-06-04
Updated: 2018-04-22

This function first evaluates the $\langle initial\ value \rangle$, $\langle step \rangle$ and $\langle final\ value \rangle$, all of which should be integer expressions. The $\langle function \rangle$ is then placed in front of each $\langle value \rangle$ from the $\langle initial\ value \rangle$ to the $\langle final\ value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$). The $\langle step \rangle$ must be non-zero. If the $\langle step \rangle$ is positive, the loop stops when the $\langle value \rangle$ becomes larger than the $\langle final\ value \rangle$. If the $\langle step \rangle$ is negative, the loop stops when the $\langle value \rangle$ becomes smaller than the $\langle final\ value \rangle$. The $\langle function \rangle$ should absorb one numerical argument. For example

```
\cs_set:Npn \my_func:n #1 { [I~saw~#1] \quad }
\int_step_function:nnnN { 1 } { 1 } { 5 } \my_func:n
```

would print

```
[I saw 1]   [I saw 2]   [I saw 3]   [I saw 4]   [I saw 5]
```

The functions `\int_step_function:nN` and `\int_step_function:nnN` both use a fixed $\langle step \rangle$ of 1, and in the case of `\int_step_function:nN` the $\langle initial\ value \rangle$ is also fixed as 1. These functions are provided as simple short-cuts for code clarity.

<code>\int_step_inline:nn</code>	<code>\int_step_inline:nn {⟨final value⟩} {⟨code⟩}</code>
<code>\int_step_inline:nnn</code>	<code>\int_step_inline:nnn {⟨initial value⟩} {⟨final value⟩} {⟨code⟩}</code>
<code>\int_step_inline:nnnn</code>	<code>\int_step_inline:nnnn {⟨initial value⟩} {⟨step⟩} {⟨final value⟩} {⟨code⟩}</code>

New: 2012-06-04
Updated: 2018-04-22

This function first evaluates the $\langle initial\ value \rangle$, $\langle step \rangle$ and $\langle final\ value \rangle$, all of which should be integer expressions. Then for each $\langle value \rangle$ from the $\langle initial\ value \rangle$ to the $\langle final\ value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$), the $\langle code \rangle$ is inserted into the input stream with `#1` replaced by the current $\langle value \rangle$. Thus the $\langle code \rangle$ should define a function of one argument (`#1`).

The functions `\int_step_inline:nn` and `\int_step_inline:nnn` both use a fixed $\langle step \rangle$ of 1, and in the case of `\int_step_inline:nn` the $\langle initial\ value \rangle$ is also fixed as 1. These functions are provided as simple short-cuts for code clarity.

<code>\int_step_variable:nNn</code>	<code>\int_step_variable:nNn {⟨final value⟩} ⟨tl var⟩ {⟨code⟩}</code>
<code>\int_step_variable:nnNn</code>	<code>\int_step_variable:nnNn {⟨initial value⟩} {⟨final value⟩} ⟨tl var⟩ {⟨code⟩}</code>
<code>\int_step_variable:nnnNn</code>	<code>\int_step_variable:nnnNn {⟨initial value⟩} {⟨step⟩} {⟨final value⟩} ⟨tl var⟩ {⟨code⟩}</code>

New: 2012-06-04
Updated: 2018-04-22

This function first evaluates the $\langle initial\ value \rangle$, $\langle step \rangle$ and $\langle final\ value \rangle$, all of which should be integer expressions. Then for each $\langle value \rangle$ from the $\langle initial\ value \rangle$ to the $\langle final\ value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$), the $\langle code \rangle$ is inserted into the input stream, with the $\langle tl\ var \rangle$ defined as the current $\langle value \rangle$. Thus the $\langle code \rangle$ should make use of the $\langle tl\ var \rangle$.

The functions `\int_step_variable:nNn` and `\int_step_variable:nnNn` both use a fixed $\langle step \rangle$ of 1, and in the case of `\int_step_variable:nNn` the $\langle initial\ value \rangle$ is also fixed as 1. These functions are provided as simple short-cuts for code clarity.

8 Formatting integers

Integers can be placed into the output stream with formatting. These conversions apply to any integer expressions.

<code>\int_to_arabic:n</code> *	<code>\int_to_arabic:n {⟨integer expression⟩}</code>
---------------------------------	--

Updated: 2011-10-22

Places the value of the $\langle integer\ expression \rangle$ in the input stream as digits, with category code 12 (other).

<code>\int_to_alph:n</code> *	<code>\int_to_alph:n {⟨integer expression⟩}</code>
<code>\int_to_Alph:n</code> *	

Updated: 2011-09-17

Evaluates the $\langle integer\ expression \rangle$ and converts the result into a series of letters, which are then left in the input stream. The conversion rule uses the 26 letters of the English alphabet, in order, adding letters when necessary to increase the total possible range of representable numbers. Thus

```
\int_to_alph:n { 1 }
```

places a in the input stream,

```
\int_to_alph:n { 26 }
```

is represented as z and

```
\int_to_alph:n { 27 }
```

is converted to aa. For conversions using other alphabets, use `\int_to_symbols:nnn` to define an alphabet-specific function. The basic `\int_to_alph:n` and `\int_to_Alph:n` functions should not be modified. The resulting tokens are digits with category code 12 (other) and letters with category code 11 (letter).

<code>\int_to_symbols:nnn</code> *	<code>\int_to_symbols:nnn</code> $\{ \langle integer\ expression \rangle \} \{ \langle total\ symbols \rangle \}$ $\{ \langle value\ to\ symbol\ mapping \rangle \}$
------------------------------------	--

Updated: 2011-09-17

This is the low-level function for conversion of an $\langle integer\ expression \rangle$ into a symbolic form (often letters). The $\langle total\ symbols \rangle$ available should be given as an integer expression. Values are actually converted to symbols according to the $\langle value\ to\ symbol\ mapping \rangle$. This should be given as $\langle total\ symbols \rangle$ pairs of entries, a number and the appropriate symbol. Thus the `\int_to_alph:n` function is defined as

```
\cs_new:Npn \int_to_alph:n #1
{
  \int_to_symbols:nnn {#1} { 26 }
  {
    { 1 } { a }
    { 2 } { b }
    ...
    { 26 } { z }
  }
}
```

<hr/>	
<code>\int_to_bin:n *</code>	<code>\int_to_bin:n {⟨integer expression⟩}</code>
<hr/>	
<code>New: 2014-02-11</code>	Calculates the value of the <i>⟨integer expression⟩</i> and places the binary representation of the result in the input stream.
<hr/>	
<code>\int_to_hex:n *</code>	<code>\int_to_hex:n {⟨integer expression⟩}</code>
<code>\int_to_Hex:n *</code>	Calculates the value of the <i>⟨integer expression⟩</i> and places the hexadecimal (base 16) representation of the result in the input stream. Letters are used for digits beyond 9: lower case letters for <code>\int_to_hex:n</code> and upper case ones for <code>\int_to_Hex:n</code> . The resulting tokens are digits with category code 12 (other) and letters with category code 11 (letter).
<hr/>	
<code>New: 2014-02-11</code>	
<hr/>	
<code>\int_to_oct:n *</code>	<code>\int_to_oct:n {⟨integer expression⟩}</code>
<hr/>	
<code>New: 2014-02-11</code>	Calculates the value of the <i>⟨integer expression⟩</i> and places the octal (base 8) representation of the result in the input stream. The resulting tokens are digits with category code 12 (other) and letters with category code 11 (letter).
<hr/>	
<code>\int_to_base:nn *</code>	<code>\int_to_base:nn {⟨integer expression⟩} {⟨base⟩}</code>
<code>\int_to_Base:nn *</code>	Calculates the value of the <i>⟨integer expression⟩</i> and converts it into the appropriate representation in the <i>⟨base⟩</i> ; the later may be given as an integer expression. For bases greater than 10 the higher “digits” are represented by letters from the English alphabet: lower case letters for <code>\int_to_base:n</code> and upper case ones for <code>\int_to_Base:n</code> . The maximum <i>⟨base⟩</i> value is 36. The resulting tokens are digits with category code 12 (other) and letters with category code 11 (letter).
<hr/>	
<code>Updated: 2014-02-11</code>	
<hr/>	
TeXhackers note: This is a generic version of <code>\int_to_bin:n</code> , <i>etc.</i>	
<hr/>	
<code>\int_to_roman:n ☆</code>	<code>\int_to_roman:n {⟨integer expression⟩}</code>
<code>\int_to_Roman:n ☆</code>	Places the value of the <i>⟨integer expression⟩</i> in the input stream as Roman numerals, either lower case (<code>\int_to_roman:n</code>) or upper case (<code>\int_to_Roman:n</code>). If the value is negative or zero, the output is empty. The Roman numerals are letters with category code 11 (letter). The letters used are <code>mdclxvi</code> , repeated as needed: the notation with bars (such as <code>v̄</code> for 5000) is <i>not</i> used. For instance <code>\int_to_roman:n { 8249 }</code> expands to <code>mmmmmmmmccxlix</code> .
<hr/>	
<code>Updated: 2011-10-22</code>	
<hr/>	

9 Converting from other formats to integers

<hr/>	
<code>\int_from_alph:n *</code>	<code>\int_from_alph:n {⟨letters⟩}</code>
<hr/>	
<code>Updated: 2014-08-25</code>	Converts the <i>⟨letters⟩</i> into the integer (base 10) representation and leaves this in the input stream. The <i>⟨letters⟩</i> are first converted to a string, with no expansion. Lower and upper case letters from the English alphabet may be used, with “a” equal to 1 through to “z” equal to 26. The function also accepts a leading sign, made of + and -. This is the inverse function of <code>\int_to_alph:n</code> and <code>\int_to_Alph:n</code> .
<hr/>	

<hr/> <code>\int_from_bin:n</code> ★ <hr/>	<code>\int_from_bin:n {⟨binary number⟩}</code>
New: 2014-02-11 Updated: 2014-08-25 <hr/>	Converts the <i>⟨binary number⟩</i> into the integer (base 10) representation and leaves this in the input stream. The <i>⟨binary number⟩</i> is first converted to a string, with no expansion. The function accepts a leading sign, made of + and -, followed by binary digits. This is the inverse function of <code>\int_to_bin:n</code> .
<hr/> <code>\int_from_hex:n</code> ★ <hr/>	<code>\int_from_hex:n {⟨hexadecimal number⟩}</code>
New: 2014-02-11 Updated: 2014-08-25 <hr/>	Converts the <i>⟨hexadecimal number⟩</i> into the integer (base 10) representation and leaves this in the input stream. Digits greater than 9 may be represented in the <i>⟨hexadecimal number⟩</i> by upper or lower case letters. The <i>⟨hexadecimal number⟩</i> is first converted to a string, with no expansion. The function also accepts a leading sign, made of + and -. This is the inverse function of <code>\int_to_hex:n</code> and <code>\int_to_Hex:n</code> .
<hr/> <code>\int_from_oct:n</code> ★ <hr/>	<code>\int_from_oct:n {⟨octal number⟩}</code>
New: 2014-02-11 Updated: 2014-08-25 <hr/>	Converts the <i>⟨octal number⟩</i> into the integer (base 10) representation and leaves this in the input stream. The <i>⟨octal number⟩</i> is first converted to a string, with no expansion. The function accepts a leading sign, made of + and -, followed by octal digits. This is the inverse function of <code>\int_to_oct:n</code> .
<hr/> <code>\int_from_roman:n</code> ★ <hr/>	<code>\int_from_roman:n {⟨roman numeral⟩}</code>
Updated: 2014-08-25 <hr/>	Converts the <i>⟨roman numeral⟩</i> into the integer (base 10) representation and leaves this in the input stream. The <i>⟨roman numeral⟩</i> is first converted to a string, with no expansion. The <i>⟨roman numeral⟩</i> may be in upper or lower case; if the numeral contains characters besides <code>mdclxvi</code> or <code>MDCLXVI</code> then the resulting value is -1. This is the inverse function of <code>\int_to_roman:n</code> and <code>\int_to_Roman:n</code> .
<hr/> <code>\int_from_base:nn</code> ★ <hr/>	<code>\int_from_base:nn {⟨number⟩} {⟨base⟩}</code>
Updated: 2014-08-25 <hr/>	Converts the <i>⟨number⟩</i> expressed in <i>⟨base⟩</i> into the appropriate value in base 10. The <i>⟨number⟩</i> is first converted to a string, with no expansion. The <i>⟨number⟩</i> should consist of digits and letters (either lower or upper case), plus optionally a leading sign. The maximum <i>⟨base⟩</i> value is 36. This is the inverse function of <code>\int_to_base:nn</code> and <code>\int_to_Base:nn</code> .

10 Random integers

<hr/> <code>\int_rand:nn</code> ★ <hr/>	<code>\int_rand:nn {⟨integer expr₁⟩} {⟨integer expr₂⟩}</code>
New: 2016-12-06 Updated: 2018-04-27 <hr/>	Evaluates the two <i>⟨integer expressions⟩</i> and produces a pseudo-random number between the two (with bounds included). This is not available in older versions of X _Ǝ TeX.
<hr/> <code>\int_rand:n</code> ★ <hr/>	<code>\int_rand:n {⟨integer expr⟩}</code>
New: 2018-05-05 <hr/>	Evaluates the <i>⟨integer expression⟩</i> then produces a pseudo-random number between 1 and the <i>⟨integer expr⟩</i> (included). This is not available in older versions of X _Ǝ TeX.

11 Viewing integers

<hr/> <code>\int_show:N</code> <code>\int_show:c</code> <hr/>	<code>\int_show:N <integer></code> Displays the value of the <i><integer></i> on the terminal.
<hr/> <code>\int_show:n</code> <hr/> <div>New: 2011-11-22 Updated: 2015-08-07</div>	<code>\int_show:n {(integer expression)}</code> Displays the result of evaluating the <i><integer expression></i> on the terminal.
<hr/> <code>\int_log:N</code> <code>\int_log:c</code> <hr/> <div>New: 2014-08-22 Updated: 2015-08-03</div>	<code>\int_log:N <integer></code> Writes the value of the <i><integer></i> in the log file.
<hr/> <code>\int_log:n</code> <hr/> <div>New: 2014-08-22 Updated: 2015-08-07</div>	<code>\int_log:n {(integer expression)}</code> Writes the result of evaluating the <i><integer expression></i> in the log file.

12 Constant integers

<hr/> <code>\c_zero_int</code> <code>\c_one_int</code> <hr/> <div>New: 2018-05-07</div>	Integer values used with primitive tests and assignments: their self-terminating nature makes these more convenient and faster than literal numbers.
<hr/> <code>\c_max_int</code> <hr/>	The maximum value that can be stored as an integer.
<hr/> <code>\c_max_register_int</code> <hr/>	Maximum number of registers.
<hr/> <code>\c_max_char_int</code> <hr/>	Maximum character code completely supported by the engine.

13 Scratch integers

<hr/> <code>\l_tmpa_int</code> <code>\l_tmpb_int</code> <hr/>	Scratch integer for local assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<hr/> <code>\g_tmpa_int</code> <code>\g_tmpb_int</code> <hr/>	Scratch integer for global assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

13.1 Direct number expansion

`\int_value:w` ★
 New: 2018-03-27

`\int_value:w` $\langle integer \rangle$
`\int_value:w` $\langle integer\ denotation \rangle$ $\langle optional\ space \rangle$

Expands the following tokens until an $\langle integer \rangle$ is formed, and leaves a normalized form (no leading sign except for negative numbers, no leading digit 0 except for zero) in the input stream as category code 12 (other) characters. The $\langle integer \rangle$ can consist of any number of signs (with intervening spaces) followed by

- an integer variable (in fact, any T_EX register except `\toks`) or
- explicit digits (or by ‘ $\langle octal\ digits \rangle$ ’ or “ $\langle hexadecimal\ digits \rangle$ ” or ‘ $\langle character \rangle$ ’).

In this last case expansion stops once a non-digit is found; if that is a space it is removed as in `f`-expansion, and so `\exp_stop_f:` may be employed as an end marker. Note that protected functions *are* expanded by this process.

This function requires exactly one expansion to produce a value, and so is suitable for use in cases where a number is required “directly”. In general, `\int_eval:n` is the preferred approach to generating numbers.

T_EXhackers note: This is the T_EX primitive `\number`.

14 Primitive conditionals

`\if_int_compare:w` ★

`\if_int_compare:w` $\langle integer_1 \rangle$ $\langle relation \rangle$ $\langle integer_2 \rangle$
 $\langle true\ code \rangle$
`\else:`
 $\langle false\ code \rangle$
`\fi:`

Compare two integers using $\langle relation \rangle$, which must be one of =, < or > with category code 12. The `\else:` branch is optional.

T_EXhackers note: These are both names for the T_EX primitive `\ifnum`.

`\if_case:w` ★
`\or:` ★

`\if_case:w` $\langle integer \rangle$ $\langle case_0 \rangle$
`\or:` $\langle case_1 \rangle$
`\or:` ...
`\else:` $\langle default \rangle$
`\fi:`

Selects a case to execute based on the value of the $\langle integer \rangle$. The first case ($\langle case_0 \rangle$) is executed if $\langle integer \rangle$ is 0, the second ($\langle case_1 \rangle$) if the $\langle integer \rangle$ is 1, *etc.* The $\langle integer \rangle$ may be a literal, a constant or an integer expression (*e.g.* using `\int_eval:n`).

T_EXhackers note: These are the T_EX primitives `\ifcase` and `\or`.

<u><code>\if_int_odd:w</code></u> *	<code>\if_int_odd:w</code> $\langle tokens \rangle$ $\langle optional\ space \rangle$ $\langle true\ code \rangle$ <code>\else:</code> $\langle true\ code \rangle$ <code>\fi:</code>
-------------------------------------	---

Expands $\langle tokens \rangle$ until a non-numeric token or a space is found, and tests whether the resulting $\langle integer \rangle$ is odd. If so, $\langle true\ code \rangle$ is executed. The `\else:` branch is optional.

TeXhackers note: This is the TeX primitive `\ifodd`.

Part XII

The l3flag package: Expandable flags

Flags are the only data-type that can be modified in expansion-only contexts. This module is meant mostly for kernel use: in almost all cases, booleans or integers should be preferred to flags because they are very significantly faster.

A flag can hold any non-negative value, which we call its *height*. In expansion-only contexts, a flag can only be “raised”: this increases the *height* by 1. The *height* can also be queried expandably. However, decreasing it, or setting it to zero requires non-expandable assignments.

Flag variables are always local. They are referenced by a *flag name* such as `str_missing`. The *flag name* is used as part of `\use:c` constructions hence is expanded at point of use. It must expand to character tokens only, with no spaces.

A typical use case of flags would be to keep track of whether an exceptional condition has occurred during expandable processing, and produce a meaningful (non-expandable) message after the end of the expandable processing. This is exemplified by `l3str-convert`, which for performance reasons performs conversions of individual characters expandably and for readability reasons produces a single error message describing incorrect inputs that were encountered.

Flags should not be used without carefully considering the fact that raising a flag takes a time and memory proportional to its height. Flags should not be used unless unavoidable.

1 Setting up flags

<code>\flag_new:n</code>	<code>\flag_new:n {<flag name>}</code>
--------------------------	--

Creates a new flag with a name given by *flag name*, or raises an error if the name is already taken. The *flag name* may not contain spaces. The declaration is global, but flags are always local variables. The *flag* initially has zero height.

<code>\flag_clear:n</code>	<code>\flag_clear:n {<flag name>}</code>
----------------------------	--

The *flag*’s height is set to zero. The assignment is local.

<code>\flag_clear_new:n</code>	<code>\flag_clear_new:n {<flag name>}</code>
--------------------------------	--

Ensures that the *flag* exists globally by applying `\flag_new:n` if necessary, then applies `\flag_clear:n`, setting the height to zero locally.

<code>\flag_show:n</code>	<code>\flag_show:n {<flag name>}</code>
---------------------------	---

Displays the *flag*’s height in the terminal.

<code>\flag_log:n</code>	<code>\flag_log:n {<flag name>}</code>
--------------------------	--

Writes the *flag*’s height to the log file.

2 Expandable flag commands

<hr/> <code>\flag_if_exist:n *</code> <hr/> <code>\flag_if_exist:n\underline{TF} *</code>	<code>\flag_if_exist:n {⟨flag name⟩}</code> This function returns <code>true</code> if the <code>⟨flag name⟩</code> references a flag that has been defined previously, and <code>false</code> otherwise.
<hr/> <code>\flag_if_raised_p:n *</code> <hr/> <code>\flag_if_raised:n\underline{TF} *</code>	<code>\flag_if_raised:n {⟨flag name⟩}</code> This function returns <code>true</code> if the <code>⟨flag⟩</code> has non-zero height, and <code>false</code> if the <code>⟨flag⟩</code> has zero height.
<hr/> <code>\flag_height:n *</code> <hr/>	<code>\flag_height:n {⟨flag name⟩}</code> Expands to the height of the <code>⟨flag⟩</code> as an integer denotation.
<hr/> <code>\flag_raise:n *</code> <hr/>	<code>\flag_raise:n {⟨flag name⟩}</code> The <code>⟨flag⟩</code> 's height is increased by 1 locally.

Part XIII

The l3prg package

Control structures

Conditional processing in L^AT_EX3 is defined as something that performs a series of tests, possibly involving assignments and calling other functions that do not read further ahead in the input stream. After processing the input, a *state* is returned. The states returned are *⟨true⟩* and *⟨false⟩*.

L^AT_EX3 has two forms of conditional flow processing based on these states. The first form is predicate functions that turn the returned state into a boolean *⟨true⟩* or *⟨false⟩*. For example, the function `\cs_if_free_p:N` checks whether the control sequence given as its argument is free and then returns the boolean *⟨true⟩* or *⟨false⟩* values to be used in testing with `\if_predicate:w` or in functions to be described below. The second form is the kind of functions choosing a particular argument from the input stream based on the result of the testing as in `\cs_if_free:NTF` which also takes one argument (the *N*) and then executes either **true** or **false** depending on the result.

T_EXhackers note: The arguments are executed after exiting the underlying `\if... \fi` structure.

1 Defining a set of conditional functions

```
\prg_new_conditional:Npnn
\prg_set_conditional:Npnn
\prg_new_conditional:Nnn
\prg_set_conditional:Nnn
```

Updated: 2012-02-06

```
\prg_new_conditional:Npnn \<name>:<arg spec> <parameters> {\<conditions>} {\<code>}
\prg_new_conditional:Nnn \<name>:<arg spec> {\<conditions>} {\<code>}
```

These functions create a family of conditionals using the same *{⟨code⟩}* to perform the test created. Those conditionals are expandable if *⟨code⟩* is. The **new** versions check for existing definitions and perform assignments globally (cf. `\cs_new:Npn`) whereas the **set** versions do no check and perform assignments locally (cf. `\cs_set:Npn`). The conditionals created are dependent on the comma-separated list of *⟨conditions⟩*, which should be one or more of **p**, **T**, **F** and **TF**.

```
\prg_new_protected_conditional:Npnn \prg_new_protected_conditional:Npnn \<name>:<arg spec> <parameters>
\prg_set_protected_conditional:Npnn {\<conditions>} {\<code>}
\prg_new_protected_conditional:Nnn \prg_new_protected_conditional:Nnn \<name>:<arg spec>
\prg_set_protected_conditional:Nnn {\<conditions>} {\<code>}
```

Updated: 2012-02-06

These functions create a family of protected conditionals using the same *{⟨code⟩}* to perform the test created. The *⟨code⟩* does not need to be expandable. The **new** version check for existing definitions and perform assignments globally (cf. `\cs_new:Npn`) whereas the **set** version do not (cf. `\cs_set:Npn`). The conditionals created are depended on the comma-separated list of *⟨conditions⟩*, which should be one or more of **T**, **F** and **TF** (not **p**).

The conditionals are defined by `\prg_new_conditional:Npnn` and friends as:

- `\<name>_p:<arg spec>` — a predicate function which will supply either a logical `true` or logical `false`. This function is intended for use in cases where one or more logical tests are combined to lead to a final outcome. This function cannot be defined for `protected` conditionals.
- `\<name>:<arg spec>T` — a function with one more argument than the original `<arg spec>` demands. The `<true branch>` code in this additional argument will be left on the input stream only if the test is `true`.
- `\<name>:<arg spec>F` — a function with one more argument than the original `<arg spec>` demands. The `<false branch>` code in this additional argument will be left on the input stream only if the test is `false`.
- `\<name>:<arg spec>TF` — a function with two more argument than the original `<arg spec>` demands. The `<true branch>` code in the first additional argument will be left on the input stream if the test is `true`, while the `<false branch>` code in the second argument will be left on the input stream if the test is `false`.

The `<code>` of the test may use `<parameters>` as specified by the second argument to `\prg_set_conditional:Npnn`: this should match the `<argument specification>` but this is not enforced. The `Nnn` versions infer the number of arguments from the argument specification given (cf. `\cs_new:Nn`, etc.). Within the `<code>`, the functions `\prg_return_true:` and `\prg_return_false:` are used to indicate the logical outcomes of the test.

An example can easily clarify matters here:

```
\prg_set_conditional:Npnn \foo_if_bar:NN #1#2 { p , T , TF }
{
  \if_meaning:w \l_tmpa_tl #1
  \prg_return_true:
\else:
  \if_meaning:w \l_tmpa_tl #2
  \prg_return_true:
\else:
  \prg_return_false:
\fi:
\fi:
}
```

This defines the function `\foo_if_bar_p:NN`, `\foo_if_bar:NNTF` and `\foo_if_bar:NNT` but not `\foo_if_bar:NNF` (because `F` is missing from the `<conditions>` list). The return statements take care of resolving the remaining `\else:` and `\fi:` before returning the state. There must be a return statement for each branch; failing to do so will result in erroneous output if that branch is executed.

<code>\prg_new_eq_conditional:Nnn</code>	<code>\prg_new_eq_conditional:Nnn \<name1>:<arg spec1> \<name2>:<arg spec2></code>
<code>\prg_set_eq_conditional:Nnn</code>	<code>{<conditions>}</code>

These functions copy a family of conditionals. The `new` version checks for existing definitions (cf. `\cs_new_eq:NN`) whereas the `set` version does not (cf. `\cs_set_eq:NN`). The conditionals copied are depended on the comma-separated list of `<conditions>`, which should be one or more of `p`, `T`, `F` and `TF`.

<code>\prg_return_true:</code>	<code>*</code>	<code>\prg_return_true:</code>
<code>\prg_return_false:</code>	<code>*</code>	<code>\prg_return_false:</code>

These “return” functions define the logical state of a conditional statement. They appear within the code for a conditional function generated by `\prg_set_conditional:Npnn`, *etc.*, to indicate when a true or false branch should be taken. While they may appear multiple times each within the code of such conditionals, the execution of the conditional must result in the expansion of one of these two functions *exactly once*.

The return functions trigger what is internally an *f*-expansion process to complete the evaluation of the conditional. Therefore, after `\prg_return_true:` or `\prg_return_false:` there must be no non-expandable material in the input stream for the remainder of the expansion of the conditional code. This includes other instances of either of these functions.

<code>\prg_generate_conditional_variant:Nnn</code>	<code>\prg_generate_conditional_variant:Nnn \<name>:\<arg spec></code>
	<code>{\<variant argument specifiers>} {\<condition specifiers>}</code>

New: 2017-12-12

Defines argument-specifier variants of conditionals. This is equivalent to running `\cs_generate_variant:Nn \<conditional> {\<variant argument specifiers>}` on each *<conditional>* described by the *<condition specifiers>*. These base-form *<conditionals>* are obtained from the *<name>* and *<arg spec>* as described for `\prg_new_conditional:Npnn`, and they should be defined.

2 The boolean data type

This section describes a boolean data type which is closely connected to conditional processing as sometimes you want to execute some code depending on the value of a switch (*e.g.*, draft/final) and other times you perhaps want to use it as a predicate function in an `\if_predicate:w` test. The problem of the primitive `\if_false:` and `\if_true:` tokens is that it is not always safe to pass them around as they may interfere with scanning for termination of primitive conditional processing. Therefore, we employ two canonical booleans: `\c_true_bool` or `\c_false_bool`. Besides preventing problems as described above, it also allows us to implement a simple boolean parser supporting the logical operations And, Or, Not, *etc.* which can then be used on both the boolean type and predicate functions.

All conditional `\bool_` functions except assignments are expandable and expect the input to also be fully expandable (which generally means being constructed from predicate functions and booleans, possibly nested).

T_EXhackers note: The `bool` data type is not implemented using the `\iffalse/\iftrue` primitives, in contrast to `\newif`, *etc.*, in plain T_EX, L^AT_EX 2_ε and so on. Programmers should not base use of `bool` switches on any particular expectation of the implementation.

<code>\bool_new:N</code>	<code>\bool_new:N \<boolean></code>
<code>\bool_new:c</code>	

Creates a new *<boolean>* or raises an error if the name is already taken. The declaration is global. The *<boolean>* is initially **false**.

<hr/> \bool_set_false:N \bool_set_false:c \bool_gset_false:N \bool_gset_false:c <hr/>	\bool_set_false:N <boolean> Sets <boolean> logically false.
<hr/> \bool_set_true:N \bool_set_true:c \bool_gset_true:N \bool_gset_true:c <hr/>	\bool_set_true:N <boolean> Sets <boolean> logically true.
<hr/> \bool_set_eq:NN \bool_set_eq:(cN Nc cc) \bool_gset_eq:NN \bool_gset_eq:(cN Nc cc) <hr/>	\bool_set_eq:NN <boolean ₁ > <boolean ₂ > Sets <boolean ₁ > to the current value of <boolean ₂ >.
<hr/> \bool_set:Nn \bool_set:cn \bool_gset:Nn \bool_gset:cn <hr/> Updated: 2017-07-15 <hr/>	\bool_set:Nn <boolean> {<boolexpr>} Evaluates the <boolean expression> as described for \bool_if:nTF, and sets the <boolean> variable to the logical truth of this evaluation.
<hr/> \bool_if_p:N * \bool_if_p:c * \bool_if:NTF * \bool_if:cTF * <hr/> Updated: 2017-07-15 <hr/>	\bool_if_p:N <boolean> \bool_if:NTF <boolean> {<true code>} {<false code>} Tests the current truth of <boolean>, and continues expansion based on this result.
<hr/> \bool_show:N \bool_show:c <hr/> New: 2012-02-09 Updated: 2015-08-01 <hr/>	\bool_show:N <boolean> Displays the logical truth of the <boolean> on the terminal.
<hr/> \bool_show:n <hr/> New: 2012-02-09 Updated: 2017-07-15 <hr/>	\bool_show:n {<boolean expression>} Displays the logical truth of the <boolean expression> on the terminal.
<hr/> \bool_log:N \bool_log:c <hr/> New: 2014-08-22 Updated: 2015-08-03 <hr/>	\bool_log:N <boolean> Writes the logical truth of the <boolean> in the log file.
<hr/> \bool_log:n <hr/> New: 2014-08-22 Updated: 2017-07-15 <hr/>	\bool_log:n {<boolean expression>} Writes the logical truth of the <boolean expression> in the log file.

<code>\bool_if_exist_p:N</code> *	<code>\bool_if_exist_p:N</code> $\langle\text{boolean}\rangle$
<code>\bool_if_exist_p:c</code> *	<code>\bool_if_exist:NTF</code> $\langle\text{boolean}\rangle$ $\{\langle\text{true code}\rangle\}$ $\{\langle\text{false code}\rangle\}$
<code>\bool_if_exist:NTF</code> *	Tests whether the $\langle\text{boolean}\rangle$ is currently defined. This does not check that the $\langle\text{boolean}\rangle$ really is a boolean variable.
<code>\bool_if_exist:cTF</code> *	

New: 2012-03-03

<code>\l_tmpa_bool</code>	A scratch boolean for local assignment. It is never used by the kernel code, and so is safe for use with any L ^A T _E X3-defined function. However, it may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\l_tmpb_bool</code>	

<code>\g_tmpa_bool</code>	A scratch boolean for global assignment. It is never used by the kernel code, and so is safe for use with any L ^A T _E X3-defined function. However, it may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\g_tmpb_bool</code>	

3 Boolean expressions

As we have a boolean datatype and predicate functions returning boolean $\langle\text{true}\rangle$ or $\langle\text{false}\rangle$ values, it seems only fitting that we also provide a parser for $\langle\text{boolean expressions}\rangle$.

A boolean expression is an expression which given input in the form of predicate functions and boolean variables, return boolean $\langle\text{true}\rangle$ or $\langle\text{false}\rangle$. It supports the logical operations And, Or and Not as the well-known infix operators `&&` and `||` and prefix `!` with their usual precedences (namely, `&&` binds more tightly than `||`). In addition to this, parentheses can be used to isolate sub-expressions. For example,

```
\int_compare_p:n { 1 = 1 } &&
(
  \int_compare_p:n { 2 = 3 } ||
  \int_compare_p:n { 4 <= 4 } ||
  \str_if_eq_p:nn { abc } { def }
) &&
! \int_compare_p:n { 2 = 4 }
```

is a valid boolean expression.

Contrarily to some other programming languages, the operators `&&` and `||` evaluate both operands in all cases, even when the first operand is enough to determine the result. This “eager” evaluation should be contrasted with the “lazy” evaluation of `\bool_lazy_...` functions.

T_EXhackers note: The eager evaluation of boolean expressions is unfortunately necessary in T_EX. Indeed, a lazy parser can get confused if `&&` or `||` or parentheses appear as (unbraced) arguments of some predicates. For instance, the innocuous-looking expression below would break (in a lazy parser) if `#1` were a closing parenthesis and `\l_tmpa_bool` were `true`.

```
( \l_tmpa_bool || \token_if_eq_meaning_p:NN X #1 )
```

Minimal (lazy) evaluation can be obtained using the conditionals `\bool_lazy_all:nTF`, `\bool_lazy_and:nnTF`, `\bool_lazy_any:nTF`, or `\bool_lazy_or:nnTF`, which only evaluate their boolean expression arguments when they are needed to determine the resulting truth value. For example, when evaluating the boolean expression

```

\bool_lazy_and_p:nn
{
  \bool_lazy_any_p:n
  {
    { \int_compare_p:n { 2 = 3 } }
    { \int_compare_p:n { 4 <= 4 } }
    { \int_compare_p:n { 1 = \error } } % skipped
  }
}
{ ! \int_compare_p:n { 2 = 4 } }

```

the line marked with `skipped` is not expanded because the result of `\bool_lazy_any_p:n` is known once the second boolean expression is found to be logically `true`. On the other hand, the last line is expanded because its logical value is needed to determine the result of `\bool_lazy_and_p:nn`.

<code>\bool_if_p:n *</code> <code>\bool_if:nTF *</code>	<code>\bool_if_p:n {⟨boolean expression⟩}</code> <code>\bool_if:nTF {⟨boolean expression⟩} {⟨true code⟩} {⟨false code⟩}</code>
--	---

Updated: 2017-07-15 Tests the current truth of *⟨boolean expression⟩*, and continues expansion based on this result. The *⟨boolean expression⟩* should consist of a series of predicates or boolean variables with the logical relationship between these defined using `&&` (“And”), `||` (“Or”), `!` (“Not”) and parentheses. The logical Not applies to the next predicate or group.

<code>\bool_lazy_all_p:n *</code> <code>\bool_lazy_all:nTF *</code>	<code>\bool_lazy_all_p:n { {⟨boolexpr₁⟩} {⟨boolexpr₂⟩} ... {⟨boolexpr_N⟩} }</code> <code>\bool_lazy_all:nTF { {⟨boolexpr₁⟩} {⟨boolexpr₂⟩} ... {⟨boolexpr_N⟩} } {⟨true code⟩}</code> <code>{⟨false code⟩}</code>
--	---

New: 2015-11-15
Updated: 2017-07-15

Implements the “And” operation on the *⟨boolean expressions⟩*, hence is `true` if all of them are `true` and `false` if any of them is `false`. Contrarily to the infix operator `&&`, only the *⟨boolean expressions⟩* which are needed to determine the result of `\bool_lazy_all:nTF` are evaluated. See also `\bool_lazy_and:nnTF` when there are only two *⟨boolean expressions⟩*.

<code>\bool_lazy_and_p:nn *</code> <code>\bool_lazy_and:nnTF *</code>	<code>\bool_lazy_and_p:nn {⟨boolexpr₁⟩} {⟨boolexpr₂⟩}</code> <code>\bool_lazy_and:nnTF {⟨boolexpr₁⟩} {⟨boolexpr₂⟩} {⟨true code⟩} {⟨false code⟩}</code>
--	---

New: 2015-11-15
Updated: 2017-07-15

Implements the “And” operation between two boolean expressions, hence is `true` if both are `true`. Contrarily to the infix operator `&&`, the *⟨boolexpr₂⟩* is only evaluated if it is needed to determine the result of `\bool_lazy_and:nnTF`. See also `\bool_lazy_all:nTF` when there are more than two *⟨boolean expressions⟩*.

<code>\bool_lazy_any_p:n *</code> <code>\bool_lazy_any:nTF *</code>	<code>\bool_lazy_any_p:n { {⟨boolexpr₁⟩} {⟨boolexpr₂⟩} ... {⟨boolexpr_N⟩} }</code> <code>\bool_lazy_any:nTF { {⟨boolexpr₁⟩} {⟨boolexpr₂⟩} ... {⟨boolexpr_N⟩} } {⟨true code⟩}</code> <code>{⟨false code⟩}</code>
--	---

New: 2015-11-15
Updated: 2017-07-15

Implements the “Or” operation on the *⟨boolean expressions⟩*, hence is `true` if any of them is `true` and `false` if all of them are `false`. Contrarily to the infix operator `||`, only the *⟨boolean expressions⟩* which are needed to determine the result of `\bool_lazy_any:nTF` are evaluated. See also `\bool_lazy_or:nnTF` when there are only two *⟨boolean expressions⟩*.

<code>\bool_lazy_or_p:nn</code> ☆	<code>\bool_lazy_or_p:nn {<boolexpr₁>} {<boolexpr₂>}</code>
<code>\bool_lazy_or:nnTF</code> ☆	<code>\bool_lazy_or:nnTF {<boolexpr₁>} {<boolexpr₂>} {<true code>} {<false code>}</code>
New: 2015-11-15 Updated: 2017-07-15	
Implements the “Or” operation between two boolean expressions, hence is true if either one is true . Contrarily to the infix operator <code> </code> , the <code><boolexpr₂></code> is only evaluated if it is needed to determine the result of <code>\bool_lazy_or:nnTF</code> . See also <code>\bool_lazy_any:nTF</code> when there are more than two <i><boolean expressions></i> .	

<code>\bool_not_p:n</code> ☆	<code>\bool_not_p:n {<boolean expression>}</code>
Updated: 2017-07-15	Function version of <code>!(<boolean expression>)</code> within a boolean expression.

<code>\bool_xor_p:nn</code> ☆	<code>\bool_xor_p:nn {<boolexpr₁>} {<boolexpr₂>}</code>
<code>\bool_xor:nnTF</code> ☆	<code>\bool_xor:nnTF {<boolexpr₁>} {<boolexpr₂>} {<true code>} {<false code>}</code>
New: 2018-05-09	
Implements an “exclusive or” operation between two boolean expressions. There is no infix operation for this logical operation.	

4 Logical loops

Loops using either boolean expressions or stored boolean values.

<code>\bool_do_until:Nn</code> ☆	<code>\bool_do_until:Nn <boolean> {<code>}</code>
<code>\bool_do_until:cn</code> ☆	
Updated: 2017-07-15	
Places the <code><code></code> in the input stream for \TeX to process, and then checks the logical value of the <code><boolean></code> . If it is false then the <code><code></code> is inserted into the input stream again and the process loops until the <code><boolean></code> is true .	

<code>\bool_do_while:Nn</code> ☆	<code>\bool_do_while:Nn <boolean> {<code>}</code>
<code>\bool_do_while:cn</code> ☆	
Updated: 2017-07-15	
Places the <code><code></code> in the input stream for \TeX to process, and then checks the logical value of the <code><boolean></code> . If it is true then the <code><code></code> is inserted into the input stream again and the process loops until the <code><boolean></code> is false .	

<code>\bool_until_do:Nn</code> ☆	<code>\bool_until_do:Nn <boolean> {<code>}</code>
<code>\bool_until_do:cn</code> ☆	
Updated: 2017-07-15	
This function firsts checks the logical value of the <code><boolean></code> . If it is false the <code><code></code> is placed in the input stream and expanded. After the completion of the <code><code></code> the truth of the <code><boolean></code> is re-evaluated. The process then loops until the <code><boolean></code> is true .	

<code>\bool_while_do:Nn</code> ☆	<code>\bool_while_do:Nn <boolean> {<code>}</code>
<code>\bool_while_do:cn</code> ☆	
Updated: 2017-07-15	
This function firsts checks the logical value of the <code><boolean></code> . If it is true the <code><code></code> is placed in the input stream and expanded. After the completion of the <code><code></code> the truth of the <code><boolean></code> is re-evaluated. The process then loops until the <code><boolean></code> is false .	

<code>\bool_do_until:nn</code> ☆	<code>\bool_do_until:nn {<boolean expression>} {<code>}</code>
Updated: 2017-07-15	
Places the <code><code></code> in the input stream for \TeX to process, and then checks the logical value of the <i><boolean expression></i> as described for <code>\bool_if:nTF</code> . If it is false then the <code><code></code> is inserted into the input stream again and the process loops until the <i><boolean expression></i> evaluates to true .	

<hr/> <code>\bool_do_while:nn</code> ☆ <hr/>	<code>\bool_do_while:nn {\langle boolean expression \rangle} {\langle code \rangle}</code>
Updated: 2017-07-15 <hr/>	Places the $\langle code \rangle$ in the input stream for T _E X to process, and then checks the logical value of the $\langle boolean expression \rangle$ as described for <code>\bool_if:nTF</code> . If it is <code>true</code> then the $\langle code \rangle$ is inserted into the input stream again and the process loops until the $\langle boolean expression \rangle$ evaluates to <code>false</code> .
<hr/> <code>\bool_until_do:nn</code> ☆ <hr/>	<code>\bool_until_do:nn {\langle boolean expression \rangle} {\langle code \rangle}</code>
Updated: 2017-07-15 <hr/>	This function firsts checks the logical value of the $\langle boolean expression \rangle$ (as described for <code>\bool_if:nTF</code>). If it is <code>false</code> the $\langle code \rangle$ is placed in the input stream and expanded. After the completion of the $\langle code \rangle$ the truth of the $\langle boolean expression \rangle$ is re-evaluated. The process then loops until the $\langle boolean expression \rangle$ is <code>true</code> .
<hr/> <code>\bool_while_do:nn</code> ☆ <hr/>	<code>\bool_while_do:nn {\langle boolean expression \rangle} {\langle code \rangle}</code>
Updated: 2017-07-15 <hr/>	This function firsts checks the logical value of the $\langle boolean expression \rangle$ (as described for <code>\bool_if:nTF</code>). If it is <code>true</code> the $\langle code \rangle$ is placed in the input stream and expanded. After the completion of the $\langle code \rangle$ the truth of the $\langle boolean expression \rangle$ is re-evaluated. The process then loops until the $\langle boolean expression \rangle$ is <code>false</code> .

5 Producing multiple copies

<hr/> <code>\prg_replicate:nn</code> ☆ <hr/>	<code>\prg_replicate:nn {\langle integer expression \rangle} {\langle tokens \rangle}</code>
Updated: 2011-07-04 <hr/>	Evaluates the $\langle integer expression \rangle$ (which should be zero or positive) and creates the resulting number of copies of the $\langle tokens \rangle$. The function is both expandable and safe for nesting. It yields its result after two expansion steps.

6 Detecting T_EX's mode

<hr/> <code>\mode_if_horizontal_p:</code> ☆ <code>\mode_if_horizontal:TF</code> ☆ <hr/>	<code>\mode_if_horizontal_p:</code> <code>\mode_if_horizontal:TF {\langle true code \rangle} {\langle false code \rangle}</code>
	Detects if T _E X is currently in horizontal mode.
<hr/> <code>\mode_if_inner_p:</code> ☆ <code>\mode_if_inner:TF</code> ☆ <hr/>	<code>\mode_if_inner_p:</code> <code>\mode_if_inner:TF {\langle true code \rangle} {\langle false code \rangle}</code>
	Detects if T _E X is currently in inner mode.
<hr/> <code>\mode_if_math_p:</code> ☆ <code>\mode_if_math:TF</code> ☆ <hr/>	<code>\mode_if_math:TF {\langle true code \rangle} {\langle false code \rangle}</code>
Updated: 2011-09-05 <hr/>	Detects if T _E X is currently in maths mode.
<hr/> <code>\mode_if_vertical_p:</code> ☆ <code>\mode_if_vertical:TF</code> ☆ <hr/>	<code>\mode_if_vertical_p:</code> <code>\mode_if_vertical:TF {\langle true code \rangle} {\langle false code \rangle}</code>
	Detects if T _E X is currently in vertical mode.

7 Primitive conditionals

<code>\if_predicate:w</code> ★	<code>\if_predicate:w</code> $\langle predicate \rangle$ $\langle true\ code \rangle$ $\else:$ $\langle false\ code \rangle$ $\fi:$
--------------------------------	---

This function takes a predicate function and branches according to the result. (In practice this function would also accept a single boolean variable in place of the $\langle predicate \rangle$ but to make the coding clearer this should be done through `\if_bool:N`.)

<code>\if_bool:N</code> ★	<code>\if_bool:N</code> $\langle boolean \rangle$ $\langle true\ code \rangle$ $\else:$ $\langle false\ code \rangle$ $\fi:$
---------------------------	--

This function takes a boolean variable and branches according to the result.

8 Nestable recursions and mappings

There are a number of places where recursion or mapping constructs are used in `expl3`. At a low-level, these typically require insertion of tokens at the end of the content to allow “clean up”. To support such mappings in a nestable form, the following functions are provided.

<code>\prg_break_point:Nn</code> ★	<code>\prg_break_point:Nn</code> $\langle type \rangle_map_break:$ $\{\langle code \rangle\}$
------------------------------------	---

New: 2018-03-26

Used to mark the end of a recursion or mapping: the functions $\langle type \rangle_map_break:$ and $\langle type \rangle_map_break:n$ use this to break out of the loop (see `\prg_map_break:Nn` for how to set these up). After the loop ends, the $\langle code \rangle$ is inserted into the input stream. This occurs even if the break functions are *not* applied: `\prg_break_point:Nn` is functionally-equivalent in these cases to `\use_ii:nn`.

<code>\prg_map_break:Nn</code> ★	<code>\prg_map_break:Nn</code> $\langle type \rangle_map_break:$ $\{\langle user\ code \rangle\}$
----------------------------------	---

New: 2018-03-26

...
`\prg_break_point:Nn` $\langle type \rangle_map_break:$ $\{\langle ending\ code \rangle\}$

Breaks a recursion in mapping contexts, inserting in the input stream the $\langle user\ code \rangle$ after the $\langle ending\ code \rangle$ for the loop. The function breaks loops, inserting their $\langle ending\ code \rangle$, until reaching a loop with the same $\langle type \rangle$ as its first argument. This $\langle type \rangle_map_break:$ argument must be defined; it is simply used as a recognizable marker for the $\langle type \rangle$.

For types with mappings defined in the kernel, $\langle type \rangle_map_break:$ and $\langle type \rangle_map_break:n$ are defined as `\prg_map_break:Nn` $\langle type \rangle_map_break:$ $\{\}$ and the same with $\{\}$ omitted.

8.1 Simple mappings

In addition to the more complex mappings above, non-nestable mappings are used in a number of locations and support is provided for these.

<code>\prg_break_point:</code> ★	
----------------------------------	--

New: 2018-03-27

This copy of `\prg_do_nothing:` is used to mark the end of a fast short-term recursion: the function `\prg_break:n` uses this to break out of the loop.

<code>\prg_break:</code>	★	<code>\prg_break:n {⟨code⟩} ... \prg_break_point:</code>
<code>\prg_break:n</code>	★	Breaks a recursion which has no <i>⟨ending code⟩</i> and which is not a user-breakable mapping (see for instance <code>\prop_get:Nn</code>), and inserts the <i>⟨code⟩</i> in the input stream.
New: 2018-03-27		

9 Internal programming functions

<code>\group_align_safe_begin:</code>	★	<code>\group_align_safe_begin:</code>
<code>\group_align_safe_end:</code>	★	...
Updated: 2011-08-11		

These functions are used to enclose material in a \TeX alignment environment within a specially-constructed group. This group is designed in such a way that it does not add brace groups to the output but does act as a group for the `&` token inside `\halign`. This is necessary to allow grabbing of tokens for testing purposes, as \TeX uses group level to determine the effect of alignment tokens. Without the special grouping, the use of a function such as `\peek_after:Nw` would result in a forbidden comparison of the internal `\endtemplate` token, yielding a fatal error. Each `\group_align_safe_begin:` must be matched by a `\group_align_safe_end:`, although this does not have to occur within the same function.

Part XIV

The l3sys package: System/runtime functions

1 The name of the job

`\c_sys_jobname_str`

New: 2015-09-19

Constant that gets the “job name” assigned when T_EX starts.

T_EXhackers note: This copies the contents of the primitive `\jobname`. It is a constant that is set by T_EX and should not be overwritten by the package.

2 Date and time

`\c_sys_minute_int`
`\c_sys_hour_int`
`\c_sys_day_int`
`\c_sys_month_int`
`\c_sys_year_int`

New: 2015-09-22

The date and time at which the current job was started: these are all reported as integers.

T_EXhackers note: Whilst the underlying primitives can be altered by the user, this interface to the time and date is intended to be the “real” values.

3 Engine

`\sys_if_engine luatex_p:` ★
`\sys_if_engine luatex:` *TF* ★
`\sys_if_engine pdftex_p:` ★
`\sys_if_engine pdftex:` *TF* ★
`\sys_if_engine ptex_p:` ★
`\sys_if_engine ptex:` *TF* ★
`\sys_if_engine uptex_p:` ★
`\sys_if_engine uptex:` *TF* ★
`\sys_if_engine xetex_p:` ★
`\sys_if_engine xetex:` *TF* ★

New: 2015-09-07

`\sys_if_engine pdftex:TF` *{(true code)} {(false code)}*

Conditionals which allow engine-specific code to be used. The names follow naturally from those of the engine binaries: note that the (u)ptex tests are for ε -pT_EX and ε -upT_EX as expl3 requires the ε -T_EX extensions. Each conditional is true for *exactly one* supported engine. In particular, `\sys_if_engine ptex_p:` is true for ε -pT_EX but false for ε -upT_EX.

`\c_sys_engine_str`

New: 2015-09-19

The current engine given as a lower case string: one of `luatex`, `pdftex`, `ptex`, `uptex` or `xetex`.

4 Output format

<code>\sys_if_output_dvi_p: *</code>	<code>\sys_if_output_dvi:TF {\true code} {\false code}</code>
<code>\sys_if_output_dvi:<i>TF</i> *</code>	
<code>\sys_if_output_pdf_p: *</code>	Conditionals which give the current output mode the \TeX run is operating in. This is
<code>\sys_if_output_pdf:<i>TF</i> *</code>	always one of two outcomes, DVI mode or PDF mode. The two sets of conditionals are
	thus complementary and are both provided to allow the programmer to emphasise the
	most appropriate case.

New: 2015-09-19

<code>\c_sys_output_str</code>	The current output mode given as a lower case string: one of <code>dvi</code> or <code>pdf</code> .
--------------------------------	---

New: 2015-09-19

Part XV

The `l3clist` package

Comma separated lists

Comma lists contain ordered data where items can be added to the left or right end of the list. This data type allows basic list manipulations such as adding/removing items, applying a function to every item, removing duplicate items, extracting a given item, using the comma list with specified separators, and so on. Sequences (defined in `l3seq`) are safer, faster, and provide more features, so they should often be preferred to comma lists. Comma lists are mostly useful when interfacing with $\text{\LaTeX 2}_{\epsilon}$ or other code that expects or provides comma list data.

Several items can be added at once. To ease input of comma lists from data provided by a user outside an `\ExplSyntaxOn ... \ExplSyntaxOff` block, spaces are removed from both sides of each comma-delimited argument upon input. Blank arguments are ignored, to allow for trailing commas or repeated commas (which may otherwise arise when concatenating comma lists “by hand”). In addition, a set of braces is removed if the result of space-trimming is braced: this allows the storage of any item in a comma list. For instance,

```
\clist_new:N \l_my_clist
\clist_put_left:Nn \l_my_clist { ~a~ , ~{b}~ , c~\d }
\clist_put_right:Nn \l_my_clist { ~{e}~ , , {{f}} , }
```

results in `\l_my_clist` containing `a,b,c~\d,{e~},{{f}}` namely the five items `a`, `b`, `c~\d`, `e~` and `{f}`. Comma lists normally do not contain empty items so the following gives an empty comma list:

```
\clist_clear_new:N \l_my_clist
\clist_put_right:Nn \l_my_clist { , ~ , , }
\clist_if_empty:NTF \l_my_clist { true } { false }
```

and it leaves `true` in the input stream. To include an “unsafe” item (empty, or one that contains a comma, or starts or ends with a space, or is a single brace group), surround it with braces.

Almost all operations on comma lists are noticeably slower than those on sequences so converting the data to sequences using `\seq_set_from_clist:Nn` (see `l3seq`) may be advisable if speed is important. The exception is that `\clist_if_in:NnTF` and `\clist_remove_duplicates:N` may be faster than their sequence analogues for large lists. However, these functions work slowly for “unsafe” items that must be braced, and may produce errors when their argument contains `{`, `}` or `#` (assuming the usual \TeX category codes apply). In addition, comma lists cannot store quarks `\q_mark` or `\q_stop`. The sequence data type should thus certainly be preferred to comma lists to store such items.

1 Creating and initialising comma lists

<code>\clist_new:N</code>	<code>\clist_new:N <comma list></code>
<code>\clist_new:c</code>	

Creates a new *<comma list>* or raises an error if the name is already taken. The declaration is global. The *<comma list>* initially contains no items.

<hr/> <code>\clist_const:Nn</code> <code>\clist_const:(Nx cn cx)</code> <hr/> New: 2014-07-05	<code>\clist_const:Nn <clist var> {<comma list>}</code> Creates a new constant <code><clist var></code> or raises an error if the name is already taken. The value of the <code><clist var></code> is set globally to the <code><comma list></code> .
<hr/> <code>\clist_clear:N</code> <code>\clist_clear:c</code> <code>\clist_gclear:N</code> <code>\clist_gclear:c</code> <hr/>	<code>\clist_clear:N <comma list></code> Clears all items from the <code><comma list></code> .
<hr/> <code>\clist_clear_new:N</code> <code>\clist_clear_new:c</code> <code>\clist_gclear_new:N</code> <code>\clist_gclear_new:c</code> <hr/>	<code>\clist_clear_new:N <comma list></code> Ensures that the <code><comma list></code> exists globally by applying <code>\clist_new:N</code> if necessary, then applies <code>\clist_(g)clear:N</code> to leave the list empty.
<hr/> <code>\clist_set_eq:NN</code> <code>\clist_set_eq:(cN Nc cc)</code> <code>\clist_gset_eq:NN</code> <code>\clist_gset_eq:(cN Nc cc)</code> <hr/>	<code>\clist_set_eq:NN <comma list_1> <comma list_2></code> Sets the content of <code><comma list_1></code> equal to that of <code><comma list_2></code> .
<hr/> <code>\clist_set_from_seq:NN</code> <code>\clist_set_from_seq:(cN Nc cc)</code> <code>\clist_gset_from_seq:NN</code> <code>\clist_gset_from_seq:(cN Nc cc)</code> <hr/> New: 2014-07-17	<code>\clist_set_from_seq:NN <comma list> <sequence></code> Converts the data in the <code><sequence></code> into a <code><comma list></code> : the original <code><sequence></code> is unchanged. Items which contain either spaces or commas are surrounded by braces.
<hr/> <code>\clist_concat:NNN</code> <code>\clist_concat:ccc</code> <code>\clist_gconcat:NNN</code> <code>\clist_gconcat:ccc</code> <hr/>	<code>\clist_concat:NNN <comma list_1> <comma list_2> <comma list_3></code> Concatenates the content of <code><comma list_2></code> and <code><comma list_3></code> together and saves the result in <code><comma list_1></code> . The items in <code><comma list_2></code> are placed at the left side of the new comma list.
<hr/> <code>\clist_if_exist_p:N *</code> <code>\clist_if_exist_p:c *</code> <code>\clist_if_exist:N\overline{TF} *</code> <code>\clist_if_exist:c\overline{TF} *</code> <hr/> New: 2012-03-03	<code>\clist_if_exist_p:N <comma list></code> <code>\clist_if_exist:NTF <comma list> {<true code>} {<false code>}</code> Tests whether the <code><comma list></code> is currently defined. This does not check that the <code><comma list></code> really is a comma list.

2 Adding data to comma lists

<code>\clist_set:Nn</code>	<code>\clist_set:Nn <comma list> {\<item_1>, ..., \<item_n>}</code>
<code>\clist_set:(NV No Nx cn cV co cx)</code>	
<code>\clist_gset:Nn</code>	
<code>\clist_gset:(NV No Nx cn cV co cx)</code>	

New: 2011-09-06

Sets $\langle comma list \rangle$ to contain the $\langle items \rangle$, removing any previous content from the variable. Blank items are omitted, spaces are removed from both sides of each item, then a set of braces is removed if the resulting space-trimmed item is braced. To store some $\langle tokens \rangle$ as a single $\langle item \rangle$ even if the $\langle tokens \rangle$ contain commas or spaces, add a set of braces: `\clist_set:Nn <comma list> { {\<tokens>} }`.

<code>\clist_put_left:Nn</code>	<code>\clist_put_left:Nn <comma list> {\<item_1>, ..., \<item_n>}</code>
<code>\clist_put_left:(NV No Nx cn cV co cx)</code>	
<code>\clist_gput_left:Nn</code>	
<code>\clist_gput_left:(NV No Nx cn cV co cx)</code>	

Updated: 2011-09-05

Appends the $\langle items \rangle$ to the left of the $\langle comma list \rangle$. Blank items are omitted, spaces are removed from both sides of each item, then a set of braces is removed if the resulting space-trimmed item is braced. To append some $\langle tokens \rangle$ as a single $\langle item \rangle$ even if the $\langle tokens \rangle$ contain commas or spaces, add a set of braces: `\clist_put_left:Nn <comma list> { {\<tokens>} }`.

<code>\clist_put_right:Nn</code>	<code>\clist_put_right:Nn <comma list> {\<item_1>, ..., \<item_n>}</code>
<code>\clist_put_right:(NV No Nx cn cV co cx)</code>	
<code>\clist_gput_right:Nn</code>	
<code>\clist_gput_right:(NV No Nx cn cV co cx)</code>	

Updated: 2011-09-05

Appends the $\langle items \rangle$ to the right of the $\langle comma list \rangle$. Blank items are omitted, spaces are removed from both sides of each item, then a set of braces is removed if the resulting space-trimmed item is braced. To append some $\langle tokens \rangle$ as a single $\langle item \rangle$ even if the $\langle tokens \rangle$ contain commas or spaces, add a set of braces: `\clist_put_right:Nn <comma list> { {\<tokens>} }`.

3 Modifying comma lists

While comma lists are normally used as ordered lists, it may be necessary to modify the content. The functions here may be used to update comma lists, while retaining the order of the unaffected entries.

<code>\clist_remove_duplicates:N</code>	<code>\clist_remove_duplicates:N <comma list></code>
<code>\clist_remove_duplicates:c</code>	
<code>\clist_gremove_duplicates:N</code>	
<code>\clist_gremove_duplicates:c</code>	

Removes duplicate items from the $\langle comma list \rangle$, leaving the left most copy of each item in the $\langle comma list \rangle$. The $\langle item \rangle$ comparison takes place on a token basis, as for `\tl_if_eq:nn(TF)`.

TeXhackers note: This function iterates through every item in the $\langle comma list \rangle$ and does a comparison with the $\langle items \rangle$ already checked. It is therefore relatively slow with large comma lists. Furthermore, it may fail if any of the items in the $\langle comma list \rangle$ contains `{`, `}`, or `#` (assuming the usual TeX category codes apply).

<code>\clist_remove_all:Nn</code>	<code>\clist_remove_all:Nn <comma list> {<item>}</code>
<code>\clist_remove_all:cn</code>	
<code>\clist_gremove_all:Nn</code>	
<code>\clist_gremove_all:cn</code>	

Updated: 2011-09-06

Removes every occurrence of $\langle item \rangle$ from the $\langle comma list \rangle$. The $\langle item \rangle$ comparison takes place on a token basis, as for `\tl_if_eq:nn(TF)`.

TeXhackers note: The function may fail if the $\langle item \rangle$ contains `{`, `}`, or `#` (assuming the usual TeX category codes apply).

<code>\clist_reverse:N</code>	<code>\clist_reverse:N <comma list></code>
<code>\clist_reverse:c</code>	
<code>\clist_greverse:N</code>	
<code>\clist_greverse:c</code>	

New: 2014-07-18

Reverses the order of items stored in the $\langle comma list \rangle$.

<code>\clist_reverse:n</code>	<code>\clist_reverse:n {<comma list>}</code>
-------------------------------	--

New: 2014-07-18

Leaves the items in the $\langle comma list \rangle$ in the input stream in reverse order. Contrarily to other what is done for other n-type $\langle comma list \rangle$ arguments, braces and spaces are preserved by this process.

TeXhackers note: The result is returned within `\unexpanded`, which means that the comma list does not expand further when appearing in an x-type or e-type argument expansion.

<code>\clist_sort:Nn</code>	<code>\clist_sort:Nn <clist var> {<comparison code>}</code>
<code>\clist_sort:cn</code>	
<code>\clist_gsort:Nn</code>	
<code>\clist_gsort:cn</code>	

New: 2017-02-06

Sorts the items in the $\langle clist var \rangle$ according to the $\langle comparison code \rangle$, and assigns the result to $\langle clist var \rangle$. The details of sorting comparison are described in Section 1.

4 Comma list conditionals

<code>\clist_if_empty_p:N</code> *	<code>\clist_if_empty_p:N <comma list></code>
<code>\clist_if_empty_p:c</code> *	<code>\clist_if_empty:NTF <comma list> {\true code} {\false code}</code>
<code>\clist_if_empty:NTF</code> *	Tests if the <code><comma list></code> is empty (containing no items).
<code>\clist_if_empty:cTF</code> *	

<code>\clist_if_empty_p:n</code> *	<code>\clist_if_empty_p:n {\<comma list>}</code>
<code>\clist_if_empty:nTF</code> *	<code>\clist_if_empty:nTF {\<comma list>} {\true code} {\false code}</code>

New: 2014-07-05

Tests if the `<comma list>` is empty (containing no items). The rules for space trimming are as for other `n`-type comma-list functions, hence the comma list `{~,~,~}` (without outer braces) is empty, while `{~,{}},` (without outer braces) contains one element, which happens to be empty: the comma-list is not empty.

<code>\clist_if_in:NnTF</code>	<code>\clist_if_in:NnTF <comma list> {\item} {\true code} {\false code}</code>
<code>\clist_if_in:(NV No cn cV co)TF</code>	
<code>\clist_if_in:nnTF</code>	
<code>\clist_if_in:(nV no)TF</code>	

Updated: 2011-09-06

Tests if the `<item>` is present in the `<comma list>`. In the case of an `n`-type `<comma list>`, the usual rules of space trimming and brace stripping apply. Hence,

```
\clist_if_in:nnTF { a , {b}~ , {b} , c } { b } {true} {false}
```

yields `true`.

T_EXhackers note: The function may fail if the `<item>` contains `{`, `}`, or `#` (assuming the usual T_EX category codes apply).

5 Mapping to comma lists

The functions described in this section apply a specified function to each item of a comma list.

When the comma list is given explicitly, as an `n`-type argument, spaces are trimmed around each item. If the result of trimming spaces is empty, the item is ignored. Otherwise, if the item is surrounded by braces, one set is removed, and the result is passed to the mapped function. Thus, if the comma list that is being mapped is `{a_{,}{b}_{,},,{}_{,}{c},}` then the arguments passed to the mapped function are ‘`a`’, ‘`{b}_{,}`’, an empty argument, and ‘`c`’.

When the comma list is given as an `N`-type argument, spaces have already been trimmed on input, and items are simply stripped of one set of braces if any. This case is more efficient than using `n`-type comma lists.

<code>\clist_map_function:NN</code> ☆	<code>\clist_map_function:NN <comma list> <function></code>
<code>\clist_map_function:cN</code> ☆	Applies <code><function></code> to every <code><item></code> stored in the <code><comma list></code> . The <code><function></code> receives one argument for each iteration. The <code><items></code> are returned from left to right. The function <code>\clist_map_inline:Nn</code> is in general more efficient than <code>\clist_map_function:NN</code> .
<code>\clist_map_function:nN</code> ☆	

Updated: 2012-06-29

`\clist_map_inline:Nn`
`\clist_map_inline:cn`
`\clist_map_inline:nn`

Updated: 2012-06-29

`\clist_map_inline:Nn` $\langle comma list \rangle$ $\{\langle inline function \rangle\}$

Applies $\langle inline function \rangle$ to every $\langle item \rangle$ stored within the $\langle comma list \rangle$. The $\langle inline function \rangle$ should consist of code which receives the $\langle item \rangle$ as #1. The $\langle items \rangle$ are returned from left to right.

`\clist_map_variable:NNn`
`\clist_map_variable:cNn`
`\clist_map_variable:nNn`

Updated: 2012-06-29

`\clist_map_variable:NNn` $\langle comma list \rangle$ $\langle variable \rangle$ $\{\langle code \rangle\}$

Stores each $\langle item \rangle$ of the $\langle comma list \rangle$ in turn in the (token list) $\langle variable \rangle$ and applies the $\langle code \rangle$. The $\langle code \rangle$ will usually make use of the $\langle variable \rangle$, but this is not enforced. The assignments to the $\langle variable \rangle$ are local. The $\langle items \rangle$ are returned from left to right.

`\clist_map_break:` ☆

Updated: 2012-06-29

`\clist_map_break:`

Used to terminate a `\clist_map...` function before all entries in the $\langle comma list \rangle$ have been processed. This normally takes place within a conditional statement, for example

```

\clist_map_inline:Nn \l_my_clist
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \clist_map_break: }
  {
    % Do something useful
  }
}

```

Use outside of a `\clist_map...` scenario leads to low level T_EX errors.

T_EXhackers note: When the mapping is broken, additional tokens may be inserted before further items are taken from the input stream. This depends on the design of the mapping function.

`\clist_map_break:n` ☆

Updated: 2012-06-29

`\clist_map_break:n` $\{\langle code \rangle\}$

Used to terminate a `\clist_map...` function before all entries in the $\langle comma list \rangle$ have been processed, inserting the $\langle code \rangle$ after the mapping has ended. This normally takes place within a conditional statement, for example

```

\clist_map_inline:Nn \l_my_clist
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \clist_map_break:n { <code> } }
  {
    % Do something useful
  }
}

```

Use outside of a `\clist_map...` scenario leads to low level T_EX errors.

T_EXhackers note: When the mapping is broken, additional tokens may be inserted before the $\langle code \rangle$ is inserted into the input stream. This depends on the design of the mapping function.

<hr/>	<code>\clist_count:N</code> ★	<code>\clist_count:N</code> \langle <i>comma list</i> \rangle
	<code>\clist_count:c</code> ★	
	<code>\clist_count:n</code> ★	
<hr/>	New: 2012-07-13	

6 Using the content of comma lists directly

<hr/>	<code>\clist_use:Nnnn</code> ★	<code>\clist_use:Nnnn</code> \langle <i>clist var</i> \rangle $\{\langle$ <i>separator between two</i> $\rangle\}$
	<code>\clist_use:cnnn</code> ★	$\{\langle$ <i>separator between more than two</i> $\rangle\}$ $\{\langle$ <i>separator between final two</i> $\rangle\}$
<hr/>	New: 2013-05-26	

Places the contents of the \langle *clist var* \rangle in the input stream, with the appropriate \langle *separator* \rangle between the items. Namely, if the comma list has more than two items, the \langle *separator between more than two* \rangle is placed between each pair of items except the last, for which the \langle *separator between final two* \rangle is used. If the comma list has exactly two items, then they are placed in the input stream separated by the \langle *separator between two* \rangle . If the comma list has a single item, it is placed in the input stream, and a comma list with no items produces no output. An error is raised if the variable does not exist or if it is invalid.

For example,

```
\clist_set:Nn \l_tmpa_clist { a , b , , c , {de} , f }
\clist_use:Nnnn \l_tmpa_clist { ~and~ } { ,~ } { ,~and~ }
```

inserts “a, b, c, de, and f” in the input stream. The first separator argument is not used in this case because the comma list has more than 2 items.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the \langle *items* \rangle do not expand further when appearing in an x-type argument expansion.

<hr/>	<code>\clist_use:Nn</code> ★	<code>\clist_use:Nn</code> \langle <i>clist var</i> \rangle $\{\langle$ <i>separator</i> $\rangle\}$
	<code>\clist_use:cn</code> ★	
<hr/>	New: 2013-05-26	

Places the contents of the \langle *clist var* \rangle in the input stream, with the \langle *separator* \rangle between the items. If the comma list has a single item, it is placed in the input stream, and a comma list with no items produces no output. An error is raised if the variable does not exist or if it is invalid.

For example,

```
\clist_set:Nn \l_tmpa_clist { a , b , , c , {de} , f }
\clist_use:Nn \l_tmpa_clist { ~and~ }
```

inserts “a and b and c and de and f” in the input stream.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the \langle *items* \rangle do not expand further when appearing in an x-type argument expansion.

7 Comma lists as stacks

Comma lists can be used as stacks, where data is pushed to and popped from the top of the comma list. (The left of a comma list is the top, for performance reasons.) The stack functions for comma lists are not intended to be mixed with the general ordered data functions detailed in the previous section: a comma list should either be used as an ordered data type or as a stack, but not in both ways.

`\clist_get:NN`
`\clist_get:cN`
`\clist_get:NNTF`
`\clist_get:cNTF`

New: 2012-05-14
Updated: 2019-02-16

`\clist_get:NN` $\langle comma\ list \rangle$ $\langle token\ list\ variable \rangle$

Stores the left-most item from a $\langle comma\ list \rangle$ in the $\langle token\ list\ variable \rangle$ without removing it from the $\langle comma\ list \rangle$. The $\langle token\ list\ variable \rangle$ is assigned locally. In the non-branching version, if the $\langle comma\ list \rangle$ is empty the $\langle token\ list\ variable \rangle$ is set to the marker value `\q_no_value`.

`\clist_pop:NN`
`\clist_pop:cN`

Updated: 2011-09-06

`\clist_pop:NN` $\langle comma\ list \rangle$ $\langle token\ list\ variable \rangle$

Pops the left-most item from a $\langle comma\ list \rangle$ into the $\langle token\ list\ variable \rangle$, *i.e.* removes the item from the comma list and stores it in the $\langle token\ list\ variable \rangle$. Both of the variables are assigned locally.

`\clist_gpop:NN`
`\clist_gpop:cN`

`\clist_gpop:NN` $\langle comma\ list \rangle$ $\langle token\ list\ variable \rangle$

Pops the left-most item from a $\langle comma\ list \rangle$ into the $\langle token\ list\ variable \rangle$, *i.e.* removes the item from the comma list and stores it in the $\langle token\ list\ variable \rangle$. The $\langle comma\ list \rangle$ is modified globally, while the assignment of the $\langle token\ list\ variable \rangle$ is local.

`\clist_pop:NNTF`
`\clist_pop:cNTF`

New: 2012-05-14

`\clist_pop:NNTF` $\langle comma\ list \rangle$ $\langle token\ list\ variable \rangle$ $\{\langle true\ code \rangle\}$ $\{\langle false\ code \rangle\}$

If the $\langle comma\ list \rangle$ is empty, leaves the $\langle false\ code \rangle$ in the input stream. The value of the $\langle token\ list\ variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle comma\ list \rangle$ is non-empty, pops the top item from the $\langle comma\ list \rangle$ in the $\langle token\ list\ variable \rangle$, *i.e.* removes the item from the $\langle comma\ list \rangle$. Both the $\langle comma\ list \rangle$ and the $\langle token\ list\ variable \rangle$ are assigned locally.

`\clist_gpop:NNTF`
`\clist_gpop:cNTF`

New: 2012-05-14

`\clist_gpop:NNTF` $\langle comma\ list \rangle$ $\langle token\ list\ variable \rangle$ $\{\langle true\ code \rangle\}$ $\{\langle false\ code \rangle\}$

If the $\langle comma\ list \rangle$ is empty, leaves the $\langle false\ code \rangle$ in the input stream. The value of the $\langle token\ list\ variable \rangle$ is not defined in this case and should not be relied upon. If the $\langle comma\ list \rangle$ is non-empty, pops the top item from the $\langle comma\ list \rangle$ in the $\langle token\ list\ variable \rangle$, *i.e.* removes the item from the $\langle comma\ list \rangle$. The $\langle comma\ list \rangle$ is modified globally, while the $\langle token\ list\ variable \rangle$ is assigned locally.

`\clist_push:Nn`
`\clist_push:(NV|No|Nx|cn|cV|co|cx)`
`\clist_gpush:Nn`
`\clist_gpush:(NV|No|Nx|cn|cV|co|cx)`

`\clist_push:Nn` $\langle comma\ list \rangle$ $\{\langle items \rangle\}$

Adds the $\{\langle items \rangle\}$ to the top of the $\langle comma\ list \rangle$. Spaces are removed from both sides of each item as for any n-type comma list.

8 Using a single item

<hr/>	
<code>\clist_item:Nn</code> *	<code>\clist_item:Nn <comma list> {<integer expression>}</code>
<code>\clist_item:cn</code> *	
<code>\clist_item:nn</code> *	
<hr/>	
New: 2014-07-17	
	Indexing items in the <i><comma list></i> from 1 at the top (left), this function evaluates the <i><integer expression></i> and leaves the appropriate item from the comma list in the input stream. If the <i><integer expression></i> is negative, indexing occurs from the bottom (right) of the comma list. When the <i><integer expression></i> is larger than the number of items in the <i><comma list></i> (as calculated by <code>\clist_count:N</code>) then the function expands to nothing.

T_EXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the *<item>* does not expand further when appearing in an x-type argument expansion.

<hr/>	
<code>\clist_rand_item:N</code> *	<code>\clist_rand_item:N <clist var></code>
<code>\clist_rand_item:c</code> *	<code>\clist_rand_item:n {<comma list>}</code>
<code>\clist_rand_item:n</code> *	
<hr/>	
New: 2016-12-06	
	Selects a pseudo-random item of the <i><comma list></i> . If the <i><comma list></i> has no item, the result is empty.

T_EXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the *<item>* does not expand further when appearing in an x-type argument expansion.

9 Viewing comma lists

<hr/>	
<code>\clist_show:N</code>	<code>\clist_show:N <comma list></code>
<code>\clist_show:c</code>	
<hr/>	
Updated: 2015-08-03	
	Displays the entries in the <i><comma list></i> in the terminal.

<hr/>	
<code>\clist_show:n</code>	<code>\clist_show:n {<tokens>}</code>
<hr/>	
Updated: 2013-08-03	
	Displays the entries in the comma list in the terminal.

<hr/>	
<code>\clist_log:N</code>	<code>\clist_log:N <comma list></code>
<code>\clist_log:c</code>	
<hr/>	
New: 2014-08-22	
Updated: 2015-08-03	
	Writes the entries in the <i><comma list></i> in the log file. See also <code>\clist_show:N</code> which displays the result in the terminal.

<hr/>	
<code>\clist_log:n</code>	<code>\clist_log:n {<tokens>}</code>
<hr/>	
New: 2014-08-22	
	Writes the entries in the comma list in the log file. See also <code>\clist_show:n</code> which displays the result in the terminal.

10 Constant and scratch comma lists

`\c_empty_clist`

Constant that is always empty.

New: 2012-07-02

`\l_tmpa_clist`

`\l_tmpb_clist`

New: 2011-09-06

Scratch comma lists for local assignment. These are never used by the kernel code, and so are safe for use with any \LaTeX 3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

`\g_tmpa_clist`

`\g_tmpb_clist`

New: 2011-09-06

Scratch comma lists for global assignment. These are never used by the kernel code, and so are safe for use with any \LaTeX 3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

Part XVI

The l3token package

Token manipulation

This module deals with tokens. Now this is perhaps not the most precise description so let's try with a better description: When programming in T_EX, it is often desirable to know just what a certain token is: is it a control sequence or something else. Similarly one often needs to know if a control sequence is expandable or not, a macro or a primitive, how many arguments it takes etc. Another thing of great importance (especially when it comes to document commands) is looking ahead in the token stream to see if a certain character is present and maybe even remove it or disregard other tokens while scanning. This module provides functions for both and as such has two primary function categories: `\token_` for anything that deals with tokens and `\peek_` for looking ahead in the token stream.

Most functions we describe here can be used on control sequences, as those are tokens as well.

It is important to distinguish two aspects of a token: its “shape” (for lack of a better word), which affects the matching of delimited arguments and the comparison of token lists containing this token, and its “meaning”, which affects whether the token expands or what operation it performs. One can have tokens of different shapes with the same meaning, but not the converse.

For instance, `\if:w`, `\if_charcode:w`, and `\tex_if:D` are three names for the same internal operation of T_EX, namely the primitive testing the next two characters for equality of their character code. They have the same meaning hence behave identically in many situations. However, T_EX distinguishes them when searching for a delimited argument. Namely, the example function `\show_until_if:w` defined below takes everything until `\if:w` as an argument, despite the presence of other copies of `\if:w` under different names.

```
\cs_new:Npn \show_until_if:w #1 \if:w { \tl_show:n {#1} }
\show_until_if:w \tex_if:D \if_charcode:w \if:w
```

A list of all possible shapes and a list of all possible meanings are given in section 7.

1 Creating character tokens

```
\char_set_active_eq:NN
\char_set_active_eq:Nc
\char_gset_active_eq:NN
\char_gset_active_eq:Nc
```

Updated: 2015-11-12

```
\char_set_active_eq:NN <char> <function>
```

Sets the behaviour of the `<char>` in situations where it is active (category code 13) to be equivalent to that of the `<function>`. The category code of the `<char>` is *unchanged* by this process. The `<function>` may itself be an active character.

```
\char_set_active_eq:nN
\char_set_active_eq:nc
\char_gset_active_eq:nN
\char_gset_active_eq:nc
```

New: 2015-11-12

```
\char_set_active_eq:nN {<integer expression>} <function>
```

Sets the behaviour of the `<char>` which has character code as given by the `<integer expression>` in situations where it is active (category code 13) to be equivalent to that of the `<function>`. The category code of the `<char>` is *unchanged* by this process. The `<function>` may itself be an active character.

<hr/> <code>\char_generate:nn</code> ★ <hr/>	<code>\char_generate:nn</code> { $\langle charcode \rangle$ } { $\langle catcode \rangle$ }
New: 2015-09-09 Updated: 2019-01-16	Generates a character token of the given $\langle charcode \rangle$ and $\langle catcode \rangle$ (both of which may be integer expressions). The $\langle catcode \rangle$ may be one of

- 1 (begin group)
- 2 (end group)
- 3 (math toggle)
- 4 (alignment)
- 6 (parameter)
- 7 (math superscript)
- 8 (math subscript)
- 11 (letter)
- 12 (other)
- 13 (active)

and other values raise an error. The $\langle charcode \rangle$ may be any one valid for the engine in use. Active characters cannot be generated in older versions of X_YTeX.

TeXhackers note: Exactly two expansions are needed to produce the character.

<hr/> <code>\c_catcode_other_space_tl</code> <hr/>	Token list containing one character with category code 12, (“other”), and character code 32 (space).
New: 2011-09-05	

2 Manipulating and interrogating character tokens

<code>\char_set_catcode_escape:N</code>	<code>\char_set_catcode_letter:N</code> $\langle character \rangle$
<code>\char_set_catcode_group_begin:N</code>	
<code>\char_set_catcode_group_end:N</code>	
<code>\char_set_catcode_math_toggle:N</code>	
<code>\char_set_catcode_alignment:N</code>	
<code>\char_set_catcode_end_line:N</code>	
<code>\char_set_catcode_parameter:N</code>	
<code>\char_set_catcode_math_superscript:N</code>	
<code>\char_set_catcode_math_subscript:N</code>	
<code>\char_set_catcode_ignore:N</code>	
<code>\char_set_catcode_space:N</code>	
<code>\char_set_catcode_letter:N</code>	
<code>\char_set_catcode_other:N</code>	
<code>\char_set_catcode_active:N</code>	
<code>\char_set_catcode_comment:N</code>	
<code>\char_set_catcode_invalid:N</code>	

Updated: 2015-11-11

Sets the category code of the $\langle character \rangle$ to that indicated in the function name. Depending on the current category code of the $\langle token \rangle$ the escape token may also be needed:

`\char_set_catcode_other:N \%`

The assignment is local.

<code>\char_set_catcode_escape:n</code>	<code>\char_set_catcode_letter:n</code> $\{ \langle integer\ expression \rangle \}$
<code>\char_set_catcode_group_begin:n</code>	
<code>\char_set_catcode_group_end:n</code>	
<code>\char_set_catcode_math_toggle:n</code>	
<code>\char_set_catcode_alignment:n</code>	
<code>\char_set_catcode_end_line:n</code>	
<code>\char_set_catcode_parameter:n</code>	
<code>\char_set_catcode_math_superscript:n</code>	
<code>\char_set_catcode_math_subscript:n</code>	
<code>\char_set_catcode_ignore:n</code>	
<code>\char_set_catcode_space:n</code>	
<code>\char_set_catcode_letter:n</code>	
<code>\char_set_catcode_other:n</code>	
<code>\char_set_catcode_active:n</code>	
<code>\char_set_catcode_comment:n</code>	
<code>\char_set_catcode_invalid:n</code>	

Updated: 2015-11-11

Sets the category code of the $\langle character \rangle$ which has character code as given by the $\langle integer\ expression \rangle$. This version can be used to set up characters which cannot otherwise be given (*cf.* the N-type variants). The assignment is local.

<hr/> <hr/>	<hr/>
<code>\char_set_catcode:nn</code>	<code>\char_set_catcode:nn {⟨integer₁⟩} {⟨integer₂⟩}</code>
<hr/> Updated: 2015-11-11 <hr/>	These functions set the category code of the <i>⟨character⟩</i> which has character code as given by the <i>⟨integer expression⟩</i> . The first <i>⟨integer expression⟩</i> is the character code and the second is the category code to apply. The setting applies within the current T _E X group. In general, the symbolic functions <code>\char_set_catcode_⟨type⟩</code> should be preferred, but there are cases where these lower-level functions may be useful.
<hr/>	
<code>\char_value_catcode:n ★</code>	<code>\char_value_catcode:n {⟨integer expression⟩}</code>
	Expands to the current category code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> .
<hr/>	
<code>\char_show_value_catcode:n</code>	<code>\char_show_value_catcode:n {⟨integer expression⟩}</code>
	Displays the current category code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> on the terminal.
<hr/>	
<code>\char_set_lccode:nn</code>	<code>\char_set_lccode:nn {⟨integer₁⟩} {⟨integer₂⟩}</code>
<hr/> Updated: 2015-08-06 <hr/>	Sets up the behaviour of the <i>⟨character⟩</i> when found inside <code>\tl_lower_case:n</code> , such that <i>⟨character₁⟩</i> will be converted into <i>⟨character₂⟩</i> . The two <i>⟨characters⟩</i> may be specified using an <i>⟨integer expression⟩</i> for the character code concerned. This may include the T _E X ‘ <i>⟨character⟩</i> ’ method for converting a single character into its character code:
	<pre> \char_set_lccode:nn { ‘\A } { ‘\a } % Standard behaviour \char_set_lccode:nn { ‘\A } { ‘\A + 32 } \char_set_lccode:nn { 50 } { 60 } </pre>
	The setting applies within the current T _E X group.
<hr/>	
<code>\char_value_lccode:n ★</code>	<code>\char_value_lccode:n {⟨integer expression⟩}</code>
	Expands to the current lower case code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> .
<hr/>	
<code>\char_show_value_lccode:n</code>	<code>\char_show_value_lccode:n {⟨integer expression⟩}</code>
	Displays the current lower case code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> on the terminal.
<hr/>	
<code>\char_set_uccode:nn</code>	<code>\char_set_uccode:nn {⟨integer₁⟩} {⟨integer₂⟩}</code>
<hr/> Updated: 2015-08-06 <hr/>	Sets up the behaviour of the <i>⟨character⟩</i> when found inside <code>\tl_upper_case:n</code> , such that <i>⟨character₁⟩</i> will be converted into <i>⟨character₂⟩</i> . The two <i>⟨characters⟩</i> may be specified using an <i>⟨integer expression⟩</i> for the character code concerned. This may include the T _E X ‘ <i>⟨character⟩</i> ’ method for converting a single character into its character code:
	<pre> \char_set_uccode:nn { ‘\a } { ‘\A } % Standard behaviour \char_set_uccode:nn { ‘\A } { ‘\A - 32 } \char_set_uccode:nn { 60 } { 50 } </pre>
	The setting applies within the current T _E X group.

<hr/> <hr/> <code>\char_value_uccode:n</code> ★	<code>\char_value_uccode:n {⟨integer expression⟩}</code>
	Expands to the current upper case code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> .
<hr/> <hr/> <code>\char_show_value_uccode:n</code>	<code>\char_show_value_uccode:n {⟨integer expression⟩}</code>
	Displays the current upper case code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> on the terminal.
<hr/> <hr/> <code>\char_set_mathcode:nn</code>	<code>\char_set_mathcode:nn {⟨intexpr₁⟩} {⟨intexpr₂⟩}</code>
Updated: 2015-08-06	This function sets up the math code of <i>⟨character⟩</i> . The <i>⟨character⟩</i> is specified as an <i>⟨integer expression⟩</i> which will be used as the character code of the relevant character. The setting applies within the current T _E X group.
<hr/> <hr/> <code>\char_value_mathcode:n</code> ★	<code>\char_value_mathcode:n {⟨integer expression⟩}</code>
	Expands to the current math code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> .
<hr/> <hr/> <code>\char_show_value_mathcode:n</code>	<code>\char_show_value_mathcode:n {⟨integer expression⟩}</code>
	Displays the current math code of the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> on the terminal.
<hr/> <hr/> <code>\char_set_sfcode:nn</code>	<code>\char_set_sfcode:nn {⟨intexpr₁⟩} {⟨intexpr₂⟩}</code>
Updated: 2015-08-06	This function sets up the space factor for the <i>⟨character⟩</i> . The <i>⟨character⟩</i> is specified as an <i>⟨integer expression⟩</i> which will be used as the character code of the relevant character. The setting applies within the current T _E X group.
<hr/> <hr/> <code>\char_value_sfcode:n</code> ★	<code>\char_value_sfcode:n {⟨integer expression⟩}</code>
	Expands to the current space factor for the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> .
<hr/> <hr/> <code>\char_show_value_sfcode:n</code>	<code>\char_show_value_sfcode:n {⟨integer expression⟩}</code>
	Displays the current space factor for the <i>⟨character⟩</i> with character code given by the <i>⟨integer expression⟩</i> on the terminal.
<hr/> <hr/> <code>\l_char_active_seq</code>	Used to track which tokens may require special handling at the document level as they are (or have been at some point) of category <i>⟨active⟩</i> (catcode 13). Each entry in the sequence consists of a single escaped token, for example <code>\~</code> . Active tokens should be added to the sequence when they are defined for general document use.
New: 2012-01-23 Updated: 2015-11-11	
<hr/> <hr/> <code>\l_char_special_seq</code>	Used to track which tokens will require special handling when working with verbatim-like material at the document level as they are not of categories <i>⟨letter⟩</i> (catcode 11) or <i>⟨other⟩</i> (catcode 12). Each entry in the sequence consists of a single escaped token, for example <code>\</code> for the backslash or <code>\{</code> for an opening brace. Escaped tokens should be added to the sequence when they are defined for general document use.
New: 2012-01-23 Updated: 2015-11-11	

3 Generic tokens

```
\c_group_begin_token
\c_group_end_token
\c_math_toggle_token
\c_alignment_token
\c_parameter_token
\c_math_superscript_token
\c_math_subscript_token
\c_space_token
```

These are implicit tokens which have the category code described by their name. They are used internally for test purposes but are also available to the programmer for other uses.

```
\c_catcode_letter_token
\c_catcode_other_token
```

These are implicit tokens which have the category code described by their name. They are used internally for test purposes and should not be used other than for category code tests.

```
\c_catcode_active_tl
```

A token list containing an active token. This is used internally for test purposes and should not be used other than in appropriately-constructed category code tests.

4 Converting tokens

```
\token_to_meaning:N ★
\token_to_meaning:c ★
```

`\token_to_meaning:N` $\langle token \rangle$

Inserts the current meaning of the $\langle token \rangle$ into the input stream as a series of characters of category code 12 (other). This is the primitive \TeX description of the $\langle token \rangle$, thus for example both functions defined by `\cs_set_nopar:Npn` and token list variables defined using `\tl_new:N` are described as macros.

\TeX hackers note: This is the \TeX primitive `\meaning`. The $\langle token \rangle$ can thus be an explicit space tokens or an explicit begin-group or end-group character token (`{` or `}` when normal \TeX category codes apply) even though these are not valid N-type arguments.

```
\token_to_str:N ★
\token_to_str:c ★
```

`\token_to_str:N` $\langle token \rangle$

Converts the given $\langle token \rangle$ into a series of characters with category code 12 (other). If the $\langle token \rangle$ is a control sequence, this will start with the current escape character with category code 12 (the escape character is part of the $\langle token \rangle$). This function requires only a single expansion.

\TeX hackers note: `\token_to_str:N` is the \TeX primitive `\string` renamed. The $\langle token \rangle$ can thus be an explicit space tokens or an explicit begin-group or end-group character token (`{` or `}` when normal \TeX category codes apply) even though these are not valid N-type arguments.

5 Token conditionals

<code>\token_if_group_begin_p:N</code>	<code>*</code>	<code>\token_if_group_begin_p:N</code>	<code><token></code>
<code>\token_if_group_begin:NTF</code>	<code>*</code>	<code>\token_if_group_begin:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of a begin group token (`{` when normal `TEX` category codes are in force). Note that an explicit begin group token cannot be tested in this way, as it is not a valid N-type argument.

<code>\token_if_group_end_p:N</code>	<code>*</code>	<code>\token_if_group_end_p:N</code>	<code><token></code>
<code>\token_if_group_end:NTF</code>	<code>*</code>	<code>\token_if_group_end:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of an end group token (`}` when normal `TEX` category codes are in force). Note that an explicit end group token cannot be tested in this way, as it is not a valid N-type argument.

<code>\token_if_math_toggle_p:N</code>	<code>*</code>	<code>\token_if_math_toggle_p:N</code>	<code><token></code>
<code>\token_if_math_toggle:NTF</code>	<code>*</code>	<code>\token_if_math_toggle:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of a math shift token (`$` when normal `TEX` category codes are in force).

<code>\token_if_alignment_p:N</code>	<code>*</code>	<code>\token_if_alignment_p:N</code>	<code><token></code>
<code>\token_if_alignment:NTF</code>	<code>*</code>	<code>\token_if_alignment:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of an alignment token (`&` when normal `TEX` category codes are in force).

<code>\token_if_parameter_p:N</code>	<code>*</code>	<code>\token_if_parameter_p:N</code>	<code><token></code>
<code>\token_if_parameter:NTF</code>	<code>*</code>	<code>\token_if_parameter:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of a macro parameter token (`#` when normal `TEX` category codes are in force).

<code>\token_if_math_superscript_p:N</code>	<code>*</code>	<code>\token_if_math_superscript_p:N</code>	<code><token></code>
<code>\token_if_math_superscript:NTF</code>	<code>*</code>	<code>\token_if_math_superscript:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of a superscript token (`^` when normal `TEX` category codes are in force).

<code>\token_if_math_subscript_p:N</code>	<code>*</code>	<code>\token_if_math_subscript_p:N</code>	<code><token></code>
<code>\token_if_math_subscript:NTF</code>	<code>*</code>	<code>\token_if_math_subscript:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of a subscript token (`_` when normal `TEX` category codes are in force).

<code>\token_if_space_p:N</code>	<code>*</code>	<code>\token_if_space_p:N</code>	<code><token></code>
<code>\token_if_space:NTF</code>	<code>*</code>	<code>\token_if_space:NTF</code>	<code><token> {\true code} {\false code}</code>

Tests if `<token>` has the category code of a space token. Note that an explicit space token with character code 32 cannot be tested in this way, as it is not a valid N-type argument.

<code>\token_if_letter_p:N</code>	<code>\token_if_letter_p:N</code>	<code>\token</code>
<code>\token_if_letter:NTF</code>	<code>\token_if_letter:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if `\token` has the category code of a letter token.

<code>\token_if_other_p:N</code>	<code>\token_if_other_p:N</code>	<code>\token</code>
<code>\token_if_other:NTF</code>	<code>\token_if_other:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if `\token` has the category code of an “other” token.

<code>\token_if_active_p:N</code>	<code>\token_if_active_p:N</code>	<code>\token</code>
<code>\token_if_active:NTF</code>	<code>\token_if_active:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if `\token` has the category code of an active character.

<code>\token_if_eq_catcode_p:NN</code>	<code>\token_if_eq_catcode_p:NN</code>	<code>\token₁</code>	<code>\token₂</code>
<code>\token_if_eq_catcode:NNTF</code>	<code>\token_if_eq_catcode:NNTF</code>	<code>\token₁</code>	<code>\token₂</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if the two `\tokens` have the same category code.

<code>\token_if_eq_charcode_p:NN</code>	<code>\token_if_eq_charcode_p:NN</code>	<code>\token₁</code>	<code>\token₂</code>
<code>\token_if_eq_charcode:NNTF</code>	<code>\token_if_eq_charcode:NNTF</code>	<code>\token₁</code>	<code>\token₂</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if the two `\tokens` have the same character code.

<code>\token_if_eq_meaning_p:NN</code>	<code>\token_if_eq_meaning_p:NN</code>	<code>\token₁</code>	<code>\token₂</code>
<code>\token_if_eq_meaning:NNTF</code>	<code>\token_if_eq_meaning:NNTF</code>	<code>\token₁</code>	<code>\token₂</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if the two `\tokens` have the same meaning when expanded.

<code>\token_if_macro_p:N</code>	<code>\token_if_macro_p:N</code>	<code>\token</code>
<code>\token_if_macro:NTF</code>	<code>\token_if_macro:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Updated: 2011-05-23 Tests if the `\token` is a T_EX macro.

<code>\token_if_cs_p:N</code>	<code>\token_if_cs_p:N</code>	<code>\token</code>
<code>\token_if_cs:NTF</code>	<code>\token_if_cs:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if the `\token` is a control sequence.

<code>\token_if_expandable_p:N</code>	<code>\token_if_expandable_p:N</code>	<code>\token</code>
<code>\token_if_expandable:NTF</code>	<code>\token_if_expandable:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Tests if the `\token` is expandable. This test returns `\false` for an undefined token.

<code>\token_if_long_macro_p:N</code>	<code>\token_if_long_macro_p:N</code>	<code>\token</code>
<code>\token_if_long_macro:NTF</code>	<code>\token_if_long_macro:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Updated: 2012-01-20 Tests if the `\token` is a long macro.

<code>\token_if_protected_macro_p:N</code>	<code>\token_if_protected_macro_p:N</code>	<code>\token</code>
<code>\token_if_protected_macro:NTF</code>	<code>\token_if_protected_macro:NTF</code>	<code>\token</code> <code>{\true code}</code> <code>{\false code}</code>

Updated: 2012-01-20

Tests if the `\token` is a protected macro: for a macro which is both protected and long this returns `false`.

<code>\token_if_protected_long_macro_p:N</code>	<code>*</code>	<code>\token_if_protected_long_macro_p:N</code>	<code><token></code>
<code>\token_if_protected_long_macro:NTF</code>	<code>*</code>	<code>\token_if_protected_long_macro:NTF</code>	<code><token> {\true code} {\false code}</code>

Updated: 2012-01-20

Tests if the `<token>` is a protected long macro.

<code>\token_if_chardef_p:N</code>	<code>*</code>	<code>\token_if_chardef_p:N</code>	<code><token></code>
<code>\token_if_chardef:NTF</code>	<code>*</code>	<code>\token_if_chardef:NTF</code>	<code><token> {\true code} {\false code}</code>

Updated: 2012-01-20

Tests if the `<token>` is defined to be a chardef.

TeXhackers note: Booleans, boxes and small integer constants are implemented as `\chardefs`.

<code>\token_if_mathchardef_p:N</code>	<code>*</code>	<code>\token_if_mathchardef_p:N</code>	<code><token></code>
<code>\token_if_mathchardef:NTF</code>	<code>*</code>	<code>\token_if_mathchardef:NTF</code>	<code><token> {\true code} {\false code}</code>

Updated: 2012-01-20

Tests if the `<token>` is defined to be a mathchardef.

<code>\token_if_dim_register_p:N</code>	<code>*</code>	<code>\token_if_dim_register_p:N</code>	<code><token></code>
<code>\token_if_dim_register:NTF</code>	<code>*</code>	<code>\token_if_dim_register:NTF</code>	<code><token> {\true code} {\false code}</code>

Updated: 2012-01-20

Tests if the `<token>` is defined to be a dimension register.

<code>\token_if_int_register_p:N</code>	<code>*</code>	<code>\token_if_int_register_p:N</code>	<code><token></code>
<code>\token_if_int_register:NTF</code>	<code>*</code>	<code>\token_if_int_register:NTF</code>	<code><token> {\true code} {\false code}</code>

Updated: 2012-01-20

Tests if the `<token>` is defined to be a integer register.

TeXhackers note: Constant integers may be implemented as integer registers, `\chardefs`, or `\mathchardefs` depending on their value.

<code>\token_if_muskip_register_p:N</code>	<code>*</code>	<code>\token_if_muskip_register_p:N</code>	<code><token></code>
<code>\token_if_muskip_register:NTF</code>	<code>*</code>	<code>\token_if_muskip_register:NTF</code>	<code><token> {\true code} {\false code}</code>

New: 2012-02-15

Tests if the `<token>` is defined to be a muskip register.

<code>\token_if_skip_register_p:N</code>	<code>*</code>	<code>\token_if_skip_register_p:N</code>	<code><token></code>
<code>\token_if_skip_register:NTF</code>	<code>*</code>	<code>\token_if_skip_register:NTF</code>	<code><token> {\true code} {\false code}</code>

Updated: 2012-01-20

Tests if the `<token>` is defined to be a skip register.

<code>\token_if_toks_register_p:N</code>	<code>*</code>	<code>\token_if_toks_register_p:N</code>	$\langle token \rangle$
<code>\token_if_toks_register:NTF</code>	<code>*</code>	<code>\token_if_toks_register:NTF</code>	$\langle token \rangle$ $\{\langle true\ code \rangle\}$ $\{\langle false\ code \rangle\}$

Updated: 2012-01-20

Tests if the $\langle token \rangle$ is defined to be a toks register (not used by L^AT_EX3).

<code>\token_if_primitive_p:N</code>	<code>*</code>	<code>\token_if_primitive_p:N</code>	$\langle token \rangle$
<code>\token_if_primitive:NTF</code>	<code>*</code>	<code>\token_if_primitive:NTF</code>	$\langle token \rangle$ $\{\langle true\ code \rangle\}$ $\{\langle false\ code \rangle\}$

Updated: 2011-05-23

Tests if the $\langle token \rangle$ is an engine primitive.

6 Peeking ahead at the next token

There is often a need to look ahead at the next token in the input stream while leaving it in place. This is handled using the “peek” functions. The generic `\peek_after:Nw` is provided along with a family of predefined tests for common cases. As peeking ahead does *not* skip spaces the predefined tests include both a space-respecting and space-skipping version.

<code>\peek_after:Nw</code>	<code>\peek_after:Nw</code>	$\langle function \rangle$	$\langle token \rangle$
-----------------------------	-----------------------------	----------------------------	-------------------------

Locally sets the test variable `\l_peek_token` equal to $\langle token \rangle$ (as an implicit token, *not* as a token list), and then expands the $\langle function \rangle$. The $\langle token \rangle$ remains in the input stream as the next item after the $\langle function \rangle$. The $\langle token \rangle$ here may be \sqcup , $\{$ or $\}$ (assuming normal T_EX category codes), *i.e.* it is not necessarily the next argument which would be grabbed by a normal function.

<code>\peek_gafter:Nw</code>	<code>\peek_gafter:Nw</code>	$\langle function \rangle$	$\langle token \rangle$
------------------------------	------------------------------	----------------------------	-------------------------

Globally sets the test variable `\g_peek_token` equal to $\langle token \rangle$ (as an implicit token, *not* as a token list), and then expands the $\langle function \rangle$. The $\langle token \rangle$ remains in the input stream as the next item after the $\langle function \rangle$. The $\langle token \rangle$ here may be \sqcup , $\{$ or $\}$ (assuming normal T_EX category codes), *i.e.* it is not necessarily the next argument which would be grabbed by a normal function.

<code>\l_peek_token</code>	Token set by <code>\peek_after:Nw</code> and available for testing as described above.
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<code>\g_peek_token</code>	Token set by <code>\peek_gafter:Nw</code> and available for testing as described above.
----------------------------	---

<code>\peek_catcode:NTF</code>	<code>\peek_catcode:NTF</code>	$\langle test\ token \rangle$	$\{\langle true\ code \rangle\}$	$\{\langle false\ code \rangle\}$
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Updated: 2012-12-20

Tests if the next $\langle token \rangle$ in the input stream has the same category code as the $\langle test\ token \rangle$ (as defined by the test `\token_if_eq_catcode:NNTF`). Spaces are respected by the test and the $\langle token \rangle$ is left in the input stream after the $\langle true\ code \rangle$ or $\langle false\ code \rangle$ (as appropriate to the result of the test).

<code>\peek_catcode_ignore_spaces:NTF</code>	<code>\peek_catcode_ignore_spaces:NTF <test token> {(true code)} {(false code)}</code>
--	--

Updated: 2012-12-20

Tests if the next non-space *<token>* in the input stream has the same category code as the *<test token>* (as defined by the test `\token_if_eq_catcode:NNTF`). Explicit and implicit space tokens (with character code 32 and category code 10) are ignored and removed by the test and the *<token>* is left in the input stream after the *<true code>* or *<false code>* (as appropriate to the result of the test).

<code>\peek_catcode_remove:NTF</code>	<code>\peek_catcode_remove:NTF <test token> {(true code)} {(false code)}</code>
---------------------------------------	---

Updated: 2012-12-20

Tests if the next *<token>* in the input stream has the same category code as the *<test token>* (as defined by the test `\token_if_eq_catcode:NNTF`). Spaces are respected by the test and the *<token>* is removed from the input stream if the test is true. The function then places either the *<true code>* or *<false code>* in the input stream (as appropriate to the result of the test).

<code>\peek_catcode_remove_ignore_spaces:NTF</code>	<code>\peek_catcode_remove_ignore_spaces:NTF <test token> {(true code)} {(false code)}</code>
---	---

Updated: 2012-12-20

Tests if the next non-space *<token>* in the input stream has the same category code as the *<test token>* (as defined by the test `\token_if_eq_catcode:NNTF`). Explicit and implicit space tokens (with character code 32 and category code 10) are ignored and removed by the test and the *<token>* is removed from the input stream if the test is true. The function then places either the *<true code>* or *<false code>* in the input stream (as appropriate to the result of the test).

<code>\peek_charcode:NTF</code>	<code>\peek_charcode:NTF <test token> {(true code)} {(false code)}</code>
---------------------------------	---

Updated: 2012-12-20

Tests if the next *<token>* in the input stream has the same character code as the *<test token>* (as defined by the test `\token_if_eq_charcode:NNTF`). Spaces are respected by the test and the *<token>* is left in the input stream after the *<true code>* or *<false code>* (as appropriate to the result of the test).

<code>\peek_charcode_ignore_spaces:NTF</code>	<code>\peek_charcode_ignore_spaces:NTF <test token> {(true code)} {(false code)}</code>
---	---

Updated: 2012-12-20

Tests if the next non-space *<token>* in the input stream has the same character code as the *<test token>* (as defined by the test `\token_if_eq_charcode:NNTF`). Explicit and implicit space tokens (with character code 32 and category code 10) are ignored and removed by the test and the *<token>* is left in the input stream after the *<true code>* or *<false code>* (as appropriate to the result of the test).

<code>\peek_charcode_remove:NTF</code>	<code>\peek_charcode_remove:NTF <test token> {(true code)} {(false code)}</code>
--	--

Updated: 2012-12-20

Tests if the next *<token>* in the input stream has the same character code as the *<test token>* (as defined by the test `\token_if_eq_charcode:NNTF`). Spaces are respected by the test and the *<token>* is removed from the input stream if the test is true. The function then places either the *<true code>* or *<false code>* in the input stream (as appropriate to the result of the test).

<code>\peek_charcode_remove_ignore_spaces:NTF</code>	<code>\peek_charcode_remove_ignore_spaces:NTF <test token> {<true code>} {<false code>}</code>
Updated: 2012-12-20	

Tests if the next non-space *<token>* in the input stream has the same character code as the *<test token>* (as defined by the test `\token_if_eq_charcode:NNTF`). Explicit and implicit space tokens (with character code 32 and category code 10) are ignored and removed by the test and the *<token>* is removed from the input stream if the test is true. The function then places either the *<true code>* or *<false code>* in the input stream (as appropriate to the result of the test).

<code>\peek_meaning:NTF</code>	<code>\peek_meaning:NTF <test token> {<true code>} {<false code>}</code>
Updated: 2011-07-02	

Tests if the next *<token>* in the input stream has the same meaning as the *<test token>* (as defined by the test `\token_if_eq_meaning:NNTF`). Spaces are respected by the test and the *<token>* is left in the input stream after the *<true code>* or *<false code>* (as appropriate to the result of the test).

<code>\peek_meaning_ignore_spaces:NTF</code>	<code>\peek_meaning_ignore_spaces:NTF <test token> {<true code>} {<false code>}</code>
Updated: 2012-12-05	

Tests if the next non-space *<token>* in the input stream has the same meaning as the *<test token>* (as defined by the test `\token_if_eq_meaning:NNTF`). Explicit and implicit space tokens (with character code 32 and category code 10) are ignored and removed by the test and the *<token>* is left in the input stream after the *<true code>* or *<false code>* (as appropriate to the result of the test).

<code>\peek_meaning_remove:NTF</code>	<code>\peek_meaning_remove:NTF <test token> {<true code>} {<false code>}</code>
Updated: 2011-07-02	

Tests if the next *<token>* in the input stream has the same meaning as the *<test token>* (as defined by the test `\token_if_eq_meaning:NNTF`). Spaces are respected by the test and the *<token>* is removed from the input stream if the test is true. The function then places either the *<true code>* or *<false code>* in the input stream (as appropriate to the result of the test).

<code>\peek_meaning_remove_ignore_spaces:NTF</code>	<code>\peek_meaning_remove_ignore_spaces:NTF <test token> {<true code>} {<false code>}</code>
Updated: 2012-12-05	

Tests if the next non-space *<token>* in the input stream has the same meaning as the *<test token>* (as defined by the test `\token_if_eq_meaning:NNTF`). Explicit and implicit space tokens (with character code 32 and category code 10) are ignored and removed by the test and the *<token>* is removed from the input stream if the test is true. The function then places either the *<true code>* or *<false code>* in the input stream (as appropriate to the result of the test).

`\peek_N_type:TF`

Updated: 2012-12-20

`\peek_N_type:TF {⟨true code⟩} {⟨false code⟩}`

Tests if the next $\langle token \rangle$ in the input stream can be safely grabbed as an N-type argument. The test is $\langle false \rangle$ if the next $\langle token \rangle$ is either an explicit or implicit begin-group or end-group token (with any character code), or an explicit or implicit space character (with character code 32 and category code 10), or an outer token (never used in $\text{\LaTeX}3$) and $\langle true \rangle$ in all other cases. Note that a $\langle true \rangle$ result ensures that the next $\langle token \rangle$ is a valid N-type argument. However, if the next $\langle token \rangle$ is for instance `\c_space_token`, the test takes the $\langle false \rangle$ branch, even though the next $\langle token \rangle$ is in fact a valid N-type argument. The $\langle token \rangle$ is left in the input stream after the $\langle true code \rangle$ or $\langle false code \rangle$ (as appropriate to the result of the test).

7 Description of all possible tokens

Let us end by reviewing every case that a given token can fall into. This section is quite technical and some details are only meant for completeness. We distinguish the meaning of the token, which controls the expansion of the token and its effect on \TeX 's state, and its shape, which is used when comparing token lists such as for delimited arguments. Two tokens of the same shape must have the same meaning, but the converse does not hold.

A token has one of the following shapes.

- A control sequence, characterized by the sequence of characters that constitute its name: for instance, `\use:n` is a five-letter control sequence.
- An active character token, characterized by its character code (between 0 and 1114111 for \LuaTeX and \XeTeX and less for other engines) and category code 13.
- A character token, characterized by its character code and category code (one of 1, 2, 3, 4, 6, 7, 8, 10, 11 or 12 whose meaning is described below).⁷

There are also a few internal tokens. The following list may be incomplete in some engines.

- Expanding `\the\font` results in a token that looks identical to the command that was used to select the current font (such as `\tenrm`) but it differs from it in shape.
- A “frozen” `\relax`, which differs from the primitive in shape (but has the same meaning), is inserted when the closing `\fi` of a conditional is encountered before the conditional is evaluated.
- Expanding `\noexpand⟨token⟩` (when the $\langle token \rangle$ is expandable) results in an internal token, displayed (temporarily) as `\notexpanded:⟨token⟩`, whose shape coincides with the $\langle token \rangle$ and whose meaning differs from `\relax`.
- An `\outer endtemplate:` can be encountered when peeking ahead at the next token; this expands to another internal token, `end of alignment template`.
- Tricky programming might access a frozen `\endwrite`.

⁷In \LuaTeX , there is also the case of “bytes”, which behave as character tokens of category code 12 (other) and character code between 1114112 and 1114366. They are used to output individual bytes to files, rather than UTF-8.

- Some frozen tokens can only be accessed in interactive sessions: `\cr`, `\right`, `\endgroup`, `\fi`, `\inaccessible`.

The meaning of a (non-active) character token is fixed by its category code (and character code) and cannot be changed. We call these tokens *explicit* character tokens. Category codes that a character token can have are listed below by giving a sample output of the \TeX primitive `\meaning`, together with their \LaTeX 3 names and most common example:

- 1 begin-group character (`group_begin`, often `{`),
- 2 end-group character (`group_end`, often `}`),
- 3 math shift character (`math_toggle`, often `$`),
- 4 alignment tab character (`alignment`, often `&`),
- 6 macro parameter character (`parameter`, often `#`),
- 7 superscript character (`math_superscript`, often `^`),
- 8 subscript character (`math_subscript`, often `_`),
- 10 blank space (`space`, often character code 32),
- 11 the letter (`letter`, such as `A`),
- 12 the character (`other`, such as `0`).

Category code 13 (`active`) is discussed below. Input characters can also have several other category codes which do not lead to character tokens for later processing: 0 (`escape`), 5 (`end_line`), 9 (`ignore`), 14 (`comment`), and 15 (`invalid`).

The meaning of a control sequence or active character can be identical to that of any character token listed above (with any character code), and we call such tokens *implicit* character tokens. The meaning is otherwise in the following list:

- a macro, used in \LaTeX 3 for most functions and some variables (`tl`, `fp`, `seq`, ...),
- a primitive such as `\def` or `\topmark`, used in \LaTeX 3 for some functions,
- a register such as `\count123`, used in \LaTeX 3 for the implementation of some variables (`int`, `dim`, ...),
- a constant integer such as `\char"56` or `\mathchar"121`,
- a font selection command,
- undefined.

Macros be `\protected` or not, `\long` or not (the opposite of what \LaTeX 3 calls `nopar`), and `\outer` or not (unused in \LaTeX 3). Their `\meaning` takes the form

$\langle properties \rangle$ **macro:** $\langle parameters \rangle \rightarrow \langle replacement \rangle$

where *properties* is among `\protected\long\outer`, *parameters* describes parameters that the macro expects, such as `#1#2#3`, and *replacement* describes how the parameters are manipulated, such as `#2/#1/#3`.

Now is perhaps a good time to mention some subtleties relating to tokens with category code 10 (space). Any input character with this category code (normally, space and tab characters) becomes a normal space, with character code 32 and category code 10.

When a macro takes an undelimited argument, explicit space characters (with character code 32 and category code 10) are ignored. If the following token is an explicit character token with category code 1 (begin-group) and an arbitrary character code, then `TEX` scans ahead to obtain an equal number of explicit character tokens with category code 1 (begin-group) and 2 (end-group), and the resulting list of tokens (with outer braces removed) becomes the argument. Otherwise, a single token is taken as the argument for the macro: we call such single tokens “N-type”, as they are suitable to be used as an argument for a function with the signature `:N`.

Part XVII

The l3prop package

Property lists

L^AT_EX3 implements a “property list” data type, which contain an unordered list of entries each of which consists of a $\langle key \rangle$ and an associated $\langle value \rangle$. The $\langle key \rangle$ and $\langle value \rangle$ may both be any $\langle balanced\ text \rangle$. It is possible to map functions to property lists such that the function is applied to every key–value pair within the list.

Each entry in a property list must have a unique $\langle key \rangle$: if an entry is added to a property list which already contains the $\langle key \rangle$ then the new entry overwrites the existing one. The $\langle keys \rangle$ are compared on a string basis, using the same method as `\str_if_eq:nn`.

Property lists are intended for storing key-based information for use within code. This is in contrast to key–value lists, which are a form of *input* parsed by the `keys` module.

1 Creating and initialising property lists

`\prop_new:N`
`\prop_new:c`

`\prop_new:N` $\langle property\ list \rangle$

Creates a new $\langle property\ list \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle property\ list \rangle$ initially contains no entries.

`\prop_clear:N`
`\prop_clear:c`
`\prop_gclear:N`
`\prop_gclear:c`

`\prop_clear:N` $\langle property\ list \rangle$

Clears all entries from the $\langle property\ list \rangle$.

`\prop_clear_new:N`
`\prop_clear_new:c`
`\prop_gclear_new:N`
`\prop_gclear_new:c`

`\prop_clear_new:N` $\langle property\ list \rangle$

Ensures that the $\langle property\ list \rangle$ exists globally by applying `\prop_new:N` if necessary, then applies `\prop_(g)clear:N` to leave the list empty.

`\prop_set_eq:NN`
`\prop_set_eq:(cN|Nc|cc)`
`\prop_gset_eq:NN`
`\prop_gset_eq:(cN|Nc|cc)`

`\prop_set_eq:NN` $\langle property\ list_1 \rangle$ $\langle property\ list_2 \rangle$

Sets the content of $\langle property\ list_1 \rangle$ equal to that of $\langle property\ list_2 \rangle$.

2 Adding entries to property lists

<code>\prop_put:Nnn</code>	<code>\prop_put:Nnn <property list></code>
<code>\prop_put:(NnV Nno Nnx NVn NVV Non Noo cnn cnV cno cnx cVn cVV con coo)</code>	<code>{<key>} {<value>}</code>
<code>\prop_gput:Nnn</code>	
<code>\prop_gput:(NnV Nno Nnx NVn NVV Non Noo cnn cnV cno cnx cVn cVV con coo)</code>	

Updated: 2012-07-09

Adds an entry to the *<property list>* which may be accessed using the *<key>* and which has *<value>*. Both the *<key>* and *<value>* may contain any *<balanced text>*. The *<key>* is stored after processing with `\tl_to_str:n`, meaning that category codes are ignored. If the *<key>* is already present in the *<property list>*, the existing entry is overwritten by the new *<value>*.

<code>\prop_put_if_new:Nnn</code>	<code>\prop_put_if_new:Nnn <property list> {<key>} {<value>}</code>
<code>\prop_put_if_new:cnn</code>	
<code>\prop_gput_if_new:Nnn</code>	
<code>\prop_gput_if_new:cnn</code>	

If the *<key>* is present in the *<property list>* then no action is taken. If the *<key>* is not present in the *<property list>* then a new entry is added. Both the *<key>* and *<value>* may contain any *<balanced text>*. The *<key>* is stored after processing with `\tl_to_str:n`, meaning that category codes are ignored.

3 Recovering values from property lists

<code>\prop_get:NnN</code>	<code>\prop_get:NnN <property list> {<key>} <tl var></code>
<code>\prop_get:(NVN NoN cnN cVN coN)</code>	

Updated: 2011-08-28

Recovers the *<value>* stored with *<key>* from the *<property list>*, and places this in the *<token list variable>*. If the *<key>* is not found in the *<property list>* then the *<token list variable>* is set to the special marker `\q_no_value`. The *<token list variable>* is set within the current $\mathrm{T}_{\mathrm{E}}\mathrm{X}$ group. See also `\prop_get:NnNTF`.

<code>\prop_pop:NnN</code>
<code>\prop_pop:(NoN cnN coN)</code>

Updated: 2011-08-18

`\prop_pop:NnN <property list> {<key>} <tl var>`

Recovers the *<value>* stored with *<key>* from the *<property list>*, and places this in the *<token list variable>*. If the *<key>* is not found in the *<property list>* then the *<token list variable>* is set to the special marker `\q_no_value`. The *<key>* and *<value>* are then deleted from the property list. Both assignments are local. See also `\prop_pop:NnNTF`.

<code>\prop_gpop:NnN</code>
<code>\prop_gpop:(NoN cnN coN)</code>

Updated: 2011-08-18

`\prop_gpop:NnN <property list> {<key>} <tl var>`

Recovers the *<value>* stored with *<key>* from the *<property list>*, and places this in the *<token list variable>*. If the *<key>* is not found in the *<property list>* then the *<token list variable>* is set to the special marker `\q_no_value`. The *<key>* and *<value>* are then deleted from the property list. The *<property list>* is modified globally, while the assignment of the *<token list variable>* is local. See also `\prop_gpop:NnNTF`.

<code>\prop_item:Nn</code> *	<code>\prop_item:Nn</code> $\langle property list \rangle$ $\{\langle key \rangle\}$
<code>\prop_item:cn</code> *	Expands to the $\langle value \rangle$ corresponding to the $\langle key \rangle$ in the $\langle property list \rangle$. If the $\langle key \rangle$ is missing, this has an empty expansion.
New: 2014-07-17	

T_EXhackers note: This function is slower than the non-expandable analogue `\prop_get:NnN`. The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the $\langle value \rangle$ does not expand further when appearing in an **x**-type argument expansion.

<code>\prop_count:N</code> *	<code>\prop_count:N</code> $\langle property list \rangle$
<code>\prop_count:c</code> *	Leaves the number of key–value pairs in the $\langle property list \rangle$ in the input stream as an $\langle integer denotation \rangle$.

4 Modifying property lists

<code>\prop_remove:Nn</code>	<code>\prop_remove:Nn</code> $\langle property list \rangle$ $\{\langle key \rangle\}$
<code>\prop_remove:(NV cn cV)</code>	Removes the entry listed under $\langle key \rangle$ from the $\langle property list \rangle$. If the $\langle key \rangle$ is not found in the $\langle property list \rangle$ no change occurs, <i>i.e</i> there is no need to test for the existence of a key before deleting it.
<code>\prop_gremove:Nn</code>	
<code>\prop_gremove:(NV cn cV)</code>	
New: 2012-05-12	

5 Property list conditionals

<code>\prop_if_exist_p:N</code> *	<code>\prop_if_exist_p:N</code> $\langle property list \rangle$
<code>\prop_if_exist_p:c</code> *	<code>\prop_if_exist:NnTF</code> $\langle property list \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$
<code>\prop_if_exist:NnTF</code> *	Tests whether the $\langle property list \rangle$ is currently defined. This does not check that the $\langle property list \rangle$ really is a property list variable.
<code>\prop_if_exist:cTF</code> *	
New: 2012-03-03	

<code>\prop_if_empty_p:N</code> *	<code>\prop_if_empty_p:N</code> $\langle property list \rangle$
<code>\prop_if_empty_p:c</code> *	<code>\prop_if_empty:NnTF</code> $\langle property list \rangle$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$
<code>\prop_if_empty:NnTF</code> *	Tests if the $\langle property list \rangle$ is empty (containing no entries).
<code>\prop_if_empty:cTF</code> *	

<code>\prop_if_in_p:Nn</code> *	<code>\prop_if_in:NnTF</code> $\langle property list \rangle$ $\{\langle key \rangle\}$ $\{\langle true code \rangle\}$ $\{\langle false code \rangle\}$
<code>\prop_if_in_p:(NV No cn cV co)</code> *	
<code>\prop_if_in:NnTF</code> *	
<code>\prop_if_in:(NV No cn cV co)TF</code> *	
Updated: 2011-09-15	

Tests if the $\langle key \rangle$ is present in the $\langle property list \rangle$, making the comparison using the method described by `\str_if_eq:n`.

T_EXhackers note: This function iterates through every key–value pair in the $\langle property list \rangle$ and is therefore slower than using the non-expandable `\prop_get:NnNTF`.

6 Recovering values from property lists with branching

The functions in this section combine tests for the presence of a key in a property list with recovery of the associated valued. This makes them useful for cases where different cases follow dependent on the presence or absence of a key in a property list. They offer increased readability and performance over separate testing and recovery phases.

<u>\prop_get:NnNTF</u>	<u>\prop_get:NnNTF</u> $\langle\textit{property list}\rangle$ $\{\langle\textit{key}\rangle\}$ $\langle\textit{token list variable}\rangle$
<u>\prop_get:(NVN NoN cnN cVN coN)TF</u>	<u>\prop_get:(NVN NoN cnN cVN coN)TF</u> $\{\langle\textit{true code}\rangle\}$ $\{\langle\textit{false code}\rangle\}$
Updated: 2012-05-19	

If the $\langle\textit{key}\rangle$ is not present in the $\langle\textit{property list}\rangle$, leaves the $\langle\textit{false code}\rangle$ in the input stream. The value of the $\langle\textit{token list variable}\rangle$ is not defined in this case and should not be relied upon. If the $\langle\textit{key}\rangle$ is present in the $\langle\textit{property list}\rangle$, stores the corresponding $\langle\textit{value}\rangle$ in the $\langle\textit{token list variable}\rangle$ without removing it from the $\langle\textit{property list}\rangle$, then leaves the $\langle\textit{true code}\rangle$ in the input stream. The $\langle\textit{token list variable}\rangle$ is assigned locally.

<u>\prop_pop:NnNTF</u>	<u>\prop_pop:NnNTF</u> $\langle\textit{property list}\rangle$ $\{\langle\textit{key}\rangle\}$ $\langle\textit{token list variable}\rangle$ $\{\langle\textit{true code}\rangle\}$
<u>\prop_pop:cnNTF</u>	<u>\prop_pop:cnNTF</u> $\{\langle\textit{false code}\rangle\}$
New: 2011-08-18	If the $\langle\textit{key}\rangle$ is not present in the $\langle\textit{property list}\rangle$, leaves the $\langle\textit{false code}\rangle$ in the input stream. The value of the $\langle\textit{token list variable}\rangle$ is not defined in this case and should not be relied upon. If the $\langle\textit{key}\rangle$ is present in the $\langle\textit{property list}\rangle$, pops the corresponding $\langle\textit{value}\rangle$ in the $\langle\textit{token list variable}\rangle$, <i>i.e.</i> removes the item from the $\langle\textit{property list}\rangle$. Both the $\langle\textit{property list}\rangle$ and the $\langle\textit{token list variable}\rangle$ are assigned locally.
Updated: 2012-05-19	

<u>\prop_gpop:NnNTF</u>	<u>\prop_gpop:NnNTF</u> $\langle\textit{property list}\rangle$ $\{\langle\textit{key}\rangle\}$ $\langle\textit{token list variable}\rangle$ $\{\langle\textit{true code}\rangle\}$
<u>\prop_gpop:cnNTF</u>	<u>\prop_gpop:cnNTF</u> $\{\langle\textit{false code}\rangle\}$
New: 2011-08-18	If the $\langle\textit{key}\rangle$ is not present in the $\langle\textit{property list}\rangle$, leaves the $\langle\textit{false code}\rangle$ in the input stream. The value of the $\langle\textit{token list variable}\rangle$ is not defined in this case and should not be relied upon. If the $\langle\textit{key}\rangle$ is present in the $\langle\textit{property list}\rangle$, pops the corresponding $\langle\textit{value}\rangle$ in the $\langle\textit{token list variable}\rangle$, <i>i.e.</i> removes the item from the $\langle\textit{property list}\rangle$. The $\langle\textit{property list}\rangle$ is modified globally, while the $\langle\textit{token list variable}\rangle$ is assigned locally.
Updated: 2012-05-19	

7 Mapping to property lists

<u>\prop_map_function:NN</u> ☆	<u>\prop_map_function:NN</u> $\langle\textit{property list}\rangle$ $\langle\textit{function}\rangle$
<u>\prop_map_function:cN</u> ☆	Applies $\langle\textit{function}\rangle$ to every $\langle\textit{entry}\rangle$ stored in the $\langle\textit{property list}\rangle$. The $\langle\textit{function}\rangle$ receives two arguments for each iteration: the $\langle\textit{key}\rangle$ and associated $\langle\textit{value}\rangle$. The order in which $\langle\textit{entries}\rangle$ are returned is not defined and should not be relied upon.
Updated: 2013-01-08	

<u>\prop_map_inline:Nn</u>	<u>\prop_map_inline:Nn</u> $\langle\textit{property list}\rangle$ $\{\langle\textit{inline function}\rangle\}$
<u>\prop_map_inline:cn</u>	Applies $\langle\textit{inline function}\rangle$ to every $\langle\textit{entry}\rangle$ stored within the $\langle\textit{property list}\rangle$. The $\langle\textit{inline function}\rangle$ should consist of code which receives the $\langle\textit{key}\rangle$ as #1 and the $\langle\textit{value}\rangle$ as #2. The order in which $\langle\textit{entries}\rangle$ are returned is not defined and should not be relied upon.
Updated: 2013-01-08	

\prop_map_break: ☆

Updated: 2012-06-29

\prop_map_break:

Used to terminate a `\prop_map...` function before all entries in the *property list* have been processed. This normally takes place within a conditional statement, for example

```
\prop_map_inline:Nn \l_my_prop
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \prop_map_break: }
  {
    % Do something useful
  }
}
```

Use outside of a `\prop_map...` scenario leads to low level T_EX errors.

T_EXhackers note: When the mapping is broken, additional tokens may be inserted before further items are taken from the input stream. This depends on the design of the mapping function.

\prop_map_break:n ☆

Updated: 2012-06-29

\prop_map_break:n {<code>}

Used to terminate a `\prop_map...` function before all entries in the *property list* have been processed, inserting the <code> after the mapping has ended. This normally takes place within a conditional statement, for example

```
\prop_map_inline:Nn \l_my_prop
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \prop_map_break:n { <code> } }
  {
    % Do something useful
  }
}
```

Use outside of a `\prop_map...` scenario leads to low level T_EX errors.

T_EXhackers note: When the mapping is broken, additional tokens may be inserted before the <code> is inserted into the input stream. This depends on the design of the mapping function.

8 Viewing property lists

\prop_show:N**\prop_show:c**

Updated: 2015-08-01

\prop_show:N <property list>

Displays the entries in the *property list* in the terminal.

<code>\prop_log:N</code>	<code>\prop_log:N</code> \langle <i>property list</i> \rangle
<code>\prop_log:c</code>	Writes the entries in the \langle <i>property list</i> \rangle in the log file.
<hr/> New: 2014-08-12 Updated: 2015-08-01 <hr/>	

9 Scratch property lists

<code>\l_tmpa_prop</code>	Scratch property lists for local assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\l_tmpb_prop</code>	
<hr/> New: 2012-06-23 <hr/>	

<code>\g_tmpa_prop</code>	Scratch property lists for global assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<code>\g_tmpb_prop</code>	
<hr/> New: 2012-06-23 <hr/>	

10 Constants

<code>\c_empty_prop</code>	A permanently-empty property list used for internal comparisons.
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Part XVIII

The l3msg package

Messages

Messages need to be passed to the user by modules, either when errors occur or to indicate how the code is proceeding. The `l3msg` module provides a consistent method for doing this (as opposed to writing directly to the terminal or log).

The system used by `l3msg` to create messages divides the process into two distinct parts. Named messages are created in the first part of the process; at this stage, no decision is made about the type of output that the message will produce. The second part of the process is actually producing a message. At this stage a choice of message *class* has to be made, for example `error`, `warning` or `info`.

By separating out the creation and use of messages, several benefits are available. First, the messages can be altered later without needing details of where they are used in the code. This makes it possible to alter the language used, the detail level and so on. Secondly, the output which results from a given message can be altered. This can be done on a message class, module or message name basis. In this way, message behaviour can be altered and messages can be entirely suppressed.

1 Creating new messages

All messages have to be created before they can be used. The text of messages is automatically wrapped to the length available in the console. As a result, formatting is only needed where it helps to show meaning. In particular, `\\` may be used to force a new line and `_` forces an explicit space. Additionally, `\{`, `\#`, `\}`, `\%` and `\~` can be used to produce the corresponding character.

Messages may be subdivided *by one level* using the `/` character. This is used within the message filtering system to allow for example the L^AT_EX kernel messages to belong to the module `LaTeX` while still being filterable at a more granular level. Thus for example

```
\msg_new:nnnn { mymodule } { submodule / message } ...
```

will allow to filter out specifically messages from the `submodule`.

```
\msg_new:nnnn
\msg_new:nnn
```

Updated: 2011-08-16

```
\msg_new:nnnn {<module>} {<message>} {<text>} {<more text>}
```

Creates a *<message>* for a given *<module>*. The message is defined to first give *<text>* and then *<more text>* if the user requests it. If no *<more text>* is available then a standard text is given instead. Within *<text>* and *<more text>* four parameters (**#1** to **#4**) can be used: these will be supplied at the time the message is used. An error is raised if the *<message>* already exists.

```
\msg_set:nnnn
\msg_set:nnn
\msg_gset:nnnn
\msg_gset:nnn
```

```
\msg_set:nnnn {<module>} {<message>} {<text>} {<more text>}
```

Sets up the text for a *<message>* for a given *<module>*. The message is defined to first give *<text>* and then *<more text>* if the user requests it. If no *<more text>* is available then a standard text is given instead. Within *<text>* and *<more text>* four parameters (**#1** to **#4**) can be used: these will be supplied at the time the message is used.

<hr/> <code>\msg_if_exist_p:nn</code> *	<code>\msg_if_exist_p:nn {<module>} {<message>}</code>
<code>\msg_if_exist:nnTF</code> *	<code>\msg_if_exist:nnTF {<module>} {<message>} {<true code>} {<false code>}</code>
<hr/> New: 2012-03-03	Tests whether the <i><message></i> for the <i><module></i> is currently defined.

2 Contextual information for messages

<hr/> <code>\msg_line_context:</code> ☆	<code>\msg_line_context:</code>
	Prints the current line number when a message is given, and thus suitable for giving context to messages. The number itself is proceeded by the text on line.

<hr/> <code>\msg_line_number:</code> *	<code>\msg_line_number:</code>
	Prints the current line number when a message is given.

<hr/> <code>\msg_fatal_text:n</code> *	<code>\msg_fatal_text:n {<module>}</code>
	Produces the standard text
	Fatal Package <i><module></i> Error
	This function can be redefined to alter the language in which the message is given, using #1 as the name of the <i><module></i> to be included.

<hr/> <code>\msg_critical_text:n</code> *	<code>\msg_critical_text:n {<module>}</code>
	Produces the standard text
	Critical Package <i><module></i> Error
	This function can be redefined to alter the language in which the message is given, using #1 as the name of the <i><module></i> to be included.

<hr/> <code>\msg_error_text:n</code> *	<code>\msg_error_text:n {<module>}</code>
	Produces the standard text
	Package <i><module></i> Error
	This function can be redefined to alter the language in which the message is given, using #1 as the name of the <i><module></i> to be included.

<hr/> <code>\msg_warning_text:n</code> *	<code>\msg_warning_text:n {<module>}</code>
	Produces the standard text
	Package <i><module></i> Warning
	This function can be redefined to alter the language in which the message is given, using #1 as the name of the <i><module></i> to be included. The <i><type></i> of <i><module></i> may be adjusted: Package is the standard outcome: see <code>\msg_module_type:n</code> .

<hr/> \msg_info_text:n ★ <hr/>	\msg_info_text:n {<module>}
	Produces the standard text:
	Package <module> Info
	This function can be redefined to alter the language in which the message is given, using #1 as the name of the <module> to be included. The <type> of <module> may be adjusted: Package is the standard outcome: see \msg_module_type:n .
<hr/> \msg_module_name:n ★ <hr/>	\msg_module_name:n {<module>}
<hr/> New: 2018-10-10 <hr/>	Expands to the public name of the <module> as defined by \g_msg_module_name_prop (or otherwise leaves the <module> unchanged).
<hr/> \msg_module_type:n ★ <hr/>	\msg_module_type:n {<module>}
<hr/> New: 2018-10-10 <hr/>	Expands to the description which applies to the <module>, for example a Package or Class . The information here is defined in \g_msg_module_type_prop , and will default to Package if an entry is not present.
<hr/> \msg_see_documentation_text:n ★ <hr/>	\msg_see_documentation_text:n {<module>}
<hr/> Updated: 2018-09-30 <hr/>	
	Produces the standard text
	See the <module> documentation for further information.
	This function can be redefined to alter the language in which the message is given, using #1 as the name of the <module> to be included. The name of the <module> may be altered by use of \g_msg_module_documentation_prop
<hr/> \g_msg_module_name_prop <hr/>	Provides a mapping between the module name used for messages, and that for documentation. For example, L ^A T _E X3 core messages are stored in the reserved L ^A T _E X tree, but are printed as L ^A T _E X3.
<hr/> New: 2018-10-10 <hr/>	
<hr/> \g_msg_module_type_prop <hr/>	Provides a mapping between the module name used for messages, and that type of module. For example, for L ^A T _E X3 core messages, an empty entry is set here meaning that they are not described using the standard Package text.
<hr/> New: 2018-10-10 <hr/>	

3 Issuing messages

Messages behave differently depending on the message class. In all cases, the message may be issued supplying 0 to 4 arguments. If the number of arguments supplied here does not match the number in the definition of the message, extra arguments are ignored, or empty arguments added (of course the sense of the message may be impaired). The four arguments are converted to strings before being added to the message text: the x-type variants should be used to expand material.

```

\msg_fatal:nnnnnn
\msg_fatal:nnxxxx
\msg_fatal:nnnnn
\msg_fatal:nnxxx
\msg_fatal:nnnn
\msg_fatal:nnxx
\msg_fatal:nnn
\msg_fatal:nnx
\msg_fatal:nn

```

Updated: 2012-08-11

```

\msg_fatal:nnnnnn {\module} {\message} {\arg one} {\arg two} {\arg three}
{\arg four}

```

Issues $\langle module \rangle$ error $\langle message \rangle$, passing $\langle arg one \rangle$ to $\langle arg four \rangle$ to the text-creating functions. After issuing a fatal error the T_EX run halts. No PDF file will be produced in this case (DVI mode runs may produce a truncated DVI file).

```

\msg_critical:nnnnnn
\msg_critical:nnxxxx
\msg_critical:nnnnn
\msg_critical:nnxxx
\msg_critical:nnnn
\msg_critical:nnxx
\msg_critical:nnn
\msg_critical:nnx
\msg_critical:nn

```

Updated: 2012-08-11

```

\msg_critical:nnnnnn {\module} {\message} {\arg one} {\arg two} {\arg three}
{\arg four}

```

Issues $\langle module \rangle$ error $\langle message \rangle$, passing $\langle arg one \rangle$ to $\langle arg four \rangle$ to the text-creating functions. After issuing a critical error, T_EX stops reading the current input file. This may halt the T_EX run (if the current file is the main file) or may abort reading a sub-file.

T_EXhackers note: The T_EX `\endinput` primitive is used to exit the file. In particular, the rest of the current line remains in the input stream.

```

\msg_error:nnnnnn
\msg_error:nnxxxx
\msg_error:nnnnn
\msg_error:nnxxx
\msg_error:nnnn
\msg_error:nnxx
\msg_error:nnn
\msg_error:nnx
\msg_error:nn

```

Updated: 2012-08-11

```

\msg_error:nnnnnn {\module} {\message} {\arg one} {\arg two} {\arg three}
{\arg four}

```

Issues $\langle module \rangle$ error $\langle message \rangle$, passing $\langle arg one \rangle$ to $\langle arg four \rangle$ to the text-creating functions. The error interrupts processing and issues the text at the terminal. After user input, the run continues.

```

\msg_warning:nnnnnn
\msg_warning:nnxxxx
\msg_warning:nnnnn
\msg_warning:nnxxx
\msg_warning:nnnn
\msg_warning:nnxx
\msg_warning:nnn
\msg_warning:nnx
\msg_warning:nn

```

Updated: 2012-08-11

```

\msg_warning:nnxxxx {\module} {\message} {\arg one} {\arg two} {\arg three}
{\arg four}

```

Issues $\langle module \rangle$ warning $\langle message \rangle$, passing $\langle arg one \rangle$ to $\langle arg four \rangle$ to the text-creating functions. The warning text is added to the log file and the terminal, but the T_EX run is not interrupted.

<code>\msg_info:nnnnnn</code> <code>\msg_info:nnxxxx</code> <code>\msg_info:nnnnn</code> <code>\msg_info:nnxxx</code> <code>\msg_info:nnnn</code> <code>\msg_info:nnxx</code> <code>\msg_info:nnn</code> <code>\msg_info:nnx</code> <code>\msg_info:nn</code>	<code>\msg_info:nnnnnn {<module>} {<message>} {<arg one>} {<arg two>} {<arg three>} {<arg four>}</code> Issues <i><module></i> information <i><message></i> , passing <i><arg one></i> to <i><arg four></i> to the text-creating functions. The information text is added to the log file.
---	---

Updated: 2012-08-11

<code>\msg_log:nnnnnn</code> <code>\msg_log:nnxxxx</code> <code>\msg_log:nnnnn</code> <code>\msg_log:nnxxx</code> <code>\msg_log:nnnn</code> <code>\msg_log:nnxx</code> <code>\msg_log:nnn</code> <code>\msg_log:nnx</code> <code>\msg_log:nn</code>	<code>\msg_log:nnnnnn {<module>} {<message>} {<arg one>} {<arg two>} {<arg three>} {<arg four>}</code> Issues <i><module></i> information <i><message></i> , passing <i><arg one></i> to <i><arg four></i> to the text-creating functions. The information text is added to the log file: the output is briefer than <code>\msg_info:nnnnnn</code> .
--	---

Updated: 2012-08-11

<code>\msg_none:nnnnnn</code> <code>\msg_none:nnxxxx</code> <code>\msg_none:nnnnn</code> <code>\msg_none:nnxxx</code> <code>\msg_none:nnnn</code> <code>\msg_none:nnxx</code> <code>\msg_none:nnn</code> <code>\msg_none:nnx</code> <code>\msg_none:nn</code>	<code>\msg_none:nnnnnn {<module>} {<message>} {<arg one>} {<arg two>} {<arg three>} {<arg four>}</code> Does nothing: used as a message class to prevent any output at all (see the discussion of message redirection).
---	--

Updated: 2012-08-11

4 Redirecting messages

Each message has a “name”, which can be used to alter the behaviour of the message when it is given. Thus we might have

```
\msg_new:nnnn { module } { my-message } { Some-text } { Some-more-text }
```

to define a message, with

```
\msg_error:nn { module } { my-message }
```

when it is used. With no filtering, this raises an error. However, we could alter the behaviour with

```
\msg_redirect_class:nn { error } { warning }
```

to turn all errors into warnings, or with

```
\msg_redirect_module:nnn { module } { error } { warning }
```

to alter only messages from that module, or even

```
\msg_redirect_name:nnn { module } { my-message } { warning }
```

to target just one message. Redirection applies first to individual messages, then to messages from one module and finally to messages of one class. Thus it is possible to select out an individual message for special treatment even if the entire class is already redirected.

Multiple redirections are possible. Redirections can be cancelled by providing an empty argument for the target class. Redirection to a missing class raises an error immediately. Infinite loops are prevented by eliminating the redirection starting from the target of the redirection that caused the loop to appear. Namely, if redirections are requested as $A \rightarrow B$, $B \rightarrow C$ and $C \rightarrow A$ in this order, then the $A \rightarrow B$ redirection is cancelled.

```
\msg_redirect_class:nn
```

Updated: 2012-04-27

```
\msg_redirect_class:nn {<class one>} {<class two>}
```

Changes the behaviour of messages of *<class one>* so that they are processed using the code for those of *<class two>*.

```
\msg_redirect_module:nnn
```

Updated: 2012-04-27

```
\msg_redirect_module:nnn {<module>} {<class one>} {<class two>}
```

Redirects message of *<class one>* for *<module>* to act as though they were from *<class two>*. Messages of *<class one>* from sources other than *<module>* are not affected by this redirection. This function can be used to make some messages “silent” by default. For example, all of the **warning** messages of *<module>* could be turned off with:

```
\msg_redirect_module:nnn { module } { warning } { none }
```

```
\msg_redirect_name:nnn
```

Updated: 2012-04-27

```
\msg_redirect_name:nnn {<module>} {<message>} {<class>}
```

Redirects a specific *<message>* from a specific *<module>* to act as a member of *<class>* of messages. No further redirection is performed. This function can be used to make a selected message “silent” without changing global parameters:

```
\msg_redirect_name:nnn { module } { annoying-message } { none }
```

Part XIX

The l3file package

File and I/O operations

This module provides functions for working with external files. Some of these functions apply to an entire file, and have prefix `\file_...`, while others are used to work with files on a line by line basis and have prefix `\ior_...` (reading) or `\iow_...` (writing).

It is important to remember that when reading external files T_EX attempts to locate them using both the operating system path and entries in the T_EX file database (most T_EX systems use such a database). Thus the “current path” for T_EX is somewhat broader than that for other programs.

For functions which expect a *⟨file name⟩* argument, this argument may contain both literal items and expandable content, which should on full expansion be the desired file name. Active characters (as declared in `\l_char_active_seq`) are *not* expanded, allowing the direct use of these in file names. File names are quoted using `"` tokens if they contain spaces: as a result, `"` tokens are *not* permitted in file names.

1 Input–output stream management

As T_EX engines have a limited number of input and output streams, direct use of the streams by the programmer is not supported in L^AT_EX3. Instead, an internal pool of streams is maintained, and these are allocated and deallocated as needed by other modules. As a result, the programmer should close streams when they are no longer needed, to release them for other processes.

Note that I/O operations are global: streams should all be declared with global names and treated accordingly.

<code>\ior_new:N</code>
<code>\ior_new:c</code>
<code>\iow_new:N</code>
<code>\iow_new:c</code>

New: 2011-09-26
Updated: 2011-12-27

<code>\ior_new:N</code>	<code>⟨stream⟩</code>
<code>\iow_new:N</code>	<code>⟨stream⟩</code>

Globally reserves the name of the *⟨stream⟩*, either for reading or for writing as appropriate. The *⟨stream⟩* is not opened until the appropriate `\..._open:Nn` function is used. Attempting to use a *⟨stream⟩* which has not been opened is an error, and the *⟨stream⟩* will behave as the corresponding `\c_term_....`

<code>\ior_open:Nn</code>
<code>\ior_open:cn</code>

Updated: 2012-02-10

<code>\ior_open:Nn</code>	<code>⟨stream⟩ {⟨file name⟩}</code>
---------------------------	-------------------------------------

Opens *⟨file name⟩* for reading using *⟨stream⟩* as the control sequence for file access. If the *⟨stream⟩* was already open it is closed before the new operation begins. The *⟨stream⟩* is available for access immediately and will remain allocated to *⟨file name⟩* until a `\ior_close:N` instruction is given or the T_EX run ends. If the file is not found, an error is raised.

<hr/> <code>\ior_open:NnTF</code> <hr/>	<code>\ior_open:NnTF <stream> {<file name>} {<true code>} {<false code>}</code>
<code>\ior_open:cnTF</code> <hr/>	
<hr/> New: 2013-01-12 <hr/>	Opens <i><file name></i> for reading using <i><stream></i> as the control sequence for file access. If the <i><stream></i> was already open it is closed before the new operation begins. The <i><stream></i> is available for access immediately and will remain allocated to <i><file name></i> until a <code>\ior_close:N</code> instruction is given or the TeX run ends. The <i><true code></i> is then inserted into the input stream. If the file is not found, no error is raised and the <i><false code></i> is inserted into the input stream.
<hr/>	
<code>\iow_open:Nn</code> <hr/>	<code>\iow_open:Nn <stream> {<file name>}</code>
<code>\iow_open:cn</code> <hr/>	
<hr/> Updated: 2012-02-09 <hr/>	Opens <i><file name></i> for writing using <i><stream></i> as the control sequence for file access. If the <i><stream></i> was already open it is closed before the new operation begins. The <i><stream></i> is available for access immediately and will remain allocated to <i><file name></i> until a <code>\iow_close:N</code> instruction is given or the TeX run ends. Opening a file for writing clears any existing content in the file (<i>i.e.</i> writing is <i>not</i> additive).
<hr/>	
<code>\ior_close:N</code> <hr/>	<code>\ior_close:N <stream></code>
<code>\ior_close:c</code> <hr/>	<code>\iow_close:N <stream></code>
<code>\iow_close:N</code> <hr/>	
<code>\iow_close:c</code> <hr/>	Closes the <i><stream></i> . Streams should always be closed when they are finished with as this ensures that they remain available to other programmers.
<hr/> Updated: 2012-07-31 <hr/>	
<hr/>	
<code>\ior_show_list:</code> <hr/>	<code>\ior_show_list:</code>
<code>\ior_log_list:</code> <hr/>	<code>\ior_log_list:</code>
<code>\iow_show_list:</code> <hr/>	<code>\iow_show_list:</code>
<code>\iow_log_list:</code> <hr/>	<code>\iow_log_list:</code>
<hr/> New: 2017-06-27 <hr/>	Display (to the terminal or log file) a list of the file names associated with each open (read or write) stream. This is intended for tracking down problems.

1.1 Reading from files

Reading from files and reading from the terminal are separate processes in `expl3`. The functions `\ior_get:NN` and `\ior_str_get:NN`, and their branching equivalents, are designed to work with files.

<code>\ior_get:NN</code>
<code>\ior_get:NNTF</code>
New: 2012-06-24
Updated: 2019-03-23

`\ior_get:NN` $\langle stream \rangle$ $\langle token\ list\ variable \rangle$
`\ior_get:NNTF` $\langle stream \rangle$ $\langle token\ list\ variable \rangle$ $\langle true\ code \rangle$ $\langle false\ code \rangle$

Function that reads one or more lines (until an equal number of left and right braces are found) from the input $\langle stream \rangle$ and stores the result locally in the $\langle token\ list \rangle$ variable. The material read from the $\langle stream \rangle$ is tokenized by T_EX according to the category codes and `\endlinechar` in force when the function is used. Assuming normal settings, any lines which do not end in a comment character % have the line ending converted to a space, so for example input

a b c

results in a token list `a b c`. Any blank line is converted to the token `\par`. Therefore, blank lines can be skipped by using a test such as

```
\ior_get:NN \l_my_stream \l_tmpa_tl
\tl_set:Nn \l_tmpb_tl { \par }
\tl_if_eq:NMF \l_tmpa_tl \l_tmpb_tl
...
```

Also notice that if multiple lines are read to match braces then the resulting token list can contain `\par` tokens. In the non-branching version, where the $\langle stream \rangle$ is not open the $\langle tl\ var \rangle$ is set to `\q_no_value`.

T_EXhackers note: This protected macro is a wrapper around the T_EX primitive `\read`. Regardless of settings, T_EX replaces trailing space and tab characters (character codes 32 and 9) in each line by an end-of-line character (character code `\endlinechar`, omitted if `\endlinechar` is negative or too large) before turning characters into tokens according to current category codes. With default settings, spaces appearing at the beginning of lines are also ignored.

<code>\ior_str_get:NN</code>
<code>\ior_str_get:NNTF</code>
New: 2016-12-04
Updated: 2019-03-23

`\ior_str_get:NN` $\langle stream \rangle$ $\langle token\ list\ variable \rangle$
`\ior_str_get:NNTF` $\langle stream \rangle$ $\langle token\ list\ variable \rangle$ $\langle true\ code \rangle$ $\langle false\ code \rangle$

Function that reads one line from the input $\langle stream \rangle$ and stores the result locally in the $\langle token\ list \rangle$ variable. The material is read from the $\langle stream \rangle$ as a series of tokens with category code 12 (other), with the exception of space characters which are given category code 10 (space). Multiple whitespace characters are retained by this process. It always only reads one line and any blank lines in the input result in the $\langle token\ list\ variable \rangle$ being empty. Unlike `\ior_get:NN`, line ends do not receive any special treatment. Thus input

a b c

results in a token list `a b c` with the letters a, b, and c having category code 12. In the non-branching version, where the $\langle stream \rangle$ is not open the $\langle tl\ var \rangle$ is set to `\q_no_value`.

T_EXhackers note: This protected macro is a wrapper around the ε -T_EX primitive `\readline`. Regardless of settings, T_EX removes trailing space and tab characters (character codes 32 and 9). However, the end-line character normally added by this primitive is not included in the result of `\ior_str_get:NN`.

<hr/> <code>\ior_map_inline:Nn</code> <hr/>	<code>\ior_map_inline:Nn <stream> {<inline function>}</code>
<hr/> New: 2012-02-11 <hr/>	Applies the <i><inline function></i> to each set of <i><lines></i> obtained by calling <code>\ior_get:NN</code> until reaching the end of the file. T _E X ignores any trailing new-line marker from the file it reads. The <i><inline function></i> should consist of code which receives the <i><line></i> as #1.
<hr/> <code>\ior_str_map_inline:Nn</code> <hr/>	<code>\ior_str_map_inline:Nn <stream> {<inline function>}</code>
<hr/> New: 2012-02-11 <hr/>	Applies the <i><inline function></i> to every <i><line></i> in the <i><stream></i> . The material is read from the <i><stream></i> as a series of tokens with category code 12 (other), with the exception of space characters which are given category code 10 (space). The <i><inline function></i> should consist of code which receives the <i><line></i> as #1. Note that T _E X removes trailing space and tab characters (character codes 32 and 9) from every line upon input. T _E X also ignores any trailing new-line marker from the file it reads.
<hr/> <code>\ior_map_break:</code> <hr/>	<code>\ior_map_break:</code>
<hr/> New: 2012-06-29 <hr/>	Used to terminate a <code>\ior_map_...</code> function before all lines from the <i><stream></i> have been processed. This normally takes place within a conditional statement, for example <pre> \ior_map_inline:Nn \l_my_ior { \str_if_eq:nnTF { #1 } { bingo } { \ior_map_break: } { % Do something useful } }</pre>
	Use outside of a <code>\ior_map_...</code> scenario leads to low level T _E X errors.
	T_EXhackers note: When the mapping is broken, additional tokens may be inserted before further items are taken from the input stream. This depends on the design of the mapping function.

\ior_map_break:n

New: 2012-06-29

\ior_map_break:n {*code*}

Used to terminate a `\ior_map_...` function before all lines in the *stream* have been processed, inserting the *code* after the mapping has ended. This normally takes place within a conditional statement, for example

```
\ior_map_inline:Nn \l_my_ior
{
  \str_if_eq:nnTF { #1 } { bingo }
  { \ior_map_break:n { <code> } }
  {
    % Do something useful
  }
}
```

Use outside of a `\ior_map_...` scenario leads to low level TeX errors.

TeXhackers note: When the mapping is broken, additional tokens may be inserted before the *code* is inserted into the input stream. This depends on the design of the mapping function.

\ior_if_eof_p:N ***\ior_if_eof:NTF** *

Updated: 2012-02-10

\ior_if_eof_p:N *stream***\ior_if_eof:NTF** *stream* {*true code*} {*false code*}

Tests if the end of a *stream* has been reached during a reading operation. The test also returns a `true` value if the *stream* is not open.

1.2 Writing to files

\iow_now:Nn**\iow_now:(Nx|cn|cx)**

Updated: 2012-06-05

\iow_now:Nn *stream* {*tokens*}

This functions writes *tokens* to the specified *stream* immediately (*i.e.* the write operation is called on expansion of `\iow_now:Nn`).

\iow_log:n**\iow_log:x****\iow_log:n** {*tokens*}

This function writes the given *tokens* to the log (transcript) file immediately: it is a dedicated version of `\iow_now:Nn`.

\iow_term:n**\iow_term:x****\iow_term:n** {*tokens*}

This function writes the given *tokens* to the terminal file immediately: it is a dedicated version of `\iow_now:Nn`.

<hr/>	
<code>\iow_shipout:Nn</code>	<code>\iow_shipout:Nn <stream> {\tokens}</code>
<code>\iow_shipout:(Nx cn cx)</code>	
<hr/>	
	This functions writes $\langle tokens \rangle$ to the specified $\langle stream \rangle$ when the current page is finalised (<i>i.e.</i> at shipout). The x -type variants expand the $\langle tokens \rangle$ at the point where the function is used but <i>not</i> when the resulting tokens are written to the $\langle stream \rangle$ (<i>cf.</i> <code>\iow_shipout_x:Nn</code>).

T_EXhackers note: When using expl3 with a format other than L^AT_EX, new line characters inserted using `\iow_newline:` or using the line-wrapping code `\iow_wrap:nnnN` are not recognized in the argument of `\iow_shipout:Nn`. This may lead to the insertion of additional unwanted line-breaks.

<hr/>	
<code>\iow_shipout_x:Nn</code>	<code>\iow_shipout_x:Nn <stream> {\tokens}</code>
<code>\iow_shipout_x:(Nx cn cx)</code>	
<hr/>	
Updated: 2012-09-08	
<hr/>	
	This functions writes $\langle tokens \rangle$ to the specified $\langle stream \rangle$ when the current page is finalised (<i>i.e.</i> at shipout). The $\langle tokens \rangle$ are expanded at the time of writing in addition to any expansion when the function is used. This makes these functions suitable for including material finalised during the page building process (such as the page number integer).

T_EXhackers note: This is a wrapper around the T_EX primitive `\write`. When using expl3 with a format other than L^AT_EX, new line characters inserted using `\iow_newline:` or using the line-wrapping code `\iow_wrap:nnnN` are not recognized in the argument of `\iow_shipout:Nn`. This may lead to the insertion of additional unwanted line-breaks.

<hr/>	
<code>\iow_char:N *</code>	<code>\iow_char:N \<char></code>
<hr/>	
	Inserts $\langle char \rangle$ into the output stream. Useful when trying to write difficult characters such as %, {, }, <i>etc.</i> in messages, for example:

`\iow_now:Nx \g_my_iow { \iow_char:N \{ text \iow_char:N \} }`

The function has no effect if writing is taking place without expansion (*e.g.* in the second argument of `\iow_now:Nn`).

<hr/>	
<code>\iow_newline: *</code>	<code>\iow_newline:</code>
<hr/>	
	Function to add a new line within the $\langle tokens \rangle$ written to a file. The function has no effect if writing is taking place without expansion (<i>e.g.</i> in the second argument of <code>\iow_now:Nn</code>).

T_EXhackers note: When using expl3 with a format other than L^AT_EX, the character inserted by `\iow_newline:` is not recognized by T_EX, which may lead to the insertion of additional unwanted line-breaks. This issue only affects `\iow_shipout:Nn`, `\iow_shipout_x:Nn` and direct uses of primitive operations.

1.3 Wrapping lines in output

`\iow_wrap:nnnN`
`\iow_wrap:nxnN`

New: 2012-06-28
Updated: 2017-12-04

`\iow_wrap:nnnN` $\{\langle text \rangle\}$ $\{\langle run-on text \rangle\}$ $\{\langle set up \rangle\}$ $\langle function \rangle$

This function wraps the $\langle text \rangle$ to a fixed number of characters per line. At the start of each line which is wrapped, the $\langle run-on text \rangle$ is inserted. The line character count targeted is the value of `\l_iow_line_count_int` minus the number of characters in the $\langle run-on text \rangle$ for all lines except the first, for which the target number of characters is simply `\l_iow_line_count_int` since there is no run-on text. The $\langle text \rangle$ and $\langle run-on text \rangle$ are exhaustively expanded by the function, with the following substitutions:

- `\` or `\iow_newline`: may be used to force a new line,
- `_` may be used to represent a forced space (for example after a control sequence),
- `\#`, `\%`, `\{`, `\}`, `\~` may be used to represent the corresponding character,
- `\iow_allow_break`: may be used to allow a line-break without inserting a space (this is experimental),
- `\iow_indent:n` may be used to indent a part of the $\langle text \rangle$ (not the $\langle run-on text \rangle$).

Additional functions may be added to the wrapping by using the $\langle set up \rangle$, which is executed before the wrapping takes place: this may include overriding the substitutions listed.

Any expandable material in the $\langle text \rangle$ which is not to be expanded on wrapping should be converted to a string using `\token_to_str:N`, `\tl_to_str:n`, `\tl_to_str:N`, etc.

The result of the wrapping operation is passed as a braced argument to the $\langle function \rangle$, which is typically a wrapper around a write operation. The output of `\iow_wrap:nnnN` (i.e. the argument passed to the $\langle function \rangle$) consists of characters of category “other” (category code 12), with the exception of spaces which have category “space” (category code 10). This means that the output does *not* expand further when written to a file.

T_EXhackers note: Internally, `\iow_wrap:nnnN` carries out an x-type expansion on the $\langle text \rangle$ to expand it. This is done in such a way that `\exp_not:N` or `\exp_not:n` could be used to prevent expansion of material. However, this is less conceptually clear than conversion to a string, which is therefore the supported method for handling expandable material in the $\langle text \rangle$.

`\iow_indent:n`

New: 2011-09-21

`\iow_indent:n` $\{\langle text \rangle\}$

In the first argument of `\iow_wrap:nnnN` (for instance in messages), indents $\langle text \rangle$ by four spaces. This function does not cause a line break, and only affects lines which start within the scope of the $\langle text \rangle$. In case the indented $\langle text \rangle$ should appear on separate lines from the surrounding text, use `\` to force line breaks.

`\l_iow_line_count_int`

New: 2012-06-24

The maximum number of characters in a line to be written by the `\iow_wrap:nnnN` function. This value depends on the T_EX system in use: the standard value is 78, which is typically correct for unmodified T_EXlive and MiK_T_EX systems.

1.4 Constant input–output streams, and variables

<code>\c_term_ior</code>	Constant input stream for reading from the terminal. Reading from this stream using <code>\ior_get:NN</code> or similar results in a prompt from T _E X of the form
--------------------------	---

`<tl>=`

<code>\g_tmpa_ior</code> <code>\g_tmppb_ior</code>	Scratch input stream for global use. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
---	--

New: 2017-12-11

<code>\c_log_ior</code> <code>\c_term_ior</code>	Constant output streams for writing to the log and to the terminal (plus the log), respectively.
---	--

<code>\g_tmpa_ior</code> <code>\g_tmppb_ior</code>	Scratch output stream for global use. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
---	---

New: 2017-12-11

1.5 Primitive conditionals

<code>\if_eof:w *</code>	<code>\if_eof:w <stream></code> <code> <true code></code> <code>\else:</code> <code> <false code></code> <code>\fi:</code>
--------------------------	--

Tests if the `<stream>` returns “end of file”, which is true for non-existent files. The `\else:` branch is optional.

T_EXhackers note: This is the T_EX primitive `\ifeof`.

2 File operation functions

<code>\g_file_curr_dir_str</code> <code>\g_file_curr_name_str</code> <code>\g_file_curr_ext_str</code>	
--	--

New: 2017-06-21

Contain the directory, name and extension of the current file. The directory is empty if the file was loaded without an explicit path (*i.e.* if it is in the T_EX search path), and does *not* end in / other than the case that it is exactly equal to the root directory. The `<name>` and `<ext>` parts together make up the file name, thus the `<name>` part may be thought of as the “job name” for the current file. Note that T_EX does not provide information on the `<ext>` part for the main (top level) file and that this file always has an empty `<dir>` component. Also, the `<name>` here will be equal to `\c_sys_jobname_str`, which may be different from the real file name (if set using `--jobname`, for example).

<code>\l_file_search_path_seq</code>
New: 2017-06-18

Each entry is the path to a directory which should be searched when seeking a file. Each path can be relative or absolute, and should not include the trailing slash. The entries are not expanded when used so may contain active characters but should not feature any variable content. Spaces need not be quoted.

T_EXhackers note: When working as a package in L^AT_EX 2_ε, `expl3` will automatically append the current `\input@path` to the set of values from `\l_file_search_path_seq`.

<code>\file_if_exist:nTF</code>
Updated: 2012-02-10

`\file_if_exist:nTF {<file name>} {<true code>} {<false code>}`

Searches for `<file name>` using the current T_EX search path and the additional paths controlled by `\l_file_search_path_seq`.

<code>\file_get:nnN</code>
<code>\file_get:nnNTF</code>
New: 2019-01-16
Updated: 2019-02-16

`\file_get:nnN {<filename>} {<setup>} <tl>`

`\file_get:nnNTF {<filename>} {<setup>} <tl> {<true code>} {<false code>}`

Defines `<tl>` to the contents of `<filename>`. Category codes may need to be set appropriately via the `<setup>` argument. The non-branching version sets the `<tl>` to `\q_no_value` if the file is not found. The branching version runs the `<true code>` after the assignment to `<tl>` if the file is found, and `<false code>` otherwise.

<code>\file_get_full_name:nN</code>
<code>\file_get_full_name:VN</code>
<code>\file_get_full_name:nNTF</code>
<code>\file_get_full_name:VNTF</code>
Updated: 2019-02-16

`\file_get_full_name:nN {<file name>} <tl>`

`\file_get_full_name:nNTF {<file name>} <tl> {<true code>} {<false code>}`

Searches for `<file name>` in the path as detailed for `\file_if_exist:nTF`, and if found sets the `<tl var>` the fully-qualified name of the file, *i.e.* the path and file name. This includes an extension `.tex` when the given `<file name>` has no extension but the file found has that extension. In the non-branching version, the `<tl var>` will be set to `\q_no_value` in the case that the file does not exist.

<code>\file_parse_full_name:nNNN</code>
<code>\file_parse_full_name:VNNN</code>
New: 2017-06-23
Updated: 2017-06-26

`\file_parse_full_name:nNNN {<full name>} <dir> <name> <ext>`

Parses the `<full name>` and splits it into three parts, each of which is returned by setting the appropriate local string variable:

- The `<dir>`: everything up to the last `/` (path separator) in the `<file path>`. As with system `PATH` variables and related functions, the `<dir>` does *not* include the trailing `/` unless it points to the root directory. If there is no path (only a file name), `<dir>` is empty.
- The `<name>`: everything after the last `/` up to the last `.`, where both of those characters are optional. The `<name>` may contain multiple `.` characters. It is empty if `<full name>` consists only of a directory name.
- The `<ext>`: everything after the last `.` (including the dot). The `<ext>` is empty if there is no `.` after the last `/`.

This function does not expand the `<full name>` before turning it to a string. It assume that the `<full name>` either contains no quote (") characters or is surrounded by a pair of quotes.

<code>\file_get_md5hash:nN</code>
<code>\file_get_md5hash:nNTF</code>
New: 2017-07-11
Updated: 2019-02-16

`\file_get_md5hash:nN` $\{ \langle file\ name \rangle \}$ $\langle tl\ var \rangle$

Searches for $\langle file\ name \rangle$ using the current T_EX search path and the additional paths controlled by `\l_file_search_path_seq`. If found, sets the $\langle tl\ var \rangle$ to the MD5 sum generated from the content of the file. The file is read as bytes, which means that in contrast to most T_EX behaviour there will be a difference in result depending on the line endings used in text files. The same file will produce the same result between different engines: the algorithm used is the same in all cases. Where the file is not found, the $\langle tl\ var \rangle$ will set to `\q_no_value`.

<code>\file_get_size:nN</code>
<code>\file_get_size:nNTF</code>
New: 2017-07-09
Updated: 2019-02-16

`\file_get_size:nN` $\{ \langle file\ name \rangle \}$ $\langle tl\ var \rangle$

Searches for $\langle file\ name \rangle$ using the current T_EX search path and the additional paths controlled by `\l_file_search_path_seq`. If found, sets the $\langle tl\ var \rangle$ to the size of the file in bytes. Where the file is not found, the $\langle tl\ var \rangle$ will set to `\q_no_value`. This is not available in older versions of X_YT_EX.

<code>\file_get_timestamp:nN</code>
<code>\file_get_timestamp:nNTF</code>
New: 2017-07-09
Updated: 2019-02-16

`\file_get_timestamp:nN` $\{ \langle file\ name \rangle \}$ $\langle tl\ var \rangle$

Searches for $\langle file\ name \rangle$ using the current T_EX search path and the additional paths controlled by `\l_file_search_path_seq`. If found, sets the $\langle tl\ var \rangle$ to the modification timestamp of the file in the form D: $\langle year \rangle \langle month \rangle \langle day \rangle \langle hour \rangle \langle minute \rangle \langle second \rangle \langle offset \rangle$, where the latter may be Z (UTC) or $\langle plus-minus \rangle \langle hours \rangle' \langle minutes \rangle'$. Where the file is not found, the $\langle tl\ var \rangle$ will be set to `\q_no_value`. This is not available in older versions of X_YT_EX.

<code>\file_input:n</code>
Updated: 2017-06-26

`\file_input:n` $\{ \langle file\ name \rangle \}$

Searches for $\langle file\ name \rangle$ in the path as detailed for `\file_if_exist:nTF`, and if found reads in the file as additional L^AT_EX source. All files read are recorded for information and the file name stack is updated by this function. An error is raised if the file is not found.

<code>\file_if_exist_input:n</code>
<code>\file_if_exist_input:nF</code>
New: 2014-07-02

`\file_if_exist_input:n` $\{ \langle file\ name \rangle \}$
`\file_if_exist_input:nF` $\{ \langle file\ name \rangle \}$ $\{ \langle false\ code \rangle \}$

Searches for $\langle file\ name \rangle$ using the current T_EX search path and the additional paths controlled by `\file_path_include:n`. If found then reads in the file as additional L^AT_EX source as described for `\file_input:n`, otherwise inserts the $\langle false\ code \rangle$. Note that these functions do not raise an error if the file is not found, in contrast to `\file_input:n`.

<code>\file_input_stop:</code>
New: 2017-07-07

`\file_input_stop:`

Ends the reading of a file started by `\file_input:n` or similar before the end of the file is reached. Where the file reading is being terminated due to an error, `\msg_critical:nn(nn)` should be preferred.

T_EXhackers note: This function must be used on a line on its own: T_EX reads files line-by-line and so any additional tokens in the “current” line will still be read.

This is also true if the function is hidden inside another function (which will be the normal case), i.e., all tokens on the same line in the source file are still processed. Putting it on a line by itself in the definition doesn’t help as it is the line where it is used that counts!

<code>\file_show_list:</code>	<code>\file_show_list:</code>
<code>\file_log_list:</code>	<code>\file_log_list:</code>

These functions list all files loaded by L^AT_EX 2_ε commands that populate `\@filelist` or by `\file_input:n`. While `\file_show_list:` displays the list in the terminal, `\file_log_list:` outputs it to the log file only.

Part XX

The l3skip package

Dimensions and skips

L^AT_EX3 provides two general length variables: `dim` and `skip`. Lengths stored as `dim` variables have a fixed length, whereas `skip` lengths have a rubber (stretch/shrink) component. In addition, the `muskip` type is available for use in math mode: this is a special form of `skip` where the lengths involved are determined by the current math font (in μ). There are common features in the creation and setting of length variables, but for clarity the functions are grouped by variable type.

1 Creating and initialising `dim` variables

<code>\dim_new:N</code>
<code>\dim_new:c</code>

`\dim_new:N` $\langle dimension \rangle$

Creates a new $\langle dimension \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle dimension \rangle$ is initially equal to 0pt.

<code>\dim_const:Nn</code>
<code>\dim_const:cn</code>

`\dim_const:Nn` $\langle dimension \rangle$ $\{ \langle dimension expression \rangle \}$

Creates a new constant $\langle dimension \rangle$ or raises an error if the name is already taken. The value of the $\langle dimension \rangle$ is set globally to the $\langle dimension expression \rangle$.

New: 2012-03-05

<code>\dim_zero:N</code>
<code>\dim_zero:c</code>
<code>\dim_gzero:N</code>
<code>\dim_gzero:c</code>

`\dim_zero:N` $\langle dimension \rangle$

Sets $\langle dimension \rangle$ to 0pt.

<code>\dim_zero_new:N</code>
<code>\dim_zero_new:c</code>
<code>\dim_gzero_new:N</code>
<code>\dim_gzero_new:c</code>

`\dim_zero_new:N` $\langle dimension \rangle$

Ensures that the $\langle dimension \rangle$ exists globally by applying `\dim_new:N` if necessary, then applies `\dim_(g)zero:N` to leave the $\langle dimension \rangle$ set to zero.

New: 2012-01-07

<code>\dim_if_exist_p:N</code> \star
<code>\dim_if_exist_p:c</code> \star
<code>\dim_if_exist:N\overline{TF}</code> \star
<code>\dim_if_exist:c\overline{TF}</code> \star

`\dim_if_exist_p:N` $\langle dimension \rangle$

`\dim_if_exist:N \overline{TF}` $\langle dimension \rangle$ $\{ \langle true code \rangle \} \{ \langle false code \rangle \}$

Tests whether the $\langle dimension \rangle$ is currently defined. This does not check that the $\langle dimension \rangle$ really is a dimension variable.

New: 2012-03-03

2 Setting dim variables

<code>\dim_add:Nn</code>	<code>\dim_add:Nn <dimension> {<dimension expression>}</code>
<code>\dim_add:cn</code>	
<code>\dim_gadd:Nn</code>	Adds the result of the $\langle dimension\ expression \rangle$ to the current content of the $\langle dimension \rangle$.
<code>\dim_gadd:cn</code>	

Updated: 2011-10-22

<code>\dim_set:Nn</code>	<code>\dim_set:Nn <dimension> {<dimension expression>}</code>
<code>\dim_set:cn</code>	
<code>\dim_gset:Nn</code>	Sets $\langle dimension \rangle$ to the value of $\langle dimension\ expression \rangle$, which must evaluate to a length with units.
<code>\dim_gset:cn</code>	

Updated: 2011-10-22

<code>\dim_set_eq:NN</code>	<code>\dim_set_eq:NN <dimension₁> <dimension₂></code>
<code>\dim_set_eq:(cN Nc cc)</code>	
<code>\dim_gset_eq:NN</code>	Sets the content of $\langle dimension_1 \rangle$ equal to that of $\langle dimension_2 \rangle$.
<code>\dim_gset_eq:(cN Nc cc)</code>	

<code>\dim_sub:Nn</code>	<code>\dim_sub:Nn <dimension> {<dimension expression>}</code>
<code>\dim_sub:cn</code>	
<code>\dim_gsub:Nn</code>	Subtracts the result of the $\langle dimension\ expression \rangle$ from the current content of the $\langle dimension \rangle$.
<code>\dim_gsub:cn</code>	

Updated: 2011-10-22

3 Utilities for dimension calculations

<code>\dim_abs:n</code>	<code>\dim_abs:n {<dimexpr>}</code>
<code>\dim_abs:n *</code>	
Updated: 2012-09-26	Converts the $\langle dimexpr \rangle$ to its absolute value, leaving the result in the input stream as a $\langle dimension\ denotation \rangle$.

<code>\dim_max:nn</code>	<code>\dim_max:nn {<dimexpr₁>} {<dimexpr₂>}</code>
<code>\dim_min:nn</code>	<code>\dim_min:nn {<dimexpr₁>} {<dimexpr₂>}</code>
<code>\dim_max:nn *</code>	
<code>\dim_min:nn *</code>	
New: 2012-09-09	Evaluates the two $\langle dimension\ expressions \rangle$ and leaves either the maximum or minimum value in the input stream as appropriate, as a $\langle dimension\ denotation \rangle$.
Updated: 2012-09-26	

`\dim_ratio:nn` ☆

Updated: 2011-10-22

`\dim_ratio:nn` { $\langle dimexpr_1 \rangle$ } { $\langle dimexpr_2 \rangle$ }

Parses the two $\langle dimension expressions \rangle$ and converts the ratio of the two to a form suitable for use inside a $\langle dimension expression \rangle$. This ratio is then left in the input stream, allowing syntax such as

```
\dim_set:Nn \l_my_dim
{ 10 pt * \dim_ratio:nn { 5 pt } { 10 pt } }
```

The output of `\dim_ratio:nn` on full expansion is a ratio expression between two integers, with all distances converted to scaled points. Thus

```
\tl_set:Nx \l_my_tl { \dim_ratio:nn { 5 pt } { 10 pt } }
\tl_show:N \l_my_tl
```

displays 327680/655360 on the terminal.

4 Dimension expression conditionals

`\dim_compare_p:nNn` ★

`\dim_compare:nNnTF` ★

`\dim_compare_p:nNn` { $\langle dimexpr_1 \rangle$ } $\langle relation \rangle$ { $\langle dimexpr_2 \rangle$ }

`\dim_compare:nNnTF`

{ $\langle dimexpr_1 \rangle$ } $\langle relation \rangle$ { $\langle dimexpr_2 \rangle$ }
{ $\langle true code \rangle$ } { $\langle false code \rangle$ }

This function first evaluates each of the $\langle dimension expressions \rangle$ as described for `\dim_eval:n`. The two results are then compared using the $\langle relation \rangle$:

Equal	=
Greater than	>
Less than	<

This function is less flexible than `\dim_compare:nTF` but around 5 times faster.

```

\dim_compare_p:n * \dim_compare_p:n
\dim_compare:nTF * {
    <dimexpr1> <relation1>
    ...
    <dimexprN> <relationN>
    <dimexprN+1>
}
\dim_compare:nTF
{
    <dimexpr1> <relation1>
    ...
    <dimexprN> <relationN>
    <dimexprN+1>
}
{{true code}} {{false code}}

```

Updated: 2013-01-13

This function evaluates the *<dimension expressions>* as described for `\dim_eval:n` and compares consecutive result using the corresponding *<relation>*, namely it compares *<dimexpr₁>* and *<dimexpr₂>* using the *<relation₁>*, then *<dimexpr₂>* and *<dimexpr₃>* using the *<relation₂>*, until finally comparing *<dimexpr_N>* and *<dimexpr_{N+1}>* using the *<relation_N>*. The test yields `true` if all comparisons are `true`. Each *<dimension expression>* is evaluated only once, and the evaluation is lazy, in the sense that if one comparison is `false`, then no other *<dimension expression>* is evaluated and no other comparison is performed. The *<relations>* can be any of the following:

Equal	= or ==
Greater than or equal to	>=
Greater than	>
Less than or equal to	<=
Less than	<
Not equal	!=

This function is more flexible than `\dim_compare:nNnTF` but around 5 times slower.

<code>\dim_case:nn</code> ☆	<code>\dim_case:nnTF {⟨test dimension expression⟩}</code>
<code>\dim_case:nnTF</code> ☆	<code>{</code>
New: 2013-07-24	<code>{⟨dimexpr case₁⟩} {⟨code case₁⟩}</code>
	<code>{⟨dimexpr case₂⟩} {⟨code case₂⟩}</code>
	<code>...</code>
	<code>{⟨dimexpr case_n⟩} {⟨code case_n⟩}</code>
	<code>}</code>
	<code>{⟨true code⟩}</code>
	<code>{⟨false code⟩}</code>

This function evaluates the *⟨test dimension expression⟩* and compares this in turn to each of the *⟨dimension expression cases⟩*. If the two are equal then the associated *⟨code⟩* is left in the input stream and other cases are discarded. If any of the cases are matched, the *⟨true code⟩* is also inserted into the input stream (after the code for the appropriate case), while if none match then the *⟨false code⟩* is inserted. The function `\dim_case:nn`, which does nothing if there is no match, is also available. For example

```

\dim_set:Nn \l_tmpa_dim { 5 pt }
\dim_case:nnF
{ 2 \l_tmpa_dim }
{
  { 5 pt }      { Small }
  { 4 pt + 6 pt } { Medium }
  { - 10 pt }   { Negative }
}
{ No idea! }
```

leaves “Medium” in the input stream.

5 Dimension expression loops

<code>\dim_do_until:nNnn</code> ☆	<code>\dim_do_until:nNnn {⟨dimexpr₁⟩} ⟨relation⟩ {⟨dimexpr₂⟩} {⟨code⟩}</code>
-----------------------------------	---

Places the *⟨code⟩* in the input stream for T_EX to process, and then evaluates the relationship between the two *⟨dimension expressions⟩* as described for `\dim_compare:nNnTF`. If the test is **false** then the *⟨code⟩* is inserted into the input stream again and a loop occurs until the *⟨relation⟩* is **true**.

<code>\dim_do_while:nNnn</code> ☆	<code>\dim_do_while:nNnn {⟨dimexpr₁⟩} ⟨relation⟩ {⟨dimexpr₂⟩} {⟨code⟩}</code>
-----------------------------------	---

Places the *⟨code⟩* in the input stream for T_EX to process, and then evaluates the relationship between the two *⟨dimension expressions⟩* as described for `\dim_compare:nNnTF`. If the test is **true** then the *⟨code⟩* is inserted into the input stream again and a loop occurs until the *⟨relation⟩* is **false**.

<code>\dim_until_do:nNnn</code> ☆	<code>\dim_until_do:nNnn {⟨dimexpr₁⟩} ⟨relation⟩ {⟨dimexpr₂⟩} {⟨code⟩}</code>
-----------------------------------	---

Evaluates the relationship between the two *⟨dimension expressions⟩* as described for `\dim_compare:nNnTF`, and then places the *⟨code⟩* in the input stream if the *⟨relation⟩* is **false**. After the *⟨code⟩* has been processed by T_EX the test is repeated, and a loop occurs until the test is **true**.

<hr/> <code>\dim_while_do:nNnn</code> ☆ <hr/>	<code>\dim_while_do:nNnn {<dimexpr₁>} <relation> {<dimexpr₂>} {<code>}</code>
	Evaluates the relationship between the two <i><dimension expressions></i> as described for <code>\dim_compare:nNnTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is true . After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is false .
<hr/> <code>\dim_do_until:nn</code> ☆ <hr/> <div>Updated: 2013-01-13</div> <hr/>	<code>\dim_do_until:nn {<dimension relation>} {<code>}</code>
	Places the <i><code></i> in the input stream for T _E X to process, and then evaluates the <i><dimension relation></i> as described for <code>\dim_compare:nTF</code> . If the test is false then the <i><code></i> is inserted into the input stream again and a loop occurs until the <i><relation></i> is true .
<hr/> <code>\dim_do_while:nn</code> ☆ <hr/> <div>Updated: 2013-01-13</div> <hr/>	<code>\dim_do_while:nn {<dimension relation>} {<code>}</code>
	Places the <i><code></i> in the input stream for T _E X to process, and then evaluates the <i><dimension relation></i> as described for <code>\dim_compare:nTF</code> . If the test is true then the <i><code></i> is inserted into the input stream again and a loop occurs until the <i><relation></i> is false .
<hr/> <code>\dim_until_do:nn</code> ☆ <hr/> <div>Updated: 2013-01-13</div> <hr/>	<code>\dim_until_do:nn {<dimension relation>} {<code>}</code>
	Evaluates the <i><dimension relation></i> as described for <code>\dim_compare:nTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is false . After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is true .
<hr/> <code>\dim_while_do:nn</code> ☆ <hr/> <div>Updated: 2013-01-13</div> <hr/>	<code>\dim_while_do:nn {<dimension relation>} {<code>}</code>
	Evaluates the <i><dimension relation></i> as described for <code>\dim_compare:nTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is true . After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is false .

6 Dimension step functions

<hr/> <code>\dim_step_function:nnnN</code> ☆ <hr/> <div>New: 2018-02-18</div> <hr/>	<code>\dim_step_function:nnnN {<initial value>} {<step>} {<final value>} <function></code>
	This function first evaluates the <i><initial value></i> , <i><step></i> and <i><final value></i> , all of which should be dimension expressions. The <i><function></i> is then placed in front of each <i><value></i> from the <i><initial value></i> to the <i><final value></i> in turn (using <i><step></i> between each <i><value></i>). The <i><step></i> must be non-zero. If the <i><step></i> is positive, the loop stops when the <i><value></i> becomes larger than the <i><final value></i> . If the <i><step></i> is negative, the loop stops when the <i><value></i> becomes smaller than the <i><final value></i> . The <i><function></i> should absorb one argument.
<hr/> <code>\dim_step_inline:nnnn</code> <hr/> <div>New: 2018-02-18</div> <hr/>	<code>\dim_step_inline:nnnn {<initial value>} {<step>} {<final value>} {<code>}</code>
	This function first evaluates the <i><initial value></i> , <i><step></i> and <i><final value></i> , all of which should be dimension expressions. Then for each <i><value></i> from the <i><initial value></i> to the <i><final value></i> in turn (using <i><step></i> between each <i><value></i>), the <i><code></i> is inserted into the input stream with #1 replaced by the current <i><value></i> . Thus the <i><code></i> should define a function of one argument (#1).

`\dim_step_variable:nnnNn`
 New: 2018-02-18

`\dim_step_variable:nnnNn`
`{\langle initial value \rangle}{\langle step \rangle}{\langle final value \rangle}{\langle tl var \rangle}{\langle code \rangle}`

This function first evaluates the $\langle initial value \rangle$, $\langle step \rangle$ and $\langle final value \rangle$, all of which should be dimension expressions. Then for each $\langle value \rangle$ from the $\langle initial value \rangle$ to the $\langle final value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$), the $\langle code \rangle$ is inserted into the input stream, with the $\langle tl var \rangle$ defined as the current $\langle value \rangle$. Thus the $\langle code \rangle$ should make use of the $\langle tl var \rangle$.

7 Using dim expressions and variables

`\dim_eval:n` ★
 Updated: 2011-10-22

`\dim_eval:n` $\{\langle dimension expression \rangle\}$

Evaluates the $\langle dimension expression \rangle$, expanding any dimensions and token list variables within the $\langle expression \rangle$ to their content (without requiring `\dim_use:N/\tl_use:N`) and applying the standard mathematical rules. The result of the calculation is left in the input stream as a $\langle dimension denotation \rangle$ after two expansions. This is expressed in points (**pt**), and requires suitable termination if used in a T_EX-style assignment as it is *not* an $\langle internal dimension \rangle$.

`\dim_use:N` ★
`\dim_use:c` ★

`\dim_use:N` $\langle dimension \rangle$

Recovers the content of a $\langle dimension \rangle$ and places it directly in the input stream. An error is raised if the variable does not exist or if it is invalid. Can be omitted in places where a $\langle dimension \rangle$ is required (such as in the argument of `\dim_eval:n`).

T_EXhackers note: `\dim_use:N` is the T_EX primitive `\the`: this is one of several L^AT_EX3 names for this primitive.

`\dim_to_decimal:n` ★
 New: 2014-07-15

`\dim_to_decimal:n` $\{\langle dimexpr \rangle\}$

Evaluates the $\langle dimension expression \rangle$, and leaves the result, expressed in points (**pt**) in the input stream, with *no units*. The result is rounded by T_EX to four or five decimal places. If the decimal part of the result is zero, it is omitted, together with the decimal marker.

For example

`\dim_to_decimal:n { 1bp }`

leaves 1.00374 in the input stream, *i.e.* the magnitude of one “big point” when converted to (T_EX) points.

<hr/> <code>\dim_to_decimal_in_bp:n</code> ★ <hr/>	<code>\dim_to_decimal_in_bp:n {⟨dimexpr⟩}</code>
<hr/> New: 2014-07-15 <hr/>	Evaluates the <i>⟨dimension expression⟩</i> , and leaves the result, expressed in big points (bp) in the input stream, with <i>no units</i> . The result is rounded by T _E X to four or five decimal places. If the decimal part of the result is zero, it is omitted, together with the decimal marker.

For example

```
\dim_to_decimal_in_bp:n { 1pt }
```

leaves 0.99628 in the input stream, *i.e.* the magnitude of one (T_EX) point when converted to big points.

<hr/> <code>\dim_to_decimal_in_sp:n</code> ★ <hr/>	<code>\dim_to_decimal_in_sp:n {⟨dimexpr⟩}</code>
<hr/> New: 2015-05-18 <hr/>	Evaluates the <i>⟨dimension expression⟩</i> , and leaves the result, expressed in scaled points (sp) in the input stream, with <i>no units</i> . The result is necessarily an integer.

<hr/> <code>\dim_to_decimal_in_unit:nn</code> ★ <hr/>	<code>\dim_to_decimal_in_unit:nn {⟨dimexpr₁⟩} {⟨dimexpr₂⟩}</code>
<hr/> New: 2014-07-15 <hr/>	

Evaluates the *⟨dimension expressions⟩*, and leaves the value of *⟨dimexpr₁⟩*, expressed in a unit given by *⟨dimexpr₂⟩*, in the input stream. The result is a decimal number, rounded by T_EX to four or five decimal places. If the decimal part of the result is zero, it is omitted, together with the decimal marker.

For example

```
\dim_to_decimal_in_unit:nn { 1bp } { 1mm }
```

leaves 0.35277 in the input stream, *i.e.* the magnitude of one big point when converted to millimetres.

Note that this function is not optimised for any particular output and as such may give different results to `\dim_to_decimal_in_bp:n` or `\dim_to_decimal_in_sp:n`. In particular, the latter is able to take a wider range of input values as it is not limited by the ability to calculate a ratio using ε -T_EX primitives, which is required internally by `\dim_to_decimal_in_unit:nn`.

<hr/> <code>\dim_to_fp:n</code> ★ <hr/>	<code>\dim_to_fp:n {⟨dimexpr⟩}</code>
<hr/> New: 2012-05-08 <hr/>	Expands to an internal floating point number equal to the value of the <i>⟨dimexpr⟩</i> in pt. Since dimension expressions are evaluated much faster than their floating point equivalent, <code>\dim_to_fp:n</code> can be used to speed up parts of a computation where a low precision and a smaller range are acceptable.

8 Viewing dim variables

<hr/> <code>\dim_show:N</code> <hr/>	<code>\dim_show:N ⟨dimension⟩</code>
<hr/> <code>\dim_show:c</code> <hr/>	Displays the value of the <i>⟨dimension⟩</i> on the terminal.

<hr/> <code>\dim_show:n</code> <hr/>	<code>\dim_show:n {⟨<i>dimension expression</i>⟩}</code>
New: 2011-11-22 Updated: 2015-08-07	Displays the result of evaluating the $\langle dimension\ expression \rangle$ on the terminal.
<hr/> <code>\dim_log:N</code> <code>\dim_log:c</code> <hr/>	<code>\dim_log:N ⟨<i>dimension</i>⟩</code>
New: 2014-08-22 Updated: 2015-08-03	Writes the value of the $\langle dimension \rangle$ in the log file.
<hr/> <code>\dim_log:n</code> <hr/>	<code>\dim_log:n {⟨<i>dimension expression</i>⟩}</code>
New: 2014-08-22 Updated: 2015-08-07	Writes the result of evaluating the $\langle dimension\ expression \rangle$ in the log file.

9 Constant dimensions

`\c_max_dim`

 The maximum value that can be stored as a dimension. This can also be used as a component of a skip.

`\c_zero_dim`

 A zero length as a dimension. This can also be used as a component of a skip.

10 Scratch dimensions

`\l_tmpa_dim`
`\l_tmpp_dim`

 Scratch dimension for local assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

`\g_tmpa_dim`
`\g_tmpp_dim`

 Scratch dimension for global assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

11 Creating and initialising skip variables

`\skip_new:N`
`\skip_new:c`

 `\skip_new:N ⟨skip⟩`
Creates a new $\langle skip \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle skip \rangle$ is initially equal to 0 pt.

<code>\skip_const:Nn</code>	<code>\skip_const:Nn <skip> {<skip expression>}</code>
<code>\skip_const:cn</code>	Creates a new constant <i><skip></i> or raises an error if the name is already taken. The value of the <i><skip></i> is set globally to the <i><skip expression></i> .
New: 2012-03-05	

<code>\skip_zero:N</code>	<code>\skip_zero:N <skip></code>
<code>\skip_zero:c</code>	Sets <i><skip></i> to 0 pt.
<code>\skip_gzero:N</code>	
<code>\skip_gzero:c</code>	

<code>\skip_zero_new:N</code>	<code>\skip_zero_new:N</code> $\langle skip \rangle$
<code>\skip_zero_new:c</code>	Ensures that the $\langle skip \rangle$ exists globally by applying <code>\skip_new:N</code> if necessary, then applies <code>\skip_(g)zero:N</code> to leave the $\langle skip \rangle$ set to zero.
<code>\skip_gzero_new:N</code>	
<code>\skip_gzero_new:c</code>	
<hr/>	
New: 2012-01-07	

<code>\skip_if_exist_p:N *</code>	<code>\skip_if_exist_p:N <skip></code>
<code>\skip_if_exist_p:c *</code>	<code>\skip_if_exist:NTF <skip> {<true code>} {<false code>}</code>
<code>\skip_if_exist:NTF *</code>	Tests whether the <code><skip></code> is currently defined. This does not check that the <code><skip></code> really is a skip variable.
<code>\skip_if_exist:cTF *</code>	

New: 2012-03-03

12 Setting skip variables

<code>\skip_add:Nn</code>	<code>\skip_add:Nn <skip> {<skip expression>}</code>
<code>\skip_add:cn</code>	Adds the result of the <i><skip expression></i> to the current content of the <i><skip></i> .
<code>\skip_gadd:Nn</code>	
<code>\skip_gadd:cn</code>	
Updated: 2011-10-22	

<code>\skip_set:Nn</code>	<code>\skip_set:Nn <skip> {<skip expression>}</code>
<code>\skip_set:cn</code>	Sets <code><skip></code> to the value of <code><skip expression></code> , which must evaluate to a length with units and may include a rubber component (for example 1 cm plus 0.5 cm).
<code>\skip_gset:Nn</code>	
<code>\skip_gset:cn</code>	
Updated: 2011-10-22	

<code>\skip_set_eq:NN</code>	<code>\skip_set_eq:NN <skip₁₂</code>
<code>\skip_set_eq:(cN Nc cc)</code>	Sets the content of <i><skip_{1 equal to that of <i><skip_{2.}</i>}</i>
<code>\skip_gset_eq:NN</code>	
<code>\skip_gset_eq:(cN Nc cc)</code>	

<code>\skip_sub:Nn</code>	<code>\skip_sub:Nn <skip> {<skip expression>}</code>
<code>\skip_sub:cn</code>	Subtracts the result of the <i><skip expression></i> from the current content of the <i><skip></i> .
<code>\skip_gsub:Nn</code>	
<code>\skip_gsub:cn</code>	

Updated: 2011-10-22

13 Skip expression conditionals

<code>\skip_if_eq_p:nn</code> *	<code>\skip_if_eq_p:nn {\langle skipexpr_1 \rangle} {\langle skipexpr_2 \rangle}</code>
<code>\skip_if_eq:nnTF</code> *	<code>\skip_if_eq:nnTF</code> <code> {\langle skipexpr_1 \rangle} {\langle skipexpr_2 \rangle}</code> <code> {\langle true code \rangle} {\langle false code \rangle}</code>

This function first evaluates each of the $\langle skip\ expressions \rangle$ as described for `\skip_eval:n`. The two results are then compared for exact equality, *i.e.* both the fixed and rubber components must be the same for the test to be true.

<code>\skip_if_finite_p:n</code> *	<code>\skip_if_finite_p:n {\langle skipexpr \rangle}</code>
<code>\skip_if_finite:nTF</code> *	<code>\skip_if_finite:nTF {\langle skipexpr \rangle} {\langle true code \rangle} {\langle false code \rangle}</code>

New: 2012-03-05

Evaluates the $\langle skip\ expression \rangle$ as described for `\skip_eval:n`, and then tests if all of its components are finite.

14 Using skip expressions and variables

<code>\skip_eval:n</code> *	<code>\skip_eval:n {\langle skip expression \rangle}</code>
-----------------------------	---

Updated: 2011-10-22

Evaluates the $\langle skip\ expression \rangle$, expanding any skips and token list variables within the $\langle expression \rangle$ to their content (without requiring `\skip_use:N/\tl_use:N`) and applying the standard mathematical rules. The result of the calculation is left in the input stream as a $\langle glue\ denotation \rangle$ after two expansions. This is expressed in points (`pt`), and requires suitable termination if used in a \TeX -style assignment as it is *not* an $\langle internal\ glue \rangle$.

<code>\skip_use:N</code> *	<code>\skip_use:N \langle skip \rangle</code>
<code>\skip_use:c</code> *	

Recovers the content of a $\langle skip \rangle$ and places it directly in the input stream. An error is raised if the variable does not exist or if it is invalid. Can be omitted in places where a $\langle dimension \rangle$ or $\langle skip \rangle$ is required (such as in the argument of `\skip_eval:n`).

\TeX hackers note: `\skip_use:N` is the \TeX primitive `\the`: this is one of several \LaTeX 3 names for this primitive.

15 Viewing skip variables

<code>\skip_show:N</code>	<code>\skip_show:N \langle skip \rangle</code>
<code>\skip_show:c</code>	

Updated: 2015-08-03

Displays the value of the $\langle skip \rangle$ on the terminal.

<code>\skip_show:n</code>	<code>\skip_show:n {\langle skip expression \rangle}</code>
---------------------------	---

New: 2011-11-22
Updated: 2015-08-07

Displays the result of evaluating the $\langle skip\ expression \rangle$ on the terminal.

<code>\skip_log:N</code>	<code>\skip_log:N <skip></code>
<code>\skip_log:c</code>	Writes the value of the $\langle skip \rangle$ in the log file.
New: 2014-08-22	
Updated: 2015-08-03	

<code>\skip_log:n</code>	<code>\skip_log:n {\langle skip expression \rangle}</code>
	Writes the result of evaluating the $\langle skip expression \rangle$ in the log file.
New: 2014-08-22	
Updated: 2015-08-07	

16 Constant skips

<code>\c_max_skip</code>	The maximum value that can be stored as a skip (equal to <code>\c_max_dim</code> in length), with no stretch nor shrink component.
Updated: 2012-11-02	

<code>\c_zero_skip</code>	A zero length as a skip, with no stretch nor shrink component.
Updated: 2012-11-01	

17 Scratch skips

<code>\l_tmpa_skip</code> <code>\l_tmpb_skip</code>	Scratch skip for local assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
--	--

<code>\g_tmpa_skip</code> <code>\g_tmpb_skip</code>	Scratch skip for global assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
--	---

18 Inserting skips into the output

<code>\skip_horizontal:N</code>	<code>\skip_horizontal:N <skip></code>
<code>\skip_horizontal:c</code>	<code>\skip_horizontal:n {\langle skipexpr \rangle}</code>
<code>\skip_horizontal:n</code>	Inserts a horizontal $\langle skip \rangle$ into the current list. The argument can also be a $\langle dim \rangle$.
Updated: 2011-10-22	
T_EXhackers note: <code>\skip_horizontal:N</code> is the T _E X primitive <code>\hskip</code> renamed.	

<hr/>	
<code>\skip_vertical:N</code>	<code>\skip_vertical:N <skip></code>
<code>\skip_vertical:c</code>	<code>\skip_vertical:n {<skipexpr>}</code>
<code>\skip_vertical:n</code>	Inserts a vertical <code><skip></code> into the current list. The argument can also be a <code><dim></code> .
<hr/> Updated: 2011-10-22 <hr/>	
T _E Xhackers note: <code>\skip_vertical:N</code> is the T _E X primitive <code>\vskip</code> renamed.	

19 Creating and initialising muskip variables

<hr/>	
<code>\muskip_new:N</code>	<code>\muskip_new:N <muskip></code>
<code>\muskip_new:c</code>	Creates a new <code><muskip></code> or raises an error if the name is already taken. The declaration is global. The <code><muskip></code> is initially equal to 0 mu.
<hr/>	

<hr/>	
<code>\muskip_const:Nn</code>	<code>\muskip_const:Nn <muskip> {<muskip expression>}</code>
<code>\muskip_const:cn</code>	Creates a new constant <code><muskip></code> or raises an error if the name is already taken. The value of the <code><muskip></code> is set globally to the <code><muskip expression></code> .
<hr/> New: 2012-03-05 <hr/>	

<hr/>	
<code>\muskip_zero:N</code>	<code>\skip_zero:N</code> $\langle muskip \rangle$
<code>\muskip_zero:c</code>	Sets $\langle muskip \rangle$ to 0 mu.
<code>\muskip_gzero:N</code>	
<code>\muskip_gzero:c</code>	
<hr/>	

<code>\muskip_zero_new:N</code>	<code>\muskip_zero_new:N <muskip></code>
<code>\muskip_zero_new:c</code>	Ensures that the $\langle muskip \rangle$ exists globally by applying <code>\muskip_new:N</code> if necessary, then applies <code>\muskip_(g)zero:N</code> to leave the $\langle muskip \rangle$ set to zero.
<code>\muskip_gzero_new:N</code>	
<code>\muskip_gzero_new:c</code>	
<hr/>	
New: 2012-01-07	

<hr/>	
<code>\muskip_if_exist_p:N *</code>	<code>\muskip_if_exist_p:N <muskip></code>
<code>\muskip_if_exist_p:c *</code>	<code>\muskip_if_exist:Ntf <muskip> {<true code>} {<false code>}</code>
<code>\muskip_if_exist:Ntf *</code>	Tests whether the <code><muskip></code> is currently defined. This does not check that the <code><muskip></code> really is a muskip variable.
<code>\muskip_if_exist:cTF *</code>	
<hr/>	
New: 2012-03-03	

20 Setting muskip variables

<code>\muskip_add:Nn</code>	<code>\muskip_add:Nn <muskip> {<muskip expression>}</code>
<code>\muskip_add:cn</code>	Adds the result of the <i><muskip expression></i> to the current content of the <i><muskip></i> .
<code>\muskip_gadd:Nn</code>	
<code>\muskip_gadd:cn</code>	
<hr/>	
Updated: 2011-10-22	

<hr/> <code>\muskip_set:Nn</code>	<code>\muskip_set:Nn <muskip> {<muskip expression>}</code>
<code>\muskip_set:cn</code>	
<code>\muskip_gset:Nn</code>	Sets $\langle muskip \rangle$ to the value of $\langle muskip expression \rangle$, which must evaluate to a math length with units and may include a rubber component (for example 1 mu plus 0.5 mu).
<code>\muskip_gset:cn</code>	
<hr/> Updated: 2011-10-22 <hr/>	

<hr/> <code>\muskip_set_eq:NN</code>	<code>\muskip_set_eq:NN <muskip₁> <muskip₂></code>
<code>\muskip_set_eq:(cN Nc cc)</code>	
<code>\muskip_gset_eq:NN</code>	Sets the content of $\langle muskip_1 \rangle$ equal to that of $\langle muskip_2 \rangle$.
<code>\muskip_gset_eq:(cN Nc cc)</code>	

<hr/> <code>\muskip_sub:Nn</code>	<code>\muskip_sub:Nn <muskip> {<muskip expression>}</code>
<code>\muskip_sub:cn</code>	
<code>\muskip_gsub:Nn</code>	Subtracts the result of the $\langle muskip expression \rangle$ from the current content of the $\langle muskip \rangle$.
<code>\muskip_gsub:cn</code>	
<hr/> Updated: 2011-10-22 <hr/>	

21 Using muskip expressions and variables

<hr/> <code>\muskip_eval:n *</code>	<code>\muskip_eval:n {<muskip expression>}</code>
<hr/> Updated: 2011-10-22 <hr/>	
	Evaluates the $\langle muskip expression \rangle$, expanding any skips and token list variables within the $\langle expression \rangle$ to their content (without requiring <code>\muskip_use:N/\tl_use:N</code>) and applying the standard mathematical rules. The result of the calculation is left in the input stream as a $\langle muglue denotation \rangle$ after two expansions. This is expressed in mu, and requires suitable termination if used in a TeX-style assignment as it is <i>not</i> an $\langle internal muglue \rangle$.

<hr/> <code>\muskip_use:N *</code>	<code>\muskip_use:N <muskip></code>
<code>\muskip_use:c *</code>	
	Recovers the content of a $\langle skip \rangle$ and places it directly in the input stream. An error is raised if the variable does not exist or if it is invalid. Can be omitted in places where a $\langle dimension \rangle$ is required (such as in the argument of <code>\muskip_eval:n</code>).

TeXhackers note: `\muskip_use:N` is the TeX primitive `\the`: this is one of several L^ATeX3 names for this primitive.

22 Viewing muskip variables

<hr/> <code>\muskip_show:N</code>	<code>\muskip_show:N <muskip></code>
<code>\muskip_show:c</code>	
	Displays the value of the $\langle muskip \rangle$ on the terminal.
<hr/> Updated: 2015-08-03 <hr/>	

<hr/> <code>\muskip_show:n</code> <hr/>	<code>\muskip_show:n {⟨<i>muskip expression</i>⟩}</code>
New: 2011-11-22 Updated: 2015-08-07	Displays the result of evaluating the $\langle muskip expression \rangle$ on the terminal.
<hr/> <code>\muskip_log:N</code> <code>\muskip_log:c</code> <hr/>	<code>\muskip_log:N ⟨<i>muskip</i>⟩</code>
New: 2014-08-22 Updated: 2015-08-03	Writes the value of the $\langle muskip \rangle$ in the log file.
<hr/> <code>\muskip_log:n</code> <hr/>	<code>\muskip_log:n {⟨<i>muskip expression</i>⟩}</code>
New: 2014-08-22 Updated: 2015-08-07	Writes the result of evaluating the $\langle muskip expression \rangle$ in the log file.

23 Constant muskips

<hr/> <code>\c_max_muskip</code> <hr/>	The maximum value that can be stored as a muskip, with no stretch nor shrink component.
<hr/> <code>\c_zero_muskip</code> <hr/>	A zero length as a muskip, with no stretch nor shrink component.

24 Scratch muskips

<hr/> <code>\l_tmpa_muskip</code> <code>\l_tmpb_muskip</code> <hr/>	Scratch muskip for local assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.
<hr/> <code>\g_tmpa_muskip</code> <code>\g_tmpb_muskip</code> <hr/>	Scratch muskip for global assignment. These are never used by the kernel code, and so are safe for use with any L ^A T _E X3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

25 Primitive conditional

<hr/> <code>\if_dim:w</code> <hr/>	<code>\if_dim:w ⟨<i>dimen</i>₁⟩ ⟨<i>relation</i>⟩ ⟨<i>dimen</i>₂⟩</code> <code>⟨<i>true code</i>⟩</code> <code>\else:</code> <code>⟨<i>false</i>⟩</code> <code>\fi:</code>
	Compare two dimensions. The $\langle relation \rangle$ is one of $<$, $=$ or $>$ with category code 12.

T_EXhackers note: This is the T_EX primitive `\ifdim`.

Part XXI

The l3keys package

Key–value interfaces

The key–value method is a popular system for creating large numbers of settings for controlling function or package behaviour. The system normally results in input of the form

```
\MyModuleSetup{
  key-one = value one,
  key-two = value two
}
```

or

```
\MyModuleMacro[
  key-one = value one,
  key-two = value two
]{argument}
```

for the user.

The high level functions here are intended as a method to create key–value controls. Keys are themselves created using a key–value interface, minimising the number of functions and arguments required. Each key is created by setting one or more *properties* of the key:

```
\keys_define:nn { mymodule }
{
  key-one .code:n = code including parameter #1,
  key-two .tl_set:N = \l_mymodule_store_tl
}
```

These values can then be set as with other key–value approaches:

```
\keys_set:nn { mymodule }
{
  key-one = value one,
  key-two = value two
}
```

At a document level, `\keys_set:nn` is used within a document function, for example

```
\DeclareDocumentCommand \MyModuleSetup { m }
{ \keys_set:nn { mymodule } { #1 } }
\DeclareDocumentCommand \MyModuleMacro { o m }
{
  \group_begin:
    \keys_set:nn { mymodule } { #1 }
    % Main code for \MyModuleMacro
  \group_end:
}
```


Key names may contain any tokens, as they are handled internally using `\tl_to_str:n`. As discussed in section 2, it is suggested that the character `/` is reserved for sub-division of keys into logical groups. Functions and variables are *not* expanded when creating key names, and so

```
\tl_set:Nn \l_mymodule_tmp_tl { key }
\keys_define:nn { mymodule }
{
  \l_mymodule_tmp_tl .code:n = code
}
```

creates a key called `\l_mymodule_tmp_tl`, and not one called `key`.

1 Creating keys

`\keys_define:nn`

Updated: 2017-11-14

`\keys_define:nn {<module>} {<keyval list>}`

Parses the *<keyval list>* and defines the keys listed there for *<module>*. The *<module>* name is treated as a string. In practice the *<module>* should be chosen to be unique to the module in question (unless deliberately adding keys to an existing module).

The *<keyval list>* should consist of one or more key names along with an associated key *property*. The properties of a key determine how it acts. The individual properties are described in the following text; a typical use of `\keys_define:nn` might read

```
\keys_define:nn { mymodule }
{
  keyname .code:n = Some~code~using~#1,
  keyname .value_required:n = true
}
```

where the properties of the key begin from the `.` after the key name.

The various properties available take either no arguments at all, or require one or more arguments. This is indicated in the name of the property using an argument specification. In the following discussion, each property is illustrated attached to an arbitrary *<key>*, which when used may be supplied with a *<value>*. All key *definitions* are local.

Key properties are applied in the reading order and so the ordering is significant. Key properties which define “actions”, such as `.code:n`, `.tl_set:N`, *etc.*, override one another. Some other properties are mutually exclusive, notably `.value_required:n` and `.value_forbidden:n`, and so they replace one another. However, properties covering non-exclusive behaviours may be given in any order. Thus for example the following definitions are equivalent.

```
\keys_define:nn { mymodule }
{
  keyname .code:n          = Some~code~using~#1,
  keyname .value_required:n = true
}
\keys_define:nn { mymodule }
{
```

```

    keyname .value_required:n = true,
    keyname .code:n           = Some~code~using~#1
}

```

Note that with the exception of the special `.undefine:` property, all key properties define the key within the current \TeX scope.

```

.bool_set:N
.bool_set:c
.bool_gset:N
.bool_gset:c

```

Updated: 2013-07-08

$\langle key \rangle$.bool_set:N = $\langle boolean \rangle$

Defines $\langle key \rangle$ to set $\langle boolean \rangle$ to $\langle value \rangle$ (which must be either `true` or `false`). If the variable does not exist, it will be created globally at the point that the key is set up.

```

.bool_set_inverse:N
.bool_set_inverse:c
.bool_gset_inverse:N
.bool_gset_inverse:c

```

New: 2011-08-28

Updated: 2013-07-08

$\langle key \rangle$.bool_set_inverse:N = $\langle boolean \rangle$

Defines $\langle key \rangle$ to set $\langle boolean \rangle$ to the logical inverse of $\langle value \rangle$ (which must be either `true` or `false`). If the $\langle boolean \rangle$ does not exist, it will be created globally at the point that the key is set up.

```

.choice:

```

$\langle key \rangle$.choice:

Sets $\langle key \rangle$ to act as a choice key. Each valid choice for $\langle key \rangle$ must then be created, as discussed in section 3.

```

.choices:nn
.choices:(Vn|on|xn)

```

New: 2011-08-21

Updated: 2013-07-10

$\langle key \rangle$.choices:nn = $\{\langle choices \rangle\}$ $\{\langle code \rangle\}$

Sets $\langle key \rangle$ to act as a choice key, and defines a series $\langle choices \rangle$ which are implemented using the $\langle code \rangle$. Inside $\langle code \rangle$, `\l_keys_choice_tl` will be the name of the choice made, and `\l_keys_choice_int` will be the position of the choice in the list of $\langle choices \rangle$ (indexed from 1). Choices are discussed in detail in section 3.

```

.clist_set:N
.clist_set:c
.clist_gset:N
.clist_gset:c

```

New: 2011-09-11

$\langle key \rangle$.clist_set:N = $\langle comma list variable \rangle$

Defines $\langle key \rangle$ to set $\langle comma list variable \rangle$ to $\langle value \rangle$. Spaces around commas and empty items will be stripped. If the variable does not exist, it is created globally at the point that the key is set up.

```

.code:n

```

Updated: 2013-07-10

$\langle key \rangle$.code:n = $\{\langle code \rangle\}$

Stores the $\langle code \rangle$ for execution when $\langle key \rangle$ is used. The $\langle code \rangle$ can include one parameter (`#1`), which will be the $\langle value \rangle$ given for the $\langle key \rangle$.

`.default:n`
`.default:(V|o|x)`
Updated: 2013-07-09

`<key> .default:n = {<default>}`

Creates a *<default>* value for *<key>*, which is used if no value is given. This will be used if only the key name is given, but not if a blank *<value>* is given:

```
\keys_define:nn { mymodule }
{
    key .code:n      = Hello~#1,
    key .default:n = World
}
\keys_set:nn { mymodule }
{
    key = Fred, % Prints 'Hello Fred'
    key,      % Prints 'Hello World'
    key = ,    % Prints 'Hello '
}
```

The default does not affect keys where values are required or forbidden. Thus a required value cannot be supplied by a default value, and giving a default value for a key which cannot take a value does not trigger an error.

`.dim_set:N`
`.dim_set:c`
`.dim_gset:N`
`.dim_gset:c`

`<key> .dim_set:N = <dimension>`

Defines *<key>* to set *<dimension>* to *<value>* (which must a dimension expression). If the variable does not exist, it is created globally at the point that the key is set up.

`.fp_set:N`
`.fp_set:c`
`.fp_gset:N`
`.fp_gset:c`

`<key> .fp_set:N = <floating point>`

Defines *<key>* to set *<floating point>* to *<value>* (which must a floating point expression). If the variable does not exist, it is created globally at the point that the key is set up.

`.groups:n`
New: 2013-07-14

`<key> .groups:n = {<groups>}`

Defines *<key>* as belonging to the *<groups>* declared. Groups provide a “secondary axis” for selectively setting keys, and are described in Section 6.

`.inherit:n`
New: 2016-11-22

`<key> .inherit:n = {<parents>}`

Specifies that the *<key>* path should inherit the keys listed as *<parents>*. For example, after setting

```
\keys_define:nn { foo } { test .code:n = \tl_show:n {#1} }
\keys_define:nn { } { bar .inherit:n = foo }
```

setting

```
\keys_set:nn { bar } { test = a }
```

will be equivalent to

```
\keys_set:nn { foo } { test = a }
```

<hr/> <code>.initial:n</code> <hr/>	<code><key> .initial:n = {<value>}</code>
<code>.initial:(V o x)</code>	Initialises the <code><key></code> with the <code><value></code> , equivalent to
<hr/> Updated: 2013-07-09 <hr/>	<code>\keys_set:nn {<module>} { <key> = <value> }</code>
<hr/>	
<code>.int_set:N</code>	<code><key> .int_set:N = <integer></code>
<code>.int_set:c</code>	Defines <code><key></code> to set <code><integer></code> to <code><value></code> (which must be an integer expression). If the
<code>.int_gset:N</code>	variable does not exist, it is created globally at the point that the key is set up.
<code>.int_gset:c</code>	
<hr/>	
<code>.meta:n</code>	<code><key> .meta:n = {<keyval list>}</code>
<hr/> Updated: 2013-07-10 <hr/>	Makes <code><key></code> a meta-key, which will set <code><keyval list></code> in one go. The <code><keyval list></code> can refer
	as <code>#1</code> to the value given at the time the <code><key></code> is used (or, if no value is given, the <code><key></code> 's
	default value).
<hr/>	
<code>.meta:nn</code>	<code><key> .meta:nn = {<path>} {<keyval list>}</code>
<hr/> New: 2013-07-10 <hr/>	Makes <code><key></code> a meta-key, which will set <code><keyval list></code> in one go using the <code><path></code> in place of
	the current one. The <code><keyval list></code> can refer as <code>#1</code> to the value given at the time the <code><key></code>
	is used (or, if no value is given, the <code><key></code> 's default value).
<hr/>	
<code>.multichoice:</code>	<code><key> .multichoice:</code>
<hr/> New: 2011-08-21 <hr/>	Sets <code><key></code> to act as a multiple choice key. Each valid choice for <code><key></code> must then be
	created, as discussed in section 3.
<hr/>	
<code>.multichoices:nn</code>	<code><key> .multichoices:nn {<choices>} {<code>}</code>
<code>.multichoices:(Vn on xn)</code>	Sets <code><key></code> to act as a multiple choice key, and defines a series <code><choices></code> which are im-
<hr/> New: 2011-08-21 <hr/>	plemented using the <code><code></code> . Inside <code><code></code> , <code>\l_keys_choice_tl</code> will be the name of the
Updated: 2013-07-10 <hr/>	choice made, and <code>\l_keys_choice_int</code> will be the position of the choice in the list of
	<code><choices></code> (indexed from 1). Choices are discussed in detail in section 3.
<hr/>	
<code>.muskip_set:N</code>	<code><key> .muskip_set:N = <muskip></code>
<code>.muskip_set:c</code>	Defines <code><key></code> to set <code><muskip></code> to <code><value></code> (which must be a muskip expression). If the
<code>.muskip_gset:N</code>	variable does not exist, it is created globally at the point that the key is set up.
<code>.muskip_gset:c</code>	
<hr/> New: 2019-05-05 <hr/>	
<hr/>	
<code>.prop_put:N</code>	<code><key> .prop_put:N = <property list></code>
<code>.prop_put:c</code>	Defines <code><key></code> to put the <code><value></code> onto the <code><property list></code> stored under the <code><key></code> . If the
<code>.prop_gput:N</code>	variable does not exist, it is created globally at the point that the key is set up.
<code>.prop_gput:c</code>	
<hr/> New: 2019-01-31 <hr/>	
<hr/>	
<code>.skip_set:N</code>	<code><key> .skip_set:N = <skip></code>
<code>.skip_set:c</code>	Defines <code><key></code> to set <code><skip></code> to <code><value></code> (which must be a skip expression). If the variable
<code>.skip_gset:N</code>	does not exist, it is created globally at the point that the key is set up.
<code>.skip_gset:c</code>	
<hr/>	

<code>.tl_set:N</code>	$\langle key \rangle$ <code>.tl_set:N = $\langle token\ list\ variable \rangle$</code>
<code>.tl_set:c</code>	
<code>.tl_gset:N</code>	Defines $\langle key \rangle$ to set $\langle token\ list\ variable \rangle$ to $\langle value \rangle$. If the variable does not exist, it is created globally at the point that the key is set up.
<code>.tl_gset:c</code>	

<code>.tl_set_x:N</code>	$\langle key \rangle$ <code>.tl_set_x:N = $\langle token\ list\ variable \rangle$</code>
<code>.tl_set_x:c</code>	
<code>.tl_gset_x:N</code>	Defines $\langle key \rangle$ to set $\langle token\ list\ variable \rangle$ to $\langle value \rangle$, which will be subjected to an x -type expansion (<i>i.e.</i> using <code>\tl_set:Nx</code>). If the variable does not exist, it is created globally at the point that the key is set up.
<code>.tl_gset_x:c</code>	

<code>.undefine:</code>	$\langle key \rangle$ <code>.undefine:</code>
<small>New: 2015-07-14</small>	Removes the definition of the $\langle key \rangle$ within the current scope.

<code>.value_forbidden:n</code>	$\langle key \rangle$ <code>.value_forbidden:n = true false</code>
<small>New: 2015-07-14</small>	Specifies that $\langle key \rangle$ cannot receive a $\langle value \rangle$ when used. If a $\langle value \rangle$ is given then an error will be issued. Setting the property false cancels the restriction.

<code>.value_required:n</code>	$\langle key \rangle$ <code>.value_required:n = true false</code>
<small>New: 2015-07-14</small>	Specifies that $\langle key \rangle$ must receive a $\langle value \rangle$ when used. If a $\langle value \rangle$ is not given then an error will be issued. Setting the property false cancels the restriction.

2 Sub-dividing keys

When creating large numbers of keys, it may be desirable to divide them into several sub-groups for a given module. This can be achieved either by adding a sub-division to the module name:

```
\keys_define:nn { mymodule / subgroup }
{ key .code:n = code }
```

or to the key name:

```
\keys_define:nn { mymodule }
{ subgroup / key .code:n = code }
```

As illustrated, the best choice of token for sub-dividing keys in this way is `/`. This is because of the method that is used to represent keys internally. Both of the above code fragments set the same key, which has full name `mymodule/subgroup/key`.

As illustrated in the next section, this subdivision is particularly relevant to making multiple choices.

3 Choice and multiple choice keys

The `l3keys` system supports two types of choice key, in which a series of pre-defined input values are linked to varying implementations. Choice keys are usually created so that the various values are mutually-exclusive: only one can apply at any one time. “Multiple” choice keys are also supported: these allow a selection of values to be chosen at the same time.

Mutually-exclusive choices are created by setting the `.choice:` property:

```
\keys_define:nn { mymodule }
{ key .choice: }
```

For keys which are set up as choices, the valid choices are generated by creating sub-keys of the choice key. This can be carried out in two ways.

In many cases, choices execute similar code which is dependant only on the name of the choice or the position of the choice in the list of all possibilities. Here, the keys can share the same code, and can be rapidly created using the `.choices:nn` property.

```
\keys_define:nn { mymodule }
{
  key .choices:nn =
    { choice-a, choice-b, choice-c }
    {
      You~gave~choice~'\tl_use:N \l_keys_choice_tl',~
      which~is~in~position~\int_use:N \l_keys_choice_int \c_space_tl
      in~the~list.
    }
}
```

The index `\l_keys_choice_int` in the list of choices starts at 1.

`\l_keys_choice_int`
`\l_keys_choice_tl`

Inside the code block for a choice generated using `.choices:nn`, the variables `\l_keys_choice_tl` and `\l_keys_choice_int` are available to indicate the name of the current choice, and its position in the comma list. The position is indexed from 1. Note that, as with standard key code generated using `.code:n`, the value passed to the key (i.e. the choice name) is also available as `#1`.

On the other hand, it is sometimes useful to create choices which use entirely different code from one another. This can be achieved by setting the `.choice:` property of a key, then manually defining sub-keys.

```
\keys_define:nn { mymodule }
{
  key .choice:,
  key / choice-a .code:n = code-a,
  key / choice-b .code:n = code-b,
  key / choice-c .code:n = code-c,
}
```

It is possible to mix the two methods, but manually-created choices should *not* use `\l_keys_choice_tl` or `\l_keys_choice_int`. These variables do not have defined behaviour when used outside of code created using `.choices:nn` (i.e. anything might happen).

It is possible to allow choice keys to take values which have not previously been defined by adding code for the special `unknown` choice. The general behavior of the `unknown` key is described in Section 5. A typical example in the case of a choice would be to issue a custom error message:

```
\keys_define:nn { mymodule }
{
  key .choice:,
```

```

key / choice-a .code:n = code-a,
key / choice-b .code:n = code-b,
key / choice-c .code:n = code-c,
key / unknown .code:n =
    \msg_error:nnxxx { mymodule } { unknown-choice }
    { key } % Name of choice key
    { choice-a , choice-b , choice-c } % Valid choices
    { \exp_not:n {#1} } % Invalid choice given
%
%
}

```

Multiple choices are created in a very similar manner to mutually-exclusive choices, using the properties `.multichoice:` and `.multichoices:nn`. As with mutually exclusive choices, multiple choices are define as sub-keys. Thus both

```

\keys_define:nn { mymodule }
{
    key .multichoices:nn =
    { choice-a, choice-b, choice-c }
    {
        You-gave~choice~'\tl_use:N \l_keys_choice_tl',~
        which~is~in~position~
        \int_use:N \l_keys_choice_int \c_space_tl
        in~the~list.
    }
}

```

and

```

\keys_define:nn { mymodule }
{
    key .multichoice:,
    key / choice-a .code:n = code-a,
    key / choice-b .code:n = code-b,
    key / choice-c .code:n = code-c,
}

```

are valid.

When a multiple choice key is set

```

\keys_set:nn { mymodule }
{
    key = { a , b , c } % 'key' defined as a multiple choice
}

```

each choice is applied in turn, equivalent to a `clist` mapping or to applying each value individually:

```

\keys_set:nn { mymodule }
{
    key = a ,
    key = b ,
}

```

```

        key = c ,
    }

```

Thus each separate choice will have passed to it the `\l_keys_choice_tl` and `\l_keys_choice_int` in exactly the same way as described for `.choices:nn`.

4 Setting keys

```

\keys_set:nn
\keys_set:(nV|nv|no)

```

Updated: 2017-11-14

```
\keys_set:nn {<module>} {<keyval list>}
```

Parses the *<keyval list>*, and sets those keys which are defined for *<module>*. The behaviour on finding an unknown key can be set by defining a special **unknown** key: this is illustrated later.

```

\l_keys_key_tl
\l_keys_path_tl
\l_keys_value_tl

```

Updated: 2015-07-14

For each key processed, information of the full *path* of the key, the *name* of the key and the *value* of the key is available within three token list variables. These may be used within the code of the key.

The *value* is everything after the `=`, which may be empty if no value was given. This is stored in `\l_keys_value_tl`, and is not processed in any way by `\keys_set:nn`.

The *path* of the key is a “full” description of the key, and is unique for each key. It consists of the module and full key name, thus for example

```
\keys_set:nn { mymodule } { key-a = some-value }
```

has path `mymodule/key-a` while

```
\keys_set:nn { mymodule } { subset / key-a = some-value }
```

has path `mymodule/subset/key-a`. This information is stored in `\l_keys_path_tl`, and will have been processed by `\tl_to_str:n`.

The *name* of the key is the part of the path after the last `/`, and thus is not unique. In the preceding examples, both keys have name `key-a` despite having different paths. This information is stored in `\l_keys_key_tl`, and will have been processed by `\tl_to_str:n`.

5 Handling of unknown keys

If a key has not previously been defined (is unknown), `\keys_set:nn` looks for a special **unknown** key for the same module, and if this is not defined raises an error indicating that the key name was unknown. This mechanism can be used for example to issue custom error texts.

```

\keys_define:nn { mymodule }
{
    unknown .code:n =
        You~tried~to~set~key~'\l_keys_key_tl'~to~'#1'.
}

```

<code>\keys_set_known:nn</code>	<code>\keys_set_known:nn {<module>} {<keyval list>}</code>
<code>\keys_set_known:(nV nv no)</code>	<code>\keys_set_known:nnN {<module>} {<keyval list>} <tl></code>
<code>\keys_set_known:nnN</code>	<code>\keys_set_known:nnnN {<module>} {<keyval list>} {<root>} <tl></code>
<code>\keys_set_known:(nVN nvN noN)</code>	
<code>\keys_set_known:nnnN</code>	
<code>\keys_set_known:(nVnN nvnnN nonN)</code>	

New: 2011-08-23

Updated: 2019-01-29

These functions set keys which are known for the *<module>*, and simply ignore other keys. The `\keys_set_known:nn` function parses the *<keyval list>*, and sets those keys which are defined for *<module>*. Any keys which are unknown are not processed further by the parser. In addition, `\keys_set_known:nnN` stores the key-value pairs in the *<tl>* in comma-separated form (*i.e.* an edited version of the *<keyval list>*). When a *<root>* is given (`\keys_set_known:nnnN`), the key-value entries are returned relative to this point in the key tree. When it is absent, only the key name and value are provided. The correct list is returned by nested calls.

6 Selective key setting

In some cases it may be useful to be able to select only some keys for setting, even though these keys have the same path. For example, with a set of keys defined using

```
\keys define:nn { mymodule }
{
  key-one   .code:n   = { \my_func:n {#1} } ,
  key-two   .tl_set:N = \l_my_a_tl           ,
  key-three .tl_set:N = \l_my_b_tl           ,
  key-four  .fp_set:N = \l_my_a_fp           ,
}
```

the use of `\keys_set:nn` attempts to set all four keys. However, in some contexts it may only be sensible to set some keys, or to control the order of setting. To do this, keys may be assigned to *groups*: arbitrary sets which are independent of the key tree. Thus modifying the example to read

```
\keys define:nn { mymodule }
{
  key-one   .code:n   = { \my_func:n {#1} } ,
  key-one   .groups:n = { first }           ,
  key-two   .tl_set:N = \l_my_a_tl           ,
  key-two   .groups:n = { first }           ,
  key-three .tl_set:N = \l_my_b_tl           ,
  key-three .groups:n = { second }          ,
  key-four  .fp_set:N = \l_my_a_fp           ,
}
```

assigns *key-one* and *key-two* to group *first*, *key-three* to group *second*, while *key-four* is not assigned to a group.

Selective key setting may be achieved either by selecting one or more groups to be made “active”, or by marking one or more groups to be ignored in key setting.

<code>\keys_set_filter:nnn</code>	<code>\keys_set_filter:nnn {<module>} {<groups>} {<keyval list>}</code>
<code>\keys_set_filter:(nnV nnv nno)</code>	<code>\keys_set_filter:nnn {<module>} {<groups>} {<keyval list>} <tl></code>
<code>\keys_set_filter:nnnN</code>	<code>\keys_set_filter:nnnn {<module>} {<groups>} {<keyval list>} <root></code>
<code>\keys_set_filter:(nnVN nnvN nnoN)</code>	<code><tl></code>
<code>\keys_set_filter:nnnnN</code>	
<code>\keys_set_filter:(nnVnN nnvnN nnonN)</code>	

New: 2013-07-14

Updated: 2019-01-29

Activates key filtering in an “opt-out” sense: keys assigned to any of the $\langle groups \rangle$ specified are ignored. The $\langle groups \rangle$ are given as a comma-separated list. Unknown keys are not assigned to any group and are thus always set. The key-value pairs for each key which is filtered out are stored in the $\langle tl \rangle$ in a comma-separated form (*i.e.* an edited version of the $\langle keyval list \rangle$). The `\keys_set_filter:nnn` version skips this stage.

Use of `\keys_set_filter:nnnN` can be nested, with the correct residual $\langle keyval list \rangle$ returned at each stage. In the version which takes a $\langle root \rangle$ argument, the key list is returned relative to that point in the key tree. In the cases without a $\langle root \rangle$ argument, only the key names and values are returned.

<code>\keys_set_groups:nnn</code>	<code>\keys_set_groups:nnn {<module>} {<groups>} {<keyval list>}</code>
<code>\keys_set_groups:(nnV nnv nno)</code>	

New: 2013-07-14

Updated: 2017-05-27

Activates key filtering in an “opt-in” sense: only keys assigned to one or more of the $\langle groups \rangle$ specified are set. The $\langle groups \rangle$ are given as a comma-separated list. Unknown keys are not assigned to any group and are thus never set.

7 Utility functions for keys

<code>\keys_if_exist_p:nn *</code>	<code>\keys_if_exist_p:nn {<module>} {<key>}</code>
<code>\keys_if_exist:nnTF *</code>	<code>\keys_if_exist:nnTF {<module>} {<key>} {<true code>} {<false code>}</code>

Updated: 2017-11-14 Tests if the $\langle key \rangle$ exists for $\langle module \rangle$, *i.e.* if any code has been defined for $\langle key \rangle$.

<code>\keys_if_choice_exist_p:nnn *</code>	<code>\keys_if_choice_exist_p:nnn {<module>} {<key>} {<choice>}</code>
<code>\keys_if_choice_exist:nnnTF *</code>	<code>\keys_if_choice_exist:nnnTF {<module>} {<key>} {<choice>} {<true code>} {<false code>}</code>

New: 2011-08-21

Updated: 2017-11-14

Tests if the $\langle choice \rangle$ is defined for the $\langle key \rangle$ within the $\langle module \rangle$, *i.e.* if any code has been defined for $\langle key \rangle / \langle choice \rangle$. The test is **false** if the $\langle key \rangle$ itself is not defined.

<code>\keys_show:nn</code>	<code>\keys_show:nn {<module>} {<key>}</code>
----------------------------	---

Updated: 2015-08-09

Displays in the terminal the information associated to the $\langle key \rangle$ for a $\langle module \rangle$, including the function which is used to actually implement it.

<code>\keys_log:nn</code>
New: 2014-08-22
Updated: 2015-08-09

`\keys_log:nn {<module>} {<key>}`

Writes in the log file the information associated to the $\langle key \rangle$ for a $\langle module \rangle$. See also `\keys_show:nn` which displays the result in the terminal.

8 Low-level interface for parsing key–val lists

To re-cap from earlier, a key–value list is input of the form

```
KeyOne = ValueOne ,
KeyTwo = ValueTwo ,
KeyThree
```

where each key–value pair is separated by a comma from the rest of the list, and each key–value pair does not necessarily contain an equals sign or a value! Processing this type of input correctly requires a number of careful steps, to correctly account for braces, spaces and the category codes of separators.

While the functions described earlier are used as a high-level interface for processing such input, in special circumstances you may wish to use a lower-level approach. The low-level parsing system converts a $\langle key\text{--}value\ list \rangle$ into $\langle keys \rangle$ and associated $\langle values \rangle$. After the parsing phase is completed, the resulting keys and values (or keys alone) are available for further processing. This processing is not carried out by the low-level parser itself, and so the parser requires the names of two functions along with the key–value list. One function is needed to process key–value pairs (it receives two arguments), and a second function is required for keys given without any value (it is called with a single argument).

The parser does not double # tokens or expand any input. Active tokens = and , appearing at the outer level of braces are converted to category “other” (12) so that the parser does not “miss” any due to category code changes. Spaces are removed from the ends of the keys and values. Keys and values which are given in braces have exactly one set removed (after space trimming), thus

```
key = {value here},
```

and

```
key = value here,
```

are treated identically.

\keyval_parse:NNn

Updated: 2011-09-08

\keyval_parse:NNn $\langle function_1 \rangle$ $\langle function_2 \rangle$ { $\langle key-value list \rangle$ }

Parses the $\langle key-value list \rangle$ into a series of $\langle keys \rangle$ and associated $\langle values \rangle$, or keys alone (if no $\langle value \rangle$ was given). $\langle function_1 \rangle$ should take one argument, while $\langle function_2 \rangle$ should absorb two arguments. After **\keyval_parse:NNn** has parsed the $\langle key-value list \rangle$, $\langle function_1 \rangle$ is used to process keys given with no value and $\langle function_2 \rangle$ is used to process keys given with a value. The order of the $\langle keys \rangle$ in the $\langle key-value list \rangle$ is preserved. Thus

```
\keyval_parse:NNn \function:n \function:nn
{ key1 = value1 , key2 = value2, key3 = , key4 }
```

is converted into an input stream

```
\function:nn { key1 } { value1 }
\function:nn { key2 } { value2 }
\function:nn { key3 } { }
\function:n { key4 }
```

Note that there is a difference between an empty value (an equals sign followed by nothing) and a missing value (no equals sign at all). Spaces are trimmed from the ends of the $\langle key \rangle$ and $\langle value \rangle$, then one *outer* set of braces is removed from the $\langle key \rangle$ and $\langle value \rangle$ as part of the processing.

Part XXII

The l3intarray package: fast global integer arrays

1 l3intarray documentation

For applications requiring heavy use of integers, this module provides arrays which can be accessed in constant time (contrast l3seq, where access time is linear). These arrays have several important features

- The size of the array is fixed and must be given at point of initialisation
- The absolute value of each entry has maximum $2^{30} - 1$ (*i.e.* one power lower than the usual `\c_max_int` ceiling of $2^{31} - 1$)

The use of `intarray` data is therefore recommended for cases where the need for fast access is of paramount importance.

<hr/> <code>\intarray_new:Nn</code> <hr/>	<code>\intarray_new:Nn <intarray var> {<size>}</code>
<hr/> New: 2018-03-29 <hr/>	Evaluates the integer expression <code><size></code> and allocates an <i><integer array variable></i> with that number of (zero) entries. The variable name should start with <code>\g_</code> because assignments are always global.
<hr/> <code>\intarray_count:N *</code> <hr/>	<code>\intarray_count:N <intarray var></code>
<hr/> New: 2018-03-29 <hr/>	Expands to the number of entries in the <i><integer array variable></i> . Contrarily to <code>\seq_count:N</code> this is performed in constant time.
<hr/> <code>\intarray_gset:Nnn</code> <hr/>	<code>\intarray_gset:Nnn <intarray var> {<position>} {<value>}</code>
<hr/> New: 2018-03-29 <hr/>	Stores the result of evaluating the integer expression <code><value></code> into the <i><integer array variable></i> at the (integer expression) <code><position></code> . If the <code><position></code> is not between 1 and the <code>\intarray_count:N</code> , or the <code><value></code> 's absolute value is bigger than $2^{30} - 1$, an error occurs. Assignments are always global.
<hr/> <code>\intarray_gzero:N</code> <hr/>	<code>\intarray_gzero:N <intarray var></code>
<hr/> New: 2018-05-04 <hr/>	Sets all entries of the <i><integer array variable></i> to zero. Assignments are always global.
<hr/> <code>\intarray_item:Nn *</code> <hr/>	<code>\intarray_item:Nn <intarray var> {<position>}</code>
<hr/> New: 2018-03-29 <hr/>	Expands to the integer entry stored at the (integer expression) <code><position></code> in the <i><integer array variable></i> . If the <code><position></code> is not between 1 and the <code>\intarray_count:N</code> , an error occurs.
<hr/> <code>\intarray_rand_item:N *</code> <hr/>	<code>\intarray_rand_item:N <intarray var></code>
<hr/> New: 2018-05-05 <hr/>	Selects a pseudo-random item of the <i><integer array></i> . If the <i><integer array></i> is empty, produce an error.

1.1 Implementation notes

It is a wrapper around the `\fontdimen` primitive, used to store arrays of integers (with a restricted range: absolute value at most $2^{30} - 1$). In contrast to `l3seq` sequences the access to individual entries is done in constant time rather than linear time, but only integers can be stored. More precisely, the primitive `\fontdimen` stores dimensions but the `l3intarray` package transparently converts these from/to integers. Assignments are always global.

While LuaTeX's memory is extensible, other engines can “only” deal with a bit less than 4×10^6 entries in all `\fontdimen` arrays combined (with default TeXLive settings).

Part XXIII

The l3fp package: Floating points

A decimal floating point number is one which is stored as a significand and a separate exponent. The module implements expandably a wide set of arithmetic, trigonometric, and other operations on decimal floating point numbers, to be used within floating point expressions. Floating point expressions support the following operations with their usual precedence.

- Basic arithmetic: addition $x + y$, subtraction $x - y$, multiplication $x * y$, division x / y , square root \sqrt{x} , and parentheses.
- Comparison operators: $x < y$, $x \leq y$, $x > y$, $x != y$ etc.
- Boolean logic: sign $\text{sign } x$, negation $!x$, conjunction $x \&\& y$, disjunction $x || y$, ternary operator $x ? y : z$.
- Exponentials: $\exp x$, $\ln x$, x^y .
- Integer factorial: $\text{fact } x$.
- Trigonometry: $\sin x$, $\cos x$, $\tan x$, $\cot x$, $\sec x$, $\csc x$ expecting their arguments in radians, and $\text{sind } x$, $\text{cosd } x$, $\text{tand } x$, $\text{cotd } x$, $\text{secd } x$, $\text{cscd } x$ expecting their arguments in degrees.
- Inverse trigonometric functions: $\text{asin } x$, $\text{acos } x$, $\text{atan } x$, $\text{acot } x$, $\text{asec } x$, $\text{acsc } x$ giving a result in radians, and $\text{asind } x$, $\text{acosd } x$, $\text{atand } x$, $\text{acotd } x$, $\text{asecd } x$, $\text{acscd } x$ giving a result in degrees.

(*not yet*) Hyperbolic functions and their inverse functions: $\sinh x$, $\cosh x$, $\tanh x$, $\coth x$, $\text{sech } x$, $\text{csch } x$, and $\text{asinh } x$, $\text{acosh } x$, $\text{atanh } x$, $\text{acoth } x$, $\text{asech } x$, $\text{acsch } x$.

- Extrema: $\max(x_1, x_2, \dots)$, $\min(x_1, x_2, \dots)$, $\text{abs}(x)$.
- Rounding functions, controlled by two optional values, n (number of places, 0 by default) and t (behavior on a tie, NaN by default):
 - $\text{trunc}(x, n)$ rounds towards zero,
 - $\text{floor}(x, n)$ rounds towards $-\infty$,
 - $\text{ceil}(x, n)$ rounds towards $+\infty$,
 - $\text{round}(x, n, t)$ rounds to the closest value, with ties rounded to an even value by default, towards zero if $t = 0$, towards $+\infty$ if $t > 0$ and towards $-\infty$ if $t < 0$.

And (*not yet*) modulo, and “quantize”.

- Random numbers: $\text{rand}()$, $\text{randint}(m, n)$.
- Constants: pi , deg (one degree in radians).
- Dimensions, automatically expressed in points, *e.g.*, pc is 12.

- Automatic conversion (no need for `\langle type \rangle_use:N`) of integer, dimension, and skip variables to floating point numbers, expressing dimensions in points and ignoring the stretch and shrink components of skips.
- Tuples: (x_1, \dots, x_n) that can be stored in variables, added together, multiplied or divided by a floating point number, and nested.

Floating point numbers can be given either explicitly (in a form such as $1.234\text{e-}34$, or $-.0001$), or as a stored floating point variable, which is automatically replaced by its current value. A “floating point” is a floating point number or a tuple thereof. See section 9.1 for a description of what a floating point is, section 9.2 for details about how an expression is parsed, and section 9.3 to know what the various operations do. Some operations may raise exceptions (error messages), described in section 7.

An example of use could be the following.

```
\LaTeX{} can now compute: $ \frac{\sin (3.5)}{2} + 2\cdot 10^{-3}
= \ExplSyntaxOn \fp_to_decimal:n {\sin(3.5)/2 + 2e-3} $.
```

The operation `round` can be used to limit the result’s precision. Adding `+0` avoids the possibly undesirable output `-0`, replacing it by `+0`. However, the `l3fp` module is mostly meant as an underlying tool for higher-level commands. For example, one could provide a function to typeset nicely the result of floating point computations.

```
\documentclass{article}
\usepackage{xparse, siunitx}
\ExplSyntaxOn
\NewDocumentCommand { \calcnun } { m }
{ \num { \fp_to_scientific:n {#1} } }
\ExplSyntaxOff
\begin{document}
\calcnun { 2 pi * sin ( 2.3 ^ 5 ) }
\end{document}
```

See the documentation of `siunitx` for various options of `\num`.

1 Creating and initialising floating point variables

<code>\fp_new:N</code>	<code>\fp_new:N <fp var></code>
<code>\fp_new:c</code>	Creates a new <code><fp var></code> or raises an error if the name is already taken. The declaration is global. The <code><fp var></code> is initially <code>+0</code> .
Updated: 2012-05-08	
<code>\fp_const:Nn</code>	<code>\fp_const:Nn <fp var> {<floating point expression>}</code>
<code>\fp_const:cn</code>	Creates a new constant <code><fp var></code> or raises an error if the name is already taken. The <code><fp var></code> is set globally equal to the result of evaluating the <code><floating point expression></code> .
Updated: 2012-05-08	
<code>\fp_zero:N</code>	<code>\fp_zero:N <fp var></code>
<code>\fp_zero:c</code>	Sets the <code><fp var></code> to <code>+0</code> .
<code>\fp_gzero:N</code>	
<code>\fp_gzero:c</code>	
Updated: 2012-05-08	

```
\fp_zero_new:N
\fp_zero_new:c
\fp_gzero_new:N
\fp_gzero_new:c
```

Updated: 2012-05-08

`\fp_zero_new:N` $\langle fp \text{ var} \rangle$

Ensures that the $\langle fp \text{ var} \rangle$ exists globally by applying `\fp_new:N` if necessary, then applies `\fp_(g)zero:N` to leave the $\langle fp \text{ var} \rangle$ set to +0.

2 Setting floating point variables

```
\fp_set:Nn
\fp_set:cn
\fp_gset:Nn
\fp_gset:cn
```

Updated: 2012-05-08

`\fp_set:Nn` $\langle fp \text{ var} \rangle$ $\{ \langle floating \text{ point expression} \rangle \}$

Sets $\langle fp \text{ var} \rangle$ equal to the result of computing the $\langle floating \text{ point expression} \rangle$.

```
\fp_set_eq:Nn
\fp_set_eq:(cN|Nc|cc)
\fp_gset_eq:Nn
\fp_gset_eq:(cN|Nc|cc)
```

Updated: 2012-05-08

`\fp_set_eq:Nn` $\langle fp \text{ var}_1 \rangle$ $\langle fp \text{ var}_2 \rangle$

Sets the floating point variable $\langle fp \text{ var}_1 \rangle$ equal to the current value of $\langle fp \text{ var}_2 \rangle$.

```
\fp_add:Nn
\fp_add:cn
\fp_gadd:Nn
\fp_gadd:cn
```

Updated: 2012-05-08

`\fp_add:Nn` $\langle fp \text{ var} \rangle$ $\{ \langle floating \text{ point expression} \rangle \}$

Adds the result of computing the $\langle floating \text{ point expression} \rangle$ to the $\langle fp \text{ var} \rangle$. This also applies if $\langle fp \text{ var} \rangle$ and $\langle floating \text{ point expression} \rangle$ evaluate to tuples of the same size.

```
\fp_sub:Nn
\fp_sub:cn
\fp_gsub:Nn
\fp_gsub:cn
```

Updated: 2012-05-08

`\fp_sub:Nn` $\langle fp \text{ var} \rangle$ $\{ \langle floating \text{ point expression} \rangle \}$

Subtracts the result of computing the $\langle floating \text{ point expression} \rangle$ from the $\langle fp \text{ var} \rangle$. This also applies if $\langle fp \text{ var} \rangle$ and $\langle floating \text{ point expression} \rangle$ evaluate to tuples of the same size.

3 Using floating points

```
\fp_eval:n   ★
```

New: 2012-05-08
Updated: 2012-07-08

`\fp_eval:n` $\{ \langle floating \text{ point expression} \rangle \}$

Evaluates the $\langle floating \text{ point expression} \rangle$ and expresses the result as a decimal number with no exponent. Leading or trailing zeros may be inserted to compensate for the exponent. Non-significant trailing zeros are trimmed, and integers are expressed without a decimal separator. The values $\pm\infty$ and NaN trigger an “invalid operation” exception. For a tuple, each item is converted using `\fp_eval:n` and they are combined as $(\langle fp_1 \rangle, \sqcup \langle fp_2 \rangle, \sqcup \dots \langle fp_n \rangle)$ if $n > 1$ and $(\langle fp_1 \rangle,)$ or $()$ for fewer items. This function is identical to `\fp_to_decimal:n`.

<code>\fp_to_decimal:N</code> ★ <code>\fp_to_decimal:c</code> ★ <code>\fp_to_decimal:n</code> ★	<code>\fp_to_decimal:N</code> $\langle fp \text{ var} \rangle$ <code>\fp_to_decimal:n</code> $\{\langle floating \text{ point expression} \rangle\}$ Evaluates the $\langle floating \text{ point expression} \rangle$ and expresses the result as a decimal number with no exponent. Leading or trailing zeros may be inserted to compensate for the exponent. Non-significant trailing zeros are trimmed, and integers are expressed without a decimal separator. The values $\pm\infty$ and NaN trigger an “invalid operation” exception. For a tuple, each item is converted using <code>\fp_to_decimal:n</code> and they are combined as $(\langle fp_1 \rangle, \sqcup \langle fp_2 \rangle, \sqcup \dots \langle fp_n \rangle)$ if $n > 1$ and $(\langle fp_1 \rangle,)$ or $()$ for fewer items.
---	---

New: 2012-05-08
Updated: 2012-07-08

<code>\fp_to_dim:N</code> ★ <code>\fp_to_dim:c</code> ★ <code>\fp_to_dim:n</code> ★	<code>\fp_to_dim:N</code> $\langle fp \text{ var} \rangle$ <code>\fp_to_dim:n</code> $\{\langle floating \text{ point expression} \rangle\}$ Evaluates the $\langle floating \text{ point expression} \rangle$ and expresses the result as a dimension (in pt) suitable for use in dimension expressions. The output is identical to <code>\fp_to_decimal:n</code> , with an additional trailing <code>pt</code> (both letter tokens). In particular, the result may be outside the range $[-2^{14} + 2^{-17}, 2^{14} - 2^{-17}]$ of valid T _E X dimensions, leading to overflow errors if used as a dimension. Tuples, as well as the values $\pm\infty$ and NaN, trigger an “invalid operation” exception.
---	---

Updated: 2016-03-22

<code>\fp_to_int:N</code> ★ <code>\fp_to_int:c</code> ★ <code>\fp_to_int:n</code> ★	<code>\fp_to_int:N</code> $\langle fp \text{ var} \rangle$ <code>\fp_to_int:n</code> $\{\langle floating \text{ point expression} \rangle\}$ Evaluates the $\langle floating \text{ point expression} \rangle$, and rounds the result to the closest integer, rounding exact ties to an even integer. The result may be outside the range $[-2^{31} + 1, 2^{31} - 1]$ of valid T _E X integers, leading to overflow errors if used in an integer expression. Tuples, as well as the values $\pm\infty$ and NaN, trigger an “invalid operation” exception.
---	--

Updated: 2012-07-08

<code>\fp_to_scientific:N</code> ★ <code>\fp_to_scientific:c</code> ★ <code>\fp_to_scientific:n</code> ★	<code>\fp_to_scientific:N</code> $\langle fp \text{ var} \rangle$ <code>\fp_to_scientific:n</code> $\{\langle floating \text{ point expression} \rangle\}$ Evaluates the $\langle floating \text{ point expression} \rangle$ and expresses the result in scientific notation:
--	---

New: 2012-05-08
Updated: 2016-03-22

$\langle optional - \rangle \langle digit \rangle . \langle 15 \text{ digits} \rangle e \langle optional sign \rangle \langle exponent \rangle$

The leading $\langle digit \rangle$ is non-zero except in the case of ± 0 . The values $\pm\infty$ and NaN trigger an “invalid operation” exception. Normal category codes apply: thus the `e` is category code 11 (a letter). For a tuple, each item is converted using `\fp_to_scientific:n` and they are combined as $(\langle fp_1 \rangle, \sqcup \langle fp_2 \rangle, \sqcup \dots \langle fp_n \rangle)$ if $n > 1$ and $(\langle fp_1 \rangle,)$ or $()$ for fewer items.

<code>\fp_to_tl:N</code> ★ <code>\fp_to_tl:c</code> ★ <code>\fp_to_tl:n</code> ★	<code>\fp_to_tl:N</code> $\langle fp \text{ var} \rangle$ <code>\fp_to_tl:n</code> $\{\langle floating \text{ point expression} \rangle\}$ Evaluates the $\langle floating \text{ point expression} \rangle$ and expresses the result in (almost) the shortest possible form. Numbers in the ranges $(0, 10^{-3})$ and $[10^{16}, \infty)$ are expressed in scientific notation with trailing zeros trimmed and no decimal separator when there is a single significant digit (this differs from <code>\fp_to_scientific:n</code>). Numbers in the range $[10^{-3}, 10^{16})$ are expressed in a decimal notation without exponent, with trailing zeros trimmed, and no decimal separator for integer values (see <code>\fp_to_decimal:n</code>). Negative numbers start with <code>-</code> . The special values ± 0 , $\pm\infty$ and NaN are rendered as <code>0</code> , <code>-0</code> , <code>inf</code> , <code>-inf</code> , and <code>nan</code> respectively. Normal category codes apply and thus <code>inf</code> or <code>nan</code> , if produced, are made up of letters. For a tuple, each item is converted using <code>\fp_to_tl:n</code> and they are combined as $(\langle fp_1 \rangle, \sqcup \langle fp_2 \rangle, \sqcup \dots \langle fp_n \rangle)$ if $n > 1$ and $(\langle fp_1 \rangle,)$ or $()$ for fewer items.
--	---

Updated: 2016-03-22

<code>\fp_use:N</code>	★	<code>\fp_use:N <fp var></code>
------------------------	---	---------------------------------------

<code>\fp_use:c</code>	★
------------------------	---

Updated: 2012-07-08

Inserts the value of the `<fp var>` into the input stream as a decimal number with no exponent. Leading or trailing zeros may be inserted to compensate for the exponent. Non-significant trailing zeros are trimmed. Integers are expressed without a decimal separator. The values $\pm\infty$ and `NaN` trigger an “invalid operation” exception. For a tuple, each item is converted using `\fp_to_decimal:n` and they are combined as $(\langle fp_1 \rangle, \sqcup \langle fp_2 \rangle, \sqcup \dots \langle fp_n \rangle)$ if $n > 1$ and $(\langle fp_1 \rangle,)$ or $()$ for fewer items. This function is identical to `\fp_to_decimal:N`.

4 Floating point conditionals

<code>\fp_if_exist_p:N</code>	★	<code>\fp_if_exist_p:N <fp var></code>
-------------------------------	---	--

<code>\fp_if_exist_p:c</code>	★
-------------------------------	---

<code>\fp_if_exist:NTF</code>	★	<code>\fp_if_exist:NTF <fp var> {<true code>} {<false code>}</code>
-------------------------------	---	---

<code>\fp_if_exist:cTF</code>	★
-------------------------------	---

Updated: 2012-05-08

Tests whether the `<fp var>` is currently defined. This does not check that the `<fp var>` really is a floating point variable.

<code>\fp_compare_p:nNn</code>	★	<code>\fp_compare_p:nNn {<fpexpr₁>} <relation> {<fpexpr₂>}</code>
--------------------------------	---	---

<code>\fp_compare:nNnTF</code>	★	<code>\fp_compare:nNnTF {<fpexpr₁>} <relation> {<fpexpr₂>} {<true code>} {<false code>}</code>
--------------------------------	---	--

Updated: 2012-05-08

Compares the `<fpexpr1>` and the `<fpexpr2>`, and returns `true` if the `<relation>` is obeyed. Two floating points x and y may obey four mutually exclusive relations: $x < y$, $x = y$, $x > y$, or $x?y$ (“not ordered”). The last case occurs exactly if one or both operands is `NaN` or is a tuple, unless they are equal tuples. Note that a `NaN` is distinct from any value, even another `NaN`, hence $x = x$ is not true for a `NaN`. To test if a value is `NaN`, compare it to an arbitrary number with the “not ordered” relation.

```

\fp_compare:nNnTF { <value> } ? { 0 }
{ } % <value> is nan
{ } % <value> is not nan

```

Tuples are equal if they have the same number of items and items compare equal (in particular there must be no `NaN`). At present any other comparison with tuples yields `?` (not ordered). This is experimental.

This function is less flexible than `\fp_compare:nTF` but slightly faster. It is provided for consistency with `\int_compare:nNnTF` and `\dim_compare:nNnTF`.

<code>\fp_compare_p:n</code> ☆	<code>\fp_compare_p:n</code>
<code>\fp_compare:nTF</code> ☆	{
Updated: 2013-12-14	$\langle fpexpr_1 \rangle$ $\langle relation_1 \rangle$
	...
	$\langle fpexpr_N \rangle$ $\langle relation_N \rangle$
	$\langle fpexpr_{N+1} \rangle$
	}
	<code>\fp_compare:nTF</code>
	{
	$\langle fpexpr_1 \rangle$ $\langle relation_1 \rangle$
	...
	$\langle fpexpr_N \rangle$ $\langle relation_N \rangle$
	$\langle fpexpr_{N+1} \rangle$
	}
	{ $\langle true\ code \rangle$ } { $\langle false\ code \rangle$ }

Evaluates the $\langle floating\ point\ expressions \rangle$ as described for `\fp_eval:n` and compares consecutive result using the corresponding $\langle relation \rangle$, namely it compares $\langle intexpr_1 \rangle$ and $\langle intexpr_2 \rangle$ using the $\langle relation_1 \rangle$, then $\langle intexpr_2 \rangle$ and $\langle intexpr_3 \rangle$ using the $\langle relation_2 \rangle$, until finally comparing $\langle intexpr_N \rangle$ and $\langle intexpr_{N+1} \rangle$ using the $\langle relation_N \rangle$. The test yields **true** if all comparisons are **true**. Each $\langle floating\ point\ expression \rangle$ is evaluated only once. Contrarily to `\int_compare:nTF`, all $\langle floating\ point\ expressions \rangle$ are computed, even if one comparison is **false**. Two floating points x and y may obey four mutually exclusive relations: $x < y$, $x = y$, $x > y$, or $x?y$ (“not ordered”). The last case occurs exactly if one or both operands is NaN or is a tuple, unless they are equal tuples. Each $\langle relation \rangle$ can be any (non-empty) combination of $<$, $=$, $>$, and $?$, plus an optional leading $!$ (which negates the $\langle relation \rangle$), with the restriction that the $\langle relation \rangle$ may not start with $?$, as this symbol has a different meaning (in combination with $:$) within floating point expressions. The comparison $x \langle relation \rangle y$ is then **true** if the $\langle relation \rangle$ does not start with $!$ and the actual relation ($<$, $=$, $>$, or $?$) between x and y appears within the $\langle relation \rangle$, or on the contrary if the $\langle relation \rangle$ starts with $!$ and the relation between x and y does not appear within the $\langle relation \rangle$. Common choices of $\langle relation \rangle$ include $>=$ (greater or equal), $!=$ (not equal), $!?$ or $<=>$ (comparable).

This function is more flexible than `\fp_compare:nNnTF` and only slightly slower.

5 Floating point expression loops

<code>\fp_do_until:nNnn</code> ☆	<code>\fp_do_until:nNnn {$\langle fpexpr_1 \rangle$} $\langle relation \rangle$ {$\langle fpexpr_2 \rangle$} {$\langle code \rangle$}</code>
New: 2012-08-16	Places the $\langle code \rangle$ in the input stream for \TeX to process, and then evaluates the relationship between the two $\langle floating\ point\ expressions \rangle$ as described for <code>\fp_compare:nNnTF</code> . If the test is false then the $\langle code \rangle$ is inserted into the input stream again and a loop occurs until the $\langle relation \rangle$ is true .
<code>\fp_do_while:nNnn</code> ☆	<code>\fp_do_while:nNnn {$\langle fpexpr_1 \rangle$} $\langle relation \rangle$ {$\langle fpexpr_2 \rangle$} {$\langle code \rangle$}</code>
New: 2012-08-16	Places the $\langle code \rangle$ in the input stream for \TeX to process, and then evaluates the relationship between the two $\langle floating\ point\ expressions \rangle$ as described for <code>\fp_compare:nNnTF</code> . If the test is true then the $\langle code \rangle$ is inserted into the input stream again and a loop occurs until the $\langle relation \rangle$ is false .

<hr/>	
<code>\fp_until_do:nNnn</code> ☆	<code>\fp_until_do:nNnn {<fpexpr1>} <relation> {<fpexpr2>} {<code>}</code>
New: 2012-08-16	Evaluates the relationship between the two <i><floating point expressions></i> as described for <code>\fp_compare:nNnTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is false. After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is true .
<hr/>	
<code>\fp_while_do:nNnn</code> ☆	<code>\fp_while_do:nNnn {<fpexpr1>} <relation> {<fpexpr2>} {<code>}</code>
New: 2012-08-16	Evaluates the relationship between the two <i><floating point expressions></i> as described for <code>\fp_compare:nNnTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is true. After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is false .
<hr/>	
<code>\fp_do_until:nn</code> ☆	<code>\fp_do_until:nn { <fpexpr1> <relation> <fpexpr2> } {<code>}</code>
New: 2012-08-16 Updated: 2013-12-14	Places the <i><code></i> in the input stream for T _E X to process, and then evaluates the relationship between the two <i><floating point expressions></i> as described for <code>\fp_compare:nTF</code> . If the test is false then the <i><code></i> is inserted into the input stream again and a loop occurs until the <i><relation></i> is true .
<hr/>	
<code>\fp_do_while:nn</code> ☆	<code>\fp_do_while:nn { <fpexpr1> <relation> <fpexpr2> } {<code>}</code>
New: 2012-08-16 Updated: 2013-12-14	Places the <i><code></i> in the input stream for T _E X to process, and then evaluates the relationship between the two <i><floating point expressions></i> as described for <code>\fp_compare:nTF</code> . If the test is true then the <i><code></i> is inserted into the input stream again and a loop occurs until the <i><relation></i> is false .
<hr/>	
<code>\fp_until_do:nn</code> ☆	<code>\fp_until_do:nn { <fpexpr1> <relation> <fpexpr2> } {<code>}</code>
New: 2012-08-16 Updated: 2013-12-14	Evaluates the relationship between the two <i><floating point expressions></i> as described for <code>\fp_compare:nTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is false. After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is true .
<hr/>	
<code>\fp_while_do:nn</code> ☆	<code>\fp_while_do:nn { <fpexpr1> <relation> <fpexpr2> } {<code>}</code>
New: 2012-08-16 Updated: 2013-12-14	Evaluates the relationship between the two <i><floating point expressions></i> as described for <code>\fp_compare:nTF</code> , and then places the <i><code></i> in the input stream if the <i><relation></i> is true. After the <i><code></i> has been processed by T _E X the test is repeated, and a loop occurs until the test is false .

`\fp_step_function:nnnN` ☆
`\fp_step_function:nnnc` ☆

New: 2016-11-21
Updated: 2016-12-06

`\fp_step_function:nnnN` { $\langle initial\ value \rangle$ } { $\langle step \rangle$ } { $\langle final\ value \rangle$ } $\langle function \rangle$

This function first evaluates the $\langle initial\ value \rangle$, $\langle step \rangle$ and $\langle final\ value \rangle$, each of which should be a floating point expression evaluating to a floating point number, not a tuple. The $\langle function \rangle$ is then placed in front of each $\langle value \rangle$ from the $\langle initial\ value \rangle$ to the $\langle final\ value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$). The $\langle step \rangle$ must be non-zero. If the $\langle step \rangle$ is positive, the loop stops when the $\langle value \rangle$ becomes larger than the $\langle final\ value \rangle$. If the $\langle step \rangle$ is negative, the loop stops when the $\langle value \rangle$ becomes smaller than the $\langle final\ value \rangle$. The $\langle function \rangle$ should absorb one numerical argument. For example

```
\cs_set:Npn \my_func:n #1 { [I~saw~#1] \quad }
\fp_step_function:nnnN { 1.0 } { 0.1 } { 1.5 } \my_func:n
```

would print

```
[I saw 1.0]   [I saw 1.1]   [I saw 1.2]   [I saw 1.3]   [I saw 1.4]   [I saw 1.5]
```

TpXhackers note: Due to rounding, it may happen that adding the $\langle step \rangle$ to the $\langle value \rangle$ does not change the $\langle value \rangle$; such cases give an error, as they would otherwise lead to an infinite loop.

`\fp_step_inline:nnnn`

New: 2016-11-21
Updated: 2016-12-06

`\fp_step_inline:nnnn` { $\langle initial\ value \rangle$ } { $\langle step \rangle$ } { $\langle final\ value \rangle$ } { $\langle code \rangle$ }

This function first evaluates the $\langle initial\ value \rangle$, $\langle step \rangle$ and $\langle final\ value \rangle$, all of which should be floating point expressions evaluating to a floating point number, not a tuple. Then for each $\langle value \rangle$ from the $\langle initial\ value \rangle$ to the $\langle final\ value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$), the $\langle code \rangle$ is inserted into the input stream with `#1` replaced by the current $\langle value \rangle$. Thus the $\langle code \rangle$ should define a function of one argument (`#1`).

`\fp_step_variable:nnnNn`

New: 2017-04-12

`\fp_step_variable:nnnNn`
{ $\langle initial\ value \rangle$ } { $\langle step \rangle$ } { $\langle final\ value \rangle$ } $\langle tl\ var \rangle$ { $\langle code \rangle$ }

This function first evaluates the $\langle initial\ value \rangle$, $\langle step \rangle$ and $\langle final\ value \rangle$, all of which should be floating point expressions evaluating to a floating point number, not a tuple. Then for each $\langle value \rangle$ from the $\langle initial\ value \rangle$ to the $\langle final\ value \rangle$ in turn (using $\langle step \rangle$ between each $\langle value \rangle$), the $\langle code \rangle$ is inserted into the input stream, with the $\langle tl\ var \rangle$ defined as the current $\langle value \rangle$. Thus the $\langle code \rangle$ should make use of the $\langle tl\ var \rangle$.

6 Some useful constants, and scratch variables

`\c_zero_fp`
`\c_minus_zero_fp`

New: 2012-05-08

Zero, with either sign.

`\c_one_fp`

New: 2012-05-08

One as an fp: useful for comparisons in some places.

<hr/> <code>\c_inf_fp</code> <code>\c_minus_inf_fp</code> <hr/> New: 2012-05-08 <hr/>	<p>Infinity, with either sign. These can be input directly in a floating point expression as <code>inf</code> and <code>-inf</code>.</p>
<hr/> <code>\c_e_fp</code> <hr/> Updated: 2012-05-08 <hr/>	<p>The value of the base of the natural logarithm, $e = \exp(1)$.</p>
<hr/> <code>\c_pi_fp</code> <hr/> Updated: 2013-11-17 <hr/>	<p>The value of π. This can be input directly in a floating point expression as <code>pi</code>.</p>
<hr/> <code>\c_one_degree_fp</code> <hr/> New: 2012-05-08 Updated: 2013-11-17 <hr/>	<p>The value of 1° in radians. Multiply an angle given in degrees by this value to obtain a result in radians. Note that trigonometric functions expecting an argument in radians or in degrees are both available. Within floating point expressions, this can be accessed as <code>deg</code>.</p>
<hr/> <code>\l_tmpa_fp</code> <code>\l_tmpb_fp</code> <hr/>	<p>Scratch floating points for local assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.</p>
<hr/> <code>\g_tmpa_fp</code> <code>\g_tmpb_fp</code> <hr/>	<p>Scratch floating points for global assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.</p>

7 Floating point exceptions

The functions defined in this section are experimental, and their functionality may be altered or removed altogether.

“Exceptions” may occur when performing some floating point operations, such as $0 / 0$, or $10 ** 1e9999$. The relevant IEEE standard defines 5 types of exceptions, of which we implement 4.

- *Overflow* occurs whenever the result of an operation is too large to be represented as a normal floating point number. This results in $\pm\infty$.
- *Underflow* occurs whenever the result of an operation is too close to 0 to be represented as a normal floating point number. This results in ± 0 .
- *Invalid operation* occurs for operations with no defined outcome, for instance $0/0$ or $\sin(\infty)$, and results in a NaN. It also occurs for conversion functions whose target type does not have the appropriate infinite or NaN value (e.g., `\fp_to_dim:n`).
- *Division by zero* occurs when dividing a non-zero number by 0, or when evaluating functions at poles, e.g., $\ln(0)$ or $\cot(0)$. This results in $\pm\infty$.

(*not yet*) *Inexact* occurs whenever the result of a computation is not exact, in other words, almost always. At the moment, this exception is entirely ignored in L^AT_EX3.

To each exception we associate a “flag”: `fp_overflow`, `fp_underflow`, `fp_invalid_operation` and `fp_division_by_zero`. The state of these flags can be tested and modified with commands from `l3flag`

By default, the “invalid operation” exception triggers an (expandable) error, and raises the corresponding flag. Other exceptions raise the corresponding flag but do not trigger an error. The behaviour when an exception occurs can be modified (using `\fp_trap:nn`) to either produce an error and raise the flag, or only raise the flag, or do nothing at all.

<code>\fp_trap:nn</code>	<code>\fp_trap:nn {⟨exception⟩} {⟨trap type⟩}</code>
New: 2012-07-19 Updated: 2017-02-13	All occurrences of the <code>⟨exception⟩</code> (<code>overflow</code> , <code>underflow</code> , <code>invalid_operation</code> or <code>division_by_zero</code>) within the current group are treated as <code>⟨trap type⟩</code> , which can be <ul style="list-style-type: none"> • none: the <code>⟨exception⟩</code> will be entirely ignored, and leave no trace; • flag: the <code>⟨exception⟩</code> will turn the corresponding flag on when it occurs; • error: additionally, the <code>⟨exception⟩</code> will halt the T_EX run and display some information about the current operation in the terminal.

This function is experimental, and may be altered or removed.

`flag_fp_overflow`
`flag_fp_underflow`
`flag_fp_invalid_operation`
`flag_fp_division_by_zero`

Flags denoting the occurrence of various floating-point exceptions.

8 Viewing floating points

<code>\fp_show:N</code>	<code>\fp_show:N ⟨fp var⟩</code>
<code>\fp_show:c</code>	<code>\fp_show:n {⟨floating point expression⟩}</code>
<code>\fp_show:n</code>	Evaluates the <code>⟨floating point expression⟩</code> and displays the result in the terminal.

New: 2012-05-08
Updated: 2015-08-07

<code>\fp_log:N</code>	<code>\fp_log:N ⟨fp var⟩</code>
<code>\fp_log:c</code>	<code>\fp_log:n {⟨floating point expression⟩}</code>
<code>\fp_log:n</code>	Evaluates the <code>⟨floating point expression⟩</code> and writes the result in the log file.

New: 2014-08-22
Updated: 2015-08-07

9 Floating point expressions

9.1 Input of floating point numbers

We support four types of floating point numbers:

- $\pm m \cdot 10^n$, a floating point number, with integer $1 \leq m \leq 10^{16}$, and $-10000 \leq n \leq 10000$;
- ± 0 , zero, with a given sign;
- $\pm \infty$, infinity, with a given sign;
- NaN, is “not a number”, and can be either quiet or signalling (*not yet*: this distinction is currently unsupported);

Normal floating point numbers are stored in base 10, with up to 16 significant figures.

On input, a normal floating point number consists of:

- $\langle sign \rangle$: a possibly empty string of + and - characters;
- $\langle significand \rangle$: a non-empty string of digits together with zero or one dot;
- $\langle exponent \rangle$ optionally: the character **e**, followed by a possibly empty string of + and - tokens, and a non-empty string of digits.

The sign of the resulting number is + if $\langle sign \rangle$ contains an even number of -, and - otherwise, hence, an empty $\langle sign \rangle$ denotes a non-negative input. The stored significand is obtained from $\langle significand \rangle$ by omitting the decimal separator and leading zeros, and rounding to 16 significant digits, filling with trailing zeros if necessary. In particular, the value stored is exact if the input $\langle significand \rangle$ has at most 16 digits. The stored $\langle exponent \rangle$ is obtained by combining the input $\langle exponent \rangle$ (0 if absent) with a shift depending on the position of the significand and the number of leading zeros.

A special case arises if the resulting $\langle exponent \rangle$ is either too large or too small for the floating point number to be represented. This results either in an overflow (the number is then replaced by $\pm \infty$), or an underflow (resulting in ± 0).

The result is thus ± 0 if and only if $\langle significand \rangle$ contains no non-zero digit (*i.e.*, consists only in characters 0, and an optional period), or if there is an underflow. Note that a single dot is currently a valid floating point number, equal to +0, but that is not guaranteed to remain true.

The $\langle significand \rangle$ must be non-empty, so **e1** and **e-1** are not valid floating point numbers. Note that the latter could be mistaken with the difference of “**e**” and 1. To avoid confusions, the base of natural logarithms cannot be input as **e** and should be input as **exp(1)** or **\c_e_fp**.

Special numbers are input as follows:

- **inf** represents $+\infty$, and can be preceded by any $\langle sign \rangle$, yielding $\pm \infty$ as appropriate.
- **nan** represents a (quiet) non-number. It can be preceded by any sign, but that sign is ignored.
- Any unrecognizable string triggers an error, and produces a NaN.
- Note that commands such as **\infy**, **\pi**, or **\sin** *do not* work in floating point expressions. They may silently be interpreted as completely unexpected numbers, because integer constants (allowed in expressions) are commonly stored as mathematical characters.

9.2 Precedence of operators

We list here all the operations supported in floating point expressions, in order of decreasing precedence: operations listed earlier bind more tightly than operations listed below them.

- Function calls (`sin`, `ln`, *etc.*).
- Binary `**` and `^` (right associative).
- Unary `+`, `-`, `!`.
- Implicit multiplication by juxtaposition (`2pi`) when neither factor is in parentheses.
- Binary `*` and `/`, implicit multiplication by juxtaposition with parentheses (for instance `3(4+5)`).
- Binary `+` and `-`.
- Comparisons `>=`, `!=`, `<?`, *etc.*
- Logical `and`, denoted by `&&`.
- Logical `or`, denoted by `||`.
- Ternary operator `?:` (right associative).
- Comma (to build tuples).

The precedence of operations can be overridden using parentheses. In particular, the precedence of juxtaposition implies that

$$\begin{aligned}1/2\text{pi} &= 1/(2\pi), \\1/2\text{pi}(\text{pi} + \text{pi}) &= (2\pi)^{-1}(\pi + \pi) \simeq 1, \\ \text{sin}2\text{pi} &= \sin(2)\pi \neq 0, \\ 2^2\text{max}(3, 5) &= 2^2 \max(3, 5) = 20, \\ 1\text{in}/1\text{cm} &= (1\text{in})/(1\text{cm}) = 2.54.\end{aligned}$$

Functions are called on the value of their argument, contrarily to `TeX` macros.

9.3 Operations

We now present the various operations allowed in floating point expressions, from the lowest precedence to the highest. When used as a truth value, a floating point expression is `false` if it is ± 0 , and `true` otherwise, including when it is `NaN` or a tuple such as `(0, 0)`. Tuples are only supported to some extent by operations that work with truth values (`?:`, `||`, `&&`, `!`), by comparisons (`!<=>?`), and by `+`, `-`, `*`, `/`. Unless otherwise specified, providing a tuple as an argument of any other operation yields the “invalid operation” exception and a `NaN` result.

```
?: \fp_eval:n { <operand1> ? <operand2> : <operand3> }
```

The ternary operator `?:` results in $\langle operand_2 \rangle$ if $\langle operand_1 \rangle$ is true (not ± 0), and $\langle operand_3 \rangle$ if $\langle operand_1 \rangle$ is false (± 0). All three $\langle operands \rangle$ are evaluated in all cases; they may be tuples. The operator is right associative, hence

```
\fp_eval:n
{
  1 + 3 > 4 ? 1 :
  2 + 4 > 5 ? 2 :
  3 + 5 > 6 ? 3 : 4
}
```

first tests whether $1 + 3 > 4$; since this isn't true, the branch following `:` is taken, and $2 + 4 > 5$ is compared; since this is true, the branch before `:` is taken, and everything else is (evaluated then) ignored. That allows testing for various cases in a concise manner, with the drawback that all computations are made in all cases.

```
|| \fp_eval:n { <operand1> || <operand2> }
```

If $\langle operand_1 \rangle$ is true (not ± 0), use that value, otherwise the value of $\langle operand_2 \rangle$. Both $\langle operands \rangle$ are evaluated in all cases; they may be tuples. In $\langle operand_1 \rangle || \langle operand_2 \rangle || \dots || \langle operands_n \rangle$, the first true (nonzero) $\langle operand \rangle$ is used and if all are zero the last one (± 0) is used.

```
&& \fp_eval:n { <operand1> && <operand2> }
```

If $\langle operand_1 \rangle$ is false (equal to ± 0), use that value, otherwise the value of $\langle operand_2 \rangle$. Both $\langle operands \rangle$ are evaluated in all cases; they may be tuples. In $\langle operand_1 \rangle \&\& \langle operand_2 \rangle \&\& \dots \&\& \langle operands_n \rangle$, the first false (± 0) $\langle operand \rangle$ is used and if none is zero the last one is used.

```
< \fp_eval:n
= {
>   <operand1> <relation1>
?   ...
    <operand_N> <relation_N>
    <operand_{N+1}>
}
```

Updated: 2013-12-14

Each $\langle relation \rangle$ consists of a non-empty string of `<`, `=`, `>`, and `?`, optionally preceded by `!`, and may not start with `?`. This evaluates to $+1$ if all comparisons $\langle operand_i \rangle \langle relation_i \rangle \langle operand_{i+1} \rangle$ are true, and $+0$ otherwise. All $\langle operands \rangle$ are evaluated (once) in all cases. See `\fp_compare:nTF` for details.

```
+ \fp_eval:n { <operand1> + <operand2> }
- \fp_eval:n { <operand1> - <operand2> }
```

Computes the sum or the difference of its two $\langle operands \rangle$. The “invalid operation” exception occurs for $\infty - \infty$. “Underflow” and “overflow” occur when appropriate. These operations supports the itemwise addition or subtraction of two tuples, but if they have a different number of items the “invalid operation” exception occurs and the result is NaN.

```

* \fp_eval:n { <operand1> * <operand2> }
/ \fp_eval:n { <operand1> / <operand2> }

```

Computes the product or the ratio of its two $\langle \text{operands} \rangle$. The “invalid operation” exception occurs for ∞/∞ , $0/0$, or $0 * \infty$. “Division by zero” occurs when dividing a finite non-zero number by ± 0 . “Underflow” and “overflow” occur when appropriate. When $\langle \text{operand}_1 \rangle$ is a tuple and $\langle \text{operand}_2 \rangle$ is a floating point number, each item of $\langle \text{operand}_1 \rangle$ is multiplied or divided by $\langle \text{operand}_2 \rangle$. Multiplication also supports the case where $\langle \text{operand}_1 \rangle$ is a floating point number and $\langle \text{operand}_2 \rangle$ a tuple. Other combinations yield an “invalid operation” exception and a NaN result.

```

+ \fp_eval:n { + <operand> }
- \fp_eval:n { - <operand> }
! \fp_eval:n { ! <operand> }

```

The unary $+$ does nothing, the unary $-$ changes the sign of the $\langle \text{operand} \rangle$ (for a tuple, of all its components), and $!$ $\langle \text{operand} \rangle$ evaluates to 1 if $\langle \text{operand} \rangle$ is false (is ± 0) and 0 otherwise (this is the `not` boolean function). Those operations never raise exceptions.

```

** \fp_eval:n { <operand1> ** <operand2> }
^ \fp_eval:n { <operand1> ^ <operand2> }

```

Raises $\langle \text{operand}_1 \rangle$ to the power $\langle \text{operand}_2 \rangle$. This operation is right associative, hence $2^{**} 2^{**} 3$ equals $2^{2^3} = 256$. If $\langle \text{operand}_1 \rangle$ is negative or -0 then: the result’s sign is $+$ if the $\langle \text{operand}_2 \rangle$ is infinite and $(-1)^p$ if the $\langle \text{operand}_2 \rangle$ is $p/5^q$ with p, q integers; the result is $+0$ if $\text{abs}(\langle \text{operand}_1 \rangle)^{\langle \text{operand}_2 \rangle}$ evaluates to zero; in other cases the “invalid operation” exception occurs because the sign cannot be determined. “Division by zero” occurs when raising ± 0 to a finite strictly negative power. “Underflow” and “overflow” occur when appropriate. If either operand is a tuple, “invalid operation” occurs.

```

abs \fp_eval:n { abs( <fpexpr> ) }

```

Computes the absolute value of the $\langle \text{fpexpr} \rangle$. If the operand is a tuple, “invalid operation” occurs. This operation does not raise exceptions in other cases. See also `\fp_abs:n`.

```

exp \fp_eval:n { exp( <fpexpr> ) }

```

Computes the exponential of the $\langle \text{fpexpr} \rangle$. “Underflow” and “overflow” occur when appropriate. If the operand is a tuple, “invalid operation” occurs.

```

fact \fp_eval:n { fact( <fpexpr> ) }

```

Computes the factorial of the $\langle \text{fpexpr} \rangle$. If the $\langle \text{fpexpr} \rangle$ is an integer between -0 and 3248 included, the result is finite and correctly rounded. Larger positive integers give $+\infty$ with “overflow”, while $\text{fact}(+\infty) = +\infty$ and $\text{fact}(\text{nan}) = \text{nan}$ with no exception. All other inputs give NaN with the “invalid operation” exception.

```

ln \fp_eval:n { ln( <fpexpr> ) }

```

Computes the natural logarithm of the $\langle \text{fpexpr} \rangle$. Negative numbers have no (real) logarithm, hence the “invalid operation” is raised in that case, including for $\ln(-0)$. “Division by zero” occurs when evaluating $\ln(+0) = -\infty$. “Underflow” and “overflow” occur when appropriate. If the operand is a tuple, “invalid operation” occurs.

max	<code>\fp_eval:n { max(<fpexpr₁> , <fpexpr₂> , ...) }</code>
min	<code>\fp_eval:n { min(<fpexpr₁> , <fpexpr₂> , ...) }</code>

Evaluates each $\langle fpexpr \rangle$ and computes the largest (smallest) of those. If any of the $\langle fpexpr \rangle$ is a NaN or tuple, the result is NaN. If any operand is a tuple, “invalid operation” occurs; these operations do not raise exceptions in other cases.

round	<code>\fp_eval:n { round (<fpexpr>) }</code>
trunc	<code>\fp_eval:n { round (<fpexpr₁> , <fpexpr₂>) }</code>
ceil	<code>\fp_eval:n { round (<fpexpr₁> , <fpexpr₂> , <fpexpr₃>) }</code>
floor	

New: 2013-12-14
Updated: 2015-08-08

Only **round** accepts a third argument. Evaluates $\langle fpexpr_1 \rangle = x$ and $\langle fpexpr_2 \rangle = n$ and $\langle fpexpr_3 \rangle = t$ then rounds x to n places. If n is an integer, this rounds x to a multiple of 10^{-n} ; if $n = +\infty$, this always yields x ; if $n = -\infty$, this yields one of ± 0 , $\pm\infty$, or NaN; if n is neither $\pm\infty$ nor an integer, then an “invalid operation” exception is raised. When $\langle fpexpr_2 \rangle$ is omitted, $n = 0$, *i.e.*, $\langle fpexpr_1 \rangle$ is rounded to an integer. The rounding direction depends on the function.

- **round** yields the multiple of 10^{-n} closest to x , with ties (x half-way between two such multiples) rounded as follows. If t is **nan** or not given the even multiple is chosen (“ties to even”), if $t = \pm 0$ the multiple closest to 0 is chosen (“ties to zero”), if t is positive/negative the multiple closest to $\infty/-\infty$ is chosen (“ties towards positive/negative infinity”).
- **floor** yields the largest multiple of 10^{-n} smaller or equal to x (“round towards negative infinity”);
- **ceil** yields the smallest multiple of 10^{-n} greater or equal to x (“round towards positive infinity”);
- **trunc** yields a multiple of 10^{-n} with the same sign as x and with the largest absolute value less than that of x (“round towards zero”).

“Overflow” occurs if x is finite and the result is infinite (this can only happen if $\langle fpexpr_2 \rangle < -9984$). If any operand is a tuple, “invalid operation” occurs.

sign	<code>\fp_eval:n { sign(<fpexpr>) }</code>
-------------	--

Evaluates the $\langle fpexpr \rangle$ and determines its sign: +1 for positive numbers and for $+\infty$, -1 for negative numbers and for $-\infty$, ± 0 for ± 0 , and NaN for NaN. If the operand is a tuple, “invalid operation” occurs. This operation does not raise exceptions in other cases.

<code>sin</code>	<code>\fp_eval:n { sin(<fpexpr>) }</code>
<code>cos</code>	<code>\fp_eval:n { cos(<fpexpr>) }</code>
<code>tan</code>	<code>\fp_eval:n { tan(<fpexpr>) }</code>
<code>cot</code>	<code>\fp_eval:n { cot(<fpexpr>) }</code>
<code>csc</code>	<code>\fp_eval:n { csc(<fpexpr>) }</code>
<code>sec</code>	<code>\fp_eval:n { sec(<fpexpr>) }</code>

Updated: 2013-11-17

Computes the sine, cosine, tangent, cotangent, cosecant, or secant of the $\langle fpexpr \rangle$ given in radians. For arguments given in degrees, see `sind`, `cosd`, *etc.* Note that since π is irrational, `sin(8pi)` is not quite zero, while its analogue `sind(8 × 180)` is exactly zero. The trigonometric functions are undefined for an argument of $\pm\infty$, leading to the “invalid operation” exception. Additionally, evaluating tangent, cotangent, cosecant, or secant at one of their poles leads to a “division by zero” exception. “Underflow” and “overflow” occur when appropriate. If the operand is a tuple, “invalid operation” occurs.

<code>sind</code>	<code>\fp_eval:n { sind(<fpexpr>) }</code>
<code>cosd</code>	<code>\fp_eval:n { cosd(<fpexpr>) }</code>
<code>tand</code>	<code>\fp_eval:n { tand(<fpexpr>) }</code>
<code>cotd</code>	<code>\fp_eval:n { cotd(<fpexpr>) }</code>
<code>cscd</code>	<code>\fp_eval:n { cscd(<fpexpr>) }</code>
<code>secd</code>	<code>\fp_eval:n { secd(<fpexpr>) }</code>

New: 2013-11-02

Computes the sine, cosine, tangent, cotangent, cosecant, or secant of the $\langle fpexpr \rangle$ given in degrees. For arguments given in radians, see `sin`, `cos`, *etc.* Note that since π is irrational, `sin(8pi)` is not quite zero, while its analogue `sind(8 × 180)` is exactly zero. The trigonometric functions are undefined for an argument of $\pm\infty$, leading to the “invalid operation” exception. Additionally, evaluating tangent, cotangent, cosecant, or secant at one of their poles leads to a “division by zero” exception. “Underflow” and “overflow” occur when appropriate. If the operand is a tuple, “invalid operation” occurs.

<code>asin</code>	<code>\fp_eval:n { asin(<fpexpr>) }</code>
<code>acos</code>	<code>\fp_eval:n { acos(<fpexpr>) }</code>
<code>acsc</code>	<code>\fp_eval:n { acsc(<fpexpr>) }</code>
<code>asec</code>	<code>\fp_eval:n { asec(<fpexpr>) }</code>

New: 2013-11-02

Computes the arcsine, arccosine, arccosecant, or arcsecant of the $\langle fpexpr \rangle$ and returns the result in radians, in the range $[-\pi/2, \pi/2]$ for `asin` and `acsc` and $[0, \pi]$ for `acos` and `asec`. For a result in degrees, use `asind`, *etc.* If the argument of `asin` or `acos` lies outside the range $[-1, 1]$, or the argument of `acsc` or `asec` inside the range $(-1, 1)$, an “invalid operation” exception is raised. “Underflow” and “overflow” occur when appropriate. If the operand is a tuple, “invalid operation” occurs.

<code>asind</code>	<code>\fp_eval:n { asind(<fpexpr>) }</code>
<code>acosd</code>	<code>\fp_eval:n { acosd(<fpexpr>) }</code>
<code>acscd</code>	<code>\fp_eval:n { acscd(<fpexpr>) }</code>
<code>asecd</code>	<code>\fp_eval:n { asecd(<fpexpr>) }</code>

New: 2013-11-02

Computes the arcsine, arccosine, arccosecant, or arcsecant of the $\langle fpexpr \rangle$ and returns the result in degrees, in the range $[-90, 90]$ for `asin` and `acsc` and $[0, 180]$ for `acos` and `asec`. For a result in radians, use `asin`, *etc.* If the argument of `asin` or `acos` lies outside the range $[-1, 1]$, or the argument of `acsc` or `asec` inside the range $(-1, 1)$, an “invalid operation” exception is raised. “Underflow” and “overflow” occur when appropriate. If the operand is a tuple, “invalid operation” occurs.

atan	<code>\fp_eval:n { atan(<fpexpr>) }</code>
acot	<code>\fp_eval:n { atan(<fpexpr₁> , <fpexpr₂>) }</code>
<hr/>	
New: 2013-11-02	<code>\fp_eval:n { acot(<fpexpr>) }</code>
	<code>\fp_eval:n { acot(<fpexpr₁> , <fpexpr₂>) }</code>

Those functions yield an angle in radians: **atand** and **acotd** are their analogs in degrees. The one-argument versions compute the arctangent or arccotangent of the $\langle fpexpr \rangle$: arctangent takes values in the range $[-\pi/2, \pi/2]$, and arccotangent in the range $[0, \pi]$. The two-argument arctangent computes the angle in polar coordinates of the point with Cartesian coordinates $(\langle fpexpr_2 \rangle, \langle fpexpr_1 \rangle)$: this is the arctangent of $\langle fpexpr_1 \rangle / \langle fpexpr_2 \rangle$, possibly shifted by π depending on the signs of $\langle fpexpr_1 \rangle$ and $\langle fpexpr_2 \rangle$. The two-argument arccotangent computes the angle in polar coordinates of the point $(\langle fpexpr_1 \rangle, \langle fpexpr_2 \rangle)$, equal to the arccotangent of $\langle fpexpr_1 \rangle / \langle fpexpr_2 \rangle$, possibly shifted by π . Both two-argument functions take values in the wider range $[-\pi, \pi]$. The ratio $\langle fpexpr_1 \rangle / \langle fpexpr_2 \rangle$ need not be defined for the two-argument arctangent: when both expressions yield ± 0 , or when both yield $\pm \infty$, the resulting angle is one of $\{\pm\pi/4, \pm 3\pi/4\}$ depending on signs. The “underflow” exception can occur. If any operand is a tuple, “invalid operation” occurs.

atand	<code>\fp_eval:n { atand(<fpexpr>) }</code>
acotd	<code>\fp_eval:n { atand(<fpexpr₁> , <fpexpr₂>) }</code>
<hr/>	
New: 2013-11-02	<code>\fp_eval:n { acotd(<fpexpr>) }</code>
	<code>\fp_eval:n { acotd(<fpexpr₁> , <fpexpr₂>) }</code>

Those functions yield an angle in degrees: **atand** and **acotd** are their analogs in radians. The one-argument versions compute the arctangent or arccotangent of the $\langle fpexpr \rangle$: arctangent takes values in the range $[-90, 90]$, and arccotangent in the range $[0, 180]$. The two-argument arctangent computes the angle in polar coordinates of the point with Cartesian coordinates $(\langle fpexpr_2 \rangle, \langle fpexpr_1 \rangle)$: this is the arctangent of $\langle fpexpr_1 \rangle / \langle fpexpr_2 \rangle$, possibly shifted by 180 depending on the signs of $\langle fpexpr_1 \rangle$ and $\langle fpexpr_2 \rangle$. The two-argument arccotangent computes the angle in polar coordinates of the point $(\langle fpexpr_1 \rangle, \langle fpexpr_2 \rangle)$, equal to the arccotangent of $\langle fpexpr_1 \rangle / \langle fpexpr_2 \rangle$, possibly shifted by 180. Both two-argument functions take values in the wider range $[-180, 180]$. The ratio $\langle fpexpr_1 \rangle / \langle fpexpr_2 \rangle$ need not be defined for the two-argument arctangent: when both expressions yield ± 0 , or when both yield $\pm \infty$, the resulting angle is one of $\{\pm 45, \pm 135\}$ depending on signs. The “underflow” exception can occur. If any operand is a tuple, “invalid operation” occurs.

sqrt	<code>\fp_eval:n { sqrt(<fpexpr>) }</code>
-------------	--

New: 2013-12-14 Computes the square root of the $\langle fpexpr \rangle$. The “invalid operation” is raised when the $\langle fpexpr \rangle$ is negative or is a tuple; no other exception can occur. Special values yield $\sqrt{-0} = -0$, $\sqrt{+0} = +0$, $\sqrt{+\infty} = +\infty$ and $\sqrt{\text{NaN}} = \text{NaN}$.

<hr/> rand <hr/>	<code>\fp_eval:n { rand() }</code>
<hr/> <small>New: 2016-12-05</small> <hr/>	<p>Produces a pseudo-random floating-point number (multiple of 10^{-16}) between 0 included and 1 excluded. This is not available in older versions of $\text{X}\text{_}\text{T}\text{E}\text{X}$. The random seed can be queried using <code>\sys_rand_seed:</code> and set using <code>\sys_gset_rand_seed:n</code>.</p> <p>TEXhackers note: This is based on pseudo-random numbers provided by the engine’s primitive <code>\pdfuniformdeviate</code> in $\text{pdf}\text{_}\text{T}\text{E}\text{X}$, $\text{p}\text{T}\text{E}\text{X}$, $\text{up}\text{T}\text{E}\text{X}$ and <code>\uniformdeviate</code> in $\text{Lua}\text{_}\text{T}\text{E}\text{X}$ and $\text{X}\text{_}\text{T}\text{E}\text{X}$. The underlying code is based on Metapost, which follows an additive scheme recommended in Section 3.6 of “The Art of Computer Programming, Volume 2”.</p> <p>While we are more careful than <code>\uniformdeviate</code> to preserve uniformity of the underlying stream of 28-bit pseudo-random integers, these pseudo-random numbers should of course not be relied upon for serious numerical computations nor cryptography.</p>
<hr/> randint <hr/>	<code>\fp_eval:n { randint(<fpexpr>) }</code>
<hr/> <small>New: 2016-12-05</small> <hr/>	<p><code>\fp_eval:n { randint(<fpexpr₁> , <fpexpr₂>) }</code></p> <p>Produces a pseudo-random integer between 1 and $\langle fpexpr \rangle$ or between $\langle fpexpr_1 \rangle$ and $\langle fpexpr_2 \rangle$ inclusive. The bounds must be integers in the range $(-10^{16}, 10^{16})$ and the first must be smaller or equal to the second. See rand for important comments on how these pseudo-random numbers are generated.</p>
<hr/> inf nan <hr/>	The special values $+\infty$, $-\infty$, and NaN are represented as inf , -inf and nan (see <code>\c_minus_inf_fp</code> , <code>\c_minus_inf_fp</code> and <code>\c_nan_fp</code>).
<hr/> pi <hr/>	The value of π (see <code>\c_pi_fp</code>).
<hr/> deg <hr/>	The value of 1° in radians (see <code>\c_one_degree_fp</code>).

<hr/>	Those units of measurement are equal to their values in <code>pt</code> , namely
<code>em</code>	
<code>ex</code>	
<code>in</code>	$1\text{in} = 72.27\text{pt}$
<code>pt</code>	$1\text{pt} = 1\text{pt}$
<code>pc</code>	
<code>cm</code>	$1\text{pc} = 12\text{pt}$
<code>mm</code>	
<code>dd</code>	$1\text{cm} = \frac{1}{2.54}\text{in} = 28.45275590551181\text{pt}$
<code>cc</code>	
<code>nd</code>	$1\text{mm} = \frac{1}{25.4}\text{in} = 2.845275590551181\text{pt}$
<code>nc</code>	
<code>bp</code>	$1\text{dd} = 0.376065\text{mm} = 1.07000856496063\text{pt}$
<code>sp</code>	
<hr/>	
	$1\text{cc} = 12\text{dd} = 12.84010277952756\text{pt}$
	$1\text{nd} = 0.375\text{mm} = 1.066978346456693\text{pt}$
	$1\text{nc} = 12\text{nd} = 12.80374015748031\text{pt}$
	$1\text{bp} = \frac{1}{72}\text{in} = 1.00375\text{pt}$
	$1\text{sp} = 2^{-16}\text{pt} = 1.52587890625e - 5\text{pt}.$

The values of the (font-dependent) units `em` and `ex` are gathered from \TeX when the surrounding floating point expression is evaluated.

<hr/>	
<code>true</code>	Other names for 1 and +0.
<code>false</code>	
<hr/>	

<hr/>	
<code>\fp_abs:n</code> *	<code>\fp_abs:n {⟨floating point expression⟩}</code>
<hr/>	
New: 2012-05-14	Evaluates the <i>⟨floating point expression⟩</i> as described for <code>\fp_eval:n</code> and leaves the
Updated: 2012-07-08	absolute value of the result in the input stream. If the argument is a tuple, “invalid
<hr/>	operation” occurs, but no other case raises exceptions. Within floating point expressions,
	<code>abs()</code> can be used.

<hr/>	
<code>\fp_max:nn</code> *	<code>\fp_max:nn {⟨fp expression 1⟩} {⟨fp expression 2⟩}</code>
<code>\fp_min:nn</code> *	
<hr/>	
New: 2012-09-26	Evaluates the <i>⟨floating point expressions⟩</i> as described for <code>\fp_eval:n</code> and leaves the
	resulting larger (<code>max</code>) or smaller (<code>min</code>) value in the input stream. If the argument is a
	tuple, “invalid operation” occurs, but no other case raises exceptions. Within floating
	point expressions, <code>max()</code> and <code>min()</code> can be used.

10 Disclaimer and roadmap

The package may break down if the escape character is among `0123456789_+`, or if it receives a \TeX primitive conditional affected by `\exp_not:N`.

The following need to be done. I’ll try to time-order the items.

- Function to count items in a tuple (and to determine if something is a tuple).
- Decide what exponent range to consider.

- Support signalling `nan`.
- Modulo and remainder, and rounding function `quantize` (and its friends analogous to `trunc`, `ceil`, `floor`).
- `\fp_format:nn {<fpepr>} {<format>}`, but what should `<format>` be? More general pretty printing?
- Add `and`, `or`, `xor`? Perhaps under the names `all`, `any`, and `xor`?
- Add `log(x, b)` for logarithm of x in base b .
- `hypot` (Euclidean length). Cartesian-to-polar transform.
- Hyperbolic functions `cosh`, `sinh`, `tanh`.
- Inverse hyperbolics.
- Base conversion, input such as `0xAB.CDEF`.
- Factorial (not with `!`), gamma function.
- Improve coefficients of the `sin` and `tan` series.
- Treat upper and lower case letters identically in identifiers, and ignore underscores.
- Add an `array(1,2,3)` and `i=complex(0,1)`.
- Provide an experimental `map` function? Perhaps easier to implement if it is a single character, `@sin(1,2)`?
- Provide `\fp_if_nan:nTF`, and an `isnan` function?
- Support keyword arguments?

`Pgfmth` also provides box-measurements (depth, height, width), but boxes are not possible expandably.

Bugs, and tests to add.

- Check that functions are monotonic when they should.
- Add exceptions to `?:`, `!<=>?`, `&&`, `||`, and `!`.
- Logarithms of numbers very close to 1 are inaccurate.
- When rounding towards $-\infty$, `\dim_to_fp:n {Opt}` should return -0 , not $+0$.
- The result of $(\pm 0) + (\pm 0)$, of $x + (-x)$, and of $(-x) + x$ should depend on the rounding mode.
- `0e9999999999` gives a `TEX` “number too large” error.
- Subnormals are not implemented.

Possible optimizations/improvements.

- Document that `l3trial/l3fp-types` introduces tools for adding new types.
- In subsection 9.1, write a grammar.

- It would be nice if the `parse` auxiliaries for each operation were set up in the corresponding module, rather than centralizing in `l3fp-parse`.
- Some functions should get an `_o` ending to indicate that they expand after their result.
- More care should be given to distinguish expandable/restricted expandable (auxiliary and internal) functions.
- The code for the `ternary` set of functions is ugly.
- There are many `~` missing in the doc to avoid bad line-breaks.
- The algorithm for computing the logarithm of the significand could be made to use a 5 terms Taylor series instead of 10 terms by taking $c = 2000/([200x]+1) \in [10, 95]$ instead of $c \in [1, 10]$. Also, it would then be possible to simplify the computation of t . However, we would then have to hard-code the logarithms of 44 small integers instead of 9.
- Improve notations in the explanations of the division algorithm (`l3fp-basics`).
- Understand and document `_fp_basics_pack_weird_low:NNNNw` and `_fp_basics_pack_weird_high:NNNNNNNNw` better. Move the other `basics_pack` auxiliaries to `l3fp-aux` under a better name.
- Find out if underflow can really occur for trigonometric functions, and redoc as appropriate.
- Add bibliography. Some of Kahan’s articles, some previous T_EX fp packages, the international standards,...
- Also take into account the “inexact” exception?
- Support multi-character prefix operators (*e.g.*, `@/` or whatever)?

Part XXIV

The `l3farray` package: fast global floating point arrays

1 `l3farray` documentation

For applications requiring heavy use of floating points, this module provides arrays which can be accessed in constant time (contrast `l3seq`, where access time is linear). The interface is very close to that of `l3intarray`. The size of the array is fixed and must be given at point of initialisation

Currently *all* functions in this module are candidates. Their documentation can be found in `l3candidates`.

Part XXV

The l3sort package

Sorting functions

1 Controlling sorting

L^AT_EX3 comes with a facility to sort list variables (sequences, token lists, or comma-lists) according to some user-defined comparison. For instance,

```
\clist_set:Nn \l_foo_clist { 3 , 01 , -2 , 5 , +1 }
\clist_sort:Nn \l_foo_clist
{
  \int_compare:nNnTF { #1 } > { #2 }
  { \sort_return_swapped: }
  { \sort_return_same: }
}
```

results in `\l_foo_clist` holding the values `{ -2 , 01 , +1 , 3 , 5 }` sorted in non-decreasing order.

The code defining the comparison should call `\sort_return_swapped:` if the two items given as `#1` and `#2` are not in the correct order, and otherwise it should call `\sort_return_same:` to indicate that the order of this pair of items should not be changed.

For instance, a *comparison code* consisting only of `\sort_return_same:` with no test yields a trivial sort: the final order is identical to the original order. Conversely, using a *comparison code* consisting only of `\sort_return_swapped:` reverses the list (in a fairly inefficient way).

T_EXhackers note: The current implementation is limited to sorting approximately 20000 items (40000 in LuaT_EX), depending on what other packages are loaded.

Internally, the code from l3sort stores items in `\toks` registers allocated locally. Thus, the *comparison code* should not call `\newtoks` or other commands that allocate new `\toks` registers. On the other hand, altering the value of a previously allocated `\toks` register is not a problem.

```
\sort_return_same:
\sort_return_swapped:
```

New: 2017-02-06

```
\seq_sort:Nn <seq var>
{ ... \sort_return_same: or \sort_return_swapped: ... }
```

Indicates whether to keep the order or swap the order of two items that are compared in the sorting code. Only one of the `\sort_return_...` functions should be used by the code, according to the results of some tests on the items `#1` and `#2` to be compared.

Part XXVI

The l3tl-analysis package: Analysing token lists

1 l3tl-analysis documentation

This module mostly provides internal functions for use in the l3regex module. However, it provides as a side-effect a user debugging function, very similar to the \ShowTokens macro from the ted package.

\tl_analysis_show:N	\tl_analysis_show:n {<token list>}
\tl_analysis_show:n	

New: 2018-04-09

Displays to the terminal the detailed decomposition of the <token list> into tokens, showing the category code of each character token, the meaning of control sequences and active characters, and the value of registers.

\tl_analysis_map_inline:nn	\tl_analysis_map_inline:nn {<token list>} {<inline function>}
\tl_analysis_map_inline:Nn	

New: 2018-04-09

\tl_analysis_map_inline:nn {<token list>} {<inline function>}

Applies the <inline function> to each individual <token> in the <token list>. The <inline function> receives three arguments:

- <tokens>, which both o-expand and x-expand to the <token>. The detailed form of <token> may change in later releases.
- <char code>, a decimal representation of the character code of the token, -1 if it is a control sequence (with <catcode> 0).
- <catcode>, a capital hexadecimal digit which denotes the category code of the <token> (0: control sequence, 1: begin-group, 2: end-group, 3: math shift, 4: alignment tab, 6: parameter, 7: superscript, 8: subscript, A: space, B: letter, C:other, D:active).

Part XXVII

The `l3regex` package: Regular expressions in `TEX`

The `l3regex` package provides regular expression testing, extraction of submatches, splitting, and replacement, all acting on token lists. The syntax of regular expressions is mostly a subset of the PCRE syntax (and very close to POSIX), with some additions due to the fact that `TEX` manipulates tokens rather than characters. For performance reasons, only a limited set of features are implemented. Notably, back-references are not supported.

Let us give a few examples. After

```
\tl_set:Nn \l_my_tl { That~cat. }
\regex_replace_once:nnN { at } { is } \l_my_tl
```

the token list variable `\l_my_tl` holds the text “`This cat.`”, where the first occurrence of “`at`” was replaced by “`is`”. A more complicated example is a pattern to emphasize each word and add a comma after it:

```
\regex_replace_all:nnN { \w+ } { \c{emph}\cB\{ \0 \cE\} , } \l_my_tl
```

The `\w` sequence represents any “word” character, and `+` indicates that the `\w` sequence should be repeated as many times as possible (at least once), hence matching a word in the input token list. In the replacement text, `\0` denotes the full match (here, a word). The command `\emph` is inserted using `\c{emph}`, and its argument `\0` is put between braces `\cB\{` and `\cE\}`.

If a regular expression is to be used several times, it can be compiled once, and stored in a regex variable using `\regex_const:Nn`. For example,

```
\regex_const:Nn \c_foo_regex { \c{begin} \cB. (\c[~BE].*) \cE. }
```

stores in `\c_foo_regex` a regular expression which matches the starting marker for an environment: `\begin`, followed by a begin-group token (`\cB.`), then any number of tokens which are neither begin-group nor end-group character tokens (`\c[~BE].*`), ending with an end-group token (`\cE.`). As explained in the next section, the parentheses “capture” the result of `\c[~BE].*`, giving us access to the name of the environment when doing replacements.

1 Syntax of regular expressions

We start with a few examples, and encourage the reader to apply `\regex_show:n` to these regular expressions.

- `Cat` matches the word “Cat” capitalized in this way, but also matches the beginning of the word “Cattle”: use `\bCat\b` to match a complete word only.
- `[abc]` matches one letter among “a”, “b”, “c”; the pattern `(a|b|c)` matches the same three possible letters (but see the discussion of submatches below).
- `[A-Za-z]*` matches any number (due to the quantifier `*`) of Latin letters (not accented).

- `\c{[A-Za-z]*}` matches a control sequence made of Latin letters.
- `_[^_]*_` matches an underscore, any number of characters other than underscore, and another underscore; it is equivalent to `_.*?_` where `.` matches arbitrary characters and the lazy quantifier `*?` means to match as few characters as possible, thus avoiding matching underscores.
- `[\+|-]?[d+]` matches an explicit integer with at most one sign.
- `[\+|-_]*[d+_]*` matches an explicit integer with any number of `+` and `-` signs, with spaces allowed except within the mantissa, and surrounded by spaces.
- `[\+|-_]*(\d+|\d*\.\d+)__*` matches an explicit integer or decimal number; using `[.,]` instead of `\.` would allow the comma as a decimal marker.
- `[\+|-_]*(\d+|\d*\.\d+)__*((?i)pt|in|[cem]m|ex|[bs]p|[dn]d|[pcn]c)__*` matches an explicit dimension with any unit that T_EX knows, where `(?i)` means to treat lowercase and uppercase letters identically.
- `[\+|-_]*((?i)nan|inf|(\d+|\d*\.\d+)__*(e[\+|-_]*/\d+)__*)` matches an explicit floating point number or the special values `nan` and `inf` (with signs and spaces allowed).
- `[\+|-_]*(\d+|\dC.)__*` matches an explicit integer or control sequence (without checking whether it is an integer variable).
- `\G.*?\K` at the beginning of a regular expression matches and discards (due to `\K`) everything between the end of the previous match (`\G`) and what is matched by the rest of the regular expression; this is useful in `\regex_replace_all:nnN` when the goal is to extract matches or submatches in a finer way than with `\regex_extract_all:nnN`.

While it is impossible for a regular expression to match only integer expressions, `[\+|-\(\)*\d+\)*(\+|-*/[\+|-\(\)*\d+\)\]*)` matches among other things all valid integer expressions (made only with explicit integers). One should follow it with further testing.

Most characters match exactly themselves, with an arbitrary category code. Some characters are special and must be escaped with a backslash (*e.g.*, `*` matches a star character). Some escape sequences of the form backslash-letter also have a special meaning (for instance `\d` matches any digit). As a rule,

- every alphanumeric character (`A-Z`, `a-z`, `0-9`) matches exactly itself, and should not be escaped, because `\A`, `\B`, ... have special meanings;
- non-alphanumeric printable ascii characters can (and should) always be escaped: many of them have special meanings (*e.g.*, use `\(`, `\)`, `\?`, `\.`);
- spaces should always be escaped (even in character classes);
- any other character may be escaped or not, without any effect: both versions match exactly that character.

Note that these rules play nicely with the fact that many non-alphanumeric characters are difficult to input into T_EX under normal category codes. For instance, `\abc%` matches the characters `\abc%` (with arbitrary category codes), but does not match the control sequence `\abc` followed by a percent character. Matching control sequences can be done using the `\c{<regex>}` syntax (see below).

Any special character which appears at a place where its special behaviour cannot apply matches itself instead (for instance, a quantifier appearing at the beginning of a string), after raising a warning.

Characters.

`\x{hh...}` Character with hex code `hh...`

`\xhh` Character with hex code `hh`.

`\a` Alarm (hex 07).

`\e` Escape (hex 1B).

`\f` Form-feed (hex 0C).

`\n` New line (hex 0A).

`\r` Carriage return (hex 0D).

`\t` Horizontal tab (hex 09).

Character types.

`.` A single period matches any token.

`\d` Any decimal digit.

`\h` Any horizontal space character, equivalent to `[\ \^^I]`: space and tab.

`\s` Any space character, equivalent to `[\ \^^I\^^J\^^L\^^M]`.

`\v` Any vertical space character, equivalent to `[\^^J\^^K\^^L\^^M]`. Note that `\^^K` is a vertical space, but not a space, for compatibility with Perl.

`\w` Any word character, *i.e.*, alphanumerics and underscore, equivalent to the explicit class `[A-Za-z0-9_]`.

`\D` Any token not matched by `\d`.

`\H` Any token not matched by `\h`.

`\N` Any token other than the `\n` character (hex 0A).

`\S` Any token not matched by `\s`.

`\V` Any token not matched by `\v`.

`\W` Any token not matched by `\w`.

Of those, `.`, `\D`, `\H`, `\N`, `\S`, `\V`, and `\W` match arbitrary control sequences.

Character classes match exactly one token in the subject.

`[...]` Positive character class. Matches any of the specified tokens.

[**^...**] Negative character class. Matches any token other than the specified characters.

x-y Within a character class, this denotes a range (can be used with escaped characters).

[:**<name>**:] Within a character class (one more set of brackets), this denotes the POSIX character class **<name>**, which can be **alnum**, **alpha**, **ascii**, **blank**, **cntrl**, **digit**, **graph**, **lower**, **print**, **punct**, **space**, **upper**, **word**, or **xdigit**.

[:**~<name>**:] Negative POSIX character class.

For instance, [**a-oq-z\cC.**] matches any lowercase latin letter except **p**, as well as control sequences (see below for a description of **\c**).

Quantifiers (repetition).

? 0 or 1, greedy.

?? 0 or 1, lazy.

***** 0 or more, greedy.

***?** 0 or more, lazy.

+ 1 or more, greedy.

+? 1 or more, lazy.

{n} Exactly *n*.

{n,} *n* or more, greedy.

{n,}? *n* or more, lazy.

{n,m} At least *n*, no more than *m*, greedy.

{n,m}? At least *n*, no more than *m*, lazy.

Anchors and simple assertions.

\b Word boundary: either the previous token is matched by **\w** and the next by **\W**, or the opposite. For this purpose, the ends of the token list are considered as **\W**.

\B Not a word boundary: between two **\w** tokens or two **\W** tokens (including the boundary).

^ or **\A** Start of the subject token list.

\$, **\Z** or **\z** End of the subject token list.

\G Start of the current match. This is only different from **^** in the case of multiple matches: for instance **\regex_count:nnN { \G a } { aaba } \l_tmpa_int** yields 2, but replacing **\G** by **^** would result in **\l_tmpa_int** holding the value 1.

Alternation and capturing groups.

A|B|C Either one of **A**, **B**, or **C**.

(...) Capturing group.

(?:...) Non-capturing group.

(?<|...)) Non-capturing group which resets the group number for capturing groups in each alternative. The following group is numbered with the first unused group number.

The `\c` escape sequence allows to test the category code of tokens, and match control sequences. Each character category is represented by a single uppercase letter:

- C for control sequences;
- B for begin-group tokens;
- E for end-group tokens;
- M for math shift;
- T for alignment tab tokens;
- P for macro parameter tokens;
- U for superscript tokens (up);
- D for subscript tokens (down);
- S for spaces;
- L for letters;
- O for others; and
- A for active characters.

The `\c` escape sequence is used as follows.

`\c{<regex>}` A control sequence whose *cname* matches the *<regex>*, anchored at the beginning and end, so that `\c{begin}` matches exactly `\begin`, and nothing else.

`\cX` Applies to the next object, which can be a character, character property, class, or group, and forces this object to only match tokens with category **X** (any of CBEMTPUDSLOA). For instance, `\cL[A-Z\d]` matches uppercase letters and digits of category code letter, `\cC.` matches any control sequence, and `\cO(abc)` matches `abc` where each character has category other.

`\c[XYZ]` Applies to the next object, and forces it to only match tokens with category **X**, **Y**, or **Z** (each being any of CBEMTPUDSLOA). For instance, `\c[LSO](..)` matches two tokens of category letter, space, or other.

`\c[^XYZ]` Applies to the next object and prevents it from matching any token with category **X**, **Y**, or **Z** (each being any of CBEMTPUDSLOA). For instance, `\c[^O]\d` matches digits which have any category different from other.

The category code tests can be used inside classes; for instance, `[\cO\d \c[LO][A-F]]` matches what \TeX considers as hexadecimal digits, namely digits with category other, or uppercase letters from **A** to **F** with category either letter or other. Within a group affected by a category code test, the outer test can be overridden by a nested test: for instance, `\cL(ab\cO*cd)` matches `ab*cd` where all characters are of category letter, except `*` which has category other.

The `\u` escape sequence allows to insert the contents of a token list directly into a regular expression or a replacement, avoiding the need to escape special characters.

Namely, `\u{<tl var name>}` matches the exact contents of the token list `<tl var>`. Within a `\c{...}` control sequence matching, the `\u` escape sequence only expands its argument once, in effect performing `\tl_to_str:v`. Quantifiers are not supported directly: use a group.

The option `(?i)` makes the match case insensitive (identifying A–Z with a–z; no Unicode support yet). This applies until the end of the group in which it appears, and can be reverted using `(?-i)`. For instance, in `(?i)(a(?-i)b|c)d`, the letters `a` and `d` are affected by the `i` option. Characters within ranges and classes are affected individually: `(?i)[Y-\]` is equivalent to `[YZ\[\]yz]`, and `(?i)[^aeiou]` matches any character which is not a vowel. Neither character properties, nor `\c{...}` nor `\u{...}` are affected by the `i` option.

In character classes, only `[`, `^`, `-`, `]`, `\` and spaces are special, and should be escaped. Other non-alphanumeric characters can still be escaped without harm. Any escape sequence which matches a single character (`\d`, `\D`, *etc.*) is supported in character classes. If the first character is `^`, then the meaning of the character class is inverted; `^` appearing anywhere else in the range is not special. If the first character (possibly following a leading `^`) is `]` then it does not need to be escaped since ending the range there would make it empty. Ranges of characters can be expressed using `-`, for instance, `[\D 0–5]` and `[\^6–9]` are equivalent.

Capturing groups are a means of extracting information about the match. Parenthesized groups are labelled in the order of their opening parenthesis, starting at 1. The contents of those groups corresponding to the “best” match (leftmost longest) can be extracted and stored in a sequence of token lists using for instance `\regex_extract_once:nnTF`.

The `\K` escape sequence resets the beginning of the match to the current position in the token list. This only affects what is reported as the full match. For instance,

```
\regex_extract_all:nnN { a \K . } { a123aaxyz } \l_foo_seq
```

results in `\l_foo_seq` containing the items `{1}` and `{a}`: the true matches are `{a1}` and `{aa}`, but they are trimmed by the use of `\K`. The `\K` command does not affect capturing groups: for instance,

```
\regex_extract_once:nnN { (. \K c)+ \d } { acbc3 } \l_foo_seq
```

results in `\l_foo_seq` containing the items `{c3}` and `{bc}`: the true match is `{acbc3}`, with first submatch `{bc}`, but `\K` resets the beginning of the match to the last position where it appears.

2 Syntax of the replacement text

Most of the features described in regular expressions do not make sense within the replacement text. Backslash introduces various special constructions, described further below:

- `\0` is the whole match;
- `\1` is the submatch that was matched by the first (capturing) group `(...)`; similarly for `\2`, ..., `\9` and `\g{<number>}`;
- `_` inserts a space (spaces are ignored when not escaped);

- `\a, \e, \f, \n, \r, \t, \xhh, \x{hhh}` correspond to single characters as in regular expressions;
- `\c{<cs name>}` inserts a control sequence;
- `\c{<category>}<character>` (see below);
- `\u{<tl var name>}` inserts the contents of the `<tl var>` (see below).

Characters other than backslash and space are simply inserted in the result (but since the replacement text is first converted to a string, one should also escape characters that are special for T_EX, for instance use `\#`). Non-alphanumeric characters can always be safely escaped with a backslash.

For instance,

```
\tl_set:Nn \l_my_tl { Hello,~world! }
\regex_replace_all:nnN { ([er]?l|o) . } { (\0--\1) } \l_my_tl
```

results in `\l_my_tl` holding `H(e1l--e1)(o,--o) w(or--o)(ld--l)!`

The submatches are numbered according to the order in which the opening parenthesis of capturing groups appear in the regular expression to match. The n -th submatch is empty if there are fewer than n capturing groups or for capturing groups that appear in alternatives that were not used for the match. In case a capturing group matches several times during a match (due to quantifiers) only the last match is used in the replacement text. Submatches always keep the same category codes as in the original token list.

The characters inserted by the replacement have category code 12 (other) by default, with the exception of space characters. Spaces inserted through `_` have category code 10, while spaces inserted through `\x20` or `\x{20}` have category code 12. The escape sequence `\c` allows to insert characters with arbitrary category codes, as well as control sequences.

`\cX(...)` Produces the characters “...” with category `X`, which must be one of `CBEMTPUDSLOA` as in regular expressions. Parentheses are optional for a single character (which can be an escape sequence). When nested, the innermost category code applies, for instance `\cL(Hello\cS\ world)!` gives this text with standard category codes.

`\c{<text>}` Produces the control sequence with csname `<text>`. The `<text>` may contain references to the submatches `\0`, `\1`, and so on, as in the example for `\u` below.

The escape sequence `\u{<tl var name>}` allows to insert the contents of the token list with name `<tl var name>` directly into the replacement, giving an easier control of category codes. When nested in `\c{...}` and `\u{...}` constructions, the `\u` and `\c` escape sequences perform `\tl_to_str:v`, namely extract the value of the control sequence and turn it into a string. Matches can also be used within the arguments of `\c` and `\u`. For instance,

```
\tl_set:Nn \l_my_one_tl { first }
\tl_set:Nn \l_my_two_tl { \emph{second} }
\tl_set:Nn \l_my_tl { one , two , one , one }
\regex_replace_all:nnN { [^,]+ } { \u{1_my_\0_tl} } \l_my_tl
```

results in `\l_my_tl` holding `first,\emph{second},first,first`.

3 Pre-compiling regular expressions

If a regular expression is to be used several times, it is better to compile it once rather than doing it each time the regular expression is used. The compiled regular expression is stored in a variable. All of the `l3regex` module's functions can be given their regular expression argument either as an explicit string or as a compiled regular expression.

`\regex_new:N`

New: 2017-05-26

`\regex_new:N` $\langle regex\ var \rangle$

Creates a new $\langle regex\ var \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle regex\ var \rangle$ is initially such that it never matches.

`\regex_set:Nn`
`\regex_gset:Nn`
`\regex_const:Nn`

New: 2017-05-26

`\regex_set:Nn` $\langle regex\ var \rangle$ $\{ \langle regex \rangle \}$

Stores a compiled version of the $\langle regular\ expression \rangle$ in the $\langle regex\ var \rangle$. For instance, this function can be used as

```
\regex_new:N \l_my_regex
\regex_set:Nn \l_my_regex { my\ (simple\ )? reg(ex|ular\ expression) }
```

The assignment is local for `\regex_set:Nn` and global for `\regex_gset:Nn`. Use `\regex_const:Nn` for compiled expressions which never change.

`\regex_show:n`
`\regex_show:N`

New: 2017-05-26

`\regex_show:n` $\{ \langle regex \rangle \}$

Shows how `l3regex` interprets the $\langle regex \rangle$. For instance, `\regex_show:n {\A X|Y}` shows

```
+--branch
  anchor at start (\A)
  char code 88
+--branch
  char code 89
```

indicating that the anchor `\A` only applies to the first branch: the second branch is not anchored to the beginning of the match.

4 Matching

All regular expression functions are available in both `:n` and `:N` variants. The former require a “standard” regular expression, while the later require a compiled expression as generated by `\regex_(g)set:Nn`.

`\regex_match:nnTF`
`\regex_match:NnTF`

New: 2017-05-26

`\regex_match:nnTF` $\{ \langle regex \rangle \}$ $\{ \langle token\ list \rangle \}$ $\{ \langle true\ code \rangle \}$ $\{ \langle false\ code \rangle \}$

Tests whether the $\langle regular\ expression \rangle$ matches any part of the $\langle token\ list \rangle$. For instance,

```
\regex_match:nnTF { b [cde]* } { abedcdx } { TRUE } { FALSE }
\regex_match:nnTF { [b-dq-w] } { example } { TRUE } { FALSE }
```

leaves TRUE then FALSE in the input stream.

```
\regex_count:nnN
\regex_count:NnN
```

New: 2017-05-26

```
\regex_count:nnN {<regex>} {<token list>} {<int var>}
```

Sets *<int var>* within the current T_EX group level equal to the number of times *<regular expression>* appears in *<token list>*. The search starts by finding the left-most longest match, respecting greedy and lazy (non-greedy) operators. Then the search starts again from the character following the last character of the previous match, until reaching the end of the token list. Infinite loops are prevented in the case where the regular expression can match an empty token list: then we count one match between each pair of characters. For instance,

```
\int_new:N \l_foo_int
\regex_count:nnN { (b+|c) } { abbababcb } \l_foo_int
```

results in `\l_foo_int` taking the value 5.

5 Submatch extraction

```
\regex_extract_once:nnN
\regex_extract_once:nnNTF
\regex_extract_once:NnN
\regex_extract_once:NnNTF
```

New: 2017-05-26

```
\regex_extract_once:nnN {<regex>} {<token list>} {<seq var>}
\regex_extract_once:nnNTF {<regex>} {<token list>} {<seq var>} {<true code>} {<false code>}
```

Finds the first match of the *<regular expression>* in the *<token list>*. If it exists, the match is stored as the first item of the *<seq var>*, and further items are the contents of capturing groups, in the order of their opening parenthesis. The *<seq var>* is assigned locally. If there is no match, the *<seq var>* is cleared. The testing versions insert the *<true code>* into the input stream if a match was found, and the *<false code>* otherwise.

For instance, assume that you type

```
\regex_extract_once:nnNTF { \A(La)?TeX(!*)\Z } { LaTeX!!! } \l_foo_seq
{ true } { false }
```

Then the regular expression (anchored at the start with `\A` and at the end with `\Z`) must match the whole token list. The first capturing group, `(La)?`, matches `La`, and the second capturing group, `(!*)`, matches `!!!`. Thus, `\l_foo_seq` contains as a result the items `{LaTeX!!!}`, `{La}`, and `{!!!}`, and the `true` branch is left in the input stream. Note that the n -th item of `\l_foo_seq`, as obtained using `\seq_item:Nn`, correspond to the submatch numbered $(n - 1)$ in functions such as `\regex_replace_once:nnN`.

```
\regex_extract_all:nnN
\regex_extract_all:nnNTF
\regex_extract_all:NnN
\regex_extract_all:NnNTF
```

New: 2017-05-26

```
\regex_extract_all:nnN {<regex>} {<token list>} {<seq var>}
\regex_extract_all:nnNTF {<regex>} {<token list>} {<seq var>} {<true code>} {<false code>}
```

Finds all matches of the *<regular expression>* in the *<token list>*, and stores all the submatch information in a single sequence (concatenating the results of multiple `\regex_extract_once:nnN` calls). The *<seq var>* is assigned locally. If there is no match, the *<seq var>* is cleared. The testing versions insert the *<true code>* into the input stream if a match was found, and the *<false code>* otherwise. For instance, assume that you type

```
\regex_extract_all:nnNTF { \w+ } { Hello,~world! } \l_foo_seq
{ true } { false }
```

Then the regular expression matches twice, the resulting sequence contains the two items `{Hello}` and `{world}`, and the `true` branch is left in the input stream.

```
\regex_split:nnN
\regex_split:nnNTF
\regex_split:NnN
\regex_split:NnNTF
```

New: 2017-05-26

```
\regex_split:nnN {<regular expression>} {<token list>} <seq var>
\regex_split:nnNTF {<regular expression>} {<token list>} <seq var> {<true code>}
{<false code>}
```

Splits the *<token list>* into a sequence of parts, delimited by matches of the *<regular expression>*. If the *<regular expression>* has capturing groups, then the token lists that they match are stored as items of the sequence as well. The assignment to *<seq var>* is local. If no match is found the resulting *<seq var>* has the *<token list>* as its sole item. If the *<regular expression>* matches the empty token list, then the *<token list>* is split into single tokens. The testing versions insert the *<true code>* into the input stream if a match was found, and the *<false code>* otherwise. For example, after

```
\seq_new:N \l_path_seq
\regex_split:nnNTF { / } { the/path/for/this/file.tex } \l_path_seq
{ true } { false }
```

the sequence `\l_path_seq` contains the items `{the}`, `{path}`, `{for}`, `{this}`, and `{file.tex}`, and the `true` branch is left in the input stream.

6 Replacement

```
\regex_replace_once:nnN
\regex_replace_once:nnNTF
\regex_replace_once:NnN
\regex_replace_once:NnNTF
```

New: 2017-05-26

```
\regex_replace_once:nnN {<regular expression>} {<replacement>} <tl var>
\regex_replace_once:nnNTF {<regular expression>} {<replacement>} <tl var> {<true
code>} {<false code>}
```

Searches for the *<regular expression>* in the *<token list>* and replaces the first match with the *<replacement>*. The result is assigned locally to *<tl var>*. In the *<replacement>*, `\0` represents the full match, `\1` represent the contents of the first capturing group, `\2` of the second, *etc.*

```
\regex_replace_all:nnN
\regex_replace_all:nnNTF
\regex_replace_all:NnN
\regex_replace_all:NnNTF
```

New: 2017-05-26

```
\regex_replace_all:nnN {<regular expression>} {<replacement>} <tl var>
\regex_replace_all:nnNTF {<regular expression>} {<replacement>} <tl var> {<true
code>} {<false code>}
```

Replaces all occurrences of the *<regular expression>* in the *<token list>* by the *<replacement>*, where `\0` represents the full match, `\1` represent the contents of the first capturing group, `\2` of the second, *etc.* Every match is treated independently, and matches cannot overlap. The result is assigned locally to *<tl var>*.

7 Constants and variables

```
\l_tmpa_regex
\l_tmpb_regex
```

New: 2017-12-11

Scratch regex for local assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

```
\g_tmpa_regex
\g_tmpb_regex
```

New: 2017-12-11

Scratch regex for global assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

8 Bugs, misfeatures, future work, and other possibilities

The following need to be done now.

- Rewrite the documentation in a more ordered way, perhaps add a BNF?

Additional error-checking to come.

- Clean up the use of messages.
- Cleaner error reporting in the replacement phase.
- Add tracing information.
- Detect attempts to use back-references and other non-implemented syntax.
- Test for the maximum register `\c_max_register_int`.
- Find out whether the fact that `\W` and friends match the end-marker leads to bugs. Possibly update `__regex_item_reverse:n`.
- The empty `cs` should be matched by `\c{}`, not by `\c{csname.?endcsname\s?}`.

Code improvements to come.

- Shift arrays so that the useful information starts at position 1.
- Only build `\c{...}` once.
- Use arrays for the left and right state stacks when compiling a regex.
- Should `__regex_action_free_group:n` only be used for greedy `{n,}` quantifier? (I think not.)
- Quantifiers for `\u` and assertions.
- When matching, keep track of an explicit stack of `current_state` and `current_submatches`.
- If possible, when a state is reused by the same thread, kill other subthreads.
- Use an array rather than `\l__regex_balance_tl` to build the function `__regex_replacement_balance_one_match:n`.
- Reduce the number of epsilon-transitions in alternatives.
- Optimize simple strings: use less states (`abcade` should give two states, for `abc` and `ade`). [Does that really make sense?]
- Optimize groups with no alternative.
- Optimize states with a single `__regex_action_free:n`.
- Optimize the use of `__regex_action_success:` by inserting it in state 2 directly instead of having an extra transition.
- Optimize the use of `\int_step_...` functions.

- Groups don't capture within regexes for csnames; optimize and document.
- Better “show” for anchors, properties, and catcode tests.
- Does \K really need a new state for itself?
- When compiling, use a boolean `in_cs` and less magic numbers.
- Instead of checking whether the character is special or alphanumeric using its character code, check if it is special in regexes with `\cs_if_exist` tests.

The following features are likely to be implemented at some point in the future.

- General look-ahead/behind assertions.
- Regex matching on external files.
- Conditional subpatterns with look ahead/behind: “if what follows is [...], then [...]”.
- `(*..)` and `(?..)` sequences to set some options.
- UTF-8 mode for pdfTeX.
- Newline conventions are not done. In particular, we should have an option for `.` not to match newlines. Also, `\A` should differ from `^`, and `\Z`, `\z` and `$` should differ.
- Unicode properties: `\p{..}` and `\P{..}`; `\X` which should match any “extended” Unicode sequence. This requires to manipulate a lot of data, probably using tree-boxes.
- Provide a syntax such as `\ur{1_my_regex}` to use an already-compiled regex in a more complicated regex. This makes regexes more easily composable.
- Allowing `\u{1_my_t1}` in more places, for instance as the number of repetitions in a quantifier.

The following features of PCRE or Perl may or may not be implemented.

- Callout with `(?C...)` or other syntax: some internal code changes make that possible, and it can be useful for instance in the replacement code to stop a regex replacement when some marker has been found; this raises the question of a potential `\regex_break`: and then of playing well with `\t1_map_break`: called from within the code in a regex. It also raises the question of nested calls to the regex machinery, which is a problem since `\fontdimen` are global.
- Conditional subpatterns (other than with a look-ahead or look-behind condition): this is non-regular, isn't it?
- Named subpatterns: TeX programmers have lived so far without any need for named macro parameters.

The following features of PCRE or Perl will definitely not be implemented.

- Back-references: non-regular feature, this requires backtracking, which is prohibitively slow.

- Recursion: this is a non-regular feature.
- Atomic grouping, possessive quantifiers: those tools, mostly meant to fix catastrophic backtracking, are unnecessary in a non-backtracking algorithm, and difficult to implement.
- Subroutine calls: this syntactic sugar is difficult to include in a non-backtracking algorithm, in particular because the corresponding group should be treated as atomic.
- Backtracking control verbs: intrinsically tied to backtracking.
- `\ddd`, matching the character with octal code `ddd`: we already have `\x{...}` and the syntax is confusingly close to what we could have used for backreferences (`\1`, `\2`, ...), making it harder to produce useful error message.
- `\cx`, similar to $\mathrm{T}_{\mathrm{E}}\mathrm{X}$'s own `\^x`.
- Comments: $\mathrm{T}_{\mathrm{E}}\mathrm{X}$ already has its own system for comments.
- `\Q...\E` escaping: this would require to read the argument verbatim, which is not in the scope of this module.
- `\C` single byte in UTF-8 mode: $\mathrm{X}_{\mathrm{Y}}\mathrm{T}_{\mathrm{E}}\mathrm{X}$ and $\mathrm{LuaT}_{\mathrm{E}}\mathrm{X}$ serve us characters directly, and splitting those into bytes is tricky, encoding dependent, and most likely not useful anyways.

Part XXVIII

The l3box package

Boxes

There are three kinds of box operations: horizontal mode denoted with prefix `\hbox_`, vertical mode with prefix `\vbox_`, and the generic operations working in both modes with prefix `\box_`.

1 Creating and initialising boxes

<code>\box_new:N</code>	<code>\box_new:N</code> $\langle box \rangle$
<code>\box_new:c</code>	Creates a new $\langle box \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle box \rangle$ is initially void.

<code>\box_clear:N</code>	<code>\box_clear:N</code> $\langle box \rangle$
<code>\box_clear:c</code>	Clears the content of the $\langle box \rangle$ by setting the box equal to <code>\c_empty_box</code> .
<code>\box_gclear:N</code>	
<code>\box_gclear:c</code>	

<code>\box_clear_new:N</code>	<code>\box_clear_new:N</code> $\langle box \rangle$
<code>\box_clear_new:c</code>	Ensures that the $\langle box \rangle$ exists globally by applying <code>\box_new:N</code> if necessary, then applies <code>\box_(g)clear:N</code> to leave the $\langle box \rangle$ empty.
<code>\box_gclear_new:N</code>	
<code>\box_gclear_new:c</code>	

<code>\box_set_eq:NN</code>	<code>\box_set_eq:NN</code> $\langle box_1 \rangle$ $\langle box_2 \rangle$
<code>\box_set_eq:(cN Nc cc)</code>	Sets the content of $\langle box_1 \rangle$ equal to that of $\langle box_2 \rangle$.
<code>\box_gset_eq:NN</code>	
<code>\box_gset_eq:(cN Nc cc)</code>	

<code>\box_if_exist_p:N</code> *	<code>\box_if_exist_p:N</code> $\langle box \rangle$
<code>\box_if_exist_p:c</code> *	<code>\box_if_exist:NTF</code> $\langle box \rangle$ $\{ \langle true\ code \rangle \}$ $\{ \langle false\ code \rangle \}$
<code>\box_if_exist:NTF</code> *	Tests whether the $\langle box \rangle$ is currently defined. This does not check that the $\langle box \rangle$ really is a box.
<code>\box_if_exist:cTF</code> *	

New: 2012-03-03

2 Using boxes

<code>\box_use:N</code>	<code>\box_use:N</code> $\langle box \rangle$
<code>\box_use:c</code>	Inserts the current content of the $\langle box \rangle$ onto the current list for typesetting. An error is raised if the variable does not exist or if it is invalid.

T_EXhackers note: This is the T_EX primitive `\copy`.

<hr/> <code>\box_move_right:nn</code> <hr/>	<code>\box_move_right:nn {<dimexpr>} {<box function>}</code>
<code>\box_move_left:nn</code> <hr/>	This function operates in vertical mode, and inserts the material specified by the <i><box function></i> such that its reference point is displaced horizontally by the given <i><dimexpr></i> from the reference point for typesetting, to the right or left as appropriate. The <i><box function></i> should be a box operation such as <code>\box_use:N \<box></code> or a “raw” box specification such as <code>\vbox:n { xyz }</code> .

<hr/> <code>\box_move_up:nn</code> <hr/>	<code>\box_move_up:nn {<dimexpr>} {<box function>}</code>
<code>\box_move_down:nn</code> <hr/>	This function operates in horizontal mode, and inserts the material specified by the <i><box function></i> such that its reference point is displaced vertically by the given <i><dimexpr></i> from the reference point for typesetting, up or down as appropriate. The <i><box function></i> should be a box operation such as <code>\box_use:N \<box></code> or a “raw” box specification such as <code>\vbox:n { xyz }</code> .

3 Measuring and setting box dimensions

<hr/> <code>\box_dp:N</code> <hr/>	<code>\box_dp:N <box></code>
<code>\box_dp:c</code> <hr/>	Calculates the depth (below the baseline) of the <i><box></i> in a form suitable for use in a <i><dimension expression></i> .

TeXhackers note: This is the TeX primitive `\dp`.

<hr/> <code>\box_ht:N</code> <hr/>	<code>\box_ht:N <box></code>
<code>\box_ht:c</code> <hr/>	Calculates the height (above the baseline) of the <i><box></i> in a form suitable for use in a <i><dimension expression></i> .

TeXhackers note: This is the TeX primitive `\ht`.

<hr/> <code>\box_wd:N</code> <hr/>	<code>\box_wd:N <box></code>
<code>\box_wd:c</code> <hr/>	Calculates the width of the <i><box></i> in a form suitable for use in a <i><dimension expression></i> .

TeXhackers note: This is the TeX primitive `\wd`.

<hr/> <code>\box_set_dp:Nn</code> <hr/>	<code>\box_set_dp:Nn <box> {<dimension expression>}</code>
<code>\box_set_dp:cn</code> <hr/>	Set the depth (below the baseline) of the <i><box></i> to the value of the <i>{<dimension expression>}</i> .
<code>\box_gset_dp:Nn</code> <hr/>	
<code>\box_gset_dp:cn</code> <hr/>	

Updated: 2019-01-22

<hr/> <code>\box_set_ht:Nn</code> <hr/>	<code>\box_set_ht:Nn <box> {<dimension expression>}</code>
<code>\box_set_ht:cn</code> <hr/>	Set the height (above the baseline) of the <i><box></i> to the value of the <i>{<dimension expression>}</i> .
<code>\box_gset_ht:Nn</code> <hr/>	
<code>\box_gset_ht:cn</code> <hr/>	

Updated: 2019-01-22

<code>\box_set_wd:Nn</code>	<code>\box_set_wd:Nn <box> {<dimension expression>}</code>
<code>\box_set_wd:cn</code>	Set the width of the <code><box></code> to the value of the <code>{<dimension expression>}</code> .
<code>\box_gset_wd:Nn</code>	
<code>\box_gset_wd:cn</code>	

Updated: 2019-01-22

4 Box conditionals

<code>\box_if_empty_p:N</code> *	<code>\box_if_empty_p:N <box></code>
<code>\box_if_empty_p:c</code> *	<code>\box_if_empty:NTF <box> {<true code>} {<false code>}</code>
<code>\box_if_empty:NTF</code> *	Tests if <code><box></code> is a empty (equal to <code>\c_empty_box</code>).
<code>\box_if_empty:cTF</code> *	

<code>\box_if_horizontal_p:N</code> *	<code>\box_if_horizontal_p:N <box></code>
<code>\box_if_horizontal_p:c</code> *	<code>\box_if_horizontal:NTF <box> {<true code>} {<false code>}</code>
<code>\box_if_horizontal:NTF</code> *	Tests if <code><box></code> is a horizontal box.
<code>\box_if_horizontal:cTF</code> *	

<code>\box_if_vertical_p:N</code> *	<code>\box_if_vertical_p:N <box></code>
<code>\box_if_vertical_p:c</code> *	<code>\box_if_vertical:NTF <box> {<true code>} {<false code>}</code>
<code>\box_if_vertical:NTF</code> *	Tests if <code><box></code> is a vertical box.
<code>\box_if_vertical:cTF</code> *	

5 The last box inserted

<code>\box_set_to_last:N</code>	<code>\box_set_to_last:N <box></code>
<code>\box_set_to_last:c</code>	Sets the <code><box></code> equal to the last item (box) added to the current partial list, removing the item from the list at the same time. When applied to the main vertical list, the <code><box></code> is always void as it is not possible to recover the last added item.
<code>\box_gset_to_last:N</code>	
<code>\box_gset_to_last:c</code>	

6 Constant boxes

<code>\c_empty_box</code>	This is a permanently empty box, which is neither set as horizontal nor vertical.
---------------------------	---

Updated: 2012-11-04

TeXhackers note: At the TeX level this is a void box.

7 Scratch boxes

`\l_tmpa_box`
`\l_tmpb_box`

Updated: 2012-11-04

Scratch boxes for local assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

`\g_tmpa_box`
`\g_tmpb_box`

Scratch boxes for global assignment. These are never used by the kernel code, and so are safe for use with any L^AT_EX3-defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

8 Viewing box contents

`\box_show:N`
`\box_show:c`

Updated: 2012-05-11

`\box_show:N` $\langle box \rangle$

Shows full details of the content of the $\langle box \rangle$ in the terminal.

`\box_show:Nnn`
`\box_show:cnn`

New: 2012-05-11

`\box_show:Nnn` $\langle box \rangle$ $\{\langle intexpr_1 \rangle\}$ $\{\langle intexpr_2 \rangle\}$

Display the contents of $\langle box \rangle$ in the terminal, showing the first $\langle intexpr_1 \rangle$ items of the box, and descending into $\langle intexpr_2 \rangle$ group levels.

`\box_log:N`
`\box_log:c`

New: 2012-05-11

`\box_log:N` $\langle box \rangle$

Writes full details of the content of the $\langle box \rangle$ to the log.

`\box_log:Nnn`
`\box_log:cnn`

New: 2012-05-11

`\box_log:Nnn` $\langle box \rangle$ $\{\langle intexpr_1 \rangle\}$ $\{\langle intexpr_2 \rangle\}$

Writes the contents of $\langle box \rangle$ to the log, showing the first $\langle intexpr_1 \rangle$ items of the box, and descending into $\langle intexpr_2 \rangle$ group levels.

9 Boxes and color

All L^AT_EX3 boxes are “color safe”: a color set inside the box stops applying after the end of the box has occurred.

10 Horizontal mode boxes

`\hbox:n`

Updated: 2017-04-05

`\hbox:n` $\{\langle contents \rangle\}$

Typesets the $\langle contents \rangle$ into a horizontal box of natural width and then includes this box in the current list for typesetting.

<hr/> <code>\hbox_to_wd:nn</code> <hr/>	<code>\hbox_to_wd:nn {<dimexpr>} {<contents>}</code>
Updated: 2017-04-05 <hr/>	Typesets the $\langle contents \rangle$ into a horizontal box of width $\langle dimexpr \rangle$ and then includes this box in the current list for typesetting.
<hr/> <code>\hbox_to_zero:n</code> <hr/>	<code>\hbox_to_zero:n {<contents>}</code>
Updated: 2017-04-05 <hr/>	Typesets the $\langle contents \rangle$ into a horizontal box of zero width and then includes this box in the current list for typesetting.
<hr/> <code>\hbox_set:Nn</code> <code>\hbox_set:cn</code> <code>\hbox_gset:Nn</code> <code>\hbox_gset:cn</code> <hr/>	<code>\hbox_set:Nn <box> {<contents>}</code> Typesets the $\langle contents \rangle$ at natural width and then stores the result inside the $\langle box \rangle$.
Updated: 2017-04-05 <hr/>	
<hr/> <code>\hbox_set_to_wd:Nnn</code> <code>\hbox_set_to_wd:cnn</code> <code>\hbox_gset_to_wd:Nnn</code> <code>\hbox_gset_to_wd:cnn</code> <hr/>	<code>\hbox_set_to_wd:Nnn <box> {<dimexpr>} {<contents>}</code> Typesets the $\langle contents \rangle$ to the width given by the $\langle dimexpr \rangle$ and then stores the result inside the $\langle box \rangle$.
Updated: 2017-04-05 <hr/>	
<hr/> <code>\hbox_overlap_right:n</code> <hr/>	<code>\hbox_overlap_right:n {<contents>}</code>
Updated: 2017-04-05 <hr/>	Typesets the $\langle contents \rangle$ into a horizontal box of zero width such that material protrudes to the right of the insertion point.
<hr/> <code>\hbox_overlap_left:n</code> <hr/>	<code>\hbox_overlap_left:n {<contents>}</code>
Updated: 2017-04-05 <hr/>	Typesets the $\langle contents \rangle$ into a horizontal box of zero width such that material protrudes to the left of the insertion point.
<hr/> <code>\hbox_set:Nw</code> <code>\hbox_set:cw</code> <code>\hbox_set_end:</code> <code>\hbox_gset:Nw</code> <code>\hbox_gset:cw</code> <code>\hbox_gset_end:</code> <hr/>	<code>\hbox_set:Nw <box> <contents> \hbox_set_end:</code> Typesets the $\langle contents \rangle$ at natural width and then stores the result inside the $\langle box \rangle$. In contrast to <code>\hbox_set:Nn</code> this function does not absorb the argument when finding the $\langle content \rangle$, and so can be used in circumstances where the $\langle content \rangle$ may not be a simple argument.
Updated: 2017-04-05 <hr/>	
<hr/> <code>\hbox_set_to_wd:Nnw</code> <code>\hbox_set_to_wd:cnw</code> <code>\hbox_gset_to_wd:Nnw</code> <code>\hbox_gset_to_wd:cnw</code> <hr/>	<code>\hbox_set_to_wd:Nnw <box> {<dimexpr>} <contents> \hbox_set_end:</code> Typesets the $\langle contents \rangle$ to the width given by the $\langle dimexpr \rangle$ and then stores the result inside the $\langle box \rangle$. In contrast to <code>\hbox_set_to_wd:Nnn</code> this function does not absorb the argument when finding the $\langle content \rangle$, and so can be used in circumstances where the $\langle content \rangle$ may not be a simple argument
New: 2017-06-08 <hr/>	
<hr/> <code>\hbox_unpack:N</code> <code>\hbox_unpack:c</code> <hr/>	<code>\hbox_unpack:N <box></code> Unpacks the content of the horizontal $\langle box \rangle$, retaining any stretching or shrinking applied when the $\langle box \rangle$ was set.

T_EXhackers note: This is the T_EX primitive `\unhcopy`.

11 Vertical mode boxes

Vertical boxes inherit their baseline from their contents. The standard case is that the baseline of the box is at the same position as that of the last item added to the box. This means that the box has no depth unless the last item added to it had depth. As a result most vertical boxes have a large height value and small or zero depth. The exception are `_top` boxes, where the reference point is that of the first item added. These tend to have a large depth and small height, although the latter is typically non-zero.

<hr/> <code>\vbox:n</code> <hr/>	<code>\vbox:n {⟨contents⟩}</code>
<hr/> Updated: 2017-04-05 <hr/>	Typesets the <code>⟨contents⟩</code> into a vertical box of natural height and includes this box in the current list for typesetting.
<hr/> <code>\vbox_top:n</code> <hr/>	<code>\vbox_top:n {⟨contents⟩}</code>
<hr/> Updated: 2017-04-05 <hr/>	Typesets the <code>⟨contents⟩</code> into a vertical box of natural height and includes this box in the current list for typesetting. The baseline of the box is equal to that of the <i>first</i> item added to the box.
<hr/> <code>\vbox_to_ht:nn</code> <hr/>	<code>\vbox_to_ht:nn {⟨dimexpr⟩} {⟨contents⟩}</code>
<hr/> Updated: 2017-04-05 <hr/>	Typesets the <code>⟨contents⟩</code> into a vertical box of height <code>⟨dimexpr⟩</code> and then includes this box in the current list for typesetting.
<hr/> <code>\vbox_to_zero:n</code> <hr/>	<code>\vbox_to_zero:n {⟨contents⟩}</code>
<hr/> Updated: 2017-04-05 <hr/>	Typesets the <code>⟨contents⟩</code> into a vertical box of zero height and then includes this box in the current list for typesetting.
<hr/> <code>\vbox_set:Nn</code> <code>\vbox_set:cn</code> <code>\vbox_gset:Nn</code> <code>\vbox_gset:cn</code> <hr/>	<code>\vbox_set:Nn ⟨box⟩ {⟨contents⟩}</code> Typesets the <code>⟨contents⟩</code> at natural height and then stores the result inside the <code>⟨box⟩</code> .
<hr/> Updated: 2017-04-05 <hr/>	
<hr/> <code>\vbox_set_top:Nn</code> <code>\vbox_set_top:cn</code> <code>\vbox_gset_top:Nn</code> <code>\vbox_gset_top:cn</code> <hr/>	<code>\vbox_set_top:Nn ⟨box⟩ {⟨contents⟩}</code> Typesets the <code>⟨contents⟩</code> at natural height and then stores the result inside the <code>⟨box⟩</code> . The baseline of the box is equal to that of the <i>first</i> item added to the box.
<hr/> Updated: 2017-04-05 <hr/>	
<hr/> <code>\vbox_set_to_ht:Nnn</code> <code>\vbox_set_to_ht:cnn</code> <code>\vbox_gset_to_ht:Nnn</code> <code>\vbox_gset_to_ht:cnn</code> <hr/>	<code>\vbox_set_to_ht:Nnn ⟨box⟩ {⟨dimexpr⟩} {⟨contents⟩}</code> Typesets the <code>⟨contents⟩</code> to the height given by the <code>⟨dimexpr⟩</code> and then stores the result inside the <code>⟨box⟩</code> .
<hr/> Updated: 2017-04-05 <hr/>	

```

\ vbox_set:Nw
\ vbox_set:cw
\ vbox_set:end:
\ vbox_gset:Nw
\ vbox_gset:cw
\ vbox_gset:end:

```

Updated: 2017-04-05

```

\ vbox_set_to_ht:Nnw
\ vbox_set_to_ht:cnw
\ vbox_gset_to_ht:Nnw
\ vbox_gset_to_ht:cnw

```

New: 2017-06-08

`\vbox_set:Nw` $\langle box \rangle$ $\langle contents \rangle$ `\vbox_set:end:`

Typesets the $\langle contents \rangle$ at natural height and then stores the result inside the $\langle box \rangle$. In contrast to `\vbox_set:Nn` this function does not absorb the argument when finding the $\langle content \rangle$, and so can be used in circumstances where the $\langle content \rangle$ may not be a simple argument.

`\vbox_set_to_ht:Nnw` $\langle box \rangle$ $\{\langle dimexpr \rangle\}$ $\langle contents \rangle$ `\vbox_set:end:`

Typesets the $\langle contents \rangle$ to the height given by the $\langle dimexpr \rangle$ and then stores the result inside the $\langle box \rangle$. In contrast to `\vbox_set_to_ht:Nnn` this function does not absorb the argument when finding the $\langle content \rangle$, and so can be used in circumstances where the $\langle content \rangle$ may not be a simple argument

```

\ vbox_set_split_to_ht:NNn
\ vbox_set_split_to_ht:(cNn|Ncn|ccn)
\ vbox_gset_split_to_ht:NNn
\ vbox_gset_split_to_ht:(cNn|Ncn|ccn)

```

Updated: 2018-12-29

`\vbox_set_split_to_ht:NNn` $\langle box_1 \rangle$ $\langle box_2 \rangle$ $\{\langle dimexpr \rangle\}$

Sets $\langle box_1 \rangle$ to contain material to the height given by the $\langle dimexpr \rangle$ by removing content from the top of $\langle box_2 \rangle$ (which must be a vertical box).

```

\ vbox_unpack:N
\ vbox_unpack:c

```

`\vbox_unpack:N` $\langle box \rangle$

Unpacks the content of the vertical $\langle box \rangle$, retaining any stretching or shrinking applied when the $\langle box \rangle$ was set.

T_EXhackers note: This is the T_EX primitive `\unvcopy`.

12 Using boxes efficiently

The functions above for using box contents work in exactly the same way as for any other `expl3` variable. However, for efficiency reasons, it is also useful to have functions which *drop* box contents on use. When a box is dropped, the box becomes empty at the group level *where the box was originally set* rather than necessarily *at the current group level*. For example, with

```

\ hbox_set:Nn \l_tmpa_box { A }
\ group_begin:
  \ hbox_set:Nn \l_tmpa_box { B }
  \ group_begin:
    \ box_use_drop:N \l_tmpa_box
  \ group_end:
  \ box_show:N \l_tmpa_box
\ group_end:
\ box_show:N \l_tmpa_box

```

the first use of `\box_show:N` will show an entirely cleared (void) box, and the second will show the letter **A** in the box.

These functions should be preferred when the content of the box is no longer required after use. Note that due to the unusual scoping behaviour of `drop` functions they may be applied to both local and global boxes: the latter will naturally be set and thus cleared at a global level.

`\box_use_drop:N`
`\box_use_drop:c`

`\box_use_drop:N` $\langle box \rangle$

Inserts the current content of the $\langle box \rangle$ onto the current list for typesetting then drops the box content. An error is raised if the variable does not exist or if it is invalid. This function may be applied to local or global boxes.

T_EXhackers note: This is the `\box` primitive.

`\box_set_eq_drop:NN`
`\box_set_eq_drop:(cN|Nc|cc)`

New: 2019-01-17

`\box_set_eq_drop:NN` $\langle box_1 \rangle$ $\langle box_2 \rangle$

Sets the content of $\langle box_1 \rangle$ equal to that of $\langle box_2 \rangle$, then drops $\langle box_2 \rangle$.

`\box_gset_eq_drop:NN`
`\box_gset_eq_drop:(cN|Nc|cc)`

New: 2019-01-17

`\box_gset_eq_drop:NN` $\langle box_1 \rangle$ $\langle box_2 \rangle$

Sets the content of $\langle box_1 \rangle$ globally equal to that of $\langle box_2 \rangle$, then drops $\langle box_2 \rangle$.

`\hbox_unpack_drop:N`
`\hbox_unpack_drop:c`

New: 2019-01-17

`\hbox_unpack_drop:N` $\langle box \rangle$

Unpacks the content of the horizontal $\langle box \rangle$, retaining any stretching or shrinking applied when the $\langle box \rangle$ was set. The original $\langle box \rangle$ is then dropped.

T_EXhackers note: This is the T_EX primitive `\unhbox`.

`\vbox_unpack_drop:N`
`\vbox_unpack_drop:c`

New: 2019-01-17

`\vbox_unpack_drop:N` $\langle box \rangle$

Unpacks the content of the vertical $\langle box \rangle$, retaining any stretching or shrinking applied when the $\langle box \rangle$ was set. The original $\langle box \rangle$ is then dropped.

T_EXhackers note: This is the T_EX primitive `\unvbox`.

13 Affine transformations

Affine transformations are changes which (informally) preserve straight lines. Simple translations are affine transformations, but are better handled in T_EX by doing the translation first, then inserting an unmodified box. On the other hand, rotation and resizing of boxed material can best be handled by modifying boxes. These transformations are described here.

<code>\box_autosize_to_wd_and_ht:Nnn</code>	<code>\box_autosize_to_wd_and_ht:Nnn <box> {<x-size>} {<y-size>}</code>
<code>\box_autosize_to_wd_and_ht:cnn</code>	
<code>\box_gautosize_to_wd_and_ht:Nnn</code>	
<code>\box_gautosize_to_wd_and_ht:cnn</code>	

New: 2017-04-04

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to fit within the given $\langle x-size \rangle$ (horizontally) and $\langle y-size \rangle$ (vertically); both of the sizes are dimension expressions. The $\langle y-size \rangle$ is the height only: it does not include any depth. The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. The final size of the $\langle box \rangle$ is the smaller of $\{ \langle x-size \rangle \}$ and $\{ \langle y-size \rangle \}$, *i.e.* the result fits within the dimensions specified. Negative sizes cause the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_autosize_to_wd_and_ht_plus_dp:Nnn</code>	<code>\box_autosize_to_wd_and_ht_plus_dp:Nnn <box> {<x-size>}</code>
<code>\box_autosize_to_wd_and_ht_plus_dp:cnn</code>	<code>{<y-size>}</code>
<code>\box_gautosize_to_wd_and_ht_plus_dp:Nnn</code>	
<code>\box_gautosize_to_wd_and_ht_plus_dp:cnn</code>	

New: 2017-04-04

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to fit within the given $\langle x-size \rangle$ (horizontally) and $\langle y-size \rangle$ (vertically); both of the sizes are dimension expressions. The $\langle y-size \rangle$ is the total vertical size (height plus depth). The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. The final size of the $\langle box \rangle$ is the smaller of $\{ \langle x-size \rangle \}$ and $\{ \langle y-size \rangle \}$, *i.e.* the result fits within the dimensions specified. Negative sizes cause the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_resize_to_ht:Nn</code>	<code>\box_resize_to_ht:Nn <box> {<y-size>}</code>
<code>\box_resize_to_ht:cn</code>	
<code>\box_gresize_to_ht:Nn</code>	
<code>\box_gresize_to_ht:cn</code>	

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to $\langle y-size \rangle$ (vertically), scaling the horizontal size by the same amount; $\langle y-size \rangle$ is a dimension expression. The $\langle y-size \rangle$ is the height only: it does not include any depth. The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. A negative $\langle y-size \rangle$ causes the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_resize_to_ht_plus_dp:Nn</code>	<code>\box_resize_to_ht_plus_dp:Nn <box> {<y-size>}</code>
<code>\box_resize_to_ht_plus_dp:cn</code>	
<code>\box_gresize_to_ht_plus_dp:Nn</code>	
<code>\box_gresize_to_ht_plus_dp:cn</code>	

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to $\langle y-size \rangle$ (vertically), scaling the horizontal size by the same amount; $\langle y-size \rangle$ is a dimension expression. The $\langle y-size \rangle$ is the total vertical size (height plus depth). The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. A negative $\langle y-size \rangle$ causes the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_resize_to_wd:Nn</code>	<code>\box_resize_to_wd:Nn <box> {<x-size>}</code>
<code>\box_resize_to_wd:cn</code>	
<code>\box_gresize_to_wd:Nn</code>	
<code>\box_gresize_to_wd:cn</code>	

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to $\langle x-size \rangle$ (horizontally), scaling the vertical size by the same amount; $\langle x-size \rangle$ is a dimension expression. The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. A negative $\langle x-size \rangle$ causes the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle x-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_resize_to_wd_and_ht:Nnn</code>	<code>\box_resize_to_wd_and_ht:Nnn <box> {<x-size>} {<y-size>}</code>
<code>\box_resize_to_wd_and_ht:cnn</code>	
<code>\box_gresize_to_wd_and_ht:Nnn</code>	
<code>\box_gresize_to_wd_and_ht:cnn</code>	

New: 2014-07-03

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to $\langle x-size \rangle$ (horizontally) and $\langle y-size \rangle$ (vertically): both of the sizes are dimension expressions. The $\langle y-size \rangle$ is the height only and does not include any depth. The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. Negative sizes cause the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_resize_to_wd_and_ht_plus_dp:Nnn</code>	<code>\box_resize_to_wd_and_ht_plus_dp:Nnn <box> {<x-size>} {<y-size>}</code>
<code>\box_resize_to_wd_and_ht_plus_dp:cnn</code>	
<code>\box_gresize_to_wd_and_ht_plus_dp:Nnn</code>	
<code>\box_gresize_to_wd_and_ht_plus_dp:cnn</code>	

New: 2017-04-06

Updated: 2019-01-22

Resizes the $\langle box \rangle$ to $\langle x-size \rangle$ (horizontally) and $\langle y-size \rangle$ (vertically): both of the sizes are dimension expressions. The $\langle y-size \rangle$ is the total vertical size (height plus depth). The updated $\langle box \rangle$ is an `hbox`, irrespective of the nature of the $\langle box \rangle$ before the resizing is applied. Negative sizes cause the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-size \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and *vice versa*.

<code>\box_rotate:Nn</code> <code>\box_rotate:cn</code> <code>\box_grotate:Nn</code> <code>\box_grotate:cn</code>	<code>\box_rotate:Nn <box> {<angle>}</code> Rotates the $\langle box \rangle$ by $\langle angle \rangle$ (in degrees) anti-clockwise about its reference point. The reference point of the updated box is moved horizontally such that it is at the left side of the smallest rectangle enclosing the rotated material. The updated $\langle box \rangle$ is an <code>hbox</code> , irrespective of the nature of the $\langle box \rangle$ before the rotation is applied.
--	--

Updated: 2019-01-22

<code>\box_scale:Nnn</code> <code>\box_scale:cnn</code> <code>\box_gscale:Nnn</code> <code>\box_gscale:cnn</code>	<code>\box_scale:Nnn <box> {<x-scale>} {<y-scale>}</code> Scales the $\langle box \rangle$ by factors $\langle x-scale \rangle$ and $\langle y-scale \rangle$ in the horizontal and vertical directions, respectively (both scales are integer expressions). The updated $\langle box \rangle$ is an <code>hbox</code> , irrespective of the nature of the $\langle box \rangle$ before the scaling is applied. Negative scalings cause the material in the $\langle box \rangle$ to be reversed in direction, but the reference point of the $\langle box \rangle$ is unchanged. Thus a negative $\langle y-scale \rangle$ results in the $\langle box \rangle$ having a depth dependent on the height of the original and <i>vice versa</i> .
--	--

Updated: 2019-01-22

14 Primitive box conditionals

<code>\if_hbox:N *</code>	<code>\if_hbox:N <box></code> <code> <true code></code> <code>\else:</code> <code> <false code></code> <code>\fi:</code> Tests is $\langle box \rangle$ is a horizontal box.
---------------------------	---

T_EXhackers note: This is the T_EX primitive `\ifhbox`.

<code>\if_vbox:N *</code>	<code>\if_vbox:N <box></code> <code> <true code></code> <code>\else:</code> <code> <false code></code> <code>\fi:</code> Tests is $\langle box \rangle$ is a vertical box.
---------------------------	---

T_EXhackers note: This is the T_EX primitive `\ifvbox`.

<code>\if_box_empty:N *</code>	<code>\if_box_empty:N <box></code> <code> <true code></code> <code>\else:</code> <code> <false code></code> <code>\fi:</code> Tests is $\langle box \rangle$ is an empty (void) box.
--------------------------------	---

T_EXhackers note: This is the T_EX primitive `\ifvoid`.

Part XXIX

The l3coffins package

Coffin code layer

The material in this module provides the low-level support system for coffins. For details about the design concept of a coffin, see the xcoffins module (in the l3experimental bundle).

1 Creating and initialising coffins

<code>\coffin_new:N</code>
<code>\coffin_new:c</code>
<code>New: 2011-08-17</code>

`\coffin_new:N` $\langle coffin \rangle$

Creates a new $\langle coffin \rangle$ or raises an error if the name is already taken. The declaration is global. The $\langle coffin \rangle$ is initially empty.

<code>\coffin_clear:N</code>
<code>\coffin_clear:c</code>
<code>\coffin_gclear:N</code>
<code>\coffin_gclear:c</code>
<code>New: 2011-08-17</code>
<code>Updated: 2019-01-21</code>

`\coffin_clear:N` $\langle coffin \rangle$

Clears the content of the $\langle coffin \rangle$.

<code>\coffin_set_eq:NN</code>
<code>\coffin_set_eq:(Nc cN cc)</code>
<code>\coffin_gset_eq:NN</code>
<code>\coffin_gset_eq:(Nc cN cc)</code>
<code>New: 2011-08-17</code>
<code>Updated: 2019-01-21</code>

`\coffin_set_eq:NN` $\langle coffin_1 \rangle$ $\langle coffin_2 \rangle$

Sets both the content and poles of $\langle coffin_1 \rangle$ equal to those of $\langle coffin_2 \rangle$.

<code>\coffin_if_exist_p:N *</code>
<code>\coffin_if_exist_p:c *</code>
<code>\coffin_if_exist:N\overline{TF} *</code>
<code>\coffin_if_exist:c\overline{TF} *</code>
<code>New: 2012-06-20</code>

`\coffin_if_exist_p:N` $\langle box \rangle$

`\coffin_if_exist:NTF` $\langle box \rangle$ $\{\langle true\ code \rangle\}$ $\{\langle false\ code \rangle\}$

Tests whether the $\langle coffin \rangle$ is currently defined.

2 Setting coffin content and poles

<code>\hcoffin_set:Nn</code>
<code>\hcoffin_set:cn</code>
<code>\hcoffin_gset:Nn</code>
<code>\hcoffin_gset:cn</code>
<code>New: 2011-08-17</code>
<code>Updated: 2019-01-21</code>

`\hcoffin_set:Nn` $\langle coffin \rangle$ $\{\langle material \rangle\}$

Typesets the $\langle material \rangle$ in horizontal mode, storing the result in the $\langle coffin \rangle$. The standard poles for the $\langle coffin \rangle$ are then set up based on the size of the typeset material.

```

\hcoffin_set:Nw
\hcoffin_set:cw
\hcoffin_set_end:
\hcoffin_gset:Nw
\hcoffin_gset:cw
\hcoffin_gset_end:

```

New: 2011-09-10
Updated: 2019-01-21

```

\vcoffin_set:Nnn
\vcoffin_set:cnn
\vcoffin_gset:Nnn
\vcoffin_gset:cnn

```

New: 2011-08-17
Updated: 2019-01-21

```

\vcoffin_set:Nnw
\vcoffin_set:cnw
\vcoffin_set_end:
\vcoffin_gset:Nnw
\vcoffin_gset:cnw
\vcoffin_gset_end:

```

New: 2011-09-10
Updated: 2019-01-21

`\hcoffin_set:Nw <coffin> <material> \hcoffin_set_end:`

Typesets the $\langle material \rangle$ in horizontal mode, storing the result in the $\langle coffin \rangle$. The standard poles for the $\langle coffin \rangle$ are then set up based on the size of the typeset material. These functions are useful for setting the entire contents of an environment in a coffin.

`\vcoffin_set:Nnn <coffin> {\<width>} {\<material>}`

Typesets the $\langle material \rangle$ in vertical mode constrained to the given $\langle width \rangle$ and stores the result in the $\langle coffin \rangle$. The standard poles for the $\langle coffin \rangle$ are then set up based on the size of the typeset material.

`\vcoffin_set:Nnw <coffin> {\<width>} <material> \vcoffin_set_end:`

Typesets the $\langle material \rangle$ in vertical mode constrained to the given $\langle width \rangle$ and stores the result in the $\langle coffin \rangle$. The standard poles for the $\langle coffin \rangle$ are then set up based on the size of the typeset material. These functions are useful for setting the entire contents of an environment in a coffin.

```

\coffin_set_horizontal_pole:Nnn
\coffin_set_horizontal_pole:cnn
\coffin_gset_horizontal_pole:Nnn
\coffin_gset_horizontal_pole:cnn

```

New: 2012-07-20
Updated: 2019-01-21

`\coffin_set_horizontal_pole:Nnn <coffin> {\<pole>} {\<offset>}`

Sets the $\langle pole \rangle$ to run horizontally through the $\langle coffin \rangle$. The $\langle pole \rangle$ is placed at the $\langle offset \rangle$ from the bottom edge of the bounding box of the $\langle coffin \rangle$. The $\langle offset \rangle$ should be given as a dimension expression.

```

\coffin_set_vertical_pole:Nnn
\coffin_set_vertical_pole:cnn
\coffin_gset_vertical_pole:Nnn
\coffin_gset_vertical_pole:cnn

```

New: 2012-07-20
Updated: 2019-01-21

`\coffin_set_vertical_pole:Nnn <coffin> {\<pole>} {\<offset>}`

Sets the $\langle pole \rangle$ to run vertically through the $\langle coffin \rangle$. The $\langle pole \rangle$ is placed at the $\langle offset \rangle$ from the left-hand edge of the bounding box of the $\langle coffin \rangle$. The $\langle offset \rangle$ should be given as a dimension expression.

3 Coffin affine transformations

<code>\coffin_resize:Nnn</code>	<code>\coffin_resize:Nnn <coffin> {\width} {\total-height}</code>
<code>\coffin_resize:cnn</code>	
<code>\coffin_gresize:Nnn</code>	Resized the $\langle coffin \rangle$ to $\langle width \rangle$ and $\langle total-height \rangle$, both of which should be given as dimension expressions.
<code>\coffin_gresize:cnn</code>	
Updated: 2019-01-23	
<code>\coffin_rotate:Nn</code>	<code>\coffin_rotate:Nn <coffin> {\angle}</code>
<code>\coffin_rotate:cn</code>	
<code>\coffin_grotate:Nn</code>	Rotates the $\langle coffin \rangle$ by the given $\langle angle \rangle$ (given in degrees counter-clockwise). This process rotates both the coffin content and poles. Multiple rotations do not result in the bounding box of the coffin growing unnecessarily.
<code>\coffin_grotate:cn</code>	
<code>\coffin_scale:Nnn</code>	<code>\coffin_scale:Nnn <coffin> {\x-scale} {\y-scale}</code>
<code>\coffin_scale:cnn</code>	
<code>\coffin_gscale:Nnn</code>	Scales the $\langle coffin \rangle$ by a factors $\langle x-scale \rangle$ and $\langle y-scale \rangle$ in the horizontal and vertical directions, respectively. The two scale factors should be given as real numbers.
<code>\coffin_gscale:cnn</code>	
Updated: 2019-01-23	

4 Joining and using coffins

<code>\coffin_attach:NnnNnnnn</code>	<code>\coffin_attach:NnnNnnnn</code>
<code>\coffin_attach:(cnnNnnnn Nnnncnnnn cnnncnnnn)</code>	$\langle coffin_1 \rangle$ $\{\langle coffin_1-pole_1 \rangle\}$ $\{\langle coffin_1-pole_2 \rangle\}$
<code>\coffin_gattach:NnnNnnnn</code>	$\langle coffin_2 \rangle$ $\{\langle coffin_2-pole_1 \rangle\}$ $\{\langle coffin_2-pole_2 \rangle\}$
<code>\coffin_gattach:(cnnNnnnn Nnnncnnnn cnnncnnnn)</code>	$\{\langle x-offset \rangle\}$ $\{\langle y-offset \rangle\}$
Updated: 2019-01-22	
<p>This function attaches $\langle coffin_2 \rangle$ to $\langle coffin_1 \rangle$ such that the bounding box of $\langle coffin_1 \rangle$ is not altered, <i>i.e.</i> $\langle coffin_2 \rangle$ can protrude outside of the bounding box of the coffin. The alignment is carried out by first calculating $\langle handle_1 \rangle$, the point of intersection of $\langle coffin_1-pole_1 \rangle$ and $\langle coffin_1-pole_2 \rangle$, and $\langle handle_2 \rangle$, the point of intersection of $\langle coffin_2-pole_1 \rangle$ and $\langle coffin_2-pole_2 \rangle$. $\langle coffin_2 \rangle$ is then attached to $\langle coffin_1 \rangle$ such that the relationship between $\langle handle_1 \rangle$ and $\langle handle_2 \rangle$ is described by the $\langle x-offset \rangle$ and $\langle y-offset \rangle$. The two offsets should be given as dimension expressions.</p>	

<code>\coffin_join:NnnNnnnn</code>	<code>\coffin_join:NnnNnnnn</code>
<code>\coffin_join:(cnnNnnnn Nnnncnnnn cnnncnnnn)</code>	$\langle coffin_1 \rangle$ $\{\langle coffin_1-pole_1 \rangle\}$ $\{\langle coffin_1-pole_2 \rangle\}$
<code>\coffin_gjoin:NnnNnnnn</code>	$\langle coffin_2 \rangle$ $\{\langle coffin_2-pole_1 \rangle\}$ $\{\langle coffin_2-pole_2 \rangle\}$
<code>\coffin_gjoin:(cnnNnnnn Nnnncnnnn cnnncnnnn)</code>	$\{\langle x-offset \rangle\}$ $\{\langle y-offset \rangle\}$
Updated: 2019-01-22	

This function joins $\langle coffin_2 \rangle$ to $\langle coffin_1 \rangle$ such that the bounding box of $\langle coffin_1 \rangle$ may expand. The new bounding box covers the area containing the bounding boxes of the two original coffins. The alignment is carried out by first calculating $\langle handle_1 \rangle$, the point of intersection of $\langle coffin_1-pole_1 \rangle$ and $\langle coffin_1-pole_2 \rangle$, and $\langle handle_2 \rangle$, the point of intersection of $\langle coffin_2-pole_1 \rangle$ and $\langle coffin_2-pole_2 \rangle$. $\langle coffin_2 \rangle$ is then attached to $\langle coffin_1 \rangle$ such that the relationship between $\langle handle_1 \rangle$ and $\langle handle_2 \rangle$ is described by the $\langle x-offset \rangle$ and $\langle y-offset \rangle$. The two offsets should be given as dimension expressions.

```
\coffin_typeset:Nnnnn
\coffin_typeset:cnnnn
```

Updated: 2012-07-20

```
\coffin_typeset:Nnnnn <coffin> {\pole_1} {\pole_2}
{\<x-offset>} {\<y-offset>}
```

Typesetting is carried out by first calculating $\langle handle \rangle$, the point of intersection of $\langle pole_1 \rangle$ and $\langle pole_2 \rangle$. The coffin is then typeset in horizontal mode such that the relationship between the current reference point in the document and the $\langle handle \rangle$ is described by the $\langle x-offset \rangle$ and $\langle y-offset \rangle$. The two offsets should be given as dimension expressions. Typesetting a coffin is therefore analogous to carrying out an alignment where the “parent” coffin is the current insertion point.

5 Measuring coffins

```
\coffin_dp:N
\coffin_dp:c
```

```
\coffin_dp:N <coffin>
```

Calculates the depth (below the baseline) of the $\langle coffin \rangle$ in a form suitable for use in a $\langle dimension expression \rangle$.

```
\coffin_ht:N
\coffin_ht:c
```

```
\coffin_ht:N <coffin>
```

Calculates the height (above the baseline) of the $\langle coffin \rangle$ in a form suitable for use in a $\langle dimension expression \rangle$.

```
\coffin_wd:N
\coffin_wd:c
```

```
\coffin_wd:N <coffin>
```

Calculates the width of the $\langle coffin \rangle$ in a form suitable for use in a $\langle dimension expression \rangle$.

6 Coffin diagnostics

```
\coffin_display_handles:Nn
\coffin_display_handles:cn
```

Updated: 2011-09-02

```
\coffin_display_handles:Nn <coffin> {\color}
```

This function first calculates the intersections between all of the $\langle poles \rangle$ of the $\langle coffin \rangle$ to give a set of $\langle handles \rangle$. It then prints the $\langle coffin \rangle$ at the current location in the source, with the position of the $\langle handles \rangle$ marked on the coffin. The $\langle handles \rangle$ are labelled as part of this process: the locations of the $\langle handles \rangle$ and the labels are both printed in the $\langle color \rangle$ specified.

```
\coffin_mark_handle:Nnnn
\coffin_mark_handle:cnnn
```

Updated: 2011-09-02

```
\coffin_mark_handle:Nnnn <coffin> {\pole_1} {\pole_2} {\color}
```

This function first calculates the $\langle handle \rangle$ for the $\langle coffin \rangle$ as defined by the intersection of $\langle pole_1 \rangle$ and $\langle pole_2 \rangle$. It then marks the position of the $\langle handle \rangle$ on the $\langle coffin \rangle$. The $\langle handle \rangle$ are labelled as part of this process: the location of the $\langle handle \rangle$ and the label are both printed in the $\langle color \rangle$ specified.

```
\coffin_show_structure:N
\coffin_show_structure:c
```

Updated: 2015-08-01

```
\coffin_show_structure:N <coffin>
```

This function shows the structural information about the $\langle coffin \rangle$ in the terminal. The width, height and depth of the typeset material are given, along with the location of all of the poles of the coffin.

Notice that the poles of a coffin are defined by four values: the x and y co-ordinates of a point that the pole passes through and the x - and y -components of a vector denoting the direction of the pole. It is the ratio between the later, rather than the absolute values, which determines the direction of the pole.

`\coffin_log_structure:N`
`\coffin_log_structure:c`

New: 2014-08-22
Updated: 2015-08-01

`\coffin_log_structure:N` $\langle coffin \rangle$

This function writes the structural information about the $\langle coffin \rangle$ in the log file. See also

`\coffin_show_structure:N` which displays the result in the terminal.

7 Constants and variables

`\c_empty_coffin`

A permanently empty coffin.

`\l_tmpa_coffin`
`\l_tmpb_coffin`

New: 2012-06-19

Scratch coffins for local assignment. These are never used by the kernel code, and so are safe for use with any $\text{\LaTeX}3$ -defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

`\g_tmpa_coffin`
`\g_tmpb_coffin`

New: 2019-01-24

Scratch coffins for global assignment. These are never used by the kernel code, and so are safe for use with any $\text{\LaTeX}3$ -defined function. However, they may be overwritten by other non-kernel code and so should only be used for short-term storage.

Part XXX

The l3color-base package

Color support

This module provides support for color in L^AT_EX3. At present, the material here is mainly intended to support a small number of low-level requirements in other l3kernel modules.

1 Color in boxes

Controlling the color of text in boxes requires a small number of control functions, so that the boxed material uses the color at the point where it is set, rather than where it is used.

```
\color_group_begin:  
\color_group_end:
```

New: 2011-09-03

```
\color_group_begin:  
...  
\color_group_end:
```

Creates a color group: one used to “trap” color settings.

```
\color_ensure_current:
```

New: 2011-09-03

```
\color_ensure_current:
```

Ensures that material inside a box uses the foreground color at the point where the box is set, rather than that in force when the box is used. This function should usually be used within a `\color_group_begin: ... \color_group_end:` group.

Part XXXI

The l3luatex package: LuaTeX-specific functions

The LuaTeX engine provides access to the Lua programming language, and with it access to the “internals” of TeX. In order to use this within the framework provided here, a family of functions is available. When used with pdfTeX, pTeX, upTeX or XeTeX these raise an error: use `\sys_if_engine_luatex:T` to avoid this. Details on using Lua with the LuaTeX engine are given in the LuaTeX manual.

1 Breaking out to Lua

<code>\lua_now:n</code>	★	<code>\lua_now:n</code>	{ <i><token list></i> }
-------------------------	---	-------------------------	-------------------------------

<code>\lua_now:e</code>	★
-------------------------	---

New: 2018-06-18

The *<token list>* is first tokenized by TeX, which includes converting line ends to spaces in the usual TeX manner and which respects currently-applicable TeX category codes. The resulting *<Lua input>* is passed to the Lua interpreter for processing. Each `\lua_now:n` block is treated by Lua as a separate chunk. The Lua interpreter executes the *<Lua input>* immediately, and in an expandable manner.

TeXhackers note: `\lua_now:e` is a macro wrapper around `\directlua:` when LuaTeX is in use two expansions are required to yield the result of the Lua code.

<code>\lua_shipout_e:n</code>	★
-------------------------------	---

<code>\lua_shipout:n</code>	★
-----------------------------	---

New: 2018-06-18

<code>\lua_shipout:n</code>	{ <i><token list></i> }
-----------------------------	-------------------------------

The *<token list>* is first tokenized by TeX, which includes converting line ends to spaces in the usual TeX manner and which respects currently-applicable TeX category codes. The resulting *<Lua input>* is passed to the Lua interpreter when the current page is finalised (*i.e.* at shipout). Each `\lua_shipout:n` block is treated by Lua as a separate chunk. The Lua interpreter will execute the *<Lua input>* during the page-building routine: no TeX expansion of the *<Lua input>* will occur at this stage.

In the case of the `\lua_shipout_e:n` version the input is fully expanded by TeX in an e-type manner during the shipout operation.

TeXhackers note: At a TeX level, the *<Lua input>* is stored as a “whatsit”.

<code>\lua_escape:n</code>	★
----------------------------	---

<code>\lua_escape:e</code>	★
----------------------------	---

New: 2015-06-29

<code>\lua_escape:n</code>	{ <i><token list></i> }
----------------------------	-------------------------------

Converts the *<token list>* such that it can safely be passed to Lua: embedded backslashes, double and single quotes, and newlines and carriage returns are escaped. This is done by prepending an extra token consisting of a backslash with category code 12, and for the line endings, converting them to `\n` and `\r`, respectively.

TeXhackers note: `\lua_escape:e` is a macro wrapper around `\luaescapestring:` when LuaTeX is in use two expansions are required to yield the result of the Lua code.

2 Lua interfaces

As well as interfaces for T_EX, there are a small number of Lua functions provided here.

<u>l3kernel</u>	All public interfaces provided by the module are stored within the <code>l3kernel</code> table.
<u>l3kernel.charcat</u>	<p><code>l3kernel.charcat(<charcode>, <catcode>)</code></p> <p>Constructs a character of <i><charcode></i> and <i><catcode></i> and returns the result to T_EX.</p>
<u>l3kernel.elapsedtime</u>	<p><code>l3kernel.elapsedtime()</code></p> <p>Returns the CPU time in <i><scaled seconds></i> since the start of the T_EX run or since <code>l3kernel.resettimer</code> was issued. This only measures the time used by the CPU, not the real time, e.g., waiting for user input.</p>
<u>l3kernel.filemdfivesum</u>	<p><code>l3kernel.filemdfivesum(<file>)</code></p> <p>Returns the MD5 sum of the file contents read as bytes; note that the result will depend on the nature of the line endings used in the file, in contrast to normal T_EX behaviour. If the <i><file></i> is not found, nothing is returned with <i>no error raised</i>.</p>
<u>l3kernel.filemoddate</u>	<p><code>l3kernel.filemoddate(<file>)</code></p> <p>Returns the date/time of last modification of the <i><file></i> in the format</p> <p style="text-align: center;">D:<year><month><day><hour><minute><second><offset></p> <p>where the latter may be Z (UTC) or <i><plus-minus><hours>'<minutes>'</i>. If the <i><file></i> is not found, nothing is returned with <i>no error raised</i>.</p>
<u>l3kernel.filesize</u>	<p><code>l3kernel.filesize(<file>)</code></p> <p>Returns the size of the <i><file></i> in bytes. If the <i><file></i> is not found, nothing is returned with <i>no error raised</i>.</p>
<u>l3kernel.resettimer</u>	<p><code>l3kernel.resettimer()</code></p> <p>Resets the timer used by <code>l3kernel.elapsedtime</code>.</p>
<u>l3kernel.strcmp</u>	<p><code>l3kernel.strcmp(<str one>, <str two>)</code></p> <p>Compares the two strings and returns 0 to T_EX if the two are identical.</p>

Part XXXII

The l3unicode package: Unicode support functions

This module provides Unicode-specific functions along with loading data from a range of Unicode Consortium files. At present, it provides no public functions.

Part XXXIII

The l3legacy package

Interfaces to legacy concepts

There are a small number of T_EX or L^AT_EX 2_ε concepts which are not used in `expl3` code but which need to be manipulated when working as a L^AT_EX 2_ε package. To allow these to be integrated cleanly into `expl3` code, a set of legacy interfaces are provided here.

<code>\legacy_if_p:n</code> *	<code>\legacy_if:nTF</code> { <i><name></i> } { <i><true code></i> } { <i><false code></i> }
<code>\legacy_if:nTF</code> *	Tests if the L ^A T _E X 2 _ε /plain T _E X conditional (generated by <code>\newif</code>) if <code>true</code> or <code>false</code> and branches accordingly. The <i><name></i> of the conditional should <i>omit</i> the leading <code>if</code> .

Part XXXIV

The l3candidates package

Experimental additions to l3kernel

1 Important notice

This module provides a space in which functions can be added to l3kernel (expl3) while still being experimental.

As such, the functions here may not remain in their current form, or indeed at all, in l3kernel in the future.

In contrast to the material in l3experimental, the functions here are all *small* additions to the kernel. We encourage programmers to test them out and report back on the **LaTeX-L** mailing list.

Thus, if you intend to use any of these functions from the candidate module in a public package offered to others for productive use (e.g., being placed on CTAN) please consider the following points carefully:

- Be prepared that your public packages might require updating when such functions are being finalized.
- Consider informing us that you use a particular function in your public package, e.g., by discussing this on the **LaTeX-L** mailing list. This way it becomes easier to coordinate any updates necessary without issues for the users of your package.
- Discussing and understanding use cases for a particular addition or concept also helps to ensure that we provide the right interfaces in the final version so please give us feedback if you consider a certain candidate function useful (or not).

We only add functions in this space if we consider them being serious candidates for a final inclusion into the kernel. However, real use sometimes leads to better ideas, so functions from this module are **not necessarily stable** and we may have to adjust them!

2 Additions to l3basics

`\debug_on:n`
`\debug_off:n`

New: 2017-07-16
Updated: 2017-08-02

`\debug_on:n { <comma-separated list> }`
`\debug_off:n { <comma-separated list> }`

Turn on and off within a group various debugging code, some of which is also available as expl3 load-time options. The items that can be used in the *<list>* are

- **check-declarations** that checks all expl3 variables used were previously declared and that local/global variables (based on their name or on their first assignment) are only locally/globally assigned;
- **check-expressions** that checks integer, dimension, skip, and muskip expressions are not terminated prematurely;
- **deprecation** that makes soon-to-be-deprecated commands produce errors;
- **log-functions** that logs function definitions;
- **all** that does all of the above.

Providing these as switches rather than options allows testing code even if it relies on other packages: load all other packages, call `\debug_on:n`, and load the code that one is interested in testing. These functions can only be used in L^AT_EX 2_ε package mode loaded with **enable-debug** or another option implying it.

`\debug_suspend:`
`\debug_resume:`

New: 2017-11-28

`\debug_suspend: ... \debug_resume:`

Suppress (locally) errors and logging from **debug** commands, except for the **deprecation** errors or warnings. These pairs of commands can be nested. This can be used around pieces of code that are known to fail checks, if such failures should be ignored. See for instance **l3coffins**.

`\mode_leave_vertical:`

New: 2017-07-04

`\mode_leave_vertical:`

Ensures that T_EX is not in vertical (inter-paragraph) mode. In horizontal or math mode this command has no effect, in vertical mode it switches to horizontal mode, and inserts a box of width `\parindent`, followed by the `\everypar` token list.

T_EXhackers note: This results in the contents of the `\everypar` token register being inserted, after `\mode_leave_vertical:` is complete. Notice that in contrast to the L^AT_EX 2_ε `\leavevmode` approach, no box is used by the method implemented here.

3 Additions to l3box

3.1 Viewing part of a box

```
\box_clip:N  
\box_clip:c  
\box_gclip:N  
\box_gclip:c
```

Updated: 2019-01-23

```
\box_clip:N <box>
```

Clips the $\langle box \rangle$ in the output so that only material inside the bounding box is displayed in the output. The updated $\langle box \rangle$ is an hbox, irrespective of the nature of the $\langle box \rangle$ before the clipping is applied.

These functions require the L^AT_EX3 native drivers: they do not work with the L^AT_EX 2_ε graphics drivers!

T_EXhackers note: Clipping is implemented by the driver, and as such the full content of the box is placed in the output file. Thus clipping does not remove any information from the raw output, and hidden material can therefore be viewed by direct examination of the file.

```
\box_set_trim:Nnnnn  
\box_set_trim:cnnnn  
\box_gset_trim:Nnnnn  
\box_gset_trim:cnnnn
```

New: 2019-01-23

```
\box_set_trim:Nnnnn <box> {\left} {\bottom} {\right} {\top}
```

Adjusts the bounding box of the $\langle box \rangle$ $\langle left \rangle$ is removed from the left-hand edge of the bounding box, $\langle right \rangle$ from the right-hand edge and so fourth. All adjustments are *$\langle dimension expressions \rangle$* . Material outside of the bounding box is still displayed in the output unless `\box_clip:N` is subsequently applied. The updated $\langle box \rangle$ is an hbox, irrespective of the nature of the $\langle box \rangle$ before the trim operation is applied. The behavior of the operation where the trims requested is greater than the size of the box is undefined.

```
\box_set_viewport:Nnnnn  
\box_set_viewport:cnnnn  
\box_gset_viewport:Nnnnn  
\box_gset_viewport:cnnnn
```

New: 2019-01-23

```
\box_set_viewport:Nnnnn <box> {\llx} {\lly} {\urx} {\ury}
```

Adjusts the bounding box of the $\langle box \rangle$ such that it has lower-left co-ordinates ($\langle llx \rangle$, $\langle lly \rangle$) and upper-right co-ordinates ($\langle urx \rangle$, $\langle ury \rangle$). All four co-ordinate positions are *$\langle dimension expressions \rangle$* . Material outside of the bounding box is still displayed in the output unless `\box_clip:N` is subsequently applied. The updated $\langle box \rangle$ is an hbox, irrespective of the nature of the $\langle box \rangle$ before the viewport operation is applied.

4 Additions to l3expan

```
\exp_args_generate:n
```

New: 2018-04-04

Updated: 2019-02-08

```
\exp_args_generate:n {\variant argument specifiers}
```

Defines `\exp_args:N<variant>` functions for each $\langle variant \rangle$ given in the comma list $\{\langle variant argument specifiers \rangle\}$. Each $\langle variant \rangle$ should consist of the letters N, c, n, V, v, o, f, e, x, p and the resulting function is protected if the letter x appears in the $\langle variant \rangle$. This is only useful for cases where `\cs_generate_variant:Nn` is not applicable.

5 Additions to l3fp

<hr/> <code>\logb</code> <hr/> ★	<code>\fp_eval:n { \logb(<fpexpr>) }</code>
<hr/> New: 2018-11-03 <hr/>	Determines the exponent of the $\langle fpexpr \rangle$, namely the floor of the base-10 logarithm of its absolute value. “Division by zero” occurs when evaluating $\logb(\pm 0) = -\infty$. Other special values are $\logb(\pm\infty) = +\infty$ and $\logb(\text{NaN}) = \text{NaN}$. If the operand is a tuple or is NaN, then “invalid operation” occurs and the result is NaN.

<hr/> <code>\fp_sign:n</code> <hr/> ★	<code>\fp_sign:n {<fpexpr>}</code>
<hr/> New: 2018-11-03 <hr/>	Evaluates the $\langle fpexpr \rangle$ and leaves its sign in the input stream using <code>\fp_eval:n {sign(<result>)}</code> : +1 for positive numbers and for $+\infty$, -1 for negative numbers and for $-\infty$, ± 0 for ± 0 . If the operand is a tuple or is NaN, then “invalid operation” occurs and the result is 0.

6 Additions to l3fparray

<hr/> <code>\fparray_new:Nn</code> <hr/>	<code>\fparray_new:Nn <fparray var> {<size>}</code>
<hr/> New: 2018-05-05 <hr/>	Evaluates the integer expression $\langle size \rangle$ and allocates an <i>floating point array variable</i> with that number of (zero) entries. The variable name should start with <code>\g_</code> because assignments are always global.

<hr/> <code>\fparray_count:N</code> <hr/> ★	<code>\fparray_count:N <fparray var></code>
<hr/> New: 2018-05-05 <hr/>	Expands to the number of entries in the <i>floating point array variable</i> . This is performed in constant time.

<hr/> <code>\fparray_gset:Nnn</code> <hr/>	<code>\fparray_gset:Nnn <fparray var> {<position>} {<value>}</code>
<hr/> New: 2018-05-05 <hr/>	Stores the result of evaluating the floating point expression $\langle value \rangle$ into the <i>floating point array variable</i> at the (integer expression) $\langle position \rangle$. If the $\langle position \rangle$ is not between 1 and the <code>\fparray_count:N</code> , an error occurs. Assignments are always global.

<hr/> <code>\fparray_gzero:N</code> <hr/>	<code>\fparray_gzero:N <fparray var></code>
<hr/> New: 2018-05-05 <hr/>	Sets all entries of the <i>floating point array variable</i> to +0. Assignments are always global.

<hr/> <code>\fparray_item:Nn</code> <hr/> ★	<code>\fparray_item:Nn <fparray var> {<position>}</code>
<hr/> <code>\fparray_item_to_tl:Nn</code> <hr/> ★	Applies <code>\fp_use:N</code> or <code>\fp_to_tl:N</code> (respectively) to the floating point entry stored at the (integer expression) $\langle position \rangle$ in the <i>floating point array variable</i> . If the $\langle position \rangle$ is not between 1 and the <code>\fparray_count:N</code> , an error occurs.
<hr/> New: 2018-05-05 <hr/>	

7 Additions to l3file

<code>\file_compare_timestamp:nNnTF</code>	<code>\file_compare_timestamp:nNn {<file-1>} <comparator> {<file-2>} {<true code>} {<false code>}</code>
--	--

New: 2019-05-13

Compares the file stamps on the two *<files>* as indicated by the *<comparator>*, and inserts either the *<true code>* or *<false case>* as required. A file which is not found is treated as older than any file which is found. This allows for example the construct

```
\file_compare_timestamp:nNnT { source-file } > { derived-file }
{
  % Code to regenerate derived file
}
```

to work when the derived file is entirely absent. The timestamp of two absent files is regarded as different.

<code>\ior_map_variable:NNn</code>	<code>\ior_map_variable:NNn <stream> <tl var> {<code>}</code>
------------------------------------	---

New: 2019-01-13

For each set of *<lines>* obtained by calling `\ior_get:NN` until reaching the end of the file, stores the *<lines>* in the *<tl var>* then applies the *<code>*. The *<code>* will usually make use of the *<variable>*, but this is not enforced. The assignments to the *<variable>* are local. \TeX ignores any trailing new-line marker from the file it reads. This function is typically faster than `\ior_map_inline:Nn`.

<code>\ior_str_map_variable:NNn</code>	<code>\ior_str_map_variable:NNn <stream> <tl var> {<code>}</code>
--	---

New: 2019-01-13

For each *<line>* in the *<stream>*, stores the *<line>* in the *<tl var>* then applies the *<code>*. The material is read from the *<stream>* as a series of tokens with category code 12 (other), with the exception of space characters which are given category code 10 (space). The *<code>* will usually make use of the *<variable>*, but this is not enforced. The assignments to the *<variable>* are local. Note that \TeX removes trailing space and tab characters (character codes 32 and 9) from every line upon input. \TeX also ignores any trailing new-line marker from the file it reads. This function is typically faster than `\ior_str_map_inline:Nn`.

<code>\iow_allow_break:</code>	<code>\iow_allow_break:</code>
--------------------------------	--------------------------------

New: 2018-12-29

In the first argument of `\iow_wrap:nnnN` (for instance in messages), inserts a break-point that allows a line break. In other words this is a zero-width breaking space.

<code>\ior_get_term:nN</code> <code>\ior_str_get_term:nN</code>	<code>\ior_get_term:nN <prompt> <token list variable></code>
--	--

New: 2019-03-23

Function that reads one or more lines (until an equal number of left and right braces are found) from the terminal and stores the result locally in the *<token list>* variable. Tokenization occurs as described for `\ior_get:NN` or `\ior_str_get:NN`, respectively. When the *<prompt>* is empty, \TeX will wait for input without any other indication: typically the programmer will have provided a suitable text using e.g. `\iow_term:n`. Where the *<prompt>* is given, it will appear in the terminal followed by an =, e.g.

```
prompt=
```

<hr/> <code>\ior_shell_open:Nn</code> <hr/>	<code>\ior_shell_open:nN <stream> {<shell command>}</code>
<hr/> New: 2019-05-08 <hr/>	Opens the <i>pseudo</i> -file created by the output of the <i><shell command></i> for reading using <i><stream></i> as the control sequence for access. If the <i><stream></i> was already open it is closed before the new operation begins. The <i><stream></i> is available for access immediately and will remain allocated to <i><shell command></i> until a <code>\ior_close:N</code> instruction is given or the \TeX run ends. If piped system calls are disabled an error is raised. For details of handling of the <i><shell command></i> , see <code>\sys_shell_get:nnN(TF)</code> .

8 Additions to l3flag

<hr/> <code>\flag_raise_if_clear:n *</code> <hr/>	<code>\flag_raise_if_clear:n {<flag name>}</code>
<hr/> New: 2018-04-02 <hr/>	Ensures the <i><flag></i> is raised by making its height at least 1, locally.

9 Additions to l3int

<hr/> <code>\int_sign:n *</code> <hr/>	<code>\int_sign:n {<intexpr>}</code>
<hr/> New: 2018-11-03 <hr/>	Evaluates the <i><integer expression></i> then leaves 1 or 0 or -1 in the input stream according to the sign of the result.

10 Additions to l3intarray

<hr/> <code>\intarray_gset_rand:Nnn</code> <hr/>	<code>\intarray_gset_rand:Nnn <intarray var> {<minimum>} {<maximum>}</code>
<hr/> <code>\intarray_gset_rand:Nn</code> <hr/>	<code>\intarray_gset_rand:Nn <intarray var> {<maximum>}</code>
<hr/> New: 2018-05-05 <hr/>	Evaluates the integer expressions <i><minimum></i> and <i><maximum></i> then sets each entry (independently) of the <i><integer array variable></i> to a pseudo-random number between the two (with bounds included). If the absolute value of either bound is bigger than $2^{30} - 1$, an error occurs. Entries are generated in the same way as repeated calls to <code>\int_rand:nn</code> or <code>\int_rand:n</code> respectively, in particular for the second function the <i><minimum></i> is 1. Assignments are always global. This is not available in older versions of \TeX .

10.1 Working with contents of integer arrays

<hr/> <code>\intarray_const_from_clist:Nn ☆</code> <hr/>	<code>\intarray_const_from_clist:Nn <intarray var> <intexpr clist></code>
<hr/> New: 2018-05-04 <hr/>	

Creates a new constant *<integer array variable>* or raises an error if the name is already taken. The *<integer array variable>* is set (globally) to contain as its items the results of evaluating each *<integer expression>* in the *<comma list>*.

<hr/> <code>\intarray_to_clist:N ☆</code> <hr/>	<code>\intarray_to_clist:N <intarray var></code>
<hr/> New: 2018-05-04 <hr/>	Converts the <i><intarray></i> to integer denotations separated by commas. All tokens have category code other. If the <i><intarray></i> has no entry the result is empty; otherwise the result has one fewer comma than the number of items.

<hr/>	
<code>\intarray_show:N</code>	<code>\intarray_show:N <intarray var></code>
<code>\intarray_log:N</code>	<code>\intarray_log:N <intarray var></code>
<hr/>	
New: 2018-05-04	Displays the items in the <i><integer array variable></i> in the terminal or writes them in the log file.

11 Additions to l3msg

In very rare cases it may be necessary to produce errors in an expansion-only context. The functions in this section should only be used if there is no alternative approach using `\msg_error:nnnnnn` or other non-expandable commands from the previous section. Despite having a similar interface as non-expandable messages, expandable errors must be handled internally very differently from normal error messages, as none of the tools to print to the terminal or the log file are expandable. As a result, short-hands such as `\{` or `\|` do not work, and messages must be very short (with default settings, they are truncated after approximately 50 characters). It is advisable to ensure that the message is understandable even when truncated, by putting the most important information up front. Another particularity of expandable messages is that they cannot be redirected or turned off by the user.

<hr/>	
<code>\msg_expandable_error:nnnnnn</code>	<code>\msg_expandable_error:nnnnnn {<module>} {<message>} {<arg one>} {<arg two>} {<arg three>} {<arg four>}</code>
<code>\msg_expandable_error:nnffff</code>	*
<code>\msg_expandable_error:nnnnn</code>	*
<code>\msg_expandable_error:nnfff</code>	*
<code>\msg_expandable_error:nnnn</code>	*
<code>\msg_expandable_error:nnff</code>	*
<code>\msg_expandable_error:nnn</code>	*
<code>\msg_expandable_error:nnf</code>	*
<code>\msg_expandable_error:nn</code>	*
<hr/>	

New: 2015-08-06

Updated: 2019-02-28

Issues an “Undefined error” message from T_EX itself using the undefined control sequence `\::error` then prints “! *<module>*: ”*<error message>*”, which should be short. With default settings, anything beyond approximately 60 characters long (or bytes in some engines) is cropped. A leading space might be removed as well.

<hr/>	
<code>\msg_show_eval:Nn</code>	<code>\msg_show_eval:Nn <function> {<expression>}</code>
<code>\msg_log_eval:Nn</code>	Shows or logs the <i><expression></i> (turned into a string), an equal sign, and the result of applying the <i><function></i> to the <i>{<expression>}</i> (with f-expansion). For instance, if the <i><function></i> is <code>\int_eval:n</code> and the <i><expression></i> is <code>1+2</code> then this logs <code>> 1+2=3</code> .
<hr/>	
New: 2017-12-04	

<code>\msg_show:nnnnnn</code>	<code>\msg_show:nnnnnn {<module>} {<message>} {<arg one>} {<arg two>} {<arg three>} {<arg four>}</code>
<code>\msg_show:nnxxxx</code>	
<code>\msg_show:nnnnn</code>	Issues <i><module></i> information <i><message></i> , passing <i><arg one></i> to <i><arg four></i> to the text-creating functions. The information text is shown on the terminal and the TeX run is interrupted in a manner similar to <code>\tl_show:n</code> . This is used in conjunction with <code>\msg_show_item:n</code> and similar functions to print complex variable contents completely. If the formatted text does not contain <code>>~</code> at the start of a line, an additional line <code>>~.</code> will be put at the end. In addition, a final period is added if not present.
<code>\msg_show:nnxxx</code>	
<code>\msg_show:nnnn</code>	
<code>\msg_show:nnxx</code>	
<code>\msg_show:nnn</code>	
<code>\msg_show:nnx</code>	
<code>\msg_show:nn</code>	

New: 2017-12-04

<code>\msg_show_item:n</code>	★	<code>\seq_map_function:NN <seq> \msg_show_item:n</code>
<code>\msg_show_item_unbraced:n</code>	★	<code>\prop_map_function:NN <prop> \msg_show_item:nn</code>
<code>\msg_show_item:nn</code>	★	
<code>\msg_show_item_unbraced:nn</code>	★	

New: 2017-12-04

Used in the text of messages for `\msg_show:nnxxxx` to show or log a list of items or key-value pairs. The one-argument functions are used for sequences, clist or token lists and the others for property lists. These functions turn their arguments to strings.

12 Additions to l3prg

<code>\bool_const:Nn</code>	<code>\bool_const:Nn <boolean> {<boolexpr>}</code>
<code>\bool_const:cn</code>	

New: 2017-11-28

Creates a new constant *<boolean>* or raises an error if the name is already taken. The value of the *<boolean>* is set globally to the result of evaluating the *<boolexpr>*.

<code>\bool_set_inverse:N</code>	<code>\bool_set_inverse:N <boolean></code>
<code>\bool_set_inverse:c</code>	
<code>\bool_gset_inverse:N</code>	Toggles the <i><boolean></i> from true to false and conversely: sets it to the inverse of its current value.
<code>\bool_gset_inverse:c</code>	

New: 2018-05-10

13 Additions to l3prop

<code>\prop_map_tokens:Nn</code>	☆	<code>\prop_map_tokens:Nn <property list> {<code>}</code>
<code>\prop_map_tokens:cn</code>	☆	

Analogue of `\prop_map_function:NN` which maps several tokens instead of a single function. The *<code>* receives each key-value pair in the *<property list>* as two trailing brace groups. For instance,

```
\prop_map_tokens:Nn \l_my_prop { \str_if_eq:nnT { mykey } }
```

expands to the value corresponding to **mykey**: for each pair in `\l_my_prop` the function `\str_if_eq:nnT` receives **mykey**, the *<key>* and the *<value>* as its three arguments. For that specific task, `\prop_item:Nn` is faster.

`\prop_rand_key_value:N` ☆
`\prop_rand_key_value:c` ☆

New: 2016-12-06

`\prop_rand_key_value:N` $\langle prop\ var \rangle$

Selects a pseudo-random key–value pair from the $\langle property\ list \rangle$ and returns $\{\langle key \rangle\}$ and $\{\langle value \rangle\}$. If the $\langle property\ list \rangle$ is empty the result is empty. This is not available in older versions of Xe_{La}TeX.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the $\langle value \rangle$ does not expand further when appearing in an x-type argument expansion.

`\prop_set_from_keyval:Nn`
`\prop_set_from_keyval:cn`
`\prop_gset_from_keyval:Nn`
`\prop_gset_from_keyval:cn`

New: 2017-11-28

`\prop_set_from_keyval:Nn` $\langle prop\ var \rangle$

```
{
  \key1 = \value1 ,
  \key2 = \value2 , ...
}
```

Sets $\langle prop\ var \rangle$ to contain key–value pairs given in the second argument.

`\prop_const_from_keyval:Nn`
`\prop_const_from_keyval:cn`

New: 2017-11-28

`\prop_const_from_keyval:Nn` $\langle prop\ var \rangle$

```
{
  \key1 = \value1 ,
  \key2 = \value2 , ...
}
```

Creates a new constant $\langle prop\ var \rangle$ or raises an error if the name is already taken. The $\langle prop\ var \rangle$ is set globally to contain key–value pairs given in the second argument.

14 Additions to l3seq

`\seq_mapthread_function:NNN` ☆ `\seq_mapthread_function:NNN` $\langle seq_1 \rangle$ $\langle seq_2 \rangle$ $\langle function \rangle$
`\seq_mapthread_function:(NcN|cNN|ccN)` ☆

Applies $\langle function \rangle$ to every pair of items $\langle seq_1\text{-}item \rangle$ – $\langle seq_2\text{-}item \rangle$ from the two sequences, returning items from both sequences from left to right. The $\langle function \rangle$ receives two n-type arguments for each iteration. The mapping terminates when the end of either sequence is reached (*i.e.* whichever sequence has fewer items determines how many iterations occur).

`\seq_set_filter:NNn`
`\seq_gset_filter:NNn`

`\seq_set_filter:NNn` $\langle sequence_1 \rangle$ $\langle sequence_2 \rangle$ $\{\langle inline\ boolexpr \rangle\}$

Evaluates the $\langle inline\ boolexpr \rangle$ for every $\langle item \rangle$ stored within the $\langle sequence_2 \rangle$. The $\langle inline\ boolexpr \rangle$ receives the $\langle item \rangle$ as #1. The sequence of all $\langle items \rangle$ for which the $\langle inline\ boolexpr \rangle$ evaluated to `true` is assigned to $\langle sequence_1 \rangle$.

TeXhackers note: Contrarily to other mapping functions, `\seq_map_break`: cannot be used in this function, and would lead to low-level TeX errors.

<code>\seq_set_map:NNn</code>	<code>\seq_set_map:NNn <sequence₁> <sequence₂> {(inline function)}</code>
-------------------------------	---

<code>\seq_gset_map:NNn</code>

New: 2011-12-22

Applies *<inline function>* to every *<item>* stored within the *<sequence₂>*. The *<inline function>* should consist of code which will receive the *<item>* as #1. The sequence resulting from x-expanding *<inline function>* applied to each *<item>* is assigned to *<sequence₁>*. As such, the code in *<inline function>* should be expandable.

T_EXhackers note: Contrarily to other mapping functions, `\seq_map_break:` cannot be used in this function, and would lead to low-level T_EX errors.

<code>\seq_const_from_clist:Nn</code>	<code>\seq_const_from_clist:Nn <seq var> {(comma-list)}</code>
---------------------------------------	--

<code>\seq_const_from_clist:cn</code>

New: 2017-11-28

Creates a new constant *<seq var>* or raises an error if the name is already taken. The *<seq var>* is set globally to contain the items in the *<comma list>*.

<code>\seq_set_from_function:NnN</code>	<code>\seq_set_from_function:NnN <seq var> {(loop code)} <function></code>
---	--

<code>\seq_gset_from_function:NnN</code>
--

New: 2018-04-06

Sets the *<seq var>* equal to a sequence whose items are obtained by x-expanding *<loop code>* *<function>*. This expansion must result in successive calls to the *<function>* with no nonexpandable tokens in between. More precisely the *<function>* is replaced by a wrapper function that inserts the appropriate separators between items in the sequence. The *<loop code>* must be expandable; it can be for example `\tl_map_function:NN <tl var>` or `\clist_map_function:nN {(clist)}` or `\int_step_function:nnnN {(initial value)} {(step)} {(final value)}`.

<code>\seq_set_from_inline_x:Nnn</code>	<code>\seq_set_from_inline_x:Nnn <seq var> {(loop code)} {(inline code)}</code>
---	---

<code>\seq_gset_from_inline_x:Nnn</code>
--

New: 2018-04-06

Sets the *<seq var>* equal to a sequence whose items are obtained by x-expanding *<loop code>* applied to a *<function>* derived from the *<inline code>*. A *<function>* is defined, that takes one argument, x-expands the *<inline code>* with that argument as #1, then adds appropriate separators to turn the result into an item of the sequence. The x-expansion of *<loop code>* *<function>* must result in successive calls to the *<function>* with no nonexpandable tokens in between. The *<loop code>* must be expandable; it can be for example `\tl_map_function:NN <tl var>` or `\clist_map_function:nN {(clist)}` or `\int_step_function:nnnN {(initial value)} {(step)} {(final value)}`, but not the analogous “inline” mappings.

<code>\seq_shuffle:N</code>	<code>\seq_shuffle:N <seq var></code>
-----------------------------	---

<code>\seq_gshuffle:N</code>

New: 2018-04-29

Sets the *<seq var>* to the result of placing the items of the *<seq var>* in a random order. Each item is (roughly) as likely to end up in any given position.

T_EXhackers note: For sequences with more than 13 items or so, only a small proportion of all possible permutations can be reached, because the random seed `\sys_rand_seed:` only has 28-bits. The use of `\toks` internally means that sequences with more than 32767 or 65535 items (depending on the engine) cannot be shuffled.

<code>\seq_indexed_map_function:Nn</code>	<code>\seq_indexed_map_function:Nn <seq var> <function></code>
---	--

New: 2018-05-03

Applies $\langle function \rangle$ to every entry in the $\langle sequence variable \rangle$. The $\langle function \rangle$ should have signature `:nn`. It receives two arguments for each iteration: the $\langle index \rangle$ (namely 1 for the first entry, then 2 and so on) and the $\langle item \rangle$.

<code>\seq_indexed_map_inline:Nn</code>	<code>\seq_indexed_map_inline:Nn <seq var> {\inline function}</code>
---	--

New: 2018-05-03

Applies $\langle inline function \rangle$ to every entry in the $\langle sequence variable \rangle$. The $\langle inline function \rangle$ should consist of code which receives the $\langle index \rangle$ (namely 1 for the first entry, then 2 and so on) as `#1` and the $\langle item \rangle$ as `#2`.

15 Additions to l3skip

<code>\dim_sign:n *</code>	<code>\dim_sign:n {\dimexpr}</code>
----------------------------	-------------------------------------

New: 2018-11-03

Evaluates the $\langle dimexpr \rangle$ then leaves 1 or 0 or -1 in the input stream according to the sign of the result.

16 Additions to l3sys

<code>\sys_shell_get:nnN</code>	<code>\sys_shell_get:nnN {\shell command} {\setup} <tl var></code>
<code>\sys_shell_get:nnNTF</code>	<code>\sys_shell_get:nnNTF {\shell command} {\setup} <tl var> {\true code} {\false code}</code>

New: 2019-01-16

Updated: 2019-02-16

Defines $\langle tl \rangle$ to the text returned by the $\langle shell command \rangle$. The $\langle shell command \rangle$ is converted to a string using `\tl_to_str:n`. Category codes may need to be set appropriately via the $\langle setup \rangle$ argument, which is run just before running the $\langle shell command \rangle$ (in a group). If shell escape is disabled, the $\langle tl var \rangle$ will be set to `\q_no_value` in the non-branching version. Note that quote characters (") *cannot* be used inside the $\langle shell command \rangle$. The `\sys_shell_get:nnNTF` conditional returns `true` if the shell is available and no quote is detected, and `false` otherwise.

<code>\c_sys_engine_version_str</code>
--

New: 2018-05-02

The version string of the current engine, in the same form as given in the banner issued when running a job. For pdfTeX and LuaTeX this is of the form

$\langle major \rangle.\langle minor \rangle.\langle revision \rangle$

For XeTeX, the form is

$\langle major \rangle.\langle minor \rangle$

For pTeX and upTeX, only releases since TeX Live 2018 make the data available, and the form is more complex, as it comprises the pTeX version, the upTeX version and the e-pTeX version.

$p\langle major \rangle.\langle minor \rangle.\langle revision \rangle-u\langle major \rangle.\langle minor \rangle-\langle epTeX \rangle$

where the `u` part is only present for upTeX.

<hr/>	
<code>\sys_if_rand_exist_p: *</code>	<code>\sys_if_rand_exist_p:</code>
<code>\sys_if_rand_exist:TF *</code>	<code>\sys_if_rand_exist:TF {\true code}\{\false code}</code>
<hr/>	
<code>New: 2017-05-27</code>	Tests if the engine has a pseudo-random number generator. Currently this is the case in pdfTeX, LuaTeX, pTeX and upTeX.
<hr/>	

<hr/>	
<code>\sys_rand_seed: *</code>	<code>\sys_rand_seed:</code>
<hr/>	
<code>New: 2017-05-27</code>	Expands to the current value of the engine's random seed, a non-negative integer. In engines without random number support this expands to 0.
<hr/>	

<hr/>	
<code>\sys_gset_rand_seed:n</code>	<code>\sys_gset_rand_seed:n {\intexpr}</code>
<hr/>	
<code>New: 2017-05-27</code>	Globally sets the seed for the engine's pseudo-random number generator to the <i>integer expression</i> . This random seed affects all <code>\..._rand</code> functions (such as <code>\int_rand:nn</code> or <code>\clist_rand_item:n</code>) as well as other packages relying on the engine's random number generator. In engines without random number support this produces an error.
<hr/>	

TeXhackers note: While a 32-bit (signed) integer can be given as a seed, only the absolute value is used and any number beyond 2^{28} is divided by an appropriate power of 2. We recommend using an integer in $[0, 2^{28} - 1]$.

<hr/>	
<code>\sys_if_platform_unix_p: *</code>	<code>\sys_if_platform_unix:TF {\true code}\{\false code}</code>
<code>\sys_if_platform_unix:TF *</code>	
<code>\sys_if_platform_windows_p: *</code>	
<code>\sys_if_platform_windows:TF *</code>	
<hr/>	
<code>New: 2018-07-27</code>	
<hr/>	

Conditionals which allow platform-specific code to be used. The names follow the Lua `os.type()` function, *i.e.* all Unix-like systems are `unix` (including Linux and MacOS).

<hr/>	
<code>\c_sys_platform_str</code>	The current platform given as a lower case string: one of <code>unix</code> , <code>windows</code> or <code>unknown</code> .
<hr/>	
<code>New: 2018-07-27</code>	
<hr/>	

<hr/>	
<code>\c_sys_shell_escape_int</code>	This variable exposes the internal triple of the shell escape status. The possible values are
<hr/>	
<code>New: 2017-05-27</code>	
<hr/>	

- 0 Shell escape is disabled
- 1 Unrestricted shell escape is enabled
- 2 Restricted shell escape is enabled

<hr/>	
<code>\sys_if_shell_p: *</code>	<code>\sys_if_shell_p:</code>
<code>\sys_if_shell:TF *</code>	<code>\sys_if_shell:TF {\true code}\{\false code}</code>
<hr/>	
<code>New: 2017-05-27</code>	Performs a check for whether shell escape is enabled. This returns true if either of restricted or unrestricted shell escape is enabled.
<hr/>	

<code>\sys_if_shell_unrestricted_p: *</code>	<code>\sys_if_shell_unrestricted_p:</code>
<code>\sys_if_shell_unrestricted:TF *</code>	<code>\sys_if_shell_unrestricted:TF {\true code} {\false code}</code>

New: 2017-05-27

Performs a check for whether *unrestricted* shell escape is enabled.

<code>\sys_if_shell_restricted_p: *</code>	<code>\sys_if_shell_restricted_p:</code>
<code>\sys_if_shell_restricted:TF *</code>	<code>\sys_if_shell_restricted:TF {\true code} {\false code}</code>

New: 2017-05-27

Performs a check for whether *restricted* shell escape is enabled. This returns false if unrestricted shell escape is enabled. Unrestricted shell escape is not considered a superset of restricted shell escape in this case. To find whether any shell escape is enabled use `\sys_if_shell:`.

<code>\sys_shell_now:n</code>	<code>\sys_shell_now:n {\tokens}</code>
<code>\sys_shell_now:x</code>	

New: 2017-05-27

Execute `\tokens` through shell escape immediately.

<code>\sys_shell_shipout:n</code>	<code>\sys_shell_shipout:n {\tokens}</code>
<code>\sys_shell_shipout:x</code>	

New: 2017-05-27

Execute `\tokens` through shell escape at shipout.

17 Additions to l3tl

<code>\tl_lower_case:n *</code>	<code>\tl_upper_case:n {\tokens}</code>
<code>\tl_upper_case:n *</code>	<code>\tl_upper_case:nn {\language} {\tokens}</code>
<code>\tl_mixed_case:n *</code>	
<code>\tl_lower_case:nn *</code>	
<code>\tl_upper_case:nn *</code>	
<code>\tl_mixed_case:nn *</code>	

New: 2014-06-30

Updated: 2016-01-12

These functions are intended to be applied to input which may be regarded broadly as “text”. They traverse the `\tokens` and change the case of characters as discussed below. The character code of the characters replaced may be arbitrary: the replacement characters have standard document-level category codes (11 for letters, 12 for letter-like characters which can also be case-changed). Begin-group and end-group characters in the `\tokens` are normalized and become `{` and `}`, respectively.

Importantly, notice that these functions are intended for working with user text for typesetting. For case changing programmatic data see the `l3str` module and discussion there of `\str_lower_case:n`, `\str_upper_case:n` and `\str_fold_case:n`.

The functions perform expansion on the input in most cases. In particular, input in the form of token lists or expandable functions is expanded *unless* it falls within one of the special handling classes described below. This expansion approach means that in general the result of case changing matches the “natural” outcome expected from a “functional” approach to case modification. For example

```
\tl_set:Nn \l_tmpa_tl { hello }
\tl_upper_case:n { \l_tmpa_tl \c_space_tl world }
```

produces

```
HELLO WORLD
```

The expansion approach taken means that in package mode any L^AT_EX 2_ε “robust” commands which may appear in the input should be converted to engine-protected versions using for example the `\robustify` command from the `etoolbox` package.

`\l_tl_case_change_math_tl`

Case changing does not take place within math mode material so for example

```
\tl_upper_case:n { Some~text~$y = mx + c$~with~{Braces} }
```

becomes

```
SOME TEXT $y = mx + c$ WITH {BRACES}
```

Material inside math mode is left entirely unchanged: in particular, no expansion is undertaken.

Detection of math mode is controlled by the list of tokens in `\l_tl_case_change_math_tl`, which should be in open–close pairs. In package mode the standard settings is

```
$ $ \ ( \)
```

Note that while expansion occurs when searching the text it does not apply to math mode material (which should be unaffected by case changing). As such, whilst the opening token for math mode may be “hidden” inside a command/macro, the closing one cannot be as this is being searched for in math mode. Typically, in the types of “text” the case changing functions are intended to apply to this should not be an issue.

`\l_tl_case_change_exclude_tl`

Case changing can be prevented by using any command on the list `\l_tl_case_change_exclude_tl`. Each entry should be a function to be followed by one argument: the latter will be preserved as-is with no expansion. Thus for example following

```
\tl_put_right:Nn \l_tl_case_change_exclude_tl { \NoChangeCase }
```

the input

```
\tl_upper_case:n
{ Some~text~$y = mx + c$~with~\NoChangeCase {Protection} }
```

will result in

```
SOME TEXT $y = mx + c$ WITH \NoChangeCase {Protection}
```

Notice that the case changing mapping preserves the inclusion of the escape functions: it is left to other code to provide suitable definitions (typically equivalent to `\use:n`). In particular, the result of case changing is returned protected by `\exp_not:n`.

When used with L^AT_EX 2_ε the commands `\cite`, `\ensuremath`, `\label` and `\ref` are automatically included in the list for exclusion from case changing.

`\l_tl_case_change_accents_tl`

This list specifies accent commands which should be left unexpanded in the output. This allows for example

```
\tl_upper_case:n { \" { a } }
```

to yield

```
\" { A }
```

irrespective of the expandability of `\"`.

The standard contents of this variable is `\", \' , \. , \^ , \' , \~ , \c , \H , \k , \r , \t , \u` and `\v`.

“Mixed” case conversion may be regarded informally as converting the first character of the *tokens* to upper case and the rest to lower case. However, the process is more complex than this as there are some situations where a single lower case character maps to a special form, for example *ij* in Dutch which becomes *IJ*. As such, `\tl_mixed_case:n(n)` implement a more sophisticated mapping which accounts for this and for modifying accents on the first letter. Spaces at the start of the *tokens* are ignored when finding the first “letter” for conversion.

```
\tl_mixed_case:n { hello~WORLD } % => "Hello world"
\tl_mixed_case:n { ~hello~WORLD } % => " Hello world"
\tl_mixed_case:n { {hello}~WORLD } % => "{Hello} world"
```

When finding the first “letter” for this process, any content in math mode or covered by `\l_tl_case_change_exclude_tl` is ignored.

(Note that the Unicode Consortium describe this as “title case”, but that in English title case applies on a word-by-word basis. The “mixed” case implemented here is a lower level concept needed for both “title” and “sentence” casing of text.)

`\l_tl_mixed_case_ignore_tl`

The list of characters to ignore when searching for the first “letter” in mixed-casing is determined by `\l_tl_mixed_change_ignore_tl`. This has the standard setting

```
( [ { ' -
```

where comparisons are made on a character basis.

As is generally true for `expl3`, these functions are designed to work with Unicode input only. As such, UTF-8 input is assumed for *all* engines. When used with `XYTeX` or `LuaTeX` a full range of Unicode transformations are enabled. Specifically, the standard mappings here follow those defined by the [Unicode Consortium](#) in `UnicodeData.txt` and `SpecialCasing.txt`. In the case of 8-bit engines, mappings are provided for characters which can be represented in output typeset using the **T1** font encoding. Thus for example `ä` can be case-changed using `pdfTeX`. For `pTeX` only the ASCII range is covered as the engine treats input outside of this range as east Asian.

Context-sensitive mappings are enabled: language-dependent cases are discussed below. Context detection expands input but treats any unexpandable control sequences as “failures” to match a context.

Language-sensitive conversions are enabled using the *language* argument, and follow Unicode Consortium guidelines. Currently, the languages recognised for special handling are as follows.

- Azeri and Turkish (**az** and **tr**). The case pairs I/i-dotless and I-dot/i are activated for these languages. The combining dot mark is removed when lower casing I-dot and introduced when upper casing i-dotless.
- German (**de-alt**). An alternative mapping for German in which the lower case *Eszett* maps to a *großes Eszett*.
- Lithuanian (**lt**). The lower case letters i and j should retain a dot above when the accents grave, acute or tilde are present. This is implemented for lower casing of the relevant upper case letters both when input as single Unicode codepoints and when using combining accents. The combining dot is removed when upper casing in these cases. Note that *only* the accents used in Lithuanian are covered: the behaviour of other accents are not modified.
- Dutch (**nl**). Capitalisation of **ij** at the beginning of mixed cased input produces **IJ** rather than **Ij**. The output retains two separate letters, thus this transformation *is* available using pdfTeX.

Creating additional context-sensitive mappings requires knowledge of the underlying mapping implementation used here. The team are happy to add these to the kernel where they are well-documented (*e.g.* in Unicode Consortium or relevant government publications).

<code>\tl_range_braced:Nnn</code>	★	<code>\tl_range_braced:Nnn <tl var> {<start index>} {<end index>}</code>
<code>\tl_range_braced:cnn</code>	★	<code>\tl_range_braced:nnn {<token list>} {<start index>} {<end index>}</code>
<code>\tl_range_braced:nnn</code>	★	<code>\tl_range_unbraced:Nnn <tl var> {<start index>} {<end index>}</code>
<code>\tl_range_unbraced:Nnn</code>	★	<code>\tl_range_unbraced:nnn {<token list>} {<start index>} {<end index>}</code>
<code>\tl_range_unbraced:cnn</code>	★	Leaves in the input stream the items from the <i><start index></i> to the <i><end index></i> inclusive, using the same indexing as <code>\tl_range:nnn</code> . Spaces are ignored. Regardless of whether items appear with or without braces in the <i><token list></i> , the <code>\tl_range_braced:nnn</code> function wraps each item in braces, while <code>\tl_range_unbraced:nnn</code> does not (overall it removes an outer set of braces). For instance,
<code>\tl_range_unbraced:nnn</code>	★	

New: 2017-07-15

```

\tl_iow_term:x { \tl_range_braced:nnn { abcd~{e}}f } { 2 } { 5 } }
\tl_iow_term:x { \tl_range_braced:nnn { abcd~{e}}f } { -4 } { -1 } }
\tl_iow_term:x { \tl_range_braced:nnn { abcd~{e}}f } { -2 } { -1 } }
\tl_iow_term:x { \tl_range_braced:nnn { abcd~{e}}f } { 0 } { -1 } }

```

prints `{b}{c}{d}{e}}`, `{c}{d}{e}}{f}`, `{e}}{f}`, and an empty line to the terminal, while

```

\tl_iow_term:x { \tl_range_unbraced:nnn { abcd~{e}}f } { 2 } { 5 } }
\tl_iow_term:x { \tl_range_unbraced:nnn { abcd~{e}}f } { -4 } { -1 } }
\tl_iow_term:x { \tl_range_unbraced:nnn { abcd~{e}}f } { -2 } { -1 } }
\tl_iow_term:x { \tl_range_unbraced:nnn { abcd~{e}}f } { 0 } { -1 } }

```

prints `bcde{}`, `cde{f}`, `e{f}`, and an empty line to the terminal. Because braces are removed, the result of `\tl_range_unbraced:nnn` may have a different number of items as for `\tl_range:nnn` or `\tl_range_braced:nnn`. In cases where preserving spaces is important, consider the slower function `\tl_range:nnn`.

TeXhackers note: The result is returned within the `\unexpanded` primitive (`\exp_not:n`), which means that the *<item>* does not expand further when appearing in an *x*-type argument expansion.

<code>\tl_build_begin:N</code>	<code>\tl_build_begin:N <tl var></code>
<code>\tl_build_gbegin:N</code>	Clears the <i><tl var></i> and sets it up to support other <code>\tl_build_...</code> functions, which allow accumulating large numbers of tokens piece by piece much more efficiently than standard <code>\l3tl</code> functions. Until <code>\tl_build_end:N <tl var></code> is called, applying any function from <code>\l3tl</code> other than <code>\tl_build_...</code> will lead to incorrect results. The <code>begin</code> and <code>gbegin</code> functions must be used for local and global <i><tl var></i> respectively.
New: 2018-04-01	

<code>\tl_build_clear:N</code>	<code>\tl_build_clear:N <tl var></code>
<code>\tl_build_gclear:N</code>	Clears the <i><tl var></i> and sets it up to support other <code>\tl_build_...</code> functions. The <code>clear</code> and <code>gclear</code> functions must be used for local and global <i><tl var></i> respectively.
New: 2018-04-01	

```

\tl_build_put_left:Nn
\tl_build_put_left:Nx
\tl_build_gput_left:Nn
\tl_build_gput_left:Nx
\tl_build_put_right:Nn
\tl_build_put_right:Nx
\tl_build_gput_right:Nn
\tl_build_gput_right:Nx

```

New: 2018-04-01

```

\tl_build_get:NN

```

New: 2018-04-01

```

\tl_build_end:N
\tl_build_gend:N

```

New: 2018-04-01

```

\tl_build_put_left:Nn <tl var> {<tokens>}
\tl_build_put_right:Nn <tl var> {<tokens>}

```

Adds *<tokens>* to the left or right side of the current contents of *<tl var>*. The *<tl var>* must have been set up with `\tl_build_begin:N` or `\tl_build_gbegin:N`. The `put` and `gput` functions must be used for local and global *<tl var>* respectively. The `right` functions are about twice faster than the `left` functions.

```

\tl_build_get:N <tl var1> <tl var2>

```

Stores the contents of the *<tl var₁>* in the *<tl var₂>*. The *<tl var₁>* must have been set up with `\tl_build_begin:N` or `\tl_build_gbegin:N`. The *<tl var₂>* is a “normal” token list variable, assigned locally using `\tl_set:Nn`.

```

\tl_build_end:N <tl var>

```

Gets the contents of *<tl var>* and stores that into the *<tl var>* using `\tl_set:Nn`. The *<tl var>* must have been set up with `\tl_build_begin:N` or `\tl_build_gbegin:N`. The `end` and `gend` functions must be used for local and global *<tl var>* respectively. These functions completely remove the setup code that enabled *<tl var>* to be used for other `\tl_build_...` functions.

18 Additions to l3token

```

\c_catcode_active_space_tl

```

New: 2017-08-07

Token list containing one character with category code 13, (“active”), and character code 32 (space).

```

\char_lower_case:N    ★
\char_upper_case:N    ★
\char_mixed_case:N    ★
\char_fold_case:N     ★
\char_str_lower_case:N ★
\char_str_upper_case:N ★
\char_str_mixed_case:N ★
\char_str_fold_case:N ★

```

New: 2018-04-06

Updated: 2019-05-03

```

\char_lower_case:N <char>

```

Converts the *<char>* to the equivalent case-changed character as detailed by the function name (see `\str_fold_case:n` and `\tl_mixed_case:n` for details of these terms). The case mapping is carried out with no context-dependence (*cf.* `\tl_upper_case:n`, *etc.*) The `str` versions always generate “other” (category code 12) characters, whilst the standard versions generate characters with the currently-active category code (*i.e.* as if the character had been read directly here).

```

\char_codepoint_to_bytes:n ★  \char_codepoint_to_bytes:n {<codepoint>}

```

New: 2018-06-01

Converts the (Unicode) *<codepoint>* to UTF-8 bytes. The expansion of this function comprises four brace groups, each of which will contain a hexadecimal value: the appropriate byte. As UTF-8 is a variable-length, one or more of the groups may be empty: the bytes read in the logical order, such that a two-byte codepoint will have groups `#1` and `#2` filled and `#3` and `#4` empty.

<code>\peek_catcode_collect_inline:Nn</code>	<code>\peek_catcode_collect_inline:Nn <test token> {<inline code>}</code>
<code>\peek_charcode_collect_inline:Nn</code>	<code>\peek_charcode_collect_inline:Nn <test token> {<inline code>}</code>
<code>\peek_meaning_collect_inline:Nn</code>	<code>\peek_meaning_collect_inline:Nn <test token> {<inline code>}</code>

New: 2018-09-23

Collects and removes tokens from the input stream until finding a token that does not match the `<test token>` (as defined by the test `\token_if_eq_catcode:NNTF` or `\token_if_eq_charcode:NNTF` or `\token_if_eq_meaning:NNTF`). The collected tokens are passed to the `<inline code>` as #1. When begin-group or end-group tokens (usually { or }) are collected they are replaced by implicit `\c_group_begin_token` and `\c_group_end_token`, and when spaces (including `\c_space_token`) are collected they are replaced by explicit spaces.

For example the following code prints “Hello” to the terminal and leave “, world!” in the input stream.

```
\peek_catcode_collect_inline:Nn A { \iow_term:n {#1} } Hello,~world!
```

Another example is that the following code tests if the next token is *, ignoring intervening spaces, but putting them back using #1 if there is no *.

```
\peek_meaning_collect_inline:Nn \c_space_token
{ \peek_charcode:NNTF * { star } { no~star #1 } }
```

<code>\peek_remove_spaces:n</code>	<code>\peek_remove_spaces:n {<code>}</code>
------------------------------------	---

New: 2018-10-01

Removes explicit and implicit space tokens (category code 10 and character code 32) from the input stream, then inserts `<code>`.

Part XXXV

Implementation

1 l3bootstrap implementation

```
1 <*initex | package>
2 <@@=kernel>
```

1.1 Format-specific code

The very first thing to do is to bootstrap the \TeX system so that everything else will actually work. \TeX does not start with some pretty basic character codes set up.

```
3 <*initex>
4 \catcode '\{ = 1 %
5 \catcode '\} = 2 %
6 \catcode '\# = 6 %
7 \catcode '\^ = 7 %
8 </initex>
```

Tab characters should not show up in the code, but to be on the safe side.

```
9 <*initex>
10 \catcode '\^^I = 10 %
```

```
11 </initex>
```

For LuaTeX, the extra primitives need to be enabled. This is not needed in package mode: common formats have the primitives enabled.

```
12 <*initex>
13 \begingroup\expandafter\expandafter\expandafter\endgroup
14 \expandafter\ifx\csname directlua\endcsname\relax
15 \else
16 \directlua{tex.enableprimitives("", tex.extraprimitives())}%
17 \fi
18 </initex>
```

Depending on the versions available, the L^AT_EX format may not have the raw `\Umath` primitive names available. We fix that globally: it should cause no issues. Older LuaTeX versions do not have a pre-built table of the primitive names here so sort one out ourselves. These end up globally-defined but at that is true with a newer format anyway and as they all start `\U` this should be reasonably safe.

```
19 <*package>
20 \begingroup
21 \expandafter\ifx\csname directlua\endcsname\relax
22 \else
23 \directlua{%
24     local i
25     local t = { }
26     for _,i in pairs(tex.extraprimitives("luatex")) do
27         if string.match(i,"^U") then
28             if not string.match(i,"^Uchar$") then %$
29                 table.insert(t,i)
30             end
31         end
32     end
33     tex.enableprimitives("", t)
34 }%
35 \fi
36 \endgroup
37 </package>
```

1.2 The `\pdfstrcmp` primitive in X_YTeX

Only pdfTeX has a primitive called `\pdfstrcmp`. The X_YTeX version is just `\strcmp`, so there is some shuffling to do. As this is still a real primitive, using the pdfTeX name is “safe”.

```
38 \begingroup\expandafter\expandafter\expandafter\endgroup
39 \expandafter\ifx\csname pdfstrcmp\endcsname\relax
40 \let\pdfstrcmp\strcmp
41 \fi
```

1.3 Loading support Lua code

When LuaTeX is used there are various pieces of Lua code which need to be loaded. The code itself is defined in `l3luatex` and is extracted into a separate file. Thus here the task is to load the Lua code both now and (if required) at the start of each job.

```
42 \begingroup\expandafter\expandafter\expandafter\endgroup
```

```

43 \expandafter\ifx\csname directlua\endcsname\relax
44 \else
45   \ifnum\luatexversion<70 %
46   \else

```

In package mode a category code table is needed: either use a pre-loaded allocator or provide one using the L^AT_EX 2_ε-based generic code. In format mode the table used here can be hard-coded into the Lua.

```

47 (*package)
48   \begingroup\expandafter\expandafter\expandafter\endgroup
49   \expandafter\ifx\csname newcatcodetable\endcsname\relax
50     \input{ltluatex}%
51   \fi
52   \newcatcodetable\ucharcat@table
53   \directlua{
54     l3kernel = l3kernel or { }
55     local charcat_table = \number\ucharcat@table\space
56     l3kernel.charcat_table = charcat_table
57   }%
58 \package
59   \directlua{require("expl3")}%

```

As the user might be making a custom format, no assumption is made about matching package mode with only loading the Lua code once. Instead, a query to Lua reveals what mode is in operation.

```

60   \ifnum 0%
61     \directlua{
62       if status.ini_version then
63         tex.write("1")
64       end
65     }>0 %
66     \everyjob\expandafter{%
67       \the\expandafter\everyjob
68       \csname\detokenize{lua_now:n}\endcsname{require("expl3")}%
69     }%
70   \fi
71 \fi
72 \fi

```

1.4 Engine requirements

The code currently requires ϵ -T_EX and functionality equivalent to `\pdfstrcmp`, and also driver and Unicode character support. This is available in a reasonably-wide range of engines.

```

73 \begingroup
74   \def\next{\endgroup}%
75   \def\ShortText{Required primitives not found}%
76   \def\LongText%
77     {%
78       LaTeX3 requires the e-TeX primitives and additional functionality as
79       described in the README file.
80       \LineBreak
81       These are available in the engines\LineBreak
82       - pdfTeX v1.40\LineBreak

```

```

83     - XeTeX v0.99992\LineBreak
84     - LuaTeX v0.76\LineBreak
85     - e-(u)pTeX mid-2012\LineBreak
86     or later.\LineBreak
87     \LineBreak
88 }%
89 \ifnum0%
90   \expandafter\ifx\csname pdfstrcmp\endcsname\relax
91   \else
92     \expandafter\ifx\csname pdftexversion\endcsname\relax
93       \expandafter\ifx\csname Ucharcat\endcsname\relax
94         \expandafter\ifx\csname kanjiskip\endcsname\relax
95         \else
96           1%
97         \fi
98       \else
99         1%
100      \fi
101    \else
102      \ifnum\pdftexversion<140 \else 1\fi
103    \fi
104  \fi
105  \expandafter\ifx\csname directlua\endcsname\relax
106  \else
107    \ifnum\luatexversion<76 \else 1\fi
108  \fi
109  =0 %
110  \newlinechar'\^^J %
111 <*\initex>
112   \def\LineBreak{^^J}%
113   \edef\next
114   {%
115     \errhelp
116     {%
117       \LongText
118       For pdfTeX and XeTeX the '-etex' command-line switch is also
119       needed.\LineBreak
120       \LineBreak
121       Format building will abort!\LineBreak
122     }%
123     \errmessage{\ShortText}%
124     \endgroup
125     \noexpand\end
126   }%
127 </\initex>
128 <*\package>
129   \def\LineBreak{\noexpand\MessageBreak}%
130   \expandafter\ifx\csname PackageError\endcsname\relax
131     \def\LineBreak{^^J}%
132     \def\PackageError#1#2#3%
133     {%
134       \errhelp{#3}%
135       \errmessage{#1 Error: #2}%
136     }%

```

```

137     \fi
138     \edef\next
139     {%
140         \noexpand\PackageError{expl3}{\ShortText}
141         {\LongText Loading of expl3 will abort!}%
142     \endgroup
143     \noexpand\endinput
144     }%
145 </package>
146 \fi
147 \next

```

1.5 Extending allocators

In format mode, allocating registers is handled by `l3alloc`. However, in package mode it’s much safer to rely on more general code. For example, the ability to extend \TeX ’s allocation routine to allow for $\varepsilon\text{-}\TeX$ has been around since 1997 in the `etex` package.

Loading this support is delayed until here as we are now sure that the $\varepsilon\text{-}\TeX$ extensions and `\pdfstrcmp` or equivalent are available. Thus there is no danger of an “uncontrolled” error if the engine requirements are not met.

For $\text{LaTeX}_{2\varepsilon}$ we need to make sure that the extended pool is being used: `expl3` uses a lot of registers. For formats from 2015 onward there is nothing to do as this is automatic. For older formats, the `etex` package needs to be loaded to do the job. In that case, some inserts are reserved also as these have to be from the standard pool. Note that `\reserveinserts` is `\outer` and so is accessed here by `csname`. In earlier versions, loading `etex` was done directly and so `\reserveinserts` appeared in the code: this then required a `\relax` after `\RequirePackage` to prevent an error with “unsafe” definitions as seen for example with `capoptions`. The optional loading here is done using a group and `\ifx` test as we are not quite in the position to have a single name for `\pdfstrcmp` just yet.

```

148 <*package>
149 \begingroup
150   \def\@tempa{LaTeX2e}%
151   \def\next{}%
152   \ifx\fmtname\@tempa
153     \expandafter\ifx\csname extrafloats\endcsname\relax
154       \def\next
155       {%
156         \RequirePackage{etex}%
157         \csname reserveinserts\endcsname{32}%
158       }%
159   \fi
160   \fi
161 \expandafter\endgroup
162 \next
163 </package>

```

1.6 Character data

\TeX needs various pieces of data to be set about characters, in particular which ones to treat as letters and which `\lccode` values apply as these affect hyphenation. It makes most sense to set this and related information up in one place. Whilst for LuaTeX

hyphenation patterns can be read anywhere, other engines have to build them into the format and so we *must* do this set up before reading the patterns. For the Unicode engines, there are shared loaders available to obtain the relevant information directly from the Unicode Consortium data files. These need standard (Ini)T_EX category codes and primitive availability and must therefore loaded *very* early. This has a knock-on effect on the 8-bit set up: it makes sense to do the definitions for those here as well so it is all in one place.

For X_YT_EX and LuaT_EX, which are natively Unicode engines, simply load the Unicode data.

```

164 <*initex>
165 \ifdefined\Umathcode
166   \input load-unicode-data %
167   \input load-unicode-math-classes %
168 \else

```

For the 8-bit engines a font encoding scheme must be chosen. At present, this is the EC (T1) scheme, with the assumption that languages for which this is not appropriate will be used with one of the Unicode engines.

```

169 \begingroup

```

Lower case chars: map to themselves when lower casing and down by "20 when upper casing. (The characters a–z are set up correctly by iniT_EX.)

```

170   \def\temp{%
171     \ifnum\count0>\count2 %
172     \else
173       \global\lccode\count0 = \count0 %
174       \global\uccode\count0 = \numexpr\count0 - "20\relax
175       \advance\count0 by 1 %
176       \expandafter\temp
177     \fi
178   }
179   \count0 = "A0 %
180   \count2 = "BC %
181   \temp
182   \count0 = "E0 %
183   \count2 = "FF %
184   \temp

```

Upper case chars: map up by "20 when lower casing, to themselves when upper casing and require an \sfcode of 999. (The characters A–Z are set up correctly by iniT_EX.)

```

185   \def\temp{%
186     \ifnum\count0>\count2 %
187     \else
188       \global\lccode\count0 = \numexpr\count0 + "20\relax
189       \global\uccode\count0 = \count0 %
190       \global\sfcode\count0 = 999 %
191       \advance\count0 by 1 %
192       \expandafter\temp
193     \fi
194   }
195   \count0 = "80 %
196   \count2 = "9C %
197   \temp
198   \count0 = "C0 %

```



```

199     \count2 = "DF %
200     \temp

```

A few special cases where things are not as one might expect using the above pattern: dotless-I, dotless-J, dotted-I and d-bar.

```

201     \global\lccode'\^Y = '\^Y %
202     \global\uccode'\^Y = '\I %
203     \global\lccode'\^Z = '\^Z %
204     \global\uccode'\^Y = '\J %
205     \global\lccode"9D = '\i %
206     \global\uccode"9D = "9D %
207     \global\lccode"9E = "9E %
208     \global\uccode"9E = "D0 %

```

Allow hyphenation at a zero-width glyph (used to break up ligatures or to place accents between characters).

```

209     \global\lccode23 = 23 %
210     \endgroup
211     \fi
212     </initex>

```

1.7 The \LaTeX 3 code environment

The code environment is now set up.

`\ExplSyntaxOff` Before changing any category codes, in package mode we need to save the situation before loading. Note the set up here means that once applied `\ExplSyntaxOff` becomes a “do nothing” command until `\ExplSyntaxOn` is used. For format mode, there is no need to save category codes so that step is skipped.

```

213 \protected\def\ExplSyntaxOff{%
214   <*package>
215   \protected\edef\ExplSyntaxOff
216     {%
217       \protected\def\ExplSyntaxOff{%
218         \catcode 9 = \the\catcode 9\relax
219         \catcode 32 = \the\catcode 32\relax
220         \catcode 34 = \the\catcode 34\relax
221         \catcode 38 = \the\catcode 38\relax
222         \catcode 58 = \the\catcode 58\relax
223         \catcode 94 = \the\catcode 94\relax
224         \catcode 95 = \the\catcode 95\relax
225         \catcode 124 = \the\catcode 124\relax
226         \catcode 126 = \the\catcode 126\relax
227         \endlinechar = \the\endlinechar\relax
228         \chardef\csname\detokenize{l__kernel_expl_bool}\endcsname = 0\relax
229       }%
230     </package>

```

(End definition for `\ExplSyntaxOff`. This function is documented on page 7.)

The code environment is now set up.

```

231 \catcode 9 = 9\relax
232 \catcode 32 = 9\relax
233 \catcode 34 = 12\relax
234 \catcode 38 = 4\relax

```

```

235 \catcode 58 = 11\relax
236 \catcode 94 = 7\relax
237 \catcode 95 = 11\relax
238 \catcode 124 = 12\relax
239 \catcode 126 = 10\relax
240 \endlinechar = 32\relax

```

`\l__kernel_expl_bool` The status for experimental code syntax: this is on at present.

```

241 \chardef\l__kernel_expl_bool = 1\relax

```

(End definition for \l__kernel_expl_bool.)

\ExplSyntaxOn The idea here is that multiple `\ExplSyntaxOn` calls are not going to mess up category codes, and that multiple calls to `\ExplSyntaxOff` are also not wasting time. Applying `\ExplSyntaxOn` alters the definition of `\ExplSyntaxOff` and so in package mode this function should not be used until after the end of the loading process!

```

242 \protected \def \ExplSyntaxOn
243 {
244   \bool_if:NF \l__kernel_expl_bool
245   {
246     \cs_set_protected:Npx \ExplSyntaxOff
247     {
248       \char_set_catcode:nn { 9 } { \char_value_catcode:n { 9 } }
249       \char_set_catcode:nn { 32 } { \char_value_catcode:n { 32 } }
250       \char_set_catcode:nn { 34 } { \char_value_catcode:n { 34 } }
251       \char_set_catcode:nn { 38 } { \char_value_catcode:n { 38 } }
252       \char_set_catcode:nn { 58 } { \char_value_catcode:n { 58 } }
253       \char_set_catcode:nn { 94 } { \char_value_catcode:n { 94 } }
254       \char_set_catcode:nn { 95 } { \char_value_catcode:n { 95 } }
255       \char_set_catcode:nn { 124 } { \char_value_catcode:n { 124 } }
256       \char_set_catcode:nn { 126 } { \char_value_catcode:n { 126 } }
257       \tex_endlinechar:D =
258       \tex_the:D \tex_endlinechar:D \scan_stop:
259       \bool_set_false:N \l__kernel_expl_bool
260       \cs_set_protected:Npn \ExplSyntaxOff { }
261     }
262   }
263   \char_set_catcode_ignore:n { 9 } % tab
264   \char_set_catcode_ignore:n { 32 } % space
265   \char_set_catcode_other:n { 34 } % double quote
266   \char_set_catcode_alignment:n { 38 } % ampersand
267   \char_set_catcode_letter:n { 58 } % colon
268   \char_set_catcode_math_superscript:n { 94 } % circumflex
269   \char_set_catcode_letter:n { 95 } % underscore
270   \char_set_catcode_other:n { 124 } % pipe
271   \char_set_catcode_space:n { 126 } % tilde
272   \tex_endlinechar:D = 32 \scan_stop:
273   \bool_set_true:N \l__kernel_expl_bool
274 }

```

(End definition for \ExplSyntaxOn. This function is documented on page 7.)

```

275 </initex | package>

```

2 l3names implementation

276 `<*initex | package>`

The prefix here is `kernel`. A few places need `@@` to be left as is; this is obtained as `@@@`.

277 `<@@=kernel>`

The code here simply renames all of the primitives to new, internal, names. In format mode, it also deletes all of the existing names (although some do come back later).

The `\let` primitive is renamed by hand first as it is essential for the entire process to follow. This also uses `\global`, as that way we avoid leaving an unneeded csname in the hash table.

278 `\let \tex_global:D \global`

279 `\let \tex_let:D \let`

Everything is inside a (rather long) group, which keeps `__kernel_primitive:NN` trapped.

280 `\begingroup`

`__kernel_primitive:NN` A temporary function to actually do the renaming. This also allows the original names to be removed in format mode.

281 `\long \def __kernel_primitive:NN #1#2`

282 `{`

283 `\tex_global:D \tex_let:D #2 #1`

284 `<*initex>`

285 `\tex_global:D \tex_let:D #1 \tex_undefined:D`

286 `</initex>`

287 `}`

(End definition for `__kernel_primitive:NN`.)

To allow extracting “just the names”, a bit of DocStrip fiddling.

288 `</initex | package>`

289 `<*initex | names | package>`

In the current incarnation of this package, all TeX primitives are given a new name of the form `\tex_oldname:D`. But first three special cases which have symbolic original names. These are given modified new names, so that they may be entered without catcode tricks.

290 `__kernel_primitive:NN \`

`\tex_space:D`

291 `__kernel_primitive:NN \/`

`\tex_italiccorrection:D`

292 `__kernel_primitive:NN \-`

`\tex_hyphen:D`

Now all the other primitives.

293 `__kernel_primitive:NN \above`

`\tex_above:D`

294 `__kernel_primitive:NN \abovedisplayshortskip`

`\tex_abovedisplayshortskip:D`

295 `__kernel_primitive:NN \abovedisplayskip`

`\tex_abovedisplayskip:D`

296 `__kernel_primitive:NN \abovewithdelims`

`\tex_abovewithdelims:D`

297 `__kernel_primitive:NN \accent`

`\tex_accent:D`

298 `__kernel_primitive:NN \adjdemerits`

`\tex_adjdemerits:D`

299 `__kernel_primitive:NN \advance`

`\tex_advance:D`

300 `__kernel_primitive:NN \afterassignment`

`\tex_afterassignment:D`

301 `__kernel_primitive:NN \aftergroup`

`\tex_aftergroup:D`

302 `__kernel_primitive:NN \atop`

`\tex_atop:D`

303 `__kernel_primitive:NN \atopwithdelims`

`\tex_atopwithdelims:D`

304 `__kernel_primitive:NN \badness`

`\tex_badness:D`

305	_kernel_primitive:NN	\baselineskip	\tex_baselineskip:D
306	_kernel_primitive:NN	\batchmode	\tex_batchmode:D
307	_kernel_primitive:NN	\begingroup	\tex_begingroup:D
308	_kernel_primitive:NN	\belowdisplayshortskip	\tex_belowdisplayshortskip:D
309	_kernel_primitive:NN	\belowdisplayskip	\tex_belowdisplayskip:D
310	_kernel_primitive:NN	\binoppenalty	\tex_binoppenalty:D
311	_kernel_primitive:NN	\botmark	\tex_botmark:D
312	_kernel_primitive:NN	\box	\tex_box:D
313	_kernel_primitive:NN	\boxmaxdepth	\tex_boxmaxdepth:D
314	_kernel_primitive:NN	\brokenpenalty	\tex_brokenpenalty:D
315	_kernel_primitive:NN	\catcode	\tex_catcode:D
316	_kernel_primitive:NN	\char	\tex_char:D
317	_kernel_primitive:NN	\chardef	\tex_chardef:D
318	_kernel_primitive:NN	\cleaders	\tex_cleaders:D
319	_kernel_primitive:NN	\closein	\tex_closein:D
320	_kernel_primitive:NN	\closeout	\tex_closeout:D
321	_kernel_primitive:NN	\clubpenalty	\tex_clubpenalty:D
322	_kernel_primitive:NN	\copy	\tex_copy:D
323	_kernel_primitive:NN	\count	\tex_count:D
324	_kernel_primitive:NN	\countdef	\tex_countdef:D
325	_kernel_primitive:NN	\cr	\tex_cr:D
326	_kernel_primitive:NN	\crrcr	\tex_crrcr:D
327	_kernel_primitive:NN	\csname	\tex_csname:D
328	_kernel_primitive:NN	\day	\tex_day:D
329	_kernel_primitive:NN	\deadcycles	\tex_deadcycles:D
330	_kernel_primitive:NN	\def	\tex_def:D
331	_kernel_primitive:NN	\defaultthyphenchar	\tex_defaultthyphenchar:D
332	_kernel_primitive:NN	\defaultskewchar	\tex_defaultskewchar:D
333	_kernel_primitive:NN	\delcode	\tex_delcode:D
334	_kernel_primitive:NN	\delimiter	\tex_delimiter:D
335	_kernel_primitive:NN	\delimiterfactor	\tex_delimiterfactor:D
336	_kernel_primitive:NN	\delimitershortfall	\tex_delimitershortfall:D
337	_kernel_primitive:NN	\dimen	\tex_dimen:D
338	_kernel_primitive:NN	\dimendef	\tex_dimendef:D
339	_kernel_primitive:NN	\discretionary	\tex_discretionary:D
340	_kernel_primitive:NN	\displayindent	\tex_displayindent:D
341	_kernel_primitive:NN	\displaylimits	\tex_displaylimits:D
342	_kernel_primitive:NN	\displaystyle	\tex_displaystyle:D
343	_kernel_primitive:NN	\displaywidowpenalty	\tex_displaywidowpenalty:D
344	_kernel_primitive:NN	\displaywidth	\tex_displaywidth:D
345	_kernel_primitive:NN	\divide	\tex_divide:D
346	_kernel_primitive:NN	\doublehyphendemerits	\tex_doublehyphendemerits:D
347	_kernel_primitive:NN	\dp	\tex_dp:D
348	_kernel_primitive:NN	\dump	\tex_dump:D
349	_kernel_primitive:NN	\edef	\tex_edef:D
350	_kernel_primitive:NN	\else	\tex_else:D
351	_kernel_primitive:NN	\emergencystretch	\tex_emergencystretch:D
352	_kernel_primitive:NN	\end	\tex_end:D
353	_kernel_primitive:NN	\endcsname	\tex_endcsname:D
354	_kernel_primitive:NN	\endgroup	\tex_endgroup:D
355	_kernel_primitive:NN	\endinput	\tex_endinput:D
356	_kernel_primitive:NN	\endlinechar	\tex_endlinechar:D
357	_kernel_primitive:NN	\eqno	\tex_eqno:D
358	_kernel_primitive:NN	\errhelp	\tex_errhelp:D

359	_kernel_primitive:NN	\errmessage	\tex_errmessage:D
360	_kernel_primitive:NN	\errorcontextlines	\tex_errorcontextlines:D
361	_kernel_primitive:NN	\errorstopmode	\tex_errorstopmode:D
362	_kernel_primitive:NN	\escapechar	\tex_escapechar:D
363	_kernel_primitive:NN	\everycr	\tex_everycr:D
364	_kernel_primitive:NN	\everydisplay	\tex_everydisplay:D
365	_kernel_primitive:NN	\everyhbox	\tex_everyhbox:D
366	_kernel_primitive:NN	\everyjob	\tex_everyjob:D
367	_kernel_primitive:NN	\everymath	\tex_everymath:D
368	_kernel_primitive:NN	\everypar	\tex_everypar:D
369	_kernel_primitive:NN	\everyvbox	\tex_everyvbox:D
370	_kernel_primitive:NN	\exhyphenpenalty	\tex_exhyphenpenalty:D
371	_kernel_primitive:NN	\expandafter	\tex_expandafter:D
372	_kernel_primitive:NN	\fam	\tex_fam:D
373	_kernel_primitive:NN	\fi	\tex_fi:D
374	_kernel_primitive:NN	\finalhyphendemerits	\tex_finalhyphendemerits:D
375	_kernel_primitive:NN	\firstmark	\tex_firstmark:D
376	_kernel_primitive:NN	\floatingpenalty	\tex_floatingpenalty:D
377	_kernel_primitive:NN	\font	\tex_font:D
378	_kernel_primitive:NN	\fontdimen	\tex_fontdimen:D
379	_kernel_primitive:NN	\fontname	\tex_fontname:D
380	_kernel_primitive:NN	\futurelet	\tex_futurelet:D
381	_kernel_primitive:NN	\gdef	\tex_gdef:D
382	_kernel_primitive:NN	\global	\tex_global:D
383	_kernel_primitive:NN	\globaldefs	\tex_globaldefs:D
384	_kernel_primitive:NN	\halign	\tex_halign:D
385	_kernel_primitive:NN	\hangafter	\tex_hangafter:D
386	_kernel_primitive:NN	\hangindent	\tex_hangindent:D
387	_kernel_primitive:NN	\hbadness	\tex_hbadness:D
388	_kernel_primitive:NN	\hbox	\tex_hbox:D
389	_kernel_primitive:NN	\hfil	\tex_hfil:D
390	_kernel_primitive:NN	\hfill	\tex_hfill:D
391	_kernel_primitive:NN	\hfilneg	\tex_hfilneg:D
392	_kernel_primitive:NN	\hfuzz	\tex_hfuzz:D
393	_kernel_primitive:NN	\hoffset	\tex_hoffset:D
394	_kernel_primitive:NN	\holdinginserts	\tex_holdinginserts:D
395	_kernel_primitive:NN	\hrule	\tex_hrule:D
396	_kernel_primitive:NN	\hsize	\tex_hsize:D
397	_kernel_primitive:NN	\hskip	\tex_hskip:D
398	_kernel_primitive:NN	\hss	\tex_hss:D
399	_kernel_primitive:NN	\ht	\tex_ht:D
400	_kernel_primitive:NN	\hyphenation	\tex_hyphenation:D
401	_kernel_primitive:NN	\hyphenchar	\tex_hyphenchar:D
402	_kernel_primitive:NN	\hyphenpenalty	\tex_hyphenpenalty:D
403	_kernel_primitive:NN	\if	\tex_if:D
404	_kernel_primitive:NN	\ifcase	\tex_ifcase:D
405	_kernel_primitive:NN	\ifcat	\tex_ifcat:D
406	_kernel_primitive:NN	\ifdim	\tex_ifdim:D
407	_kernel_primitive:NN	\ifeof	\tex_ifeof:D
408	_kernel_primitive:NN	\iffalse	\tex_iffalse:D
409	_kernel_primitive:NN	\ifhbox	\tex_ifhbox:D
410	_kernel_primitive:NN	\ifhmode	\tex_ifhmode:D
411	_kernel_primitive:NN	\ifinner	\tex_ifinner:D
412	_kernel_primitive:NN	\ifmmode	\tex_ifmmode:D

413	<code>_kernel_primitive:NN \ifnum</code>	<code>\tex_ifnum:D</code>
414	<code>_kernel_primitive:NN \ifodd</code>	<code>\tex_ifodd:D</code>
415	<code>_kernel_primitive:NN \iftrue</code>	<code>\tex_iftrue:D</code>
416	<code>_kernel_primitive:NN \ifvbox</code>	<code>\tex_ifvbox:D</code>
417	<code>_kernel_primitive:NN \ifvmode</code>	<code>\tex_ifvmode:D</code>
418	<code>_kernel_primitive:NN \ifvoid</code>	<code>\tex_ifvoid:D</code>
419	<code>_kernel_primitive:NN \ifx</code>	<code>\tex_ifx:D</code>
420	<code>_kernel_primitive:NN \ignorespaces</code>	<code>\tex_ignorespaces:D</code>
421	<code>_kernel_primitive:NN \immediate</code>	<code>\tex_immediate:D</code>
422	<code>_kernel_primitive:NN \indent</code>	<code>\tex_indent:D</code>
423	<code>_kernel_primitive:NN \input</code>	<code>\tex_input:D</code>
424	<code>_kernel_primitive:NN \inputlineno</code>	<code>\tex_inputlineno:D</code>
425	<code>_kernel_primitive:NN \insert</code>	<code>\tex_insert:D</code>
426	<code>_kernel_primitive:NN \insertpenalties</code>	<code>\tex_insertpenalties:D</code>
427	<code>_kernel_primitive:NN \interlinepenalty</code>	<code>\tex_interlinepenalty:D</code>
428	<code>_kernel_primitive:NN \jobname</code>	<code>\tex_jobname:D</code>
429	<code>_kernel_primitive:NN \kern</code>	<code>\tex_kern:D</code>
430	<code>_kernel_primitive:NN \language</code>	<code>\tex_language:D</code>
431	<code>_kernel_primitive:NN \lastbox</code>	<code>\tex_lastbox:D</code>
432	<code>_kernel_primitive:NN \lastkern</code>	<code>\tex_lastkern:D</code>
433	<code>_kernel_primitive:NN \lastpenalty</code>	<code>\tex_lastpenalty:D</code>
434	<code>_kernel_primitive:NN \lastskip</code>	<code>\tex_lastskip:D</code>
435	<code>_kernel_primitive:NN \lccode</code>	<code>\tex_lccode:D</code>
436	<code>_kernel_primitive:NN \leaders</code>	<code>\tex_leaders:D</code>
437	<code>_kernel_primitive:NN \left</code>	<code>\tex_left:D</code>
438	<code>_kernel_primitive:NN \lefthyphenmin</code>	<code>\tex_lefthyphenmin:D</code>
439	<code>_kernel_primitive:NN \leftskip</code>	<code>\tex_leftskip:D</code>
440	<code>_kernel_primitive:NN \leqno</code>	<code>\tex_leqno:D</code>
441	<code>_kernel_primitive:NN \let</code>	<code>\tex_let:D</code>
442	<code>_kernel_primitive:NN \limits</code>	<code>\tex_limits:D</code>
443	<code>_kernel_primitive:NN \linepenalty</code>	<code>\tex_linepenalty:D</code>
444	<code>_kernel_primitive:NN \lineskip</code>	<code>\tex_lineskip:D</code>
445	<code>_kernel_primitive:NN \lineskiplimit</code>	<code>\tex_lineskiplimit:D</code>
446	<code>_kernel_primitive:NN \long</code>	<code>\tex_long:D</code>
447	<code>_kernel_primitive:NN \looseness</code>	<code>\tex_looseness:D</code>
448	<code>_kernel_primitive:NN \lower</code>	<code>\tex_lower:D</code>
449	<code>_kernel_primitive:NN \lowercase</code>	<code>\tex_lowercase:D</code>
450	<code>_kernel_primitive:NN \mag</code>	<code>\tex_mag:D</code>
451	<code>_kernel_primitive:NN \mark</code>	<code>\tex_mark:D</code>
452	<code>_kernel_primitive:NN \mathaccent</code>	<code>\tex_mathaccent:D</code>
453	<code>_kernel_primitive:NN \mathbin</code>	<code>\tex_mathbin:D</code>
454	<code>_kernel_primitive:NN \mathchar</code>	<code>\tex_mathchar:D</code>
455	<code>_kernel_primitive:NN \mathchardef</code>	<code>\tex_mathchardef:D</code>
456	<code>_kernel_primitive:NN \mathchoice</code>	<code>\tex_mathchoice:D</code>
457	<code>_kernel_primitive:NN \mathclose</code>	<code>\tex_mathclose:D</code>
458	<code>_kernel_primitive:NN \mathcode</code>	<code>\tex_mathcode:D</code>
459	<code>_kernel_primitive:NN \mathinner</code>	<code>\tex_mathinner:D</code>
460	<code>_kernel_primitive:NN \mathop</code>	<code>\tex_mathop:D</code>
461	<code>_kernel_primitive:NN \mathopen</code>	<code>\tex_mathopen:D</code>
462	<code>_kernel_primitive:NN \mathord</code>	<code>\tex_mathord:D</code>
463	<code>_kernel_primitive:NN \mathpunct</code>	<code>\tex_mathpunct:D</code>
464	<code>_kernel_primitive:NN \mathrel</code>	<code>\tex_mathrel:D</code>
465	<code>_kernel_primitive:NN \mathsurround</code>	<code>\tex_mathsurround:D</code>
466	<code>_kernel_primitive:NN \maxdeadcycles</code>	<code>\tex_maxdeadcycles:D</code>

467	_kernel_primitive:NN	\maxdepth	\tex_maxdepth:D
468	_kernel_primitive:NN	\meaning	\tex_meaning:D
469	_kernel_primitive:NN	\medmuskip	\tex_medmuskip:D
470	_kernel_primitive:NN	\message	\tex_message:D
471	_kernel_primitive:NN	\mkern	\tex_mkern:D
472	_kernel_primitive:NN	\month	\tex_month:D
473	_kernel_primitive:NN	\moveleft	\tex_moveleft:D
474	_kernel_primitive:NN	\moveright	\tex_moveright:D
475	_kernel_primitive:NN	\mskip	\tex_mskip:D
476	_kernel_primitive:NN	\multiply	\tex_multiply:D
477	_kernel_primitive:NN	\muskip	\tex_muskip:D
478	_kernel_primitive:NN	\muskipdef	\tex_muskipdef:D
479	_kernel_primitive:NN	\newlinechar	\tex_newlinechar:D
480	_kernel_primitive:NN	\noalign	\tex_noalign:D
481	_kernel_primitive:NN	\noboundary	\tex_noboundary:D
482	_kernel_primitive:NN	\noexpand	\tex_noexpand:D
483	_kernel_primitive:NN	\noindent	\tex_noindent:D
484	_kernel_primitive:NN	\nolimits	\tex_nolimits:D
485	_kernel_primitive:NN	\nonscript	\tex_nonscript:D
486	_kernel_primitive:NN	\nonstopmode	\tex_nonstopmode:D
487	_kernel_primitive:NN	\nulldelimiterspace	\tex_nulldelimiterspace:D
488	_kernel_primitive:NN	\nullfont	\tex_nullfont:D
489	_kernel_primitive:NN	\number	\tex_number:D
490	_kernel_primitive:NN	\omit	\tex_omit:D
491	_kernel_primitive:NN	\openin	\tex_openin:D
492	_kernel_primitive:NN	\openout	\tex_openout:D
493	_kernel_primitive:NN	\or	\tex_or:D
494	_kernel_primitive:NN	\outer	\tex_outer:D
495	_kernel_primitive:NN	\output	\tex_output:D
496	_kernel_primitive:NN	\outputpenalty	\tex_outputpenalty:D
497	_kernel_primitive:NN	\over	\tex_over:D
498	_kernel_primitive:NN	\overfullrule	\tex_overfullrule:D
499	_kernel_primitive:NN	\overline	\tex_overline:D
500	_kernel_primitive:NN	\overwithdelims	\tex_overwithdelims:D
501	_kernel_primitive:NN	\pagedepth	\tex_pagedepth:D
502	_kernel_primitive:NN	\pagefilllstretch	\tex_pagefilllstretch:D
503	_kernel_primitive:NN	\pagefillstretch	\tex_pagefillstretch:D
504	_kernel_primitive:NN	\pagefilstretch	\tex_pagefilstretch:D
505	_kernel_primitive:NN	\pagegoal	\tex_pagegoal:D
506	_kernel_primitive:NN	\pageshrink	\tex_pageshrink:D
507	_kernel_primitive:NN	\pagestretch	\tex_pagestretch:D
508	_kernel_primitive:NN	\pagetotal	\tex_pagetotal:D
509	_kernel_primitive:NN	\par	\tex_par:D
510	_kernel_primitive:NN	\parfillskip	\tex_parfillskip:D
511	_kernel_primitive:NN	\parindent	\tex_parindent:D
512	_kernel_primitive:NN	\parshape	\tex_parshape:D
513	_kernel_primitive:NN	\parskip	\tex_parskip:D
514	_kernel_primitive:NN	\patterns	\tex_patterns:D
515	_kernel_primitive:NN	\pausing	\tex_pausing:D
516	_kernel_primitive:NN	\penalty	\tex_penalty:D
517	_kernel_primitive:NN	\postdisplaypenalty	\tex_postdisplaypenalty:D
518	_kernel_primitive:NN	\predisdisplaypenalty	\tex_predisdisplaypenalty:D
519	_kernel_primitive:NN	\predisplaysize	\tex_predisplaysize:D
520	_kernel_primitive:NN	\pretolerance	\tex_pretolerance:D

521	_kernel_primitive:NN	\prevdepth	\tex_prevdepth:D
522	_kernel_primitive:NN	\prevgraf	\tex_prevgraf:D
523	_kernel_primitive:NN	\radical	\tex_radical:D
524	_kernel_primitive:NN	\raise	\tex_raise:D
525	_kernel_primitive:NN	\read	\tex_read:D
526	_kernel_primitive:NN	\relax	\tex_relax:D
527	_kernel_primitive:NN	\relpenalty	\tex_relpenalty:D
528	_kernel_primitive:NN	\right	\tex_right:D
529	_kernel_primitive:NN	\righthyphenmin	\tex_righthyphenmin:D
530	_kernel_primitive:NN	\rightskip	\tex_rightskip:D
531	_kernel_primitive:NN	\romannumeral	\tex_romannumeral:D
532	_kernel_primitive:NN	\scriptfont	\tex_scriptfont:D
533	_kernel_primitive:NN	\scriptscriptfont	\tex_scriptscriptfont:D
534	_kernel_primitive:NN	\scriptscriptstyle	\tex_scriptscriptstyle:D
535	_kernel_primitive:NN	\scriptspace	\tex_scriptspace:D
536	_kernel_primitive:NN	\scriptstyle	\tex_scriptstyle:D
537	_kernel_primitive:NN	\scrollmode	\tex_scrollmode:D
538	_kernel_primitive:NN	\setbox	\tex_setbox:D
539	_kernel_primitive:NN	\setlanguage	\tex_setlanguage:D
540	_kernel_primitive:NN	\sfcode	\tex_sfcode:D
541	_kernel_primitive:NN	\shipout	\tex_shipout:D
542	_kernel_primitive:NN	\show	\tex_show:D
543	_kernel_primitive:NN	\showbox	\tex_showbox:D
544	_kernel_primitive:NN	\showboxbreadth	\tex_showboxbreadth:D
545	_kernel_primitive:NN	\showboxdepth	\tex_showboxdepth:D
546	_kernel_primitive:NN	\showlists	\tex_showlists:D
547	_kernel_primitive:NN	\showthe	\tex_showthe:D
548	_kernel_primitive:NN	\skewchar	\tex_skewchar:D
549	_kernel_primitive:NN	\skip	\tex_skip:D
550	_kernel_primitive:NN	\skipdef	\tex_skipdef:D
551	_kernel_primitive:NN	\spacefactor	\tex_spacefactor:D
552	_kernel_primitive:NN	\spaceskip	\tex_spaceskip:D
553	_kernel_primitive:NN	\span	\tex_span:D
554	_kernel_primitive:NN	\special	\tex_special:D
555	_kernel_primitive:NN	\splitbotmark	\tex_splitbotmark:D
556	_kernel_primitive:NN	\splitfirstmark	\tex_splitfirstmark:D
557	_kernel_primitive:NN	\splitmaxdepth	\tex_splitmaxdepth:D
558	_kernel_primitive:NN	\splittopskip	\tex_splittopskip:D
559	_kernel_primitive:NN	\string	\tex_string:D
560	_kernel_primitive:NN	\tabskip	\tex_tabskip:D
561	_kernel_primitive:NN	\textfont	\tex_textfont:D
562	_kernel_primitive:NN	\textstyle	\tex_textstyle:D
563	_kernel_primitive:NN	\the	\tex_the:D
564	_kernel_primitive:NN	\thickmuskip	\tex_thickmuskip:D
565	_kernel_primitive:NN	\thinmuskip	\tex_thinmuskip:D
566	_kernel_primitive:NN	\time	\tex_time:D
567	_kernel_primitive:NN	\toks	\tex_toks:D
568	_kernel_primitive:NN	\toksdef	\tex_toksdef:D
569	_kernel_primitive:NN	\tolerance	\tex_tolerance:D
570	_kernel_primitive:NN	\topmark	\tex_topmark:D
571	_kernel_primitive:NN	\topskip	\tex_topskip:D
572	_kernel_primitive:NN	\tracingcommands	\tex_tracingcommands:D
573	_kernel_primitive:NN	\tracinglostchars	\tex_tracinglostchars:D
574	_kernel_primitive:NN	\tracingmacros	\tex_tracingmacros:D

575	<code>_kernel_primitive:NN</code>	<code>\tracingonline</code>	<code>\tex_tracingonline:D</code>
576	<code>_kernel_primitive:NN</code>	<code>\tracingoutput</code>	<code>\tex_tracingoutput:D</code>
577	<code>_kernel_primitive:NN</code>	<code>\tracingpages</code>	<code>\tex_tracingpages:D</code>
578	<code>_kernel_primitive:NN</code>	<code>\tracingparagraphs</code>	<code>\tex_tracingparagraphs:D</code>
579	<code>_kernel_primitive:NN</code>	<code>\tracingrestores</code>	<code>\tex_tracingrestores:D</code>
580	<code>_kernel_primitive:NN</code>	<code>\tracingstats</code>	<code>\tex_tracingstats:D</code>
581	<code>_kernel_primitive:NN</code>	<code>\uccode</code>	<code>\tex_uccode:D</code>
582	<code>_kernel_primitive:NN</code>	<code>\uchyph</code>	<code>\tex_uchyph:D</code>
583	<code>_kernel_primitive:NN</code>	<code>\underline</code>	<code>\tex_underline:D</code>
584	<code>_kernel_primitive:NN</code>	<code>\unhbox</code>	<code>\tex_unhbox:D</code>
585	<code>_kernel_primitive:NN</code>	<code>\unhcopy</code>	<code>\tex_unhcopy:D</code>
586	<code>_kernel_primitive:NN</code>	<code>\unkern</code>	<code>\tex_unkern:D</code>
587	<code>_kernel_primitive:NN</code>	<code>\unpenalty</code>	<code>\tex_unpenalty:D</code>
588	<code>_kernel_primitive:NN</code>	<code>\unskip</code>	<code>\tex_unskip:D</code>
589	<code>_kernel_primitive:NN</code>	<code>\unvbox</code>	<code>\tex_unvbox:D</code>
590	<code>_kernel_primitive:NN</code>	<code>\unvcopy</code>	<code>\tex_unvcopy:D</code>
591	<code>_kernel_primitive:NN</code>	<code>\uppercase</code>	<code>\tex_uppercase:D</code>
592	<code>_kernel_primitive:NN</code>	<code>\vadjust</code>	<code>\tex_vadjust:D</code>
593	<code>_kernel_primitive:NN</code>	<code>\valign</code>	<code>\tex_valign:D</code>
594	<code>_kernel_primitive:NN</code>	<code>\vbadness</code>	<code>\tex_vbadness:D</code>
595	<code>_kernel_primitive:NN</code>	<code>\vbox</code>	<code>\tex_vbox:D</code>
596	<code>_kernel_primitive:NN</code>	<code>\vcenter</code>	<code>\tex_vcenter:D</code>
597	<code>_kernel_primitive:NN</code>	<code>\vfil</code>	<code>\tex_vfil:D</code>
598	<code>_kernel_primitive:NN</code>	<code>\vfill</code>	<code>\tex_vfill:D</code>
599	<code>_kernel_primitive:NN</code>	<code>\vfилneg</code>	<code>\tex_vfилneg:D</code>
600	<code>_kernel_primitive:NN</code>	<code>\vfuzz</code>	<code>\tex_vfuzz:D</code>
601	<code>_kernel_primitive:NN</code>	<code>\voffset</code>	<code>\tex_voffset:D</code>
602	<code>_kernel_primitive:NN</code>	<code>\vrule</code>	<code>\tex_vrule:D</code>
603	<code>_kernel_primitive:NN</code>	<code>\vsize</code>	<code>\tex_vsize:D</code>
604	<code>_kernel_primitive:NN</code>	<code>\vskip</code>	<code>\tex_vskip:D</code>
605	<code>_kernel_primitive:NN</code>	<code>\vsplit</code>	<code>\tex_vsplit:D</code>
606	<code>_kernel_primitive:NN</code>	<code>\vss</code>	<code>\tex_vss:D</code>
607	<code>_kernel_primitive:NN</code>	<code>\vtop</code>	<code>\tex_vtop:D</code>
608	<code>_kernel_primitive:NN</code>	<code>\wd</code>	<code>\tex_wd:D</code>
609	<code>_kernel_primitive:NN</code>	<code>\widowpenalty</code>	<code>\tex_widowpenalty:D</code>
610	<code>_kernel_primitive:NN</code>	<code>\write</code>	<code>\tex_write:D</code>
611	<code>_kernel_primitive:NN</code>	<code>\xdef</code>	<code>\tex_xdef:D</code>
612	<code>_kernel_primitive:NN</code>	<code>\xleaders</code>	<code>\tex_xleaders:D</code>
613	<code>_kernel_primitive:NN</code>	<code>\xspaceskip</code>	<code>\tex_xspaceskip:D</code>
614	<code>_kernel_primitive:NN</code>	<code>\year</code>	<code>\tex_year:D</code>

Primitives introduced by ϵ -TeX.

615	<code>_kernel_primitive:NN</code>	<code>\beginL</code>	<code>\tex_beginL:D</code>
616	<code>_kernel_primitive:NN</code>	<code>\beginR</code>	<code>\tex_beginR:D</code>
617	<code>_kernel_primitive:NN</code>	<code>\botmarks</code>	<code>\tex_botmarks:D</code>
618	<code>_kernel_primitive:NN</code>	<code>\clubpenalties</code>	<code>\tex_clubpenalties:D</code>
619	<code>_kernel_primitive:NN</code>	<code>\currentgrouplevel</code>	<code>\tex_currentgrouplevel:D</code>
620	<code>_kernel_primitive:NN</code>	<code>\currentgrouptype</code>	<code>\tex_currentgrouptype:D</code>
621	<code>_kernel_primitive:NN</code>	<code>\currentifbranch</code>	<code>\tex_currentifbranch:D</code>
622	<code>_kernel_primitive:NN</code>	<code>\currentiflevel</code>	<code>\tex_currentiflevel:D</code>
623	<code>_kernel_primitive:NN</code>	<code>\currentifttype</code>	<code>\tex_currentifttype:D</code>
624	<code>_kernel_primitive:NN</code>	<code>\detokenize</code>	<code>\tex_detokenize:D</code>
625	<code>_kernel_primitive:NN</code>	<code>\dimexpr</code>	<code>\tex_dimexpr:D</code>
626	<code>_kernel_primitive:NN</code>	<code>\displaywidowpenalties</code>	<code>\tex_displaywidowpenalties:D</code>
627	<code>_kernel_primitive:NN</code>	<code>\endL</code>	<code>\tex_endL:D</code>

628	<code>__kernel_primitive:NN \endR</code>	<code>\tex_endR:D</code>
629	<code>__kernel_primitive:NN \eTeXrevision</code>	<code>\tex_eTeXrevision:D</code>
630	<code>__kernel_primitive:NN \eTeXversion</code>	<code>\tex_eTeXversion:D</code>
631	<code>__kernel_primitive:NN \everyeof</code>	<code>\tex_everyeof:D</code>
632	<code>__kernel_primitive:NN \firstmarks</code>	<code>\tex_firstmarks:D</code>
633	<code>__kernel_primitive:NN \fontchardp</code>	<code>\tex_fontchardp:D</code>
634	<code>__kernel_primitive:NN \fontcharht</code>	<code>\tex_fontcharht:D</code>
635	<code>__kernel_primitive:NN \fontcharic</code>	<code>\tex_fontcharic:D</code>
636	<code>__kernel_primitive:NN \fontcharwd</code>	<code>\tex_fontcharwd:D</code>
637	<code>__kernel_primitive:NN \glueexpr</code>	<code>\tex_glueexpr:D</code>
638	<code>__kernel_primitive:NN \glueshrink</code>	<code>\tex_glueshrink:D</code>
639	<code>__kernel_primitive:NN \glueshrinkorder</code>	<code>\tex_glueshrinkorder:D</code>
640	<code>__kernel_primitive:NN \gluestretch</code>	<code>\tex_gluestretch:D</code>
641	<code>__kernel_primitive:NN \gluestretchorder</code>	<code>\tex_gluestretchorder:D</code>
642	<code>__kernel_primitive:NN \gluetomu</code>	<code>\tex_gluetomu:D</code>
643	<code>__kernel_primitive:NN \ifcsname</code>	<code>\tex_ifcsname:D</code>
644	<code>__kernel_primitive:NN \ifdefined</code>	<code>\tex_ifdefined:D</code>
645	<code>__kernel_primitive:NN \iffontchar</code>	<code>\tex_iffontchar:D</code>
646	<code>__kernel_primitive:NN \interactionmode</code>	<code>\tex_interactionmode:D</code>
647	<code>__kernel_primitive:NN \interlinepenalties</code>	<code>\tex_interlinepenalties:D</code>
648	<code>__kernel_primitive:NN \lastlinefit</code>	<code>\tex_lastlinefit:D</code>
649	<code>__kernel_primitive:NN \lastnodetype</code>	<code>\tex_lastnodetype:D</code>
650	<code>__kernel_primitive:NN \marks</code>	<code>\tex_marks:D</code>
651	<code>__kernel_primitive:NN \middle</code>	<code>\tex_middle:D</code>
652	<code>__kernel_primitive:NN \muexpr</code>	<code>\tex_muexpr:D</code>
653	<code>__kernel_primitive:NN \mutoglua</code>	<code>\tex_mutoglua:D</code>
654	<code>__kernel_primitive:NN \numexpr</code>	<code>\tex_numexpr:D</code>
655	<code>__kernel_primitive:NN \pagediscards</code>	<code>\tex_pagediscards:D</code>
656	<code>__kernel_primitive:NN \parshapedimen</code>	<code>\tex_parshapedimen:D</code>
657	<code>__kernel_primitive:NN \parshapeindent</code>	<code>\tex_parshapeindent:D</code>
658	<code>__kernel_primitive:NN \parshapelength</code>	<code>\tex_parshapelength:D</code>
659	<code>__kernel_primitive:NN \predisplaydirection</code>	<code>\tex_predisplaydirection:D</code>
660	<code>__kernel_primitive:NN \protected</code>	<code>\tex_protected:D</code>
661	<code>__kernel_primitive:NN \readline</code>	<code>\tex_readline:D</code>
662	<code>__kernel_primitive:NN \savinghyphcodes</code>	<code>\tex_savinghyphcodes:D</code>
663	<code>__kernel_primitive:NN \savingvdiscards</code>	<code>\tex_savingvdiscards:D</code>
664	<code>__kernel_primitive:NN \scantokens</code>	<code>\tex_scantokens:D</code>
665	<code>__kernel_primitive:NN \showgroups</code>	<code>\tex_showgroups:D</code>
666	<code>__kernel_primitive:NN \showifs</code>	<code>\tex_showifs:D</code>
667	<code>__kernel_primitive:NN \showtokens</code>	<code>\tex_showtokens:D</code>
668	<code>__kernel_primitive:NN \splitbotmarks</code>	<code>\tex_splitbotmarks:D</code>
669	<code>__kernel_primitive:NN \splitdiscards</code>	<code>\tex_splitdiscards:D</code>
670	<code>__kernel_primitive:NN \splitfirstmarks</code>	<code>\tex_splitfirstmarks:D</code>
671	<code>__kernel_primitive:NN \TeXeTstate</code>	<code>\tex_TeXeTstate:D</code>
672	<code>__kernel_primitive:NN \topmarks</code>	<code>\tex_topmarks:D</code>
673	<code>__kernel_primitive:NN \tracingassigns</code>	<code>\tex_tracingassigns:D</code>
674	<code>__kernel_primitive:NN \tracinggroups</code>	<code>\tex_tracinggroups:D</code>
675	<code>__kernel_primitive:NN \tracingifs</code>	<code>\tex_tracingifs:D</code>
676	<code>__kernel_primitive:NN \tracingnesting</code>	<code>\tex_tracingnesting:D</code>
677	<code>__kernel_primitive:NN \tracingscantokens</code>	<code>\tex_tracingscantokens:D</code>
678	<code>__kernel_primitive:NN \unexpanded</code>	<code>\tex_unexpanded:D</code>
679	<code>__kernel_primitive:NN \unless</code>	<code>\tex_unless:D</code>
680	<code>__kernel_primitive:NN \widowpenalties</code>	<code>\tex_widowpenalties:D</code>

Post- ϵ -TeX primitives do not always end up with the same name in all engines, if indeed

they are available cross-engine anyway. We therefore take the approach of preferring the shortest name that makes sense. First, we deal with the primitives introduced by pdfTeX which directly relate to PDF output: these are copied with the names unchanged.

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681 \__kernel_primitive:NN \pdfannot \tex_pdfannot:D
682 \__kernel_primitive:NN \pdfcatalog \tex_pdfcatalog:D
683 \__kernel_primitive:NN \pdfcompresslevel \tex_pdfcompresslevel:D
684 \__kernel_primitive:NN \pdfcolorstack \tex_pdfcolorstack:D
685 \__kernel_primitive:NN \pdfcolorstackinit \tex_pdfcolorstackinit:D
686 \__kernel_primitive:NN \pdfcreationdate \tex_pdfcreationdate:D
687 \__kernel_primitive:NN \pdfdecimaldigits \tex_pdfdecimaldigits:D
688 \__kernel_primitive:NN \pdfdest \tex_pdfdest:D
689 \__kernel_primitive:NN \pdfdestmargin \tex_pdfdestmargin:D
690 \__kernel_primitive:NN \pdfendlink \tex_pdfendlink:D
691 \__kernel_primitive:NN \pdfendthread \tex_pdfendthread:D
692 \__kernel_primitive:NN \pdffontattr \tex_pdffontattr:D
693 \__kernel_primitive:NN \pdffontname \tex_pdffontname:D
694 \__kernel_primitive:NN \pdffontobjnum \tex_pdffontobjnum:D
695 \__kernel_primitive:NN \pdfgamma \tex_pdfgamma:D
696 \__kernel_primitive:NN \pdfimageapplygamma \tex_pdfimageapplygamma:D
697 \__kernel_primitive:NN \pdfimagegamma \tex_pdfimagegamma:D
698 \__kernel_primitive:NN \pdfgentounicode \tex_pdfgentounicode:D
699 \__kernel_primitive:NN \pdfglyptounicode \tex_pdfglyptounicode:D
700 \__kernel_primitive:NN \pdfhorigin \tex_pdfhorigin:D
701 \__kernel_primitive:NN \pdfimagehicolor \tex_pdfimagehicolor:D
702 \__kernel_primitive:NN \pdfimageresolution \tex_pdfimageresolution:D
703 \__kernel_primitive:NN \pdfincludechars \tex_pdfincludechars:D
704 \__kernel_primitive:NN \pdfinclusioncopyfonts \tex_pdfinclusioncopyfonts:D
705 \__kernel_primitive:NN \pdfinclusionerrorlevel
706 \tex_pdfinclusionerrorlevel:D
707 \__kernel_primitive:NN \pdfinfo \tex_pdfinfo:D
708 \__kernel_primitive:NN \pdflastannot \tex_pdflastannot:D
709 \__kernel_primitive:NN \pdflastlink \tex_pdflastlink:D
710 \__kernel_primitive:NN \pdflastobj \tex_pdflastobj:D
711 \__kernel_primitive:NN \pdflastxform \tex_pdflastxform:D
712 \__kernel_primitive:NN \pdflastximage \tex_pdflastximage:D
713 \__kernel_primitive:NN \pdflastximagecolordepth
714 \tex_pdflastximagecolordepth:D
715 \__kernel_primitive:NN \pdflastximagepages \tex_pdflastximagepages:D
716 \__kernel_primitive:NN \pdflinkmargin \tex_pdflinkmargin:D
717 \__kernel_primitive:NN \pdfliteral \tex_pdfliteral:D
718 \__kernel_primitive:NN \pdfminorversion \tex_pdfminorversion:D
719 \__kernel_primitive:NN \pdfnames \tex_pdfnames:D
720 \__kernel_primitive:NN \pdfobj \tex_pdfobj:D
721 \__kernel_primitive:NN \pdfobjcompresslevel \tex_pdfobjcompresslevel:D
722 \__kernel_primitive:NN \pdfoutline \tex_pdfoutline:D
723 \__kernel_primitive:NN \pdfoutput \tex_pdfoutput:D
724 \__kernel_primitive:NN \pdfpageattr \tex_pdfpageattr:D
725 \__kernel_primitive:NN \pdfpagesattr \tex_pdfpagesattr:D
726 \__kernel_primitive:NN \pdfpagebox \tex_pdfpagebox:D
727 \__kernel_primitive:NN \pdfpageref \tex_pdfpageref:D
728 \__kernel_primitive:NN \pdfpageresources \tex_pdfpageresources:D
729 \__kernel_primitive:NN \pdfpagesattr \tex_pdfpagesattr:D
730 \__kernel_primitive:NN \pdfrefobj \tex_pdfrefobj:D
731 \__kernel_primitive:NN \pdfrefxform \tex_pdfrefxform:D

```

732	_kernel_primitive:NN	\pdfrefximage	\tex_pdfrefximage:D
733	_kernel_primitive:NN	\pdfrestore	\tex_pdfrestore:D
734	_kernel_primitive:NN	\pdfretval	\tex_pdfretval:D
735	_kernel_primitive:NN	\pdfsave	\tex_pdfsave:D
736	_kernel_primitive:NN	\pdfsetmatrix	\tex_pdfsetmatrix:D
737	_kernel_primitive:NN	\pdfstartlink	\tex_pdfstartlink:D
738	_kernel_primitive:NN	\pdfstartthread	\tex_pdfstartthread:D
739	_kernel_primitive:NN	\pdfsuppressptexinfo	\tex_pdfsuppressptexinfo:D
740	_kernel_primitive:NN	\pdfthread	\tex_pdfthread:D
741	_kernel_primitive:NN	\pdfthreadmargin	\tex_pdfthreadmargin:D
742	_kernel_primitive:NN	\pdftrailer	\tex_pdftrailer:D
743	_kernel_primitive:NN	\pdfuniquestring	\tex_pdfuniquestring:D
744	_kernel_primitive:NN	\pdfvorigin	\tex_pdfvorigin:D
745	_kernel_primitive:NN	\pdfxform	\tex_pdfxform:D
746	_kernel_primitive:NN	\pdfxformattr	\tex_pdfxformattr:D
747	_kernel_primitive:NN	\pdfxformname	\tex_pdfxformname:D
748	_kernel_primitive:NN	\pdfxformresources	\tex_pdfxformresources:D
749	_kernel_primitive:NN	\pdfximage	\tex_pdfximage:D
750	_kernel_primitive:NN	\pdfximagebbox	\tex_pdfximagebbox:D

These are not related to PDF output and either already appear in other engines without the \pdf prefix, or might reasonably do so at some future stage. We therefore drop the leading pdf here.

751	_kernel_primitive:NN	\ifpdfabsdim	\tex_ifabsdim:D
752	_kernel_primitive:NN	\ifpdfabsnum	\tex_ifabsnum:D
753	_kernel_primitive:NN	\ifpdfprimitive	\tex_ifprimitive:D
754	_kernel_primitive:NN	\pdfadjustspacing	\tex_adjustspacing:D
755	_kernel_primitive:NN	\pdfcopyfont	\tex_copyfont:D
756	_kernel_primitive:NN	\pdfdraftmode	\tex_draftmode:D
757	_kernel_primitive:NN	\pdfeachlinedepth	\tex_eachlinedepth:D
758	_kernel_primitive:NN	\pdfeachlineheight	\tex_eachlineheight:D
759	_kernel_primitive:NN	\pdfelapsedtime	\tex_elapsedtime:D
760	_kernel_primitive:NN	\pdffiledump	\tex_filedump:D
761	_kernel_primitive:NN	\pdffilemoddate	\tex_filemoddate:D
762	_kernel_primitive:NN	\pdffilesize	\tex_filesize:D
763	_kernel_primitive:NN	\pdffirstlineheight	\tex_firstlineheight:D
764	_kernel_primitive:NN	\pdffontexpand	\tex_fontexpand:D
765	_kernel_primitive:NN	\pdffontsize	\tex_fontsize:D
766	_kernel_primitive:NN	\pdfignoreddimen	\tex_ignoreddimen:D
767	_kernel_primitive:NN	\pdfinsertht	\tex_insertht:D
768	_kernel_primitive:NN	\pdflastlinedepth	\tex_lastlinedepth:D
769	_kernel_primitive:NN	\pdflastxpos	\tex_lastxpos:D
770	_kernel_primitive:NN	\pdflastypos	\tex_lastypos:D
771	_kernel_primitive:NN	\pdfmapfile	\tex_mapfile:D
772	_kernel_primitive:NN	\pdfmapline	\tex_mapline:D
773	_kernel_primitive:NN	\pdfmdfivesum	\tex_mdfivesum:D
774	_kernel_primitive:NN	\pdfnoligatures	\tex_noligatures:D
775	_kernel_primitive:NN	\pdfnormaldeviate	\tex_normaldeviate:D
776	_kernel_primitive:NN	\pdfpageheight	\tex_pageheight:D
777	_kernel_primitive:NN	\pdfpagewidth	\tex_pagewidth:D
778	_kernel_primitive:NN	\pdfpkmode	\tex_pkmode:D
779	_kernel_primitive:NN	\pdfpkresolution	\tex_pkresolution:D
780	_kernel_primitive:NN	\pdfprimitive	\tex_primitive:D
781	_kernel_primitive:NN	\pdfprotrudechars	\tex_protrudechars:D

```

782 \__kernel_primitive:NN \pdfpxdimen \tex_pxdimen:D
783 \__kernel_primitive:NN \pdfrandomseed \tex_randomseed:D
784 \__kernel_primitive:NN \pdfresettimer \tex_resettimer:D
785 \__kernel_primitive:NN \pdfsavepos \tex_savepos:D
786 \__kernel_primitive:NN \pdfstrcmp \tex_strcmp:D
787 \__kernel_primitive:NN \pdfsetrandomseed \tex_setrandomseed:D
788 \__kernel_primitive:NN \pdfshellescape \tex_shellescape:D
789 \__kernel_primitive:NN \pdftracingfonts \tex_tracingfonts:D
790 \__kernel_primitive:NN \pdfuniformdeviate \tex_uniformdeviate:D

```

The version primitives are not related to PDF mode but are pdfTeX-specific, so again are carried forward unchanged.

```

791 \__kernel_primitive:NN \pdfTeXbanner \tex_pdfTeXbanner:D
792 \__kernel_primitive:NN \pdfTeXrevision \tex_pdfTeXrevision:D
793 \__kernel_primitive:NN \pdfTeXversion \tex_pdfTeXversion:D

```

These ones appear in pdfTeX but don't have pdf in the name at all: no decisions to make.

```

794 \__kernel_primitive:NN \efcode \tex_efcode:D
795 \__kernel_primitive:NN \ifincsname \tex_ifincsname:D
796 \__kernel_primitive:NN \leftmarginkern \tex_leftmarginkern:D
797 \__kernel_primitive:NN \letterspacefont \tex_letterspacefont:D
798 \__kernel_primitive:NN \lpcode \tex_lpcode:D
799 \__kernel_primitive:NN \quitvmode \tex_quitvmode:D
800 \__kernel_primitive:NN \rightmarginkern \tex_rightmarginkern:D
801 \__kernel_primitive:NN \rpcode \tex_rpcode:D
802 \__kernel_primitive:NN \synctex \tex_synctex:D
803 \__kernel_primitive:NN \tagcode \tex_tagcode:D

```

Post pdfTeX primitive availability gets more complex. Both XeTeX and LuaTeX have varying names for some primitives from pdfTeX. Particularly for LuaTeX tracking all of that would be hard. Instead, we now check that we only save primitives if they actually exist.

```

804 </initex | names | package>
805 <*:initex | package>
806 \tex_long:D \tex_def:D \use_ii:nn #1#2 {#2}
807 \tex_long:D \tex_def:D \use_none:n #1 { }
808 \tex_long:D \tex_def:D \__kernel_primitive:NN #1#2
809 {
810   \tex_ifdefined:D #1
811   \tex_expandafter:D \use_ii:nn
812   \tex_fi:D
813   \use_none:n { \tex_global:D \tex_let:D #2 #1 }
814 <*:initex>
815   \tex_global:D \tex_let:D #1 \tex_undefined:D
816 </initex>
817 }
818 </initex | package>
819 <*:initex | names | package>

```

XeTeX-specific primitives. Note that XeTeX's `\strcmp` is handled earlier and is “rolled up” into `\pdfstrcmp`. A few cross-compatibility names which lack the pdf of the original are handled later.

```

820 \__kernel_primitive:NN \suppressfontnotfounderror
821 \tex_suppressfontnotfounderror:D

```

```

822 \__kernel_primitive:NN \XeTeXcharclass \tex_XeTeXcharclass:D
823 \__kernel_primitive:NN \XeTeXcharglyph \tex_XeTeXcharglyph:D
824 \__kernel_primitive:NN \XeTeXcountfeatures \tex_XeTeXcountfeatures:D
825 \__kernel_primitive:NN \XeTeXcountglyphs \tex_XeTeXcountglyphs:D
826 \__kernel_primitive:NN \XeTeXcountselectors \tex_XeTeXcountselectors:D
827 \__kernel_primitive:NN \XeTeXcountvariations \tex_XeTeXcountvariations:D
828 \__kernel_primitive:NN \XeTeXdefaultencoding \tex_XeTeXdefaultencoding:D
829 \__kernel_primitive:NN \XeTeXdashbreakstate \tex_XeTeXdashbreakstate:D
830 \__kernel_primitive:NN \XeTeXfeaturecode \tex_XeTeXfeaturecode:D
831 \__kernel_primitive:NN \XeTeXfeaturename \tex_XeTeXfeaturename:D
832 \__kernel_primitive:NN \XeTeXfindfeaturebyname
833 \tex_XeTeXfindfeaturebyname:D
834 \__kernel_primitive:NN \XeTeXfindselectorbyname
835 \tex_XeTeXfindselectorbyname:D
836 \__kernel_primitive:NN \XeTeXfindvariationbyname
837 \tex_XeTeXfindvariationbyname:D
838 \__kernel_primitive:NN \XeTeXfirstfontchar \tex_XeTeXfirstfontchar:D
839 \__kernel_primitive:NN \XeTeXfonttype \tex_XeTeXfonttype:D
840 \__kernel_primitive:NN \XeTeXgenerateactualtext
841 \tex_XeTeXgenerateactualtext:D
842 \__kernel_primitive:NN \XeTeXglyph \tex_XeTeXglyph:D
843 \__kernel_primitive:NN \XeTeXglyphbounds \tex_XeTeXglyphbounds:D
844 \__kernel_primitive:NN \XeTeXglyphindex \tex_XeTeXglyphindex:D
845 \__kernel_primitive:NN \XeTeXglyphname \tex_XeTeXglyphname:D
846 \__kernel_primitive:NN \XeTeXinputencoding \tex_XeTeXinputencoding:D
847 \__kernel_primitive:NN \XeTeXinputnormalization
848 \tex_XeTeXinputnormalization:D
849 \__kernel_primitive:NN \XeTeXinterchartokenstate
850 \tex_XeTeXinterchartokenstate:D
851 \__kernel_primitive:NN \XeTeXinterchartoks \tex_XeTeXinterchartoks:D
852 \__kernel_primitive:NN \XeTeXisdefaultselector
853 \tex_XeTeXisdefaultselector:D
854 \__kernel_primitive:NN \XeTeXisexclusivefeature
855 \tex_XeTeXisexclusivefeature:D
856 \__kernel_primitive:NN \XeTeXlastfontchar \tex_XeTeXlastfontchar:D
857 \__kernel_primitive:NN \XeTeXlinebreakskip \tex_XeTeXlinebreakskip:D
858 \__kernel_primitive:NN \XeTeXlinebreaklocale \tex_XeTeXlinebreaklocale:D
859 \__kernel_primitive:NN \XeTeXlinebreakpenalty \tex_XeTeXlinebreakpenalty:D
860 \__kernel_primitive:NN \XeTeXOTcountfeatures \tex_XeTeXOTcountfeatures:D
861 \__kernel_primitive:NN \XeTeXOTcountlanguages \tex_XeTeXOTcountlanguages:D
862 \__kernel_primitive:NN \XeTeXOTcountscripts \tex_XeTeXOTcountscripts:D
863 \__kernel_primitive:NN \XeTeXOTfeaturetag \tex_XeTeXOTfeaturetag:D
864 \__kernel_primitive:NN \XeTeXOTlanguagetag \tex_XeTeXOTlanguagetag:D
865 \__kernel_primitive:NN \XeTeXOTscripttag \tex_XeTeXOTscripttag:D
866 \__kernel_primitive:NN \XeTeXpdffile \tex_XeTeXpdffile:D
867 \__kernel_primitive:NN \XeTeXpdfpagecount \tex_XeTeXpdfpagecount:D
868 \__kernel_primitive:NN \XeTeXpicfile \tex_XeTeXpicfile:D
869 \__kernel_primitive:NN \XeTeXrevision \tex_XeTeXrevision:D
870 \__kernel_primitive:NN \XeTeXselectorname \tex_XeTeXselectorname:D
871 \__kernel_primitive:NN \XeTeXtracingfonts \tex_XeTeXtracingfonts:D
872 \__kernel_primitive:NN \XeTeXupwardsmode \tex_XeTeXupwardsmode:D
873 \__kernel_primitive:NN \XeTeXuseglyphmetrics \tex_XeTeXuseglyphmetrics:D
874 \__kernel_primitive:NN \XeTeXvariation \tex_XeTeXvariation:D
875 \__kernel_primitive:NN \XeTeXvariationdefault \tex_XeTeXvariationdefault:D

```

876	<code>__kernel_primitive:NN \XeTeXvariationmax</code>	<code>\tex_XeTeXvariationmax:D</code>
877	<code>__kernel_primitive:NN \XeTeXvariationmin</code>	<code>\tex_XeTeXvariationmin:D</code>
878	<code>__kernel_primitive:NN \XeTeXvariationname</code>	<code>\tex_XeTeXvariationname:D</code>
879	<code>__kernel_primitive:NN \XeTeXversion</code>	<code>\tex_XeTeXversion:D</code>

Primitives from pdfTeX that XeTeX renames: also helps with LuaTeX.

880	<code>__kernel_primitive:NN \creationdate</code>	<code>\tex_creationdate:D</code>
881	<code>__kernel_primitive:NN \elapsedtime</code>	<code>\tex_elapsedtime:D</code>
882	<code>__kernel_primitive:NN \filedump</code>	<code>\tex_filedump:D</code>
883	<code>__kernel_primitive:NN \filemoddate</code>	<code>\tex_filemoddate:D</code>
884	<code>__kernel_primitive:NN \filesize</code>	<code>\tex_filesize:D</code>
885	<code>__kernel_primitive:NN \mdfivesum</code>	<code>\tex_mdfivesum:D</code>
886	<code>__kernel_primitive:NN \ifprimitive</code>	<code>\tex_ifprimitive:D</code>
887	<code>__kernel_primitive:NN \primitive</code>	<code>\tex_primitive:D</code>
888	<code>__kernel_primitive:NN \resettimer</code>	<code>\tex_resettimer:D</code>
889	<code>__kernel_primitive:NN \shellescape</code>	<code>\tex_shellescape:D</code>

Primitives from LuaTeX, some of which have been ported back to XeTeX.

890	<code>__kernel_primitive:NN \alignmark</code>	<code>\tex_alignmark:D</code>
891	<code>__kernel_primitive:NN \aligntab</code>	<code>\tex_aligntab:D</code>
892	<code>__kernel_primitive:NN \attribute</code>	<code>\tex_attribute:D</code>
893	<code>__kernel_primitive:NN \attributedef</code>	<code>\tex_attributedef:D</code>
894	<code>__kernel_primitive:NN \automaticdiscretionary</code>	
895	<code>\tex_automaticdiscretionary:D</code>	
896	<code>__kernel_primitive:NN \automatichyphenmode</code>	<code>\tex_automatichyphenmode:D</code>
897	<code>__kernel_primitive:NN \automatichyphenpenalty</code>	
898	<code>\tex_automatichyphenpenalty:D</code>	
899	<code>__kernel_primitive:NN \beginscname</code>	<code>\tex_beginscname:D</code>
900	<code>__kernel_primitive:NN \bodydir</code>	<code>\tex_bodydir:D</code>
901	<code>__kernel_primitive:NN \bodydirection</code>	<code>\tex_bodydirection:D</code>
902	<code>__kernel_primitive:NN \boxdir</code>	<code>\tex_boxdir:D</code>
903	<code>__kernel_primitive:NN \boxdirection</code>	<code>\tex_boxdirection:D</code>
904	<code>__kernel_primitive:NN \breakafterdirmode</code>	<code>\tex_breakafterdirmode:D</code>
905	<code>__kernel_primitive:NN \catcodetable</code>	<code>\tex_catcodetable:D</code>
906	<code>__kernel_primitive:NN \clearmarks</code>	<code>\tex_clearmarks:D</code>
907	<code>__kernel_primitive:NN \crampeddisplaystyle</code>	<code>\tex_crampeddisplaystyle:D</code>
908	<code>__kernel_primitive:NN \crampedscriptscriptstyle</code>	
909	<code>\tex_crampedscriptscriptstyle:D</code>	
910	<code>__kernel_primitive:NN \crampedscriptstyle</code>	<code>\tex_crampedscriptstyle:D</code>
911	<code>__kernel_primitive:NN \crampedtextstyle</code>	<code>\tex_crampedtextstyle:D</code>
912	<code>__kernel_primitive:NN \csstring</code>	<code>\tex_csstring:D</code>
913	<code>__kernel_primitive:NN \directlua</code>	<code>\tex_directlua:D</code>
914	<code>__kernel_primitive:NN \dviextension</code>	<code>\tex_dviextension:D</code>
915	<code>__kernel_primitive:NN \dvifedback</code>	<code>\tex_dvifedback:D</code>
916	<code>__kernel_primitive:NN \dvivariable</code>	<code>\tex_dvivariable:D</code>
917	<code>__kernel_primitive:NN \etoksapp</code>	<code>\tex_etoksapp:D</code>
918	<code>__kernel_primitive:NN \etokspre</code>	<code>\tex_etokspre:D</code>
919	<code>__kernel_primitive:NN \exceptionpenalty</code>	<code>\tex_exceptionpenalty:D</code>
920	<code>__kernel_primitive:NN \explicithyphenpenalty</code>	<code>\tex_explicithyphenpenalty:D</code>
921	<code>__kernel_primitive:NN \expanded</code>	<code>\tex_expanded:D</code>
922	<code>__kernel_primitive:NN \explicitdiscretionary</code>	<code>\tex_explicitdiscretionary:D</code>
923	<code>__kernel_primitive:NN \firstvalidlanguage</code>	<code>\tex_firstvalidlanguage:D</code>
924	<code>__kernel_primitive:NN \fontid</code>	<code>\tex_fontid:D</code>
925	<code>__kernel_primitive:NN \formatname</code>	<code>\tex_formatname:D</code>
926	<code>__kernel_primitive:NN \hjcode</code>	<code>\tex_hjcode:D</code>

927	_kernel_primitive:NN	\hpack	\tex_hpack:D
928	_kernel_primitive:NN	\hyphenationbounds	\tex_hyphenationbounds:D
929	_kernel_primitive:NN	\hyphenationmin	\tex_hyphenationmin:D
930	_kernel_primitive:NN	\hyphenpenaltymode	\tex_hyphenpenaltymode:D
931	_kernel_primitive:NN	\gleaders	\tex_gleaders:D
932	_kernel_primitive:NN	\ifcondition	\tex_ifcondition:D
933	_kernel_primitive:NN	\immediateassigned	\tex_immediateassigned:D
934	_kernel_primitive:NN	\immediateassignment	\tex_immediateassignment:D
935	_kernel_primitive:NN	\initcatcodetable	\tex_initcatcodetable:D
936	_kernel_primitive:NN	\lastnamedcs	\tex_lastnamedcs:D
937	_kernel_primitive:NN	\latalua	\tex_latalua:D
938	_kernel_primitive:NN	\lataluafunction	\tex_lataluafunction:D
939	_kernel_primitive:NN	\leftghost	\tex_leftghost:D
940	_kernel_primitive:NN	\letcharcode	\tex_letcharcode:D
941	_kernel_primitive:NN	\linedir	\tex_linedir:D
942	_kernel_primitive:NN	\linedirection	\tex_linedirection:D
943	_kernel_primitive:NN	\localbrokenpenalty	\tex_localbrokenpenalty:D
944	_kernel_primitive:NN	\localinterlinepenalty	\tex_localinterlinepenalty:D
945	_kernel_primitive:NN	\luabytecode	\tex_luabytecode:D
946	_kernel_primitive:NN	\luabytecodecall	\tex_luabytecodecall:D
947	_kernel_primitive:NN	\luacopyinputnodes	\tex_luacopyinputnodes:D
948	_kernel_primitive:NN	\luadef	\tex_luadef:D
949	_kernel_primitive:NN	\lcalleftbox	\tex_lcalleftbox:D
950	_kernel_primitive:NN	\lcalrightbox	\tex_lcalrightbox:D
951	_kernel_primitive:NN	\luaescapestring	\tex_luaescapestring:D
952	_kernel_primitive:NN	\luafunction	\tex_luafunction:D
953	_kernel_primitive:NN	\luafunctioncall	\tex_luafunctioncall:D
954	_kernel_primitive:NN	\luatexbanner	\tex_luatexbanner:D
955	_kernel_primitive:NN	\luatexrevision	\tex_luatexrevision:D
956	_kernel_primitive:NN	\luatexversion	\tex_luatexversion:D
957	_kernel_primitive:NN	\mathdelimitersmode	\tex_mathdelimitersmode:D
958	_kernel_primitive:NN	\mathdir	\tex_mathdir:D
959	_kernel_primitive:NN	\mathdirection	\tex_mathdirection:D
960	_kernel_primitive:NN	\mathdisplayskipmode	\tex_mathdisplayskipmode:D
961	_kernel_primitive:NN	\matheqnogapstep	\tex_matheqnogapstep:D
962	_kernel_primitive:NN	\mathnolimitsmode	\tex_mathnolimitsmode:D
963	_kernel_primitive:NN	\mathoption	\tex_mathoption:D
964	_kernel_primitive:NN	\mathpenaltiesmode	\tex_mathpenaltiesmode:D
965	_kernel_primitive:NN	\mathrulesfam	\tex_mathrulesfam:D
966	_kernel_primitive:NN	\mathscriptsmode	\tex_mathscriptsmode:D
967	_kernel_primitive:NN	\mathscriptboxmode	\tex_mathscriptboxmode:D
968	_kernel_primitive:NN	\mathscriptcharmode	\tex_mathscriptcharmode:D
969	_kernel_primitive:NN	\mathstyle	\tex_mathstyle:D
970	_kernel_primitive:NN	\mathsurroundmode	\tex_mathsurroundmode:D
971	_kernel_primitive:NN	\mathsurroundskip	\tex_mathsurroundskip:D
972	_kernel_primitive:NN	\nohrule	\tex_nohrule:D
973	_kernel_primitive:NN	\nokerns	\tex_nokerns:D
974	_kernel_primitive:NN	\noligs	\tex_noligs:D
975	_kernel_primitive:NN	\nospaces	\tex_nospaces:D
976	_kernel_primitive:NN	\novrule	\tex_novrule:D
977	_kernel_primitive:NN	\outputbox	\tex_outputbox:D
978	_kernel_primitive:NN	\pagebottomoffset	\tex_pagebottomoffset:D
979	_kernel_primitive:NN	\pagedir	\tex_pagedir:D
980	_kernel_primitive:NN	\pagedirection	\tex_pagedirection:D

981	<code>_kernel_primitive:NN</code>	<code>\pageleftoffset</code>	<code>\tex_pageleftoffset:D</code>
982	<code>_kernel_primitive:NN</code>	<code>\pagerightoffset</code>	<code>\tex_pagerightoffset:D</code>
983	<code>_kernel_primitive:NN</code>	<code>\pagetopoffset</code>	<code>\tex_pagetopoffset:D</code>
984	<code>_kernel_primitive:NN</code>	<code>\pardir</code>	<code>\tex_pardir:D</code>
985	<code>_kernel_primitive:NN</code>	<code>\pardirection</code>	<code>\tex_pardirection:D</code>
986	<code>_kernel_primitive:NN</code>	<code>\pdfextension</code>	<code>\tex_pdfextension:D</code>
987	<code>_kernel_primitive:NN</code>	<code>\pdffeedback</code>	<code>\tex_pdffeedback:D</code>
988	<code>_kernel_primitive:NN</code>	<code>\pdfvariable</code>	<code>\tex_pdfvariable:D</code>
989	<code>_kernel_primitive:NN</code>	<code>\postexhyphenchar</code>	<code>\tex_postexhyphenchar:D</code>
990	<code>_kernel_primitive:NN</code>	<code>\posthyphenchar</code>	<code>\tex_posthyphenchar:D</code>
991	<code>_kernel_primitive:NN</code>	<code>\prebinoppenalty</code>	<code>\tex_prebinoppenalty:D</code>
992	<code>_kernel_primitive:NN</code>	<code>\predisplaygapfactor</code>	<code>\tex_predisplaygapfactor:D</code>
993	<code>_kernel_primitive:NN</code>	<code>\preexhyphenchar</code>	<code>\tex_preexhyphenchar:D</code>
994	<code>_kernel_primitive:NN</code>	<code>\prehyphenchar</code>	<code>\tex_prehyphenchar:D</code>
995	<code>_kernel_primitive:NN</code>	<code>\prerelpenalty</code>	<code>\tex_prerelpenalty:D</code>
996	<code>_kernel_primitive:NN</code>	<code>\rightghost</code>	<code>\tex_rightghost:D</code>
997	<code>_kernel_primitive:NN</code>	<code>\savecatcodetable</code>	<code>\tex_savecatcodetable:D</code>
998	<code>_kernel_primitive:NN</code>	<code>\scantextokens</code>	<code>\tex_scantextokens:D</code>
999	<code>_kernel_primitive:NN</code>	<code>\setfontid</code>	<code>\tex_setfontid:D</code>
1000	<code>_kernel_primitive:NN</code>	<code>\shapemode</code>	<code>\tex_shapemode:D</code>
1001	<code>_kernel_primitive:NN</code>	<code>\suppressifcsnameerror</code>	<code>\tex_suppressifcsnameerror:D</code>
1002	<code>_kernel_primitive:NN</code>	<code>\suppresslongerror</code>	<code>\tex_suppresslongerror:D</code>
1003	<code>_kernel_primitive:NN</code>	<code>\suppressmathparerror</code>	<code>\tex_suppressmathparerror:D</code>
1004	<code>_kernel_primitive:NN</code>	<code>\suppressoutererror</code>	<code>\tex_suppressoutererror:D</code>
1005	<code>_kernel_primitive:NN</code>	<code>\suppressprimitiveerror</code>	
1006		<code>\tex_suppressprimitiveerror:D</code>	
1007	<code>_kernel_primitive:NN</code>	<code>\textdir</code>	<code>\tex_textdir:D</code>
1008	<code>_kernel_primitive:NN</code>	<code>\texdirection</code>	<code>\tex_texdirection:D</code>
1009	<code>_kernel_primitive:NN</code>	<code>\toksapp</code>	<code>\tex_toksapp:D</code>
1010	<code>_kernel_primitive:NN</code>	<code>\tokspre</code>	<code>\tex_tokspre:D</code>
1011	<code>_kernel_primitive:NN</code>	<code>\tpack</code>	<code>\tex_tpack:D</code>
1012	<code>_kernel_primitive:NN</code>	<code>\vpack</code>	<code>\tex_vpack:D</code>

Primitives from pdfTeX that LuaTeX renames.

1013	<code>_kernel_primitive:NN</code>	<code>\adjustspacing</code>	<code>\tex_adjustspacing:D</code>
1014	<code>_kernel_primitive:NN</code>	<code>\copyfont</code>	<code>\tex_copyfont:D</code>
1015	<code>_kernel_primitive:NN</code>	<code>\draftmode</code>	<code>\tex_draftmode:D</code>
1016	<code>_kernel_primitive:NN</code>	<code>\expandglyphsinfont</code>	<code>\tex_fontexpand:D</code>
1017	<code>_kernel_primitive:NN</code>	<code>\ifabsdim</code>	<code>\tex_ifabsdim:D</code>
1018	<code>_kernel_primitive:NN</code>	<code>\ifabsnum</code>	<code>\tex_ifabsnum:D</code>
1019	<code>_kernel_primitive:NN</code>	<code>\ignoreligaturesinfont</code>	<code>\tex_ignoreligaturesinfont:D</code>
1020	<code>_kernel_primitive:NN</code>	<code>\insertht</code>	<code>\tex_insertht:D</code>
1021	<code>_kernel_primitive:NN</code>	<code>\lastsavedboxresourceindex</code>	
1022		<code>\tex_pdflastxform:D</code>	
1023	<code>_kernel_primitive:NN</code>	<code>\lastsavedimageresourceindex</code>	
1024		<code>\tex_pdflastximage:D</code>	
1025	<code>_kernel_primitive:NN</code>	<code>\lastsavedimageresourcepages</code>	
1026		<code>\tex_pdflastximagepages:D</code>	
1027	<code>_kernel_primitive:NN</code>	<code>\lastxpos</code>	<code>\tex_lastxpos:D</code>
1028	<code>_kernel_primitive:NN</code>	<code>\lastypos</code>	<code>\tex_lastypos:D</code>
1029	<code>_kernel_primitive:NN</code>	<code>\normaldeviate</code>	<code>\tex_normaldeviate:D</code>
1030	<code>_kernel_primitive:NN</code>	<code>\outputmode</code>	<code>\tex_pdfoutput:D</code>
1031	<code>_kernel_primitive:NN</code>	<code>\pageheight</code>	<code>\tex_pageheight:D</code>
1032	<code>_kernel_primitive:NN</code>	<code>\pagewidth</code>	<code>\tex_pagewidth:D</code>
1033	<code>_kernel_primitive:NN</code>	<code>\protrudechars</code>	<code>\tex_protrudechars:D</code>

1034	<code>__kernel_primitive:NN</code>	<code>\pxdimen</code>	<code>\tex_pxdimen:D</code>
1035	<code>__kernel_primitive:NN</code>	<code>\randomseed</code>	<code>\tex_randomseed:D</code>
1036	<code>__kernel_primitive:NN</code>	<code>\useboxresource</code>	<code>\tex_pdfrefxform:D</code>
1037	<code>__kernel_primitive:NN</code>	<code>\useimageresource</code>	<code>\tex_pdfrefximage:D</code>
1038	<code>__kernel_primitive:NN</code>	<code>\savepos</code>	<code>\tex_savepos:D</code>
1039	<code>__kernel_primitive:NN</code>	<code>\saveboxresource</code>	<code>\tex_pdfxform:D</code>
1040	<code>__kernel_primitive:NN</code>	<code>\saveimageresource</code>	<code>\tex_pdfximage:D</code>
1041	<code>__kernel_primitive:NN</code>	<code>\setrandomseed</code>	<code>\tex_setrandomseed:D</code>
1042	<code>__kernel_primitive:NN</code>	<code>\tracingfonts</code>	<code>\tex_tracingfonts:D</code>
1043	<code>__kernel_primitive:NN</code>	<code>\uniformdeviate</code>	<code>\tex_uniformdeviate:D</code>

The set of Unicode math primitives were introduced by \XeTeX and \LuaTeX in a somewhat complex fashion: a few first as \XeTeX ... which were then renamed with \LuaTeX having a lot more. These names now all start \U... and mainly \Umath....

1044	<code>__kernel_primitive:NN</code>	<code>\Uchar</code>	<code>\tex_Uchar:D</code>
1045	<code>__kernel_primitive:NN</code>	<code>\Ucharcat</code>	<code>\tex_Ucharcat:D</code>
1046	<code>__kernel_primitive:NN</code>	<code>\Udelcode</code>	<code>\tex_Udelcode:D</code>
1047	<code>__kernel_primitive:NN</code>	<code>\Udelcodenum</code>	<code>\tex_Udelcodenum:D</code>
1048	<code>__kernel_primitive:NN</code>	<code>\Udelimiter</code>	<code>\tex_Udelimiter:D</code>
1049	<code>__kernel_primitive:NN</code>	<code>\Udelimiterover</code>	<code>\tex_Udelimiterover:D</code>
1050	<code>__kernel_primitive:NN</code>	<code>\Udelimiterunder</code>	<code>\tex_Udelimiterunder:D</code>
1051	<code>__kernel_primitive:NN</code>	<code>\Uhextensible</code>	<code>\tex_Uhextensible:D</code>
1052	<code>__kernel_primitive:NN</code>	<code>\Umathaccent</code>	<code>\tex_Umathaccent:D</code>
1053	<code>__kernel_primitive:NN</code>	<code>\Umathaxis</code>	<code>\tex_Umathaxis:D</code>
1054	<code>__kernel_primitive:NN</code>	<code>\Umathbinbinspacing</code>	<code>\tex_Umathbinbinspacing:D</code>
1055	<code>__kernel_primitive:NN</code>	<code>\Umathbinclonespacing</code>	<code>\tex_Umathbinclonespacing:D</code>
1056	<code>__kernel_primitive:NN</code>	<code>\Umathbininnerspacing</code>	<code>\tex_Umathbininnerspacing:D</code>
1057	<code>__kernel_primitive:NN</code>	<code>\Umathbinopenspacing</code>	<code>\tex_Umathbinopenspacing:D</code>
1058	<code>__kernel_primitive:NN</code>	<code>\Umathbinopspacing</code>	<code>\tex_Umathbinopspacing:D</code>
1059	<code>__kernel_primitive:NN</code>	<code>\Umathbinordspacing</code>	<code>\tex_Umathbinordspacing:D</code>
1060	<code>__kernel_primitive:NN</code>	<code>\Umathbinpunctspacing</code>	<code>\tex_Umathbinpunctspacing:D</code>
1061	<code>__kernel_primitive:NN</code>	<code>\Umathbinrelspacing</code>	<code>\tex_Umathbinrelspacing:D</code>
1062	<code>__kernel_primitive:NN</code>	<code>\Umathchar</code>	<code>\tex_Umathchar:D</code>
1063	<code>__kernel_primitive:NN</code>	<code>\Umathcharclass</code>	<code>\tex_Umathcharclass:D</code>
1064	<code>__kernel_primitive:NN</code>	<code>\Umathchardef</code>	<code>\tex_Umathchardef:D</code>
1065	<code>__kernel_primitive:NN</code>	<code>\Umathcharfam</code>	<code>\tex_Umathcharfam:D</code>
1066	<code>__kernel_primitive:NN</code>	<code>\Umathcharnum</code>	<code>\tex_Umathcharnum:D</code>
1067	<code>__kernel_primitive:NN</code>	<code>\Umathcharnumdef</code>	<code>\tex_Umathcharnumdef:D</code>
1068	<code>__kernel_primitive:NN</code>	<code>\Umathcharslot</code>	<code>\tex_Umathcharslot:D</code>
1069	<code>__kernel_primitive:NN</code>	<code>\Umathclosebinspacing</code>	<code>\tex_Umathclosebinspacing:D</code>
1070	<code>__kernel_primitive:NN</code>	<code>\Umathcloseclonespacing</code>	
1071		<code>\tex_Umathcloseclonespacing:D</code>	
1072	<code>__kernel_primitive:NN</code>	<code>\Umathcloseinnerspacing</code>	
1073		<code>\tex_Umathcloseinnerspacing:D</code>	
1074	<code>__kernel_primitive:NN</code>	<code>\Umathcloseopenspacing</code>	<code>\tex_Umathcloseopenspacing:D</code>
1075	<code>__kernel_primitive:NN</code>	<code>\Umathcloseopspacing</code>	<code>\tex_Umathcloseopspacing:D</code>
1076	<code>__kernel_primitive:NN</code>	<code>\Umathcloseordspacing</code>	<code>\tex_Umathcloseordspacing:D</code>
1077	<code>__kernel_primitive:NN</code>	<code>\Umathclosepunctspacing</code>	
1078		<code>\tex_Umathclosepunctspacing:D</code>	
1079	<code>__kernel_primitive:NN</code>	<code>\Umathcloserelspacing</code>	<code>\tex_Umathcloserelspacing:D</code>
1080	<code>__kernel_primitive:NN</code>	<code>\Umathcode</code>	<code>\tex_Umathcode:D</code>
1081	<code>__kernel_primitive:NN</code>	<code>\Umathcodenum</code>	<code>\tex_Umathcodenum:D</code>
1082	<code>__kernel_primitive:NN</code>	<code>\Umathconnectoroverlapmin</code>	
1083		<code>\tex_Umathconnectoroverlapmin:D</code>	

1084 __kernel_primitive:NN \Umathfractiondelsize \tex_Umathfractiondelsize:D
1085 __kernel_primitive:NN \Umathfractiondenomdown
1086 \tex_Umathfractiondenomdown:D
1087 __kernel_primitive:NN \Umathfractiondenomvgap
1088 \tex_Umathfractiondenomvgap:D
1089 __kernel_primitive:NN \Umathfractionnumup \tex_Umathfractionnumup:D
1090 __kernel_primitive:NN \Umathfractionnumvgap \tex_Umathfractionnumvgap:D
1091 __kernel_primitive:NN \Umathfractionrule \tex_Umathfractionrule:D
1092 __kernel_primitive:NN \Umathinnerbinspacing \tex_Umathinnerbinspacing:D
1093 __kernel_primitive:NN \Umathinnerclosespacing
1094 \tex_Umathinnerclosespacing:D
1095 __kernel_primitive:NN \Umathinnerinnerspacing
1096 \tex_Umathinnerinnerspacing:D
1097 __kernel_primitive:NN \Umathinneropenspacing \tex_Umathinneropenspacing:D
1098 __kernel_primitive:NN \Umathinnerordspacing \tex_Umathinnerordspacing:D
1099 __kernel_primitive:NN \Umathinnerordspacing \tex_Umathinnerordspacing:D
1100 __kernel_primitive:NN \Umathinnerpunctspacing
1101 \tex_Umathinnerpunctspacing:D
1102 __kernel_primitive:NN \Umathinnerrelspacing \tex_Umathinnerrelspacing:D
1103 __kernel_primitive:NN \Umathlimitabovegap \tex_Umathlimitabovegap:D
1104 __kernel_primitive:NN \Umathlimitabovekern \tex_Umathlimitabovekern:D
1105 __kernel_primitive:NN \Umathlimitabovevgap \tex_Umathlimitabovevgap:D
1106 __kernel_primitive:NN \Umathlimitbelowgap \tex_Umathlimitbelowgap:D
1107 __kernel_primitive:NN \Umathlimitbelowkern \tex_Umathlimitbelowkern:D
1108 __kernel_primitive:NN \Umathlimitbelowvgap \tex_Umathlimitbelowvgap:D
1109 __kernel_primitive:NN \Umathnolimitsubfactor \tex_Umathnolimitsubfactor:D
1110 __kernel_primitive:NN \Umathnolimitsupfactor \tex_Umathnolimitsupfactor:D
1111 __kernel_primitive:NN \Umathopbinspacing \tex_Umathopbinspacing:D
1112 __kernel_primitive:NN \Umathopclosespacing \tex_Umathopclosespacing:D
1113 __kernel_primitive:NN \Umathopenbinspacing \tex_Umathopenbinspacing:D
1114 __kernel_primitive:NN \Umathopenenclosespacing \tex_Umathopenenclosespacing:D
1115 __kernel_primitive:NN \Umathopeninnerspacing \tex_Umathopeninnerspacing:D
1116 __kernel_primitive:NN \Umathopenopenspacing \tex_Umathopenopenspacing:D
1117 __kernel_primitive:NN \Umathopenopspacing \tex_Umathopenopspacing:D
1118 __kernel_primitive:NN \Umathopenordspacing \tex_Umathopenordspacing:D
1119 __kernel_primitive:NN \Umathopenpunctspacing \tex_Umathopenpunctspacing:D
1120 __kernel_primitive:NN \Umathopenrelspacing \tex_Umathopenrelspacing:D
1121 __kernel_primitive:NN \Umathoperatorsize \tex_Umathoperatorsize:D
1122 __kernel_primitive:NN \Umathoppinnerspacing \tex_Umathoppinnerspacing:D
1123 __kernel_primitive:NN \Umathopopenspacing \tex_Umathopopenspacing:D
1124 __kernel_primitive:NN \Umathopopspacing \tex_Umathopopspacing:D
1125 __kernel_primitive:NN \Umathopordspacing \tex_Umathopordspacing:D
1126 __kernel_primitive:NN \Umathoppunctspacing \tex_Umathoppunctspacing:D
1127 __kernel_primitive:NN \Umathoprelspacing \tex_Umathoprelspacing:D
1128 __kernel_primitive:NN \Umathordbinspacing \tex_Umathordbinspacing:D
1129 __kernel_primitive:NN \Umathordclosespacing \tex_Umathordclosespacing:D
1130 __kernel_primitive:NN \Umathordinnerspacing \tex_Umathordinnerspacing:D
1131 __kernel_primitive:NN \Umathordopenspacing \tex_Umathordopenspacing:D
1132 __kernel_primitive:NN \Umathordopspacing \tex_Umathordopspacing:D
1133 __kernel_primitive:NN \Umathordordspacing \tex_Umathordordspacing:D
1134 __kernel_primitive:NN \Umathordpunctspacing \tex_Umathordpunctspacing:D
1135 __kernel_primitive:NN \Umathordrelspacing \tex_Umathordrelspacing:D
1136 __kernel_primitive:NN \Umathoverbarkern \tex_Umathoverbarkern:D
1137 __kernel_primitive:NN \Umathoverbarrule \tex_Umathoverbarrule:D

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1138 \__kernel_primitive:NN \Umathoverbarvgap \tex_Umathoverbarvgap:D
1139 \__kernel_primitive:NN \Umathoverdelimiterbgap
1140 \tex_Umathoverdelimiterbgap:D
1141 \__kernel_primitive:NN \Umathoverdelimitervgap
1142 \tex_Umathoverdelimitervgap:D
1143 \__kernel_primitive:NN \Umathpunctbinspacing \tex_Umathpunctbinspacing:D
1144 \__kernel_primitive:NN \Umathpunctclosespacing
1145 \tex_Umathpunctclosespacing:D
1146 \__kernel_primitive:NN \Umathpunctinnerspacing
1147 \tex_Umathpunctinnerspacing:D
1148 \__kernel_primitive:NN \Umathpunctopenspacing \tex_Umathpunctopenspacing:D
1149 \__kernel_primitive:NN \Umathpuncttopspacing \tex_Umathpuncttopspacing:D
1150 \__kernel_primitive:NN \Umathpunctordspacing \tex_Umathpunctordspacing:D
1151 \__kernel_primitive:NN \Umathpunctpunctspacing
1152 \tex_Umathpunctpunctspacing:D
1153 \__kernel_primitive:NN \Umathpunctrelspacing \tex_Umathpunctrelspacing:D
1154 \__kernel_primitive:NN \Umathquad \tex_Umathquad:D
1155 \__kernel_primitive:NN \Umathradicaldegreeafter
1156 \tex_Umathradicaldegreeafter:D
1157 \__kernel_primitive:NN \Umathradicaldegreebefore
1158 \tex_Umathradicaldegreebefore:D
1159 \__kernel_primitive:NN \Umathradicaldegreeraise
1160 \tex_Umathradicaldegreeraise:D
1161 \__kernel_primitive:NN \Umathradicalkern \tex_Umathradicalkern:D
1162 \__kernel_primitive:NN \Umathradicalrule \tex_Umathradicalrule:D
1163 \__kernel_primitive:NN \Umathradicalvgap \tex_Umathradicalvgap:D
1164 \__kernel_primitive:NN \Umathrelbinspacing \tex_Umathrelbinspacing:D
1165 \__kernel_primitive:NN \Umathrelclosespacing \tex_Umathrelclosespacing:D
1166 \__kernel_primitive:NN \Umathrelinnerspacing \tex_Umathrelinnerspacing:D
1167 \__kernel_primitive:NN \Umathrelopenspacing \tex_Umathrelopenspacing:D
1168 \__kernel_primitive:NN \Umathreltopspacing \tex_Umathreltopspacing:D
1169 \__kernel_primitive:NN \Umathrelordspacing \tex_Umathrelordspacing:D
1170 \__kernel_primitive:NN \Umathrelpunctspacing \tex_Umathrelpunctspacing:D
1171 \__kernel_primitive:NN \Umathrelrelspacing \tex_Umathrelrelspacing:D
1172 \__kernel_primitive:NN \Umathskewedfractionhgap
1173 \tex_Umathskewedfractionhgap:D
1174 \__kernel_primitive:NN \Umathskewedfractionvgap
1175 \tex_Umathskewedfractionvgap:D
1176 \__kernel_primitive:NN \Umathspaceafterscript \tex_Umathspaceafterscript:D
1177 \__kernel_primitive:NN \Umathstackdenomdown \tex_Umathstackdenomdown:D
1178 \__kernel_primitive:NN \Umathstacknumup \tex_Umathstacknumup:D
1179 \__kernel_primitive:NN \Umathstackvgap \tex_Umathstackvgap:D
1180 \__kernel_primitive:NN \Umathsubshiftdown \tex_Umathsubshiftdown:D
1181 \__kernel_primitive:NN \Umathsubshiftdrop \tex_Umathsubshiftdrop:D
1182 \__kernel_primitive:NN \Umathsubsupshiftdown \tex_Umathsubsupshiftdown:D
1183 \__kernel_primitive:NN \Umathsubsupvgap \tex_Umathsubsupvgap:D
1184 \__kernel_primitive:NN \Umathsubtopmax \tex_Umathsubtopmax:D
1185 \__kernel_primitive:NN \Umathsupbottommin \tex_Umathsupbottommin:D
1186 \__kernel_primitive:NN \Umathsupshiftdrop \tex_Umathsupshiftdrop:D
1187 \__kernel_primitive:NN \Umathsupshiftup \tex_Umathsupshiftup:D
1188 \__kernel_primitive:NN \Umathsupsubbottommax \tex_Umathsupsubbottommax:D
1189 \__kernel_primitive:NN \Umathunderbarkern \tex_Umathunderbarkern:D
1190 \__kernel_primitive:NN \Umathunderbarrule \tex_Umathunderbarrule:D
1191 \__kernel_primitive:NN \Umathunderbarvgap \tex_Umathunderbarvgap:D

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1192	<code>__kernel_primitive:NN \Umathunderdelimiterbgap</code>	
1193	<code>\tex_Umathunderdelimiterbgap:D</code>	
1194	<code>__kernel_primitive:NN \Umathunderdelimitervgap</code>	
1195	<code>\tex_Umathunderdelimitervgap:D</code>	
1196	<code>__kernel_primitive:NN \Unosubscript</code>	<code>\tex_Unosubscript:D</code>
1197	<code>__kernel_primitive:NN \Unosuperscript</code>	<code>\tex_Unosuperscript:D</code>
1198	<code>__kernel_primitive:NN \Uoverdelimiter</code>	<code>\tex_Uoverdelimiter:D</code>
1199	<code>__kernel_primitive:NN \Uradical</code>	<code>\tex_Uradical:D</code>
1200	<code>__kernel_primitive:NN \Uroot</code>	<code>\tex_Uroot:D</code>
1201	<code>__kernel_primitive:NN \Uskewed</code>	<code>\tex_Uskewed:D</code>
1202	<code>__kernel_primitive:NN \Uskewedwithdelims</code>	<code>\tex_Uskewedwithdelims:D</code>
1203	<code>__kernel_primitive:NN \Ustack</code>	<code>\tex_Ustack:D</code>
1204	<code>__kernel_primitive:NN \Ustartdisplaymath</code>	<code>\tex_Ustartdisplaymath:D</code>
1205	<code>__kernel_primitive:NN \Ustartmath</code>	<code>\tex_Ustartmath:D</code>
1206	<code>__kernel_primitive:NN \Ustopdisplaymath</code>	<code>\tex_Ustopdisplaymath:D</code>
1207	<code>__kernel_primitive:NN \Ustopmath</code>	<code>\tex_Ustopmath:D</code>
1208	<code>__kernel_primitive:NN \Usubscript</code>	<code>\tex_Usubscript:D</code>
1209	<code>__kernel_primitive:NN \Usuperscript</code>	<code>\tex_Usuperscript:D</code>
1210	<code>__kernel_primitive:NN \Uunderdelimiter</code>	<code>\tex_Uunderdelimiter:D</code>
1211	<code>__kernel_primitive:NN \Uvextensible</code>	<code>\tex_Uvextensible:D</code>

Primitives from HarfTeX.

1212	<code>__kernel_primitive:NN \harftexrevision</code>	<code>\tex_harftexrevision:D</code>
1213	<code>__kernel_primitive:NN \harftexversion</code>	<code>\tex_harftexversion:D</code>

Primitives from pTeX.

1214	<code>__kernel_primitive:NN \autospaceing</code>	<code>\tex_autospaceing:D</code>
1215	<code>__kernel_primitive:NN \autoxspaceing</code>	<code>\tex_autoxspaceing:D</code>
1216	<code>__kernel_primitive:NN \dtou</code>	<code>\tex_dtou:D</code>
1217	<code>__kernel_primitive:NN \epTeXinputencoding</code>	<code>\tex_epTeXinputencoding:D</code>
1218	<code>__kernel_primitive:NN \epTeXversion</code>	<code>\tex_epTeXversion:D</code>
1219	<code>__kernel_primitive:NN \euc</code>	<code>\tex_euc:D</code>
1220	<code>__kernel_primitive:NN \ifdbbox</code>	<code>\tex_ifdbbox:D</code>
1221	<code>__kernel_primitive:NN \ifddir</code>	<code>\tex_ifddir:D</code>
1222	<code>__kernel_primitive:NN \ifmdir</code>	<code>\tex_ifmdir:D</code>
1223	<code>__kernel_primitive:NN \iftbox</code>	<code>\tex_iftbox:D</code>
1224	<code>__kernel_primitive:NN \iftdir</code>	<code>\tex_iftdir:D</code>
1225	<code>__kernel_primitive:NN \ifybox</code>	<code>\tex_ifybox:D</code>
1226	<code>__kernel_primitive:NN \ifydir</code>	<code>\tex_ifydir:D</code>
1227	<code>__kernel_primitive:NN \inhibitglue</code>	<code>\tex_inhibitglue:D</code>
1228	<code>__kernel_primitive:NN \inhibitxspcode</code>	<code>\tex_inhibitxspcode:D</code>
1229	<code>__kernel_primitive:NN \jcharwidowpenalty</code>	<code>\tex_jcharwidowpenalty:D</code>
1230	<code>__kernel_primitive:NN \jfam</code>	<code>\tex_jfam:D</code>
1231	<code>__kernel_primitive:NN \jfont</code>	<code>\tex_jfont:D</code>
1232	<code>__kernel_primitive:NN \jis</code>	<code>\tex_jis:D</code>
1233	<code>__kernel_primitive:NN \kanjiskip</code>	<code>\tex_kanjiskip:D</code>
1234	<code>__kernel_primitive:NN \kansuji</code>	<code>\tex_kansuji:D</code>
1235	<code>__kernel_primitive:NN \kansujichar</code>	<code>\tex_kansujichar:D</code>
1236	<code>__kernel_primitive:NN \kcatcode</code>	<code>\tex_kcatcode:D</code>
1237	<code>__kernel_primitive:NN \kuten</code>	<code>\tex_kuten:D</code>
1238	<code>__kernel_primitive:NN \noautospaceing</code>	<code>\tex_noautospaceing:D</code>
1239	<code>__kernel_primitive:NN \noautoxspaceing</code>	<code>\tex_noautoxspaceing:D</code>
1240	<code>__kernel_primitive:NN \postbreakpenalty</code>	<code>\tex_postbreakpenalty:D</code>
1241	<code>__kernel_primitive:NN \prebreakpenalty</code>	<code>\tex_prebreakpenalty:D</code>
1242	<code>__kernel_primitive:NN \ptexminorversion</code>	<code>\tex_ptexminorversion:D</code>

1243	<code>__kernel_primitive:NN \ptexrevision</code>	<code>\tex_ptexrevision:D</code>
1244	<code>__kernel_primitive:NN \ptexversion</code>	<code>\tex_ptexversion:D</code>
1245	<code>__kernel_primitive:NN \showmode</code>	<code>\tex_showmode:D</code>
1246	<code>__kernel_primitive:NN \sjis</code>	<code>\tex_sjis:D</code>
1247	<code>__kernel_primitive:NN \tate</code>	<code>\tex_tate:D</code>
1248	<code>__kernel_primitive:NN \tbaselineshift</code>	<code>\tex_tbaselineshift:D</code>
1249	<code>__kernel_primitive:NN \tfont</code>	<code>\tex_tfont:D</code>
1250	<code>__kernel_primitive:NN \xkanjiskip</code>	<code>\tex_xkanjiskip:D</code>
1251	<code>__kernel_primitive:NN \xspcode</code>	<code>\tex_xspcode:D</code>
1252	<code>__kernel_primitive:NN \ybaselineshift</code>	<code>\tex_ybaselineshift:D</code>
1253	<code>__kernel_primitive:NN \yoko</code>	<code>\tex_yoko:D</code>

Primitives from upTeX.

1254	<code>__kernel_primitive:NN \disablecjktoken</code>	<code>\tex_disablecjktoken:D</code>
1255	<code>__kernel_primitive:NN \enablecjktoken</code>	<code>\tex_enablecjktoken:D</code>
1256	<code>__kernel_primitive:NN \forcecjktoken</code>	<code>\tex_forcecjktoken:D</code>
1257	<code>__kernel_primitive:NN \kchar</code>	<code>\tex_kchar:D</code>
1258	<code>__kernel_primitive:NN \kchardef</code>	<code>\tex_kchardef:D</code>
1259	<code>__kernel_primitive:NN \kuten</code>	<code>\tex_kuten:D</code>
1260	<code>__kernel_primitive:NN \ucs</code>	<code>\tex_ucs:D</code>
1261	<code>__kernel_primitive:NN \uptexrevision</code>	<code>\tex_uptexrevision:D</code>
1262	<code>__kernel_primitive:NN \uptexversion</code>	<code>\tex_uptexversion:D</code>

End of the “just the names” part of the source.

```

1263 </initex | names | package>
1264 (*initex | package>

```

The job is done: close the group (using the primitive renamed!).

```

1265 \tex_endgroup:D

```

L^AT_EX 2_ε moves a few primitives, so these are sorted out. A convenient test for L^AT_EX 2_ε is the `\@@end` saved primitive.

```

1266 (*package>
1267 \tex_ifdefined:D \@@end
1268 \tex_let:D \tex_end:D \@@end
1269 \tex_let:D \tex_everydisplay:D \frozen@everydisplay
1270 \tex_let:D \tex_everymath:D \frozen@everymath
1271 \tex_let:D \tex_hyphen:D \@@hyph
1272 \tex_let:D \tex_input:D \@@input
1273 \tex_let:D \tex_italiccorrection:D \@@italiccorr
1274 \tex_let:D \tex_underline:D \@@underline

```

The `\shipout` primitive is particularly tricky as a number of packages want to hook in here. First, we see if a sufficiently-new kernel has saved a copy: if it has, just use that. Otherwise, we need to check each of the possible packages/classes that might move it: here, we are looking for those which do *not* delay action to the `\AtBeginDocument` hook. (We cannot use `\primitive` as that doesn’t allow us to make a direct copy of the primitive *itself*.) As we know that L^AT_EX 2_ε is in use, we use its `\@tfor` loop here.

```

1275 \tex_ifdefined:D \@@shipout
1276 \tex_let:D \tex_shipout:D \@@shipout
1277 \tex_fi:D
1278 \tex_begingroup:D
1279 \tex_edef:D \l_tmpa_tl { \tex_string:D \shipout }
1280 \tex_edef:D \l_tmpb_tl { \tex_meaning:D \shipout }
1281 \tex_ifx:D \l_tmpa_tl \l_tmpb_tl

```

```

1282 \tex_else:D
1283 \tex_expandafter:D \@tfor \tex_expandafter:D \@tempa \tex_string:D :=
1284 \CROP@shipout
1285 \dup@shipout
1286 \GPTorg@shipout
1287 \LL@shipout
1288 \mem@oldshipout
1289 \opem@shipout
1290 \pgfpages@originalshipout
1291 \pr@shipout
1292 \Shipout
1293 \verso@orig@shipout
1294 \do
1295 {
1296 \tex_edef:D \l_tmpb_tl
1297 { \tex_expandafter:D \tex_meaning:D \@tempa }
1298 \tex_ifx:D \l_tmpa_tl \l_tmpb_tl
1299 \tex_global:D \tex_expandafter:D \tex_let:D
1300 \tex_expandafter:D \tex_shipout:D \@tempa
1301 \tex_fi:D
1302 }
1303 \tex_fi:D
1304 \tex_endgroup:D

```

Some tidying up is needed for `\(pdf)tracingfonts`. Newer LuaTeX has this simply as `\tracingfonts`, but that is overwritten by the L^AT_EX 2_ε kernel. So any spurious definition has to be removed, then the real version saved either from the pdfTeX name or from LuaTeX. In the latter case, we leave `\@@tracingfonts` available: this might be useful and almost all L^AT_EX 2_ε users will have `expl3` loaded by `fontspec`. (We follow the usual kernel convention that `@@` is used for saved primitives.)

```

1305 \tex_let:D \tex_tracingfonts:D \tex_undefined:D
1306 \tex_ifdefined:D \pdftracingfonts
1307 \tex_let:D \tex_tracingfonts:D \pdftracingfonts
1308 \tex_else:D
1309 \tex_ifdefined:D \tex_directlua:D
1310 \tex_directlua:D { tex.enableprimitives("@@", {"tracingfonts"}) }
1311 \tex_let:D \tex_tracingfonts:D \luatextracingfonts
1312 \tex_fi:D
1313 \tex_fi:D
1314 \tex_fi:D

```

That is also true for the LuaTeX primitives under L^AT_EX 2_ε (depending on the format-building date). There are a few primitives that get the right names anyway so are missing here!

```

1315 \tex_ifdefined:D \luatexsuppressfontnotfounderror
1316 \tex_let:D \tex_alignmark:D \luatexalignmark
1317 \tex_let:D \tex_aligntab:D \luatexaligntab
1318 \tex_let:D \tex_attribute:D \luatexattribute
1319 \tex_let:D \tex_attributedef:D \luatexattributedef
1320 \tex_let:D \tex_catcodetable:D \luatexcatcodetable
1321 \tex_let:D \tex_clearmarks:D \luatexclearmarks
1322 \tex_let:D \tex_crampeddisplaystyle:D \luatexcrampeddisplaystyle
1323 \tex_let:D \tex_crampedscriptscriptstyle:D
1324 \luatexcrampedscriptscriptstyle

```

```

1325 \tex_let:D \tex_crampedscriptstyle:D \luatexcrampedscriptstyle
1326 \tex_let:D \tex_crampedtextstyle:D \luatexcrampedtextstyle
1327 \tex_let:D \tex_fontid:D \luatexfontid
1328 \tex_let:D \tex_formatname:D \luatexformatname
1329 \tex_let:D \tex_gleaders:D \luatexgleaders
1330 \tex_let:D \tex_initcatcodetable:D \luatexinitcatcodetable
1331 \tex_let:D \tex_latelua:D \luatexlatelua
1332 \tex_let:D \tex_luaescapestring:D \luatexluaescapestring
1333 \tex_let:D \tex_luafunction:D \luatexluafunction
1334 \tex_let:D \tex_mathstyle:D \luatexmathstyle
1335 \tex_let:D \tex_nokerns:D \luatexnokerns
1336 \tex_let:D \tex_noligs:D \luatexnoligs
1337 \tex_let:D \tex_outputbox:D \luatexoutputbox
1338 \tex_let:D \tex_pageleftoffset:D \luatexpageleftoffset
1339 \tex_let:D \tex_pagetopoffset:D \luatexpagetopoffset
1340 \tex_let:D \tex_postexhyphenchar:D \luatexpostexhyphenchar
1341 \tex_let:D \tex_posthyphenchar:D \luatexposthyphenchar
1342 \tex_let:D \tex_preexhyphenchar:D \luatexpreexhyphenchar
1343 \tex_let:D \tex_prehyphenchar:D \luatexprehyphenchar
1344 \tex_let:D \tex_savecatcodetable:D \luatexsavecatcodetable
1345 \tex_let:D \tex_scantextokens:D \luatexscantextokens
1346 \tex_let:D \tex_suppressifcsnameerror:D
1347 \luatexsuppressifcsnameerror
1348 \tex_let:D \tex_suppresslongerror:D \luatexsuppresslongerror
1349 \tex_let:D \tex_suppressmathparerror:D
1350 \luatexsuppressmathparerror
1351 \tex_let:D \tex_suppressoutererror:D \luatexsuppressoutererror
1352 \tex_let:D \tex_Uchar:D \luatexUchar
1353 \tex_let:D \tex_suppressfontnotfounderror:D
1354 \luatexsuppressfontnotfounderror

```

Which also covers those slightly odd ones.

```

1355 \tex_let:D \tex_bodydir:D \luatexbodydir
1356 \tex_let:D \tex_boxdir:D \luatexboxdir
1357 \tex_let:D \tex_leftghost:D \luatexleftghost
1358 \tex_let:D \tex_localbrokenpenalty:D \luatexlocalbrokenpenalty
1359 \tex_let:D \tex_localinterlinepenalty:D
1360 \luatexlocalinterlinepenalty
1361 \tex_let:D \tex_localleftbox:D \luatexlocalleftbox
1362 \tex_let:D \tex_localrightbox:D \luatexlocalrightbox
1363 \tex_let:D \tex_mathdir:D \luatexmathdir
1364 \tex_let:D \tex_pagebottomoffset:D \luatexpagebottomoffset
1365 \tex_let:D \tex_pagedir:D \luatexpagedir
1366 \tex_let:D \tex_pageheight:D \luatexpageheight
1367 \tex_let:D \tex_pagerightoffset:D \luatexpagerightoffset
1368 \tex_let:D \tex_pagewidth:D \luatexpagewidth
1369 \tex_let:D \tex_pardir:D \luatexpardir
1370 \tex_let:D \tex_rightghost:D \luatexrightghost
1371 \tex_let:D \tex_textdir:D \luatextextdir
1372 \tex_fi:D

```

Only pdfTeX and LuaTeX define \pdfmapfile and \pdfmapline: Tidy up the fact that some format-building processes leave a couple of questionable decisions about that!

```

1373 \tex_ifnum:D 0
1374 \tex_ifdefined:D \tex_pdftexversion:D 1 \tex_fi:D

```



```

1375 \tex_ifdefined:D \tex_luatexversion:D 1 \tex_fi:D
1376 = 0 %
1377 \tex_let:D \tex_mapfile:D \tex_undefined:D
1378 \tex_let:D \tex_mapline:D \tex_undefined:D
1379 \tex_fi:D
1380 \endpackage

```

A few packages do unfortunate things to date-related primitives.

```

1381 \tex_begingroup:D
1382 \tex_edef:D \l_tmpa_tl { \tex_meaning:D \tex_time:D }
1383 \tex_edef:D \l_tmpb_tl { \tex_string:D \time }
1384 \tex_ifx:D \l_tmpa_tl \l_tmpb_tl
1385 \tex_else:D
1386 \tex_global:D \tex_let:D \tex_time:D \tex_undefined:D
1387 \tex_fi:D
1388 \tex_edef:D \l_tmpa_tl { \tex_meaning:D \tex_day:D }
1389 \tex_edef:D \l_tmpb_tl { \tex_string:D \day }
1390 \tex_ifx:D \l_tmpa_tl \l_tmpb_tl
1391 \tex_else:D
1392 \tex_global:D \tex_let:D \tex_day:D \tex_undefined:D
1393 \tex_fi:D
1394 \tex_edef:D \l_tmpa_tl { \tex_meaning:D \tex_month:D }
1395 \tex_edef:D \l_tmpb_tl { \tex_string:D \month }
1396 \tex_ifx:D \l_tmpa_tl \l_tmpb_tl
1397 \tex_else:D
1398 \tex_global:D \tex_let:D \tex_month:D \tex_undefined:D
1399 \tex_fi:D
1400 \tex_edef:D \l_tmpa_tl { \tex_meaning:D \tex_year:D }
1401 \tex_edef:D \l_tmpb_tl { \tex_string:D \year }
1402 \tex_ifx:D \l_tmpa_tl \l_tmpb_tl
1403 \tex_else:D
1404 \tex_global:D \tex_let:D \tex_year:D \tex_undefined:D
1405 \tex_fi:D
1406 \tex_endgroup:D

```

Up to v0.80, LuaTeX defines the pdfTeX version data: rather confusing. Removing them means that `\tex_pdftexversion:D` is a marker for pdfTeX alone: useful in engine-dependent code later.

```

1407 \begin{package}
1408 \tex_ifdefined:D \tex_luatexversion:D
1409 \tex_let:D \tex_pdftexbanner:D \tex_undefined:D
1410 \tex_let:D \tex_pdftexrevision:D \tex_undefined:D
1411 \tex_let:D \tex_pdftexversion:D \tex_undefined:D
1412 \tex_fi:D
1413 \end{package}

```

For ConTeXt, two tests are needed. Both Mark II and Mark IV move several primitives: these are all covered by the first test, again using `\end` as a marker. For Mark IV, a few more primitives are moved: they are implemented using some Lua code in the current ConTeXt.

```

1414 \begin{package}
1415 \tex_ifdefined:D \normalend
1416 \tex_let:D \tex_end:D \normalend
1417 \tex_let:D \tex_everyjob:D \normaleveryjob
1418 \tex_let:D \tex_input:D \normalinput

```

```

1419 \tex_let:D \tex_language:D \normallanguage
1420 \tex_let:D \tex_mathop:D \normalmathop
1421 \tex_let:D \tex_month:D \normalmonth
1422 \tex_let:D \tex_outer:D \normalouter
1423 \tex_let:D \tex_over:D \normalover
1424 \tex_let:D \tex_vcenter:D \normalvcenter
1425 \tex_let:D \tex_unexpanded:D \normalunexpanded
1426 \tex_let:D \tex_expanded:D \normalexpanded
1427 \tex_fi:D
1428 \tex_ifdefined:D \normalitaliccorrection
1429 \tex_let:D \tex_hoffset:D \normalhoffset
1430 \tex_let:D \tex_italiccorrection:D \normalitaliccorrection
1431 \tex_let:D \tex_voffset:D \normalvoffset
1432 \tex_let:D \tex_showtokens:D \normalshowtokens
1433 \tex_let:D \tex_bodydir:D \spac_directions_normal_body_dir
1434 \tex_let:D \tex_pagedir:D \spac_directions_normal_page_dir
1435 \tex_fi:D
1436 \tex_ifdefined:D \normalleft
1437 \tex_let:D \tex_left:D \normalleft
1438 \tex_let:D \tex_middle:D \normalmiddle
1439 \tex_let:D \tex_right:D \normalright
1440 \tex_fi:D
1441 \endpackage

```

2.1 Deprecated functions

Older versions of expl3 divided up primitives by “source”: that becomes very tricky with multiple parallel engine developments, so has been dropped. To cover the transition, we provide the older names here for a limited period (until the end of 2019).

To allow `\debug_on:n {<deprecation>}` to work we save the list of primitives into `__kernel_primitives:`

```

1442 \begin{package}
1443 \tex_begingroup:D
1444 \tex_long:D \tex_def:D \use_ii:nn #1#2 {#2}
1445 \tex_long:D \tex_def:D \use_none:n #1 { }
1446 \tex_long:D \tex_def:D \__kernel_primitive:NN #1#2
1447 {
1448   \tex_ifdefined:D #1
1449   \tex_expandafter:D \use_ii:nn
1450   \tex_fi:D
1451   \use_none:n { \tex_global:D \tex_let:D #2 #1 }
1452 }
1453 \tex_xdef:D \__kernel_primitives:
1454 {
1455   \tex_unexpanded:D
1456   {
1457     \__kernel_primitive:NN \beginL \etex_beginL:D
1458     \__kernel_primitive:NN \beginR \etex_beginR:D
1459     \__kernel_primitive:NN \botmarks \etex_botmarks:D
1460     \__kernel_primitive:NN \clubpenalties \etex_clubpenalties:D
1461     \__kernel_primitive:NN \currentgrouplevel \etex_currentgrouplevel:D
1462     \__kernel_primitive:NN \currentgroupstype \etex_currentgroupstype:D
1463     \__kernel_primitive:NN \currentifbranch \etex_currentifbranch:D

```

1464	_kernel_primitive:NN	\currentiflevel	\etex_currentiflevel:D
1465	_kernel_primitive:NN	\currentifttype	\etex_currentifttype:D
1466	_kernel_primitive:NN	\detokenize	\etex_detokenize:D
1467	_kernel_primitive:NN	\dimexpr	\etex_dimexpr:D
1468	_kernel_primitive:NN	\displaywidowpenalties	
1469		\etex_displaywidowpenalties:D	
1470	_kernel_primitive:NN	\endL	\etex_endL:D
1471	_kernel_primitive:NN	\endR	\etex_endR:D
1472	_kernel_primitive:NN	\eTeXrevision	\etex_eTeXrevision:D
1473	_kernel_primitive:NN	\eTeXversion	\etex_eTeXversion:D
1474	_kernel_primitive:NN	\everyeof	\etex_everyeof:D
1475	_kernel_primitive:NN	\firstmarks	\etex_firstmarks:D
1476	_kernel_primitive:NN	\fontchardp	\etex_fontchardp:D
1477	_kernel_primitive:NN	\fontcharht	\etex_fontcharht:D
1478	_kernel_primitive:NN	\fontcharic	\etex_fontcharic:D
1479	_kernel_primitive:NN	\fontcharwd	\etex_fontcharwd:D
1480	_kernel_primitive:NN	\glueexpr	\etex_glueexpr:D
1481	_kernel_primitive:NN	\glueshrink	\etex_glueshrink:D
1482	_kernel_primitive:NN	\glueshrinkorder	\etex_glueshrinkorder:D
1483	_kernel_primitive:NN	\gluestretch	\etex_gluestretch:D
1484	_kernel_primitive:NN	\gluestretchorder	\etex_gluestretchorder:D
1485	_kernel_primitive:NN	\gluetomu	\etex_gluetomu:D
1486	_kernel_primitive:NN	\ifcsname	\etex_ifcsname:D
1487	_kernel_primitive:NN	\ifdefined	\etex_ifdefined:D
1488	_kernel_primitive:NN	\iffontchar	\etex_iffontchar:D
1489	_kernel_primitive:NN	\interactionmode	\etex_interactionmode:D
1490	_kernel_primitive:NN	\interlinepenalties	\etex_interlinepenalties:D
1491	_kernel_primitive:NN	\lastlinefit	\etex_lastlinefit:D
1492	_kernel_primitive:NN	\lastnodetype	\etex_lastnodetype:D
1493	_kernel_primitive:NN	\marks	\etex_marks:D
1494	_kernel_primitive:NN	\middle	\etex_middle:D
1495	_kernel_primitive:NN	\muexpr	\etex_muexpr:D
1496	_kernel_primitive:NN	\mutoglua	\etex_mutoglua:D
1497	_kernel_primitive:NN	\numexpr	\etex_numexpr:D
1498	_kernel_primitive:NN	\pagediscards	\etex_pagediscards:D
1499	_kernel_primitive:NN	\parshapedimen	\etex_parshapedimen:D
1500	_kernel_primitive:NN	\parshapeindent	\etex_parshapeindent:D
1501	_kernel_primitive:NN	\parshapelength	\etex_parshapelength:D
1502	_kernel_primitive:NN	\predisplaydirection	\etex_predisplaydirection:D
1503	_kernel_primitive:NN	\protected	\etex_protected:D
1504	_kernel_primitive:NN	\readline	\etex_readline:D
1505	_kernel_primitive:NN	\savinghyphcodes	\etex_savinghyphcodes:D
1506	_kernel_primitive:NN	\savingvdiscards	\etex_savingvdiscards:D
1507	_kernel_primitive:NN	\scantokens	\etex_scantokens:D
1508	_kernel_primitive:NN	\showgroups	\etex_showgroups:D
1509	_kernel_primitive:NN	\showifs	\etex_showifs:D
1510	_kernel_primitive:NN	\showtokens	\etex_showtokens:D
1511	_kernel_primitive:NN	\splitbotmarks	\etex_splitbotmarks:D
1512	_kernel_primitive:NN	\splitdiscards	\etex_splitdiscards:D
1513	_kernel_primitive:NN	\splitfirstmarks	\etex_splitfirstmarks:D
1514	_kernel_primitive:NN	\TeXXeTstate	\etex_TeXXeTstate:D
1515	_kernel_primitive:NN	\topmarks	\etex_topmarks:D
1516	_kernel_primitive:NN	\tracingassigns	\etex_tracingassigns:D
1517	_kernel_primitive:NN	\tracinggroups	\etex_tracinggroups:D

1518	_kernel_primitive:NN	\tracingifs	\etex_tracingifs:D
1519	_kernel_primitive:NN	\tracingnesting	\etex_tracingnesting:D
1520	_kernel_primitive:NN	\tracingscantokens	\etex_tracingscantokens:D
1521	_kernel_primitive:NN	\unexpanded	\etex_unexpanded:D
1522	_kernel_primitive:NN	\unless	\etex_unless:D
1523	_kernel_primitive:NN	\widowpenalties	\etex_widowpenalties:D
1524	_kernel_primitive:NN	\pdfannot	\pdfTEX_pdfannot:D
1525	_kernel_primitive:NN	\pdfcatalog	\pdfTEX_pdfcatalog:D
1526	_kernel_primitive:NN	\pdfcompresslevel	\pdfTEX_pdfcompresslevel:D
1527	_kernel_primitive:NN	\pdfcolorstack	\pdfTEX_pdfcolorstack:D
1528	_kernel_primitive:NN	\pdfcolorstackinit	\pdfTEX_pdfcolorstackinit:D
1529	_kernel_primitive:NN	\pdfcreationdate	\pdfTEX_pdfcreationdate:D
1530	_kernel_primitive:NN	\pdfdecimaldigits	\pdfTEX_pdfdecimaldigits:D
1531	_kernel_primitive:NN	\pdfdest	\pdfTEX_pdfdest:D
1532	_kernel_primitive:NN	\pdfdestmargin	\pdfTEX_pdfdestmargin:D
1533	_kernel_primitive:NN	\pdfendlink	\pdfTEX_pdfendlink:D
1534	_kernel_primitive:NN	\pdfendthread	\pdfTEX_pdfendthread:D
1535	_kernel_primitive:NN	\pdffontattr	\pdfTEX_pdffontattr:D
1536	_kernel_primitive:NN	\pdffontname	\pdfTEX_pdffontname:D
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1842	_kernel_primitive:NN \boxdir	\luatex_boxdir:D
1843	_kernel_primitive:NN \leftghost	\luatex_leftghost:D
1844	_kernel_primitive:NN \linedir	\luatex_linedir:D
1845	_kernel_primitive:NN \localbrokenpenalty	\luatex_localbrokenpenalty:D
1846	_kernel_primitive:NN \localinterlinepenalty	
1847	\luatex_localinterlinepenalty:D	
1848	_kernel_primitive:NN \localleftbox	\luatex_localleftbox:D
1849	_kernel_primitive:NN \localrightbox	\luatex_localrightbox:D
1850	_kernel_primitive:NN \mathdir	\luatex_mathdir:D
1851	_kernel_primitive:NN \pagedir	\luatex_pagedir:D
1852	_kernel_primitive:NN \pardir	\luatex_pardir:D
1853	_kernel_primitive:NN \rightghost	\luatex_rightghost:D
1854	_kernel_primitive:NN \textdir	\luatex_textdir:D
1855	_kernel_primitive:NN \Uchar	\utex_char:D
1856	_kernel_primitive:NN \Ucharcat	\utex_charcat:D
1857	_kernel_primitive:NN \Udelcode	\utex_delcode:D
1858	_kernel_primitive:NN \Udelcodenum	\utex_delcodenum:D
1859	_kernel_primitive:NN \Udelimiter	\utex_delimiter:D
1860	_kernel_primitive:NN \Udelimiterover	\utex_delimiterover:D
1861	_kernel_primitive:NN \Udelimiterunder	\utex_delimiterunder:D
1862	_kernel_primitive:NN \Uhexensible	\utex_hexensible:D
1863	_kernel_primitive:NN \Umathaccent	\utex_mathaccent:D
1864	_kernel_primitive:NN \Umathaxis	\utex_mathaxis:D
1865	_kernel_primitive:NN \Umathbinbinspacing	\utex_binbinspacing:D
1866	_kernel_primitive:NN \Umathbinclosespacing	\utex_binclosespacing:D
1867	_kernel_primitive:NN \Umathbininnerspacing	\utex_bininnerspacing:D
1868	_kernel_primitive:NN \Umathbinopenspacing	\utex_binopenspacing:D
1869	_kernel_primitive:NN \Umathbinopspacing	\utex_binopspacing:D
1870	_kernel_primitive:NN \Umathbinordspacing	\utex_binordspacing:D
1871	_kernel_primitive:NN \Umathbinpunctspacing	\utex_binpunctspacing:D
1872	_kernel_primitive:NN \Umathbinrelspacing	\utex_binrelspacing:D
1873	_kernel_primitive:NN \Umathchar	\utex_mathchar:D
1874	_kernel_primitive:NN \Umathcharclass	\utex_mathcharclass:D
1875	_kernel_primitive:NN \Umathchardef	\utex_mathchardef:D
1876	_kernel_primitive:NN \Umathcharfam	\utex_mathcharfam:D
1877	_kernel_primitive:NN \Umathcharnum	\utex_mathcharnum:D
1878	_kernel_primitive:NN \Umathcharnumdef	\utex_mathcharnumdef:D
1879	_kernel_primitive:NN \Umathcharslot	\utex_mathcharslot:D
1880	_kernel_primitive:NN \Umathclosebinspacing	\utex_closebinspacing:D
1881	_kernel_primitive:NN \Umathcloseclosespacing	
1882	\utex_closeclosespacing:D	
1883	_kernel_primitive:NN \Umathcloseinnerspacing	
1884	\utex_closeinnerspacing:D	
1885	_kernel_primitive:NN \Umathcloseopenspacing	\utex_closeopenspacing:D
1886	_kernel_primitive:NN \Umathcloseopspacing	\utex_closeopspacing:D
1887	_kernel_primitive:NN \Umathcloseordspacing	\utex_closeordspacing:D
1888	_kernel_primitive:NN \Umathclosepunctspacing	
1889	\utex_closepunctspacing:D	
1890	_kernel_primitive:NN \Umathcloserelspacing	\utex_closerelspacing:D
1891	_kernel_primitive:NN \Umathcode	\utex_mathcode:D
1892	_kernel_primitive:NN \Umathcodenum	\utex_mathcodenum:D
1893	_kernel_primitive:NN \Umathconnectoroverlapmin	
1894	\utex_connectoroverlapmin:D	
1895	_kernel_primitive:NN \Umathfractiondelsize	\utex_fractiondelsize:D

1896 __kernel_primitive:NN \Umathfractiondenomdown
1897 \utex_fractiondenomdown:D
1898 __kernel_primitive:NN \Umathfractiondenomvgap
1899 \utex_fractiondenomvgap:D
1900 __kernel_primitive:NN \Umathfractionnumup \utex_fractionnumup:D
1901 __kernel_primitive:NN \Umathfractionnumvgap \utex_fractionnumvgap:D
1902 __kernel_primitive:NN \Umathfractionrule \utex_fractionrule:D
1903 __kernel_primitive:NN \Umathinnerbinspacing \utex_innerbinspacing:D
1904 __kernel_primitive:NN \Umathinnerclosespacing
1905 \utex_innerclosespacing:D
1906 __kernel_primitive:NN \Umathinnerinnerspacing
1907 \utex_innerinnerspacing:D
1908 __kernel_primitive:NN \Umathinneropenspacing \utex_inneropenspacing:D
1909 __kernel_primitive:NN \Umathinneropspacing \utex_inneropspacing:D
1910 __kernel_primitive:NN \Umathinnerordspacing \utex_innerordspacing:D
1911 __kernel_primitive:NN \Umathinnerpunctspacing
1912 \utex_innerpunctspacing:D
1913 __kernel_primitive:NN \Umathinnerrelspacing \utex_innerrelspacing:D
1914 __kernel_primitive:NN \Umathlimitabovebgap \utex_limitabovebgap:D
1915 __kernel_primitive:NN \Umathlimitabovekern \utex_limitabovekern:D
1916 __kernel_primitive:NN \Umathlimitabovevgap \utex_limitabovevgap:D
1917 __kernel_primitive:NN \Umathlimitbelowbgap \utex_limitbelowbgap:D
1918 __kernel_primitive:NN \Umathlimitbelowkern \utex_limitbelowkern:D
1919 __kernel_primitive:NN \Umathlimitbelowvgap \utex_limitbelowvgap:D
1920 __kernel_primitive:NN \Umathnolimitsubfactor \utex_nolimitsubfactor:D
1921 __kernel_primitive:NN \Umathnolimitsupfactor \utex_nolimitsupfactor:D
1922 __kernel_primitive:NN \Umathopbinspacing \utex_opbinspacing:D
1923 __kernel_primitive:NN \Umathopclosespacing \utex_opclosespacing:D
1924 __kernel_primitive:NN \Umathopenbinspacing \utex_openbinspacing:D
1925 __kernel_primitive:NN \Umathopenclosespacing \utex_openclosespacing:D
1926 __kernel_primitive:NN \Umathopeninnerspacing \utex_openinnerspacing:D
1927 __kernel_primitive:NN \Umathopenopenspacing \utex_openopenspacing:D
1928 __kernel_primitive:NN \Umathopenopspacing \utex_openopspacing:D
1929 __kernel_primitive:NN \Umathopenordspacing \utex_openordspacing:D
1930 __kernel_primitive:NN \Umathopenpunctspacing \utex_openpunctspacing:D
1931 __kernel_primitive:NN \Umathopenrelspacing \utex_openrelspacing:D
1932 __kernel_primitive:NN \Umathoperatorsize \utex_operatorsize:D
1933 __kernel_primitive:NN \Umathopinnerspacing \utex_opinnerspacing:D
1934 __kernel_primitive:NN \Umathopopenspacing \utex_opopenspacing:D
1935 __kernel_primitive:NN \Umathopopspacing \utex_opopspacing:D
1936 __kernel_primitive:NN \Umathopordspacing \utex_opordspacing:D
1937 __kernel_primitive:NN \Umathoppunctspacing \utex_oppunctspacing:D
1938 __kernel_primitive:NN \Umathoprelspacing \utex_oprelspacing:D
1939 __kernel_primitive:NN \Umathordbinspacing \utex_ordbinspacing:D
1940 __kernel_primitive:NN \Umathordclosespacing \utex_ordclosespacing:D
1941 __kernel_primitive:NN \Umathordinnerspacing \utex_ordinnerspacing:D
1942 __kernel_primitive:NN \Umathordopenspacing \utex_ordopenspacing:D
1943 __kernel_primitive:NN \Umathordopspacing \utex_ordopspacing:D
1944 __kernel_primitive:NN \Umathordordspacing \utex_ordordspacing:D
1945 __kernel_primitive:NN \Umathordpunctspacing \utex_ordpunctspacing:D
1946 __kernel_primitive:NN \Umathordreldspacing \utex_ordreldspacing:D
1947 __kernel_primitive:NN \Umathoverbarkern \utex_overbarkern:D
1948 __kernel_primitive:NN \Umathoverbarrule \utex_overbarrule:D
1949 __kernel_primitive:NN \Umathoverbarvgap \utex_overbarvgap:D

1950 __kernel_primitive:NN \Umathoverdelimiterbgap
1951 \utex_overdelimiterbgap:D
1952 __kernel_primitive:NN \Umathoverdelimitervgap
1953 \utex_overdelimitervgap:D
1954 __kernel_primitive:NN \Umathpunctbinspacing \utex_punctbinspacing:D
1955 __kernel_primitive:NN \Umathpunctclosespacing
1956 \utex_punctclosespacing:D
1957 __kernel_primitive:NN \Umathpunctinnerspacing
1958 \utex_punctinnerspacing:D
1959 __kernel_primitive:NN \Umathpunctopenspacing \utex_punctopenspacing:D
1960 __kernel_primitive:NN \Umathpuncttopspacing \utex_puncttopspacing:D
1961 __kernel_primitive:NN \Umathpunctordspacing \utex_punctordspacing:D
1962 __kernel_primitive:NN \Umathpunctpunctspacing\utex_punctpunctspacing:D
1963 __kernel_primitive:NN \Umathpunctrelspacing \utex_punctrelspacing:D
1964 __kernel_primitive:NN \Umathquad \utex_quad:D
1965 __kernel_primitive:NN \Umathradicaldegreeafter
1966 \utex_radicaldegreeafter:D
1967 __kernel_primitive:NN \Umathradicaldegreebefore
1968 \utex_radicaldegreebefore:D
1969 __kernel_primitive:NN \Umathradicaldegreeraise
1970 \utex_radicaldegreeraise:D
1971 __kernel_primitive:NN \Umathradicalkern \utex_radicalkern:D
1972 __kernel_primitive:NN \Umathradicalrule \utex_radicalrule:D
1973 __kernel_primitive:NN \Umathradicalvgap \utex_radicalvgap:D
1974 __kernel_primitive:NN \Umathrelbinspacing \utex_relbinspacing:D
1975 __kernel_primitive:NN \Umathrelclosespacing \utex_relclosespacing:D
1976 __kernel_primitive:NN \Umathrelinnerspacing \utex_relinnerspacing:D
1977 __kernel_primitive:NN \Umathrelopenspacing \utex_reloopenspacing:D
1978 __kernel_primitive:NN \Umathreltopspacing \utex_reloptspacing:D
1979 __kernel_primitive:NN \Umathrelordspacing \utex_relordspacing:D
1980 __kernel_primitive:NN \Umathrelpunctspacing \utex_relpunctspacing:D
1981 __kernel_primitive:NN \Umathrelrelspacing \utex_relrelspacing:D
1982 __kernel_primitive:NN \Umathskewedfractionhgap
1983 \utex_skewedfractionhgap:D
1984 __kernel_primitive:NN \Umathskewedfractionvgap
1985 \utex_skewedfractionvgap:D
1986 __kernel_primitive:NN \Umathspaceafterscript \utex_spaceafterscript:D
1987 __kernel_primitive:NN \Umathstackdenomdown \utex_stackdenomdown:D
1988 __kernel_primitive:NN \Umathstacknumup \utex_stacknumup:D
1989 __kernel_primitive:NN \Umathstackvgap \utex_stackvgap:D
1990 __kernel_primitive:NN \Umathsubshiftdown \utex_subshiftdown:D
1991 __kernel_primitive:NN \Umathsubshiftdrop \utex_subshiftdrop:D
1992 __kernel_primitive:NN \Umathsubsupshiftdown \utex_subsupshiftdown:D
1993 __kernel_primitive:NN \Umathsubsupvgap \utex_subsupvgap:D
1994 __kernel_primitive:NN \Umathsubtopmax \utex_subtopmax:D
1995 __kernel_primitive:NN \Umathsupbottommin \utex_supbottommin:D
1996 __kernel_primitive:NN \Umathsupshiftdrop \utex_supshiftdrop:D
1997 __kernel_primitive:NN \Umathsupshiftup \utex_supshiftup:D
1998 __kernel_primitive:NN \Umathsupsubbottommax \utex_supsubbottommax:D
1999 __kernel_primitive:NN \Umathunderbarkern \utex_underbarkern:D
2000 __kernel_primitive:NN \Umathunderbarrule \utex_underbarrule:D
2001 __kernel_primitive:NN \Umathunderbarvgap \utex_underbarvgap:D
2002 __kernel_primitive:NN \Umathunderdelimiterbgap
2003 \utex_underdelimiterbgap:D

2004	<code>__kernel_primitive:NN \Umathunderdelimitervgap</code>	
2005	<code>\utex_underdelimitervgap:D</code>	
2006	<code>__kernel_primitive:NN \Unosubscript</code>	<code>\utex_nosubscript:D</code>
2007	<code>__kernel_primitive:NN \Unosuperscript</code>	<code>\utex_nosuperscript:D</code>
2008	<code>__kernel_primitive:NN \Uoverdelimiter</code>	<code>\utex_overdelimiter:D</code>
2009	<code>__kernel_primitive:NN \Uradical</code>	<code>\utex_radical:D</code>
2010	<code>__kernel_primitive:NN \Uroot</code>	<code>\utex_root:D</code>
2011	<code>__kernel_primitive:NN \Uskewed</code>	<code>\utex_skewed:D</code>
2012	<code>__kernel_primitive:NN \Uskewedwithdelims</code>	<code>\utex_skewedwithdelims:D</code>
2013	<code>__kernel_primitive:NN \Ustack</code>	<code>\utex_stack:D</code>
2014	<code>__kernel_primitive:NN \Ustartdisplaymath</code>	<code>\utex_startdisplaymath:D</code>
2015	<code>__kernel_primitive:NN \Ustartmath</code>	<code>\utex_startmath:D</code>
2016	<code>__kernel_primitive:NN \Ustopdisplaymath</code>	<code>\utex_stopdisplaymath:D</code>
2017	<code>__kernel_primitive:NN \Ustopmath</code>	<code>\utex_stopmath:D</code>
2018	<code>__kernel_primitive:NN \Usubscript</code>	<code>\utex_subscript:D</code>
2019	<code>__kernel_primitive:NN \Usuperscript</code>	<code>\utex_superscript:D</code>
2020	<code>__kernel_primitive:NN \Uunderdelimiter</code>	<code>\utex_underdelimiter:D</code>
2021	<code>__kernel_primitive:NN \Uvextensible</code>	<code>\utex_vextensible:D</code>
2022	<code>__kernel_primitive:NN \autospaceing</code>	<code>\ptex_autospaceing:D</code>
2023	<code>__kernel_primitive:NN \autoxspaceing</code>	<code>\ptex_autoxspaceing:D</code>
2024	<code>__kernel_primitive:NN \dtou</code>	<code>\ptex_dtou:D</code>
2025	<code>__kernel_primitive:NN \epTeXinputencoding</code>	<code>\ptex_inputencoding:D</code>
2026	<code>__kernel_primitive:NN \epTeXversion</code>	<code>\ptex_epTeXversion:D</code>
2027	<code>__kernel_primitive:NN \euc</code>	<code>\ptex_euc:D</code>
2028	<code>__kernel_primitive:NN \ifdbbox</code>	<code>\ptex_ifdbbox:D</code>
2029	<code>__kernel_primitive:NN \ifddir</code>	<code>\ptex_ifddir:D</code>
2030	<code>__kernel_primitive:NN \ifmdir</code>	<code>\ptex_ifmdir:D</code>
2031	<code>__kernel_primitive:NN \iftbox</code>	<code>\ptex_iftbox:D</code>
2032	<code>__kernel_primitive:NN \iftdir</code>	<code>\ptex_iftdir:D</code>
2033	<code>__kernel_primitive:NN \ifybox</code>	<code>\ptex_ifybox:D</code>
2034	<code>__kernel_primitive:NN \ifydir</code>	<code>\ptex_ifydir:D</code>
2035	<code>__kernel_primitive:NN \inhibitglue</code>	<code>\ptex_inhibitglue:D</code>
2036	<code>__kernel_primitive:NN \inhibitxspcode</code>	<code>\ptex_inhibitxspcode:D</code>
2037	<code>__kernel_primitive:NN \jcharwidowpenalty</code>	<code>\ptex_jcharwidowpenalty:D</code>
2038	<code>__kernel_primitive:NN \jfam</code>	<code>\ptex_jfam:D</code>
2039	<code>__kernel_primitive:NN \jfont</code>	<code>\ptex_jfont:D</code>
2040	<code>__kernel_primitive:NN \jis</code>	<code>\ptex_jis:D</code>
2041	<code>__kernel_primitive:NN \kanjiskip</code>	<code>\ptex_kanjiskip:D</code>
2042	<code>__kernel_primitive:NN \kansuji</code>	<code>\ptex_kansuji:D</code>
2043	<code>__kernel_primitive:NN \kansujichar</code>	<code>\ptex_kansujichar:D</code>
2044	<code>__kernel_primitive:NN \kcatcode</code>	<code>\ptex_kcatcode:D</code>
2045	<code>__kernel_primitive:NN \kuten</code>	<code>\ptex_kuten:D</code>
2046	<code>__kernel_primitive:NN \noautospaceing</code>	<code>\ptex_noautospaceing:D</code>
2047	<code>__kernel_primitive:NN \noautoxspaceing</code>	<code>\ptex_noautoxspaceing:D</code>
2048	<code>__kernel_primitive:NN \postbreakpenalty</code>	<code>\ptex_postbreakpenalty:D</code>
2049	<code>__kernel_primitive:NN \prebreakpenalty</code>	<code>\ptex_prebreakpenalty:D</code>
2050	<code>__kernel_primitive:NN \ptexminorversion</code>	<code>\ptex_ptexminorversion:D</code>
2051	<code>__kernel_primitive:NN \ptexrevision</code>	<code>\ptex_ptexrevision:D</code>
2052	<code>__kernel_primitive:NN \ptexversion</code>	<code>\ptex_ptexversion:D</code>
2053	<code>__kernel_primitive:NN \showmode</code>	<code>\ptex_showmode:D</code>
2054	<code>__kernel_primitive:NN \sjis</code>	<code>\ptex_sjis:D</code>
2055	<code>__kernel_primitive:NN \tate</code>	<code>\ptex_tate:D</code>
2056	<code>__kernel_primitive:NN \tbaselineshift</code>	<code>\ptex_tbaselineshift:D</code>
2057	<code>__kernel_primitive:NN \tfont</code>	<code>\ptex_tfont:D</code>

```

2058 \__kernel_primitive:NN \xkanjiskip \ptex_xkanjiskip:D
2059 \__kernel_primitive:NN \xspcode \ptex_xspcode:D
2060 \__kernel_primitive:NN \ybaselineshift \ptex_ybaselineshift:D
2061 \__kernel_primitive:NN \yoko \ptex_yoko:D
2062 \__kernel_primitive:NN \disablecjktoken \uptex_disablecjktoken:D
2063 \__kernel_primitive:NN \enablecjktoken \uptex_enablecjktoken:D
2064 \__kernel_primitive:NN \forcecjktoken \uptex_forcecjktoken:D
2065 \__kernel_primitive:NN \kchar \uptex_kchar:D
2066 \__kernel_primitive:NN \kchardef \uptex_kchardef:D
2067 \__kernel_primitive:NN \kuten \uptex_kuten:D
2068 \__kernel_primitive:NN \ucs \uptex_ucs:D
2069 \__kernel_primitive:NN \uptexrevision \uptex_uptexrevision:D
2070 \__kernel_primitive:NN \uptexversion \uptex_uptexversion:D
2071 }
2072 }
2073 \__kernel_primitives:
2074 \tex_endgroup:D
2075 \</package>
2076 \</initex | package>

```

3 Internal kernel functions

```

\__kernel_chk_cs_exist:N
\__kernel_chk_cs_exist:c

```

```
\__kernel_chk_cs_exist:N <cs>
```

This function is only created if debugging is enabled. It checks that $\langle cs \rangle$ exists according to the criteria for $\backslash cs_if_exist_p:N$, and if not raises a kernel-level error.

```
\__kernel_chk_defined:NT
```

```
\__kernel_chk_defined:NT <variable> {\true code}
```

If $\langle variable \rangle$ is not defined (according to $\backslash cs_if_exist:N\TF$), this triggers an error, otherwise the $\langle true\ code \rangle$ is run.

```
\__kernel_chk_expr:nNnN
```

```
\__kernel_chk_expr:nNnN {\expr} \eval \{convert\} \caller
```

This function is only created if debugging is enabled. By default it is equivalent to $\backslash use_i:n\nnn$. When expression checking is enabled, it leaves in the input stream the result of $\backslash tex_the:D \langle eval \rangle \langle expr \rangle \backslash tex_relax:D$ after checking that no token was left over. If any token was not taken as part of the expression, there is an error message displaying the result of the evaluation as well as the $\langle caller \rangle$. For instance $\langle eval \rangle$ can be $\backslash_int_eval:w$ and $\langle caller \rangle$ can be $\backslash int_eval:n$ or $\backslash int_set:Nn$. The argument $\langle convert \rangle$ is empty except for mu expressions where it is $\backslash tex_mutoglue:D$, used for internal purposes.

```
\__kernel_chk_var_exist:N
```

```
\__kernel_chk_var_exist:N <var>
```

This function is only created if debugging is enabled. It checks that $\langle var \rangle$ is defined according to the criteria for $\backslash cs_if_exist_p:N$, and if not raises a kernel-level error.

<hr/> <hr/>	<code>_kernel_chk_var_scope:NN</code>	<code>_kernel_chk_var_scope:NN <scope> <var></code>	Checks the $\langle var \rangle$ has the correct $\langle scope \rangle$, and if not raises a kernel-level error. This function is only created if debugging is enabled. The $\langle scope \rangle$ is a single letter <code>l</code> , <code>g</code> , <code>c</code> denoting local variables, global variables, or constants. More precisely, if the variable name starts with a letter and an underscore (normal <code>expl3</code> convention) the function checks that this single letter matches the $\langle scope \rangle$. Otherwise the function cannot know the scope $\langle var \rangle$ the first time: instead, it defines <code>_debug_chk_/$\langle var \rangle$</code> to store that information for the next call. Thus, if a given $\langle var \rangle$ is subject to assignments of different scopes a kernel error will result.
<hr/> <hr/>	<code>_kernel_chk_var_local:N</code> <code>_kernel_chk_var_global:N</code>	<code>_kernel_chk_var_local:N <var></code> <code>_kernel_chk_var_global:N <var></code>	Applies <code>_kernel_chk_var_exist:N <var></code> , and assuming that is true applies <code>_kernel_chk_var_scope:NN <scope> <var></code> , where $\langle scope \rangle$ is <code>l</code> or <code>g</code> .
<hr/> <hr/>	<code>_kernel_cs_parm_from_arg_count:nnF</code>	<code>_kernel_cs_parm_from_arg_count:nnF {<follow-on>} {<args>}</code> <code>{<false code>}</code>	Evaluates the number of $\langle args \rangle$ and leaves the $\langle follow-on \rangle$ code followed by a brace group containing the required number of primitive parameter markers (<code>#1</code> , <i>etc.</i>). If the number of $\langle args \rangle$ is outside the range $[0, 9]$, the $\langle false \text{ code} \rangle$ is inserted <i>instead</i> of the $\langle follow-on \rangle$.
<hr/> <hr/>	<code>_kernel_deprecation_code:nn</code>	<code>_kernel_deprecation_code:nn {<error code>} {<working code>}</code>	Stores both an $\langle error \rangle$ and $\langle working \rangle$ definition for given material such that they can be exchanged by <code>\debug_on:</code> and <code>\debug_off:</code> .
<hr/> <hr/>	<code>_kernel_if_debug:TF</code>	<code>_kernel_if_debug:TF {<true code>} {<false code>}</code>	Runs the $\langle true \text{ code} \rangle$ if debugging is enabled, namely only in L ^A T _E X 2 _ε package mode with one of the options <code>check-declarations</code> , <code>enable-debug</code> , or <code>log-functions</code> . Otherwise runs the $\langle false \text{ code} \rangle$. The <code>T</code> and <code>F</code> variants are not provided for this low-level conditional.
<hr/> <hr/>	<code>_kernel_debug_log:x</code>	<code>_kernel_debug_log:x {<message text>}</code>	If the <code>log-functions</code> option is active, this function writes the $\langle message \text{ text} \rangle$ to the log file using <code>\iow_log:x</code> . Otherwise, the $\langle message \text{ text} \rangle$ is ignored using <code>\use_none:n</code> . This function is only created if debugging is enabled.
<hr/> <hr/>	<code>_kernel_exp_not:w *</code>	<code>_kernel_exp_not:w <expandable tokens> {<content>}</code>	Carries out expansion on the $\langle expandable \text{ tokens} \rangle$ before preventing further expansion of the $\langle content \rangle$ as for <code>\exp_not:n</code> . Typically, the $\langle expandable \text{ tokens} \rangle$ will alter the nature of the $\langle content \rangle$, <i>i.e.</i> allow it to be generated in some way.
<hr/> <hr/>	<code>\l_kernel_expl_bool</code>		A boolean which records the current code syntax status: <code>true</code> if currently inside a code environment. This variable should only be set by <code>\ExplSyntaxOn/\ExplSyntaxOff</code> . (End definition for <code>\l_kernel_expl_bool</code> .)
<hr/> <hr/>	<code>_kernel_file_missing:n</code>	<code>_kernel_file_missing:n {<name>}</code>	Expands the $\langle name \rangle$ as per <code>_kernel_file_name_sanitise:nN</code> then produces an error message indicating that that file was not found.

`__kernel_file_name_sanitize:nN` `__kernel_file_name_sanitize:nN` $\{\langle name \rangle\}$ $\langle str\ var \rangle$

For converting a $\langle name \rangle$ to a string where active characters are treated as strings.

`__kernel_file_input_push:n` `__kernel_file_input_push:n` $\{\langle name \rangle\}$
`__kernel_file_input_pop:` `__kernel_file_input_pop:`

Used to push and pop data from the internal file stack: needed only in package mode, where interfacing with the L^AT_EX 2_ε kernel is necessary.

`__kernel_int_add:nnn` \star `__kernel_int_add:nnn` $\{\langle integer_1 \rangle\}$ $\{\langle integer_2 \rangle\}$ $\{\langle integer_3 \rangle\}$

Expands to the result of adding the three $\langle integers \rangle$ (which must be suitable input for `\int_eval:w`), avoiding intermediate overflow. Overflow occurs only if the overall result is outside $[-2^{31}+1, 2^{31}-1]$. The $\langle integers \rangle$ may be of the form `\int_eval:w ... \scan_stop:` but may be evaluated more than once.

`__kernel_ior_open:Nn` `__kernel_ior_open:Nn` $\langle stream \rangle$ $\{\langle file\ name \rangle\}$
`__kernel_ior_open:No`

This function has identical syntax to the public version. However, it does not take precautions against active characters in the $\langle file\ name \rangle$, and it does not attempt to add a $\langle path \rangle$ to the $\langle file\ name \rangle$: it is therefore intended to be used by higher-level functions which have already fully expanded the $\langle file\ name \rangle$ and which need to perform multiple open or close operations. See for example the implementation of `\file_get_full_name:nN`,

`__kernel_iow_with:Nnn` `__kernel_iow_with:Nnn` $\langle integer \rangle$ $\{\langle value \rangle\}$ $\{\langle code \rangle\}$

If the $\langle integer \rangle$ is equal to the $\langle value \rangle$ then this function simply runs the $\langle code \rangle$. Otherwise it saves the current value of the $\langle integer \rangle$, sets it to the $\langle value \rangle$, runs the $\langle code \rangle$, and restores the $\langle integer \rangle$ to its former value. This is used to ensure that the `\newlinechar` is 10 when writing to a stream, which lets `\iow_newline:` work, and that `\errorcontextlines` is -1 when displaying a message.

`__kernel_msg_new:nnnn` `__kernel_msg_new:nnnn` $\{\langle module \rangle\}$ $\{\langle message \rangle\}$ $\{\langle text \rangle\}$ $\{\langle more\ text \rangle\}$
`__kernel_msg_new:nnn`

Creates a kernel $\langle message \rangle$ for a given $\langle module \rangle$. The message is defined to first give $\langle text \rangle$ and then $\langle more\ text \rangle$ if the user requests it. If no $\langle more\ text \rangle$ is available then a standard text is given instead. Within $\langle text \rangle$ and $\langle more\ text \rangle$ four parameters (#1 to #4) can be used: these will be supplied and expanded at the time the message is used. An error is raised if the $\langle message \rangle$ already exists.

`__kernel_msg_set:nnnn` `__kernel_msg_set:nnnn` $\{\langle module \rangle\}$ $\{\langle message \rangle\}$ $\{\langle text \rangle\}$ $\{\langle more\ text \rangle\}$
`__kernel_msg_set:nnn`

Sets up the text for a kernel $\langle message \rangle$ for a given $\langle module \rangle$. The message is defined to first give $\langle text \rangle$ and then $\langle more\ text \rangle$ if the user requests it. If no $\langle more\ text \rangle$ is available then a standard text is given instead. Within $\langle text \rangle$ and $\langle more\ text \rangle$ four parameters (#1 to #4) can be used: these will be supplied and expanded at the time the message is used.

```

\_kernel_msg_fatal:nnnnnn
\_kernel_msg_fatal:nnxxxx
\_kernel_msg_fatal:nnnnn
\_kernel_msg_fatal:nnxxx
\_kernel_msg_fatal:nnnn
\_kernel_msg_fatal:nnxx
\_kernel_msg_fatal:nnn
\_kernel_msg_fatal:nnx
\_kernel_msg_fatal:nn

```

```

\_kernel_msg_fatal:nnnnnn {\module} {\message} {\arg one} {\arg two} {\arg
three}} {\arg four}}

```

Issues kernel *<module>* error *<message>*, passing *<arg one>* to *<arg four>* to the text-creating functions. After issuing a fatal error the T_EX run halts. Cannot be redirected.

```

\_kernel_msg_error:nnnnnn
\_kernel_msg_error:nnxxxx
\_kernel_msg_error:nnnnn
\_kernel_msg_error:nnxxx
\_kernel_msg_error:nnnn
\_kernel_msg_error:nnxx
\_kernel_msg_error:nnn
\_kernel_msg_error:nnx
\_kernel_msg_error:nn

```

```

\_kernel_msg_error:nnnnnn {\module} {\message} {\arg one} {\arg two} {\arg
three}} {\arg four}}

```

Issues kernel *<module>* error *<message>*, passing *<arg one>* to *<arg four>* to the text-creating functions. The error stops processing and issues the text at the terminal. After user input, the run continues. Cannot be redirected.

```

\_kernel_msg_warning:nnnnnn
\_kernel_msg_warning:nnxxxx
\_kernel_msg_warning:nnnnn
\_kernel_msg_warning:nnxxx
\_kernel_msg_warning:nnnn
\_kernel_msg_warning:nnxx
\_kernel_msg_warning:nnn
\_kernel_msg_warning:nnx
\_kernel_msg_warning:nn

```

```

\_kernel_msg_warning:nnnnnn {\module} {\message} {\arg one} {\arg
two}} {\arg three}} {\arg four}}

```

Issues kernel *<module>* warning *<message>*, passing *<arg one>* to *<arg four>* to the text-creating functions. The warning text is added to the log file, but the T_EX run is not interrupted.

```

\_kernel_msg_info:nnnnnn
\_kernel_msg_info:nnxxxx
\_kernel_msg_info:nnnnn
\_kernel_msg_info:nnxxx
\_kernel_msg_info:nnnn
\_kernel_msg_info:nnxx
\_kernel_msg_info:nnn
\_kernel_msg_info:nnx
\_kernel_msg_info:nn

```

```

\_kernel_msg_info:nnnnnn {\module} {\message} {\arg one} {\arg two} {\arg
three}} {\arg four}}

```

Issues kernel *<module>* information *<message>*, passing *<arg one>* to *<arg four>* to the text-creating functions. The information text is added to the log file.

<code>__kernel_msg_expandable_error:nnnnnn</code>	<code>*</code>	<code>__kernel_msg_expandable_error:nnnnnn</code>	<code>{<module>}</code>	<code>{<message>}</code>	
<code>__kernel_msg_expandable_error:nnffff</code>	<code>*</code>	<code>{<arg one>}</code>	<code>{<arg two>}</code>	<code>{<arg three>}</code>	<code>{<arg four>}</code>
<code>__kernel_msg_expandable_error:nnnnn</code>	<code>*</code>				
<code>__kernel_msg_expandable_error:nnfff</code>	<code>*</code>				
<code>__kernel_msg_expandable_error:nnnn</code>	<code>*</code>				
<code>__kernel_msg_expandable_error:nnff</code>	<code>*</code>				
<code>__kernel_msg_expandable_error:nnn</code>	<code>*</code>				
<code>__kernel_msg_expandable_error:nnf</code>	<code>*</code>				
<code>__kernel_msg_expandable_error:nn</code>	<code>*</code>				

Issues an error, passing `<arg one>` to `<arg four>` to the text-creating functions. The resulting string must be much shorter than a line, otherwise it is cropped.

<code>__kernel_patch:nnNNpn</code>	<code>__kernel_patch:nnNNpn</code>	<code>{<before>}</code>	<code>{<after>}</code>
	<code><definition></code>	<code><function></code>	<code><parameters></code>
		<code>{<code>}</code>	

If debugging is not enabled, this function ignores the `<before>` and `<after>` code and performs the `<definition>` with no patching. Otherwise it replaces `<code>` by `<before>` `<code>` `<after>` (which can involve `#1` and so on) in the `<definition>` that follows. The `<definition>` must start with `\cs_new:Npn` or `\cs_set:Npn` or `\cs_gset:Npn` or their `_protected` counterparts. Other cases can be added as needed.

<code>__kernel_patch_conditional:nnNpnn</code>	<code>__kernel_patch_conditional:nnNpnn</code>	<code>{<before>}</code>
	<code><definition></code>	<code><conditional></code>
	<code><parameters></code>	<code>{<type>}</code>
		<code>{<code>}</code>

Similar to `__kernel_patch:nnNNpn` for conditionals, namely `<definition>` must be `\prg_new_conditional:Npnn` or its `_protected` counterpart. There is no `<after>` code because that would interfere with the action of the conditional.

<code>__kernel_patch_args:nnNpn</code>	<code>__kernel_patch_args:nnNpn</code>	<code>{<arguments>}</code>
<code>__kernel_patch_conditional_args:nnNpnn</code>	<code><definition></code>	<code><function></code>
		<code><parameters></code>
		<code>{<code>}</code>

Like `__kernel_patch:nnNNpn`, this tweaks the following definition, but from the “inside out” (and if debugging is not enabled, the `<arguments>` are ignored). It replaces `#1`, `#2` and so on in the `<code>` of the definition as indicated by the `<arguments>`. More precisely, a temporary function is defined using the `<definition>` with the `<parameters>` and `<code>`, then the result of expanding that function once in front of the `<arguments>` is used instead of the `<code>` when defining the actual function. For instance,

```
\__kernel_patch_args:nnNpn { { (#1) } }
\cs_new:Npn \int_eval:n #1
{ \int_value:w \__int_eval:w #1 \__int_eval_end: }
```

would replace `#1` by `(#1)` in the definition of `\int_eval:n` when debugging is enabled. This fails if the `<code>` contains `##`. The `__kernel_patch_conditional_args:nnNpnn` function is for use before `\prg_new_conditional:Npnn` or its `_protected` counterpart.

<code>__kernel_patch_args:nnnNNpn</code>	<code>__kernel_patch_args:nnnNNpn</code>	<code>{<before>}</code>	<code>{<after>}</code>
<code>__kernel_patch_conditional_args:nnnNNpnn</code>	<code>{<arguments>}</code>		
	<code><definition></code>	<code><function></code>	<code><parameters></code>
		<code>{<code>}</code>	

A combination of `__kernel_patch:nnNNpn` and `__kernel_patch_args:nnNpn`.

<code>\g__kernel_prg_map_int</code>	<p>This integer is used by non-expandable mapping functions to track the level of nesting in force. The functions <code>\<type>_map_1:w</code>, <code>\<type>_map_2:w</code>, <i>etc.</i>, labelled by <code>\g__kernel_prg_map_int</code> hold functions to be mapped over various list datatypes in inline and variable mappings.</p> <p>(End definition for <code>\g__kernel_prg_map_int</code>.)</p>
<code>\c__kernel_randint_max_int</code>	<p>Maximal allowed argument to <code>__kernel_randint:n</code>. Equal to $2^{17} - 1$.</p> <p>(End definition for <code>\c__kernel_randint_max_int</code>.)</p>
<hr/> <code>__kernel_randint:n</code> <hr/>	<p><code>__kernel_randint:n {<max>}</code></p> <p>Used in an integer expression this gives a pseudo-random number between 1 and $\langle max \rangle$ included. One must have $\langle max \rangle \leq 2^{17} - 1$. The $\langle max \rangle$ must be suitable for <code>\int_value:w</code> (and any <code>\int_eval:w</code> must be terminated by <code>\scan_stop:</code> or equivalent).</p>
<hr/> <code>__kernel_randint:nn</code> <hr/>	<p><code>__kernel_randint:nn {<min>} {<max>}</code></p> <p>Used in an integer expression this gives a pseudo-random number between $\langle min \rangle$ and $\langle max \rangle$ included. The $\langle min \rangle$ and $\langle max \rangle$ must be suitable for <code>\int_value:w</code> (and any <code>\int_eval:w</code> must be terminated by <code>\scan_stop:</code> or equivalent). For small ranges $R = \langle max \rangle - \langle min \rangle + 1 \leq 2^{17} - 1$, $\langle min \rangle - 1 + __kernel_randint:n\{R\}$ is faster.</p>
<hr/> <code>__kernel_register_show:N</code> <code>__kernel_register_show:c</code> <hr/>	<p><code>__kernel_register_show:N <register></code></p> <p>Used to show the contents of a T_EX register at the terminal, formatted such that internal parts of the mechanism are not visible.</p>
<hr/> <code>__kernel_register_log:N</code> <code>__kernel_register_log:c</code> <hr/>	<p><code>__kernel_register_log:N <register></code></p> <p>Used to write the contents of a T_EX register to the log file in a form similar to <code>__kernel_register_show:N</code>.</p>
<hr/> <code>__kernel_str_to_other:n *</code> <hr/>	<p><code>__kernel_str_to_other:n {<token list>}</code></p> <p>Converts the $\langle token list \rangle$ to a $\langle other string \rangle$, where spaces have category code “other”. This function can be f-expanded without fear of losing a leading space, since spaces do not have category code 10 in its result. It takes a time quadratic in the character count of the string.</p>
<hr/> <code>__kernel_str_to_other_fast:n ☆</code> <hr/>	<p><code>__kernel_str_to_other_fast:n {<token list>}</code></p> <p>Same behaviour <code>__kernel_str_to_other:n</code> but only restricted-expandable. It takes a time linear in the character count of the string.</p>
<hr/> <code>__kernel_tl_to_str:w *</code> <hr/>	<p><code>__kernel_tl_to_str:w <expandable tokens> {<tokens>}</code></p> <p>Carries out expansion on the $\langle expandable tokens \rangle$ before conversion of the $\langle tokens \rangle$ to a string as describe for <code>\tl_to_str:n</code>. Typically, the $\langle expandable tokens \rangle$ will alter the nature of the $\langle tokens \rangle$, <i>i.e.</i> allow it to be generated in some way. This function requires only a single expansion.</p>

4 Kernel backend functions

These functions are required to pass information to the backend. The nature of these means that they are defined only when the relevant backend is in use.

```

\__kernel_backend_literal:n \__kernel_backend_literal:n {\langle content \rangle}
\__kernel_backend_literal:x
\__kernel_backend_literal:e

```

Adds the $\langle content \rangle$ literally to the current vertical list as a whatsit. The nature of the $\langle content \rangle$ will depend on the backend in use.

```

\__kernel_backend_literal_postscript:n \__kernel_backend_literal_postscript:n {\langle PostScript \rangle}
\__kernel_backend_literal_postscript:x

```

Adds the $\langle PostScript \rangle$ literally to the current vertical list as a whatsit. No positioning is applied.

```

\__kernel_backend_literal_pdf:n \__kernel_backend_literal_pdf:n {\langle PDF instructions \rangle}
\__kernel_backend_literal_pdf:x

```

Adds the $\langle PDF instructions \rangle$ literally to the current vertical list as a whatsit. No positioning is applied.

```

\__kernel_backend_literal_svg:n \__kernel_backend_literal_svg:n {\langle SVG instructions \rangle}
\__kernel_backend_literal_svg:x

```

Adds the $\langle SVG instructions \rangle$ literally to the current vertical list as a whatsit. No positioning is applied.

```

\__kernel_backend_postscript:n \__kernel_backend_postscript:n {\langle PostScript \rangle}
\__kernel_backend_postscript:x

```

Adds the $\langle PostScript \rangle$ to the current vertical list as a whatsit. The PostScript reference point is adjusted to match the current position. The PostScript is inserted inside a `SDict begin/end` pair.

```

\__kernel_backend_postscript_header:n \__kernel_backend_postscript_header:n {\langle PostScript \rangle}

```

Adds the $\langle PostScript \rangle$ to the PostScript header.

```

\__kernel_backend_align_begin: \__kernel_backend_align_begin:
\__kernel_backend_align_end: \__kernel_backend_align_end:
\__kernel_backend_align_end:

```

Arranges to align the PostScript and DVI current positions and scales.

```

\__kernel_backend_scope_begin: \__kernel_backend_scope_begin:
\__kernel_backend_scope_end: \__kernel_backend_scope_end:
\__kernel_backend_scope_end:

```

Creates a scope for instructions at the backend level.

```

\__kernel_backend_matrix:n
\__kernel_backend_matrix:x

```

```

\__kernel_backend_matrix:n {\matrix}

```

Applies the $\langle matrix \rangle$ to the current transformation matrix.

```

\l__kernel_color_stack_int

```

The color stack used in pdfTeX and LuaTeX for the main color.

5 l3basics implementation

²⁰⁷⁷ $\langle *initex \mid package \rangle$

5.1 Renaming some TeX primitives (again)

Having given all the TeX primitives a consistent name, we need to give sensible names to the ones we actually want to use. These will be defined as needed in the appropriate modules, but we do a few now, just to get started.⁸

```

\if_true: Then some conditionals.
\if_false:
\or:
\else:
\fi:
\reverse_if:N
\if:w
\if_charcode:w
\if_catcode:w
\if_meaning:w

```

2078	<code>\tex_let:D \if_true:</code>	<code>\tex_iftrue:D</code>
2079	<code>\tex_let:D \if_false:</code>	<code>\tex_iffalse:D</code>
2080	<code>\tex_let:D \or:</code>	<code>\tex_or:D</code>
2081	<code>\tex_let:D \else:</code>	<code>\tex_else:D</code>
2082	<code>\tex_let:D \fi:</code>	<code>\tex_fi:D</code>
2083	<code>\tex_let:D \reverse_if:N</code>	<code>\tex_unless:D</code>
2084	<code>\tex_let:D \if:w</code>	<code>\tex_if:D</code>
2085	<code>\tex_let:D \if_charcode:w</code>	<code>\tex_if:D</code>
2086	<code>\tex_let:D \if_catcode:w</code>	<code>\tex_ifcat:D</code>
2087	<code>\tex_let:D \if_meaning:w</code>	<code>\tex_ifx:D</code>

(End definition for `\if_true:` and others. These functions are documented on page 23.)

```

\if_mode_math: TeX lets us detect some if its modes.
\if_mode_horizontal:
\if_mode_vertical:
\if_mode_inner:

```

2088	<code>\tex_let:D \if_mode_math:</code>	<code>\tex_ifmmode:D</code>
2089	<code>\tex_let:D \if_mode_horizontal:</code>	<code>\tex_ifhmode:D</code>
2090	<code>\tex_let:D \if_mode_vertical:</code>	<code>\tex_ifvmode:D</code>
2091	<code>\tex_let:D \if_mode_inner:</code>	<code>\tex_ifinner:D</code>

(End definition for `\if_mode_math:` and others. These functions are documented on page 23.)

```

\if_cs_exist:N Building csnames and testing if control sequences exist.
\if_cs_exist:w
\cs:w
\cs_end:

```

2092	<code>\tex_let:D \if_cs_exist:N</code>	<code>\tex_ifdefined:D</code>
2093	<code>\tex_let:D \if_cs_exist:w</code>	<code>\tex_ifcsname:D</code>
2094	<code>\tex_let:D \cs:w</code>	<code>\tex_csname:D</code>
2095	<code>\tex_let:D \cs_end:</code>	<code>\tex_endcsname:D</code>

(End definition for `\if_cs_exist:N` and others. These functions are documented on page 23.)

```

\exp_after:wN The five \exp_ functions are used in the l3expan module where they are described.
\exp_not:N
\exp_not:n

```

2096	<code>\tex_let:D \exp_after:wN</code>	<code>\tex_expandafter:D</code>
2097	<code>\tex_let:D \exp_not:N</code>	<code>\tex_noexpand:D</code>
2098	<code>\tex_let:D \exp_not:n</code>	<code>\tex_unexpanded:D</code>
2099	<code>\tex_let:D \exp:w</code>	<code>\tex_romannumeral:D</code>
2100	<code>\tex_chardef:D \exp_end: = 0 ~</code>	

⁸This renaming gets expensive in terms of csname usage, an alternative scheme would be to just use the `\tex_...:D` name in the cases where no good alternative exists.

(End definition for `\exp_after:wN`, `\exp_not:N`, and `\exp_not:n`. These functions are documented on page 32.)

`\token_to_meaning:N` Examining a control sequence or token.

`\cs_meaning:N` 2101 `\tex_let:D \token_to_meaning:N \tex_meaning:D`
 2102 `\tex_let:D \cs_meaning:N \tex_meaning:D`

(End definition for `\token_to_meaning:N` and `\cs_meaning:N`. These functions are documented on page 128.)

`\tl_to_str:n` Making strings.

`\token_to_str:N` 2103 `\tex_let:D \tl_to_str:n \tex_detokenize:D`
`__kernel_tl_to_str:w` 2104 `\tex_let:D \token_to_str:N \tex_string:D`
 2105 `\tex_let:D __kernel_tl_to_str:w \tex_detokenize:D`

(End definition for `\tl_to_str:n`, `\token_to_str:N`, and `__kernel_tl_to_str:w`. These functions are documented on page 44.)

`\scan_stop:` The next three are basic functions for which there also exist versions that are safe inside alignments. These safe versions are defined in the `l3prg` module.

`\group_begin:` 2106 `\tex_let:D \scan_stop: \tex_relax:D`
`\group_end:` 2107 `\tex_let:D \group_begin: \tex_begingroup:D`
 2108 `\tex_let:D \group_end: \tex_endgroup:D`

(End definition for `\scan_stop:`, `\group_begin:`, and `\group_end:`. These functions are documented on page 9.)

2109 `<@@=int>`

`\if_int_compare:w` For integers.

`__int_to_roman:w` 2110 `\tex_let:D \if_int_compare:w \tex_ifnum:D`
 2111 `\tex_let:D __int_to_roman:w \tex_romannumeral:D`

(End definition for `\if_int_compare:w` and `__int_to_roman:w`. This function is documented on page 97.)

`\group_insert_after:N` Adding material after the end of a group.

2112 `\tex_let:D \group_insert_after:N \tex_aftergroup:D`

(End definition for `\group_insert_after:N`. This function is documented on page 9.)

`\exp_args:Nc` Discussed in `l3expan`, but needed much earlier.

`\exp_args:cc` 2113 `\tex_long:D \tex_def:D \exp_args:Nc #1#2`
 2114 `{ \exp_after:wN #1 \cs:w #2 \cs_end: }`
 2115 `\tex_long:D \tex_def:D \exp_args:cc #1#2`
 2116 `{ \cs:w #1 \exp_after:wN \cs_end: \cs:w #2 \cs_end: }`

(End definition for `\exp_args:Nc` and `\exp_args:cc`. These functions are documented on page 28.)

`\token_to_meaning:c` A small number of variants defined by hand. Some of the necessary functions (`\use_i:nn`, `\use_ii:nn`, and `\exp_args:Nnc`) are not defined at that point yet, but will be defined before those variants are used. The `\cs_meaning:c` command must check for an undefined control sequence to avoid defining it mistakenly.

```

2117 \tex_def:D \token_to_str:c { \exp_args:Nc \token_to_str:N }
2118 \tex_long:D \tex_def:D \cs_meaning:c #1
2119 {
2120   \if_cs_exist:w #1 \cs_end:
2121     \exp_after:wN \use_i:nn
2122   \else:
2123     \exp_after:wN \use_ii:nn
2124   \fi:
2125   { \exp_args:Nc \cs_meaning:N {#1} }
2126   { \tl_to_str:n {undefined} }
2127 }
2128 \tex_let:D \token_to_meaning:c = \cs_meaning:c

```

(End definition for `\token_to_meaning:N`. This function is documented on page 128.)

5.2 Defining some constants

`\c_zero_int` We need the constant `\c_zero_int` which is used by some functions in the `l3alloc` module. The rest are defined in the `l3int` module – at least for the ones that can be defined with `\tex_chardef:D` or `\tex_mathchardef:D`. For other constants the `l3int` module is required but it can't be used until the allocation has been set up properly!

```

2129 \tex_chardef:D \c_zero_int = 0 ~

```

(End definition for `\c_zero_int`. This variable is documented on page 96.)

`\c_max_register_int` This is here as this particular integer is needed both in package mode and to bootstrap `l3alloc`, and is documented in `l3int`.

```

2130 \tex_ifdefined:D \tex_luatexversion:D
2131   \tex_chardef:D \c_max_register_int = 65 535 ~
2132 \tex_else:D
2133   \tex_mathchardef:D \c_max_register_int = 32 767 ~
2134 \tex_fi:D

```

(End definition for `\c_max_register_int`. This variable is documented on page 96.)

5.3 Defining functions

We start by providing functions for the typical definition functions. First the local ones.

`\cs_set_nopar:Npn` All assignment functions in L^AT_EX3 should be naturally protected; after all, the T_EX primitives for assignments are and it can be a cause of problems if others aren't.

`\cs_set_nopar:Npx`

`\cs_set:Npn`

`\cs_set:Npx`

`\cs_set_protected_nopar:Npn`

`\cs_set_protected_nopar:Npx`

`\cs_set_protected:Npn`

`\cs_set_protected:Npx`

```

2135 \tex_let:D \cs_set_nopar:Npn \tex_def:D
2136 \tex_let:D \cs_set_nopar:Npx \tex_edef:D
2137 \tex_protected:D \tex_long:D \tex_def:D \cs_set:Npn
2138 { \tex_long:D \tex_def:D }
2139 \tex_protected:D \tex_long:D \tex_def:D \cs_set:Npx
2140 { \tex_long:D \tex_edef:D }
2141 \tex_protected:D \tex_long:D \tex_def:D \cs_set_protected_nopar:Npn
2142 { \tex_protected:D \tex_def:D }

```

```

2143 \tex_protected:D \tex_long:D \tex_def:D \cs_set_protected_nopar:Npx
2144 { \tex_protected:D \tex_edef:D }
2145 \tex_protected:D \tex_long:D \tex_def:D \cs_set_protected:Npn
2146 { \tex_protected:D \tex_long:D \tex_def:D }
2147 \tex_protected:D \tex_long:D \tex_def:D \cs_set_protected:Npx
2148 { \tex_protected:D \tex_long:D \tex_edef:D }

```

(End definition for `\cs_set_nopar:Npn` and others. These functions are documented on page 11.)

`\cs_gset_nopar:Npn` Global versions of the above functions.

```

\cs_gset_nopar:Npx 2149 \tex_let:D \cs_gset_nopar:Npn \tex_gdef:D
\cs_gset:Npn 2150 \tex_let:D \cs_gset_nopar:Npx \tex_xdef:D
\cs_gset:Npn 2151 \cs_set_protected:Npn \cs_gset:Npn
\cs_gset_protected_nopar:Npn 2152 { \tex_long:D \tex_gdef:D }
\cs_gset_protected_nopar:Npx 2153 \cs_set_protected:Npn \cs_gset:Npx
\cs_gset_protected:Npn 2154 { \tex_long:D \tex_xdef:D }
\cs_gset_protected:Npn 2155 \cs_set_protected:Npn \cs_gset_protected_nopar:Npn
\cs_gset_protected:Npn 2156 { \tex_protected:D \tex_gdef:D }
\cs_gset_protected:Npn 2157 \cs_set_protected:Npn \cs_gset_protected_nopar:Npx
\cs_gset_protected:Npn 2158 { \tex_protected:D \tex_xdef:D }
\cs_gset_protected:Npn 2159 \cs_set_protected:Npn \cs_gset_protected:Npn
\cs_gset_protected:Npn 2160 { \tex_protected:D \tex_long:D \tex_gdef:D }
\cs_gset_protected:Npn 2161 \cs_set_protected:Npn \cs_gset_protected:Npx
\cs_gset_protected:Npn 2162 { \tex_protected:D \tex_long:D \tex_xdef:D }

```

(End definition for `\cs_gset_nopar:Npn` and others. These functions are documented on page 12.)

5.4 Selecting tokens

```

2163 <@@=exp>

```

`\l__exp_internal_tl` Scratch token list variable for `\l3expan`, used by `\use:x`, used in defining conditionals. We don't use `tl` methods because `\l3basics` is loaded earlier.

```

2164 \cs_set_nopar:Npn \l__exp_internal_tl { }

```

(End definition for `\l__exp_internal_tl`.)

`\use:c` This macro grabs its argument and returns a csname from it.

```

2165 \cs_set:Npn \use:c #1 { \cs:w #1 \cs_end: }

```

(End definition for `\use:c`. This function is documented on page 16.)

`\use:x` Fully expands its argument and passes it to the input stream. Uses the reserved `\l__exp_internal_tl` which will be set up in `\l3expan`.

```

2166 \cs_set_protected:Npn \use:x #1
2167 {
2168   \cs_set_nopar:Npx \l__exp_internal_tl {#1}
2169   \l__exp_internal_tl
2170 }

```

(End definition for `\use:x`. This function is documented on page 20.)

```

2171 <@@=use>

```


`\use:e` Currently LuaTeX-only: emulated for older engines.

```
2172 \cs_set:Npn \use:e #1 { \tex_expanded:D {#1} }
2173 \tex_ifdefined:D \tex_expanded:D \tex_else:D
2174   \cs_set:Npn \use:e #1 { \exp_args:Ne \use:n {#1} }
2175 \tex_fi:D
```

(End definition for `\use:e`. This function is documented on page 20.)

```
2176 <@@=exp>
```

`\use:n` These macros grab their arguments and return them back to the input (with outer braces removed).

```
\use:nn      2177 \cs_set:Npn \use:n   #1      {#1}
\use:nnn     2178 \cs_set:Npn \use:nn  #1#2    {#1#2}
\use:nnnn    2179 \cs_set:Npn \use:nnn #1#2#3   {#1#2#3}
              2180 \cs_set:Npn \use:nnnn #1#2#3#4 {#1#2#3#4}
```

(End definition for `\use:n` and others. These functions are documented on page 19.)

`\use_i:nn` The equivalent to L^AT_EX 2_ε's `\@firstoftwo` and `\@secondoftwo`.

```
\use_ii:nn  2181 \cs_set:Npn \use_i:nn  #1#2 {#1}
              2182 \cs_set:Npn \use_ii:nn #1#2 {#2}
```

(End definition for `\use_i:nn` and `\use_ii:nn`. These functions are documented on page 19.)

`\use_i:nnn` We also need something for picking up arguments from a longer list.

```
\use_ii:nnn 2183 \cs_set:Npn \use_i:nnn  #1#2#3 {#1}
\use_iii:nnn 2184 \cs_set:Npn \use_ii:nnn #1#2#3 {#2}
\use_i_ii:nnn 2185 \cs_set:Npn \use_iii:nnn #1#2#3 {#3}
\use_i:nnnn  2186 \cs_set:Npn \use_i_ii:nnn #1#2#3 {#1#2}
\use_ii:nnnn 2187 \cs_set:Npn \use_i:nnnn  #1#2#3#4 {#1}
\use_iii:nnnn 2188 \cs_set:Npn \use_ii:nnnn  #1#2#3#4 {#2}
\use_iv:nnnn 2189 \cs_set:Npn \use_iii:nnnn #1#2#3#4 {#3}
              2190 \cs_set:Npn \use_iv:nnnn  #1#2#3#4 {#4}
```

(End definition for `\use_i:nnn` and others. These functions are documented on page 19.)

`\use_ii_i:nn`

```
2191 \cs_set:Npn \use_ii_i:nn #1#2 { #2 #1 }
```

(End definition for `\use_ii_i:nn`. This function is documented on page 20.)

`\use_none_delimit_by_q_nil:w` Functions that gobble everything until they see either `\q_nil`, `\q_stop`, or `\q_recursion_stop`, respectively.

```
\use_none_delimit_by_q_stop:w 2192 \cs_set:Npn \use_none_delimit_by_q_nil:w #1 \q_nil { }
\use_none_delimit_by_q_recursion_stop:w 2193 \cs_set:Npn \use_none_delimit_by_q_stop:w #1 \q_stop { }
2194 \cs_set:Npn \use_none_delimit_by_q_recursion_stop:w #1 \q_recursion_stop { }
```

(End definition for `\use_none_delimit_by_q_nil:w`, `\use_none_delimit_by_q_stop:w`, and `\use_none_delimit_by_q_recursion_stop:w`. These functions are documented on page 21.)

`\use_i_delimit_by_q_nil:nw` Same as above but execute first argument after gobbling. Very useful when you need to skip the rest of a mapping sequence but want an easy way to control what should be expanded next.

```

2195 \cs_set:Npn \use_i_delimit_by_q_nil:nw #1#2 \q_nil {#1}
2196 \cs_set:Npn \use_i_delimit_by_q_stop:nw #1#2 \q_stop {#1}
2197 \cs_set:Npn \use_i_delimit_by_q_recursion_stop:nw
2198 #1#2 \q_recursion_stop {#1}

```

(End definition for `\use_i_delimit_by_q_nil:nw`, `\use_i_delimit_by_q_stop:nw`, and `\use_i_delimit_by_q_recursion_stop:nw`. These functions are documented on page 21.)

5.5 Gobbling tokens from input

`\use_none:n` To gobble tokens from the input we use a standard naming convention: the number of tokens gobbled is given by the number of `n`'s following the `:` in the name. Although we could define functions to remove ten arguments or more using separate calls of `\use_none:nnnnn`, this is very non-intuitive to the programmer who will assume that expanding such a function once takes care of gobbling all the tokens in one go.

```

\use_none:n
\use_none:nn
\use_none:nnn
\use_none:nnnn
\use_none:nnnnn
\use_none:nnnnnn
\use_none:nnnnnnn
\use_none:nnnnnnnn
\use_none:nnnnnnnnn
2199 \cs_set:Npn \use_none:n #1 { }
2200 \cs_set:Npn \use_none:nn #1#2 { }
2201 \cs_set:Npn \use_none:nnn #1#2#3 { }
2202 \cs_set:Npn \use_none:nnnn #1#2#3#4 { }
2203 \cs_set:Npn \use_none:nnnnn #1#2#3#4#5 { }
2204 \cs_set:Npn \use_none:nnnnnn #1#2#3#4#5#6 { }
2205 \cs_set:Npn \use_none:nnnnnnn #1#2#3#4#5#6#7 { }
2206 \cs_set:Npn \use_none:nnnnnnnn #1#2#3#4#5#6#7#8 { }
2207 \cs_set:Npn \use_none:nnnnnnnnn #1#2#3#4#5#6#7#8#9 { }

```

(End definition for `\use_none:n` and others. These functions are documented on page 20.)

5.6 Debugging and patching later definitions

`_kernel_if_debug:TF` `<@@=debug>` A more meaningful test of whether debugging is enabled than messing up with guards. We can also more easily change the logic in one place then. At present, debugging is disabled in the format and in generic mode, while in $\text{\LaTeX} 2_\epsilon$ mode it is enabled if one of the options `enable-debug`, `log-functions` or `check-declarations` was given.

```

2209 \cs_set_protected:Npn \_kernel_if_debug:TF #1#2 {#2}
2210 (*package)
2211 \tex_ifodd:D \l@expl@enable@debug@bool
2212 \cs_set_protected:Npn \_kernel_if_debug:TF #1#2 {#1}
2213 \fi:
2214 </package>

```

(End definition for `_kernel_if_debug:TF`.)

```

\debug_on:n
\debug_off:n
\_debug_all_on:
\_debug_all_off:
2215 \_kernel_if_debug:TF
2216 {
2217   \cs_set_protected:Npn \debug_on:n #1
2218   {
2219     \exp_args:No \clist_map_inline:nn { \tl_to_str:n {#1} }
2220     {

```

```

2221         \cs_if_exist_use:cF { __debug_ ##1 _on: }
2222         { \__kernel_msg_error:nnn { kernel } { debug } {##1} }
2223     }
2224 }
2225 \cs_set_protected:Npn \debug_off:n #1
2226 {
2227     \exp_args:No \clist_map_inline:nn { \tl_to_str:n {#1} }
2228     {
2229         \cs_if_exist_use:cF { __debug_ ##1 _off: }
2230         { \__kernel_msg_error:nnn { kernel } { debug } {##1} }
2231     }
2232 }
2233 \cs_set_protected:Npn \__debug_all_on:
2234 {
2235     \debug_on:n
2236     {
2237         check-declarations ,
2238         check-expressions ,
2239         deprecation ,
2240         log-functions ,
2241     }
2242 }
2243 \cs_set_protected:Npn \__debug_all_off:
2244 {
2245     \debug_off:n
2246     {
2247         check-declarations ,
2248         check-expressions ,
2249         deprecation ,
2250         log-functions ,
2251     }
2252 }
2253 }
2254 {
2255     \cs_set_protected:Npn \debug_on:n #1
2256     {
2257         \__kernel_msg_error:nnx { kernel } { enable-debug }
2258         { \tl_to_str:n { \debug_on:n {#1} } }
2259     }
2260     \cs_set_protected:Npn \debug_off:n #1
2261     {
2262         \__kernel_msg_error:nnx { kernel } { enable-debug }
2263         { \tl_to_str:n { \debug_off:n {#1} } }
2264     }
2265 }

```

(End definition for `\debug_on:n` and others. These functions are documented on page 250.)

\debug_suspend: Suspend and resume locally all debug-related errors and logging except deprecation errors.

\debug_resume: The `\debug_suspend:` and `\debug_resume:` pairs can be nested. We keep track of nesting in a token list containing a number of periods. At first begin with the “non-suspended” version of `__debug_suspended:T`.

`__debug_suspended:T`
`\l__debug_suspended_tl`

```

2266 \__kernel_if_debug:TF
2267 {

```

```

2268 \cs_set_nopar:Npn \l__debug_suspended_tl { }
2269 \cs_set_protected:Npn \debug_suspend:
2270 {
2271   \tl_put_right:Nn \l__debug_suspended_tl { . }
2272   \cs_set_eq:NN \__debug_suspended:T \use:n
2273 }
2274 \cs_set_protected:Npn \debug_resume:
2275 {
2276   \tl_set:Nx \l__debug_suspended_tl
2277   { \tl_tail:N \l__debug_suspended_tl }
2278   \tl_if_empty:NT \l__debug_suspended_tl
2279   {
2280     \cs_set_eq:NN \__debug_suspended:T \use_none:n
2281   }
2282 }
2283 \cs_set:Npn \__debug_suspended:T #1 { }
2284 }
2285 {
2286   \cs_set_protected:Npn \debug_suspend: { }
2287   \cs_set_protected:Npn \debug_resume: { }
2288 }

```

(End definition for `\debug_suspend:` and others. These functions are documented on page 250.)

```

\__debug_check-declarations_on:
\__debug_check-declarations_off:
\__kernel_chk_var_exist:N
\__kernel_chk_cs_exist:N
\__kernel_chk_cs_exist:c
\__kernel_chk_var_local:N
\__kernel_chk_var_global:N
\__kernel_chk_var_scope:NN

```

When debugging is enabled these two functions set up functions that test their argument (when `check-declarations` is active)

- `__kernel_chk_var_exist:N` and `__kernel_chk_cs_exist:N`, two functions that test that their argument is defined;
- `__kernel_chk_var_scope:NN` that checks that its argument #2 has scope #1.
- `__kernel_chk_var_local:N` and `__kernel_chk_var_global:N` that perform both checks.

```

2289 \__kernel_if_debug:TF
2290 {
2291   \exp_args:Nc \cs_set_protected:Npn { __debug_check-declarations_on: }
2292   {
2293     \cs_set_protected:Npn \__kernel_chk_var_exist:N ##1
2294     {
2295       \__debug_suspended:T \use_none:nnn
2296       \cs_if_exist:NF ##1
2297       {
2298         \__kernel_msg_error:nnx { kernel } { non-declared-variable }
2299         { \token_to_str:N ##1 }
2300       }
2301     }
2302     \cs_set_protected:Npn \__kernel_chk_cs_exist:N ##1
2303     {
2304       \__debug_suspended:T \use_none:nnn
2305       \cs_if_exist:NF ##1
2306       {
2307         \__kernel_msg_error:nnx { kernel } { command-not-defined }
2308         { \token_to_str:N ##1 }

```

```

2309     }
2310   }
2311   \cs_set_protected:Npn \__kernel_chk_var_scope:NN
2312   {
2313     \__debug_suspended:T \use_none:nnn
2314     \__debug_chk_var_scope_aux:NN
2315   }
2316   \cs_set_protected:Npn \__kernel_chk_var_local:N ##1
2317   {
2318     \__debug_suspended:T \use_none:nnnnn
2319     \__kernel_chk_var_exist:N ##1
2320     \__debug_chk_var_scope_aux:NN l ##1
2321   }
2322   \cs_set_protected:Npn \__kernel_chk_var_global:N ##1
2323   {
2324     \__debug_suspended:T \use_none:nnnnn
2325     \__kernel_chk_var_exist:N ##1
2326     \__debug_chk_var_scope_aux:NN g ##1
2327   }
2328 }
2329 \exp_args:Nc \cs_set_protected:Npn { __debug_check-declarations_off: }
2330 {
2331   \cs_set_protected:Npn \__kernel_chk_var_exist:N ##1 { }
2332   \cs_set_protected:Npn \__kernel_chk_cs_exist:N ##1 { }
2333   \cs_set_protected:Npn \__kernel_chk_var_local:N ##1 { }
2334   \cs_set_protected:Npn \__kernel_chk_var_global:N ##1 { }
2335   \cs_set_protected:Npn \__kernel_chk_var_scope:NN ##1##2 { }
2336 }
2337 \cs_set_protected:Npn \__kernel_chk_cs_exist:c
2338 { \exp_args:Nc \__kernel_chk_cs_exist:N }
2339 \tex_ifodd:D \l@expl@check@declarations@bool
2340 \use:c { __debug_check-declarations_on: }
2341 \else:
2342 \use:c { __debug_check-declarations_off: }
2343 \fi:
2344 }
2345 { }

```

(End definition for `__debug_check-declarations_on:` and others.)

`__debug_chk_var_scope_aux:NN` First check whether the name of the variable #2 starts with $\langle letter \rangle$ _. If it does then pass that letter, the $\langle scope \rangle$, and the variable name to `__debug_chk_var_scope_aux:NNn`.
`__debug_chk_var_scope_aux:Nn` That function compares the two letters and triggers an error if they differ (the `\scan_stop:` case is not reachable here). If the second character was not _ then pass the same data to the same auxiliary, except for its first argument which is now a control sequence.
`__debug_chk_var_scope_aux:NNn` That control sequence is actually a token list (but to avoid triggering the checking code we manipulate it using `\cs_set_nopar:Npn`) containing a single letter $\langle scope \rangle$ according to what the first assignment to the given variable was.

```

2346 \__kernel_if_debug:TF
2347 {
2348   \cs_set_protected:Npn \__debug_chk_var_scope_aux:NN #1#2
2349   { \exp_args:NNf \__debug_chk_var_scope_aux:Nn #1 { \cs_to_str:N #2 } }
2350   \cs_set_protected:Npn \__debug_chk_var_scope_aux:Nn #1#2
2351   {

```

```

2352 \if:w _ \use_i:nn \use_i_delimit_by_q_stop:nw #2 ? ? \q_stop
2353 \exp_after:wN \__debug_chk_var_scope_aux:NNn
2354 \use_i_delimit_by_q_stop:nw #2 ? \q_stop
2355 #1 {#2}
2356 \else:
2357 \exp_args:Nc \__debug_chk_var_scope_aux:NNn
2358 { __debug_chk_/ #2 }
2359 #1 {#2}
2360 \fi:
2361 }
2362 \cs_set_protected:Npn \__debug_chk_var_scope_aux:NNn #1#2#3
2363 {
2364 \if:w #1 #2
2365 \else:
2366 \if:w #1 \scan_stop:
2367 \cs_gset_nopar:Npn #1 {#2}
2368 \else:
2369 \__kernel_msg_error:nnxxx { kernel } { local-global }
2370 {#1} {#2} { \iow_char:N \ \ #3 }
2371 \fi:
2372 \fi:
2373 }
2374 }
2375 { }

```

(End definition for `__debug_chk_var_scope_aux:NN`, `__debug_chk_var_scope_aux:Nn`, and `__debug_chk_var_scope_aux:NNn`.)

```

\__debug_check-expressions_on:
\__debug_check-expressions_off:
\__kernel_chk_expr:nNnN
\__debug_chk_expr_aux:nNnN

```

When debugging is enabled these two functions set `__kernel_chk_expr:nNnN` to test or not whether the given expression is valid. The idea is to evaluate the expression within a brace group (to catch trailing `\use_none:nn` or similar), then test that the result is what we expect. This is done by turning it to an integer and hitting that with `\tex_romannumeral:D` after replacing the first character by `-0`. If all goes well, that primitive finds a non-positive integer and gives an empty output. If the original expression evaluation stopped early it leaves a trailing `\tex_relax:D`, which stops the second evaluation (used to convert to integer) before it encounters the final `\tex_relax:D`. Since `\tex_romannumeral:D` does not absorb `\tex_relax:D` the output will be nonempty. Note that `#3` is empty except for mu expressions for which it is `\tex_mutogluue:D` to avoid an “incompatible glue units” error. Note also that if we had omitted the first `\tex_relax:D` then for instance `1+2\relax+3` would incorrectly be accepted as a valid integer expression.

```

2376 \__kernel_if_debug:TF
2377 {
2378 \exp_args:Nc \cs_set_protected:Npn { __debug_check-expressions_on: }
2379 {
2380 \cs_set:Npn \__kernel_chk_expr:nNnN ##1##2
2381 {
2382 \__debug_suspended:T { ##1 \use_none:nnnnnn }
2383 \exp_after:wN \__debug_chk_expr_aux:nNnN
2384 \exp_after:wN { \tex_the:D ##2 ##1 \scan_stop: }
2385 ##2
2386 }
2387 }

```

```

2388 \exp_args:Nc \cs_set_protected:Npn { __debug_check-expressions_off: }
2389 { \cs_set:Npn \__kernel_chk_expr:nNnN ##1##2##3##4 {##1} }
2390 \use:c { __debug_check-expressions_off: }
2391 \cs_set:Npn \__debug_chk_expr_aux:nNnN #1#2#3#4
2392 {
2393   \tl_if_empty:oF
2394   {
2395     \tex_romannumeral:D - 0
2396     \exp_after:wN \use_none:n
2397     \int_value:w #3 #2 #1 \scan_stop:
2398   }
2399   {
2400     \__kernel_msg_expandable_error:nnnn
2401     { kernel } { expr } {#4} {#1}
2402   }
2403   #1
2404 }
2405 }
2406 { }

```

(End definition for __debug_check-expressions_on: and others.)

__debug_log-functions_on: These two functions (corresponding to the expl3 option log-functions) control whether
 __debug_log-functions_off: __kernel_debug_log:x writes to the log file or not. Since \iow_log:x does not yet
 __kernel_debug_log:x have its final definition we do not use \cs_set_eq:NN (not defined yet anyway). Once
 everything is defined, turn logging on or off depending on what option was given. When
 debugging is not enabled, simply produce an error.

```

2407 \__kernel_if_debug:TF
2408 {
2409   \exp_args:Nc \cs_set_protected:Npn { __debug_log-functions_on: }
2410   {
2411     \cs_set_protected:Npn \__kernel_debug_log:x
2412     { \__debug_suspended:T \use_none:nn \iow_log:x }
2413   }
2414   \exp_args:Nc \cs_set_protected:Npn { __debug_log-functions_off: }
2415   { \cs_set_protected:Npn \__kernel_debug_log:x { \use_none:n } }
2416   \tex_ifodd:D \l@expl@log@functions@bool
2417   \use:c { __debug_log-functions_on: }
2418   \else:
2419     \use:c { __debug_log-functions_off: }
2420   \fi:
2421 }
2422 { }

```

(End definition for __debug_log-functions_on:, __debug_log-functions_off:, and __kernel-debug_log:x.)

__debug_deprecation_on: Some commands were more recently deprecated and not yet removed; only make these
 __debug_deprecation_off: into errors if the user requests it. This relies on two token lists, filled up in l3deprecation.
 __kernel_deprecation_code:nn
 \g__debug_deprecation_on_tl
 \g__debug_deprecation_off_tl

```

2423 \__kernel_if_debug:TF
2424 {
2425   \cs_set_protected:Npn \__debug_deprecation_on:
2426   { \g__debug_deprecation_on_tl }
2427   \cs_set_protected:Npn \__debug_deprecation_off:

```

```

2428     { \g__debug_deprecation_off_tl }
2429 \cs_set_nopar:Npn \g__debug_deprecation_on_tl { }
2430 \cs_set_nopar:Npn \g__debug_deprecation_off_tl { }
2431 \cs_set_protected:Npn \__kernel_deprecation_code:nn #1#2
2432 {
2433     \tl_gput_right:Nn \g__debug_deprecation_on_tl {#1}
2434     \tl_gput_right:Nn \g__debug_deprecation_off_tl {#2}
2435 }
2436 }
2437 {
2438     \cs_set_protected:Npn \__kernel_deprecation_code:nn #1#2 { }
2439 }

```

(End definition for __debug_deprecation_on: and others.)

__kernel_patch:nnNNpn When debugging is not enabled, __kernel_patch:nnNNpn and __kernel_patch_conditional:nnNpn throw the patch away. Otherwise they can be followed by \cs_new:Npn (or similar), and \prg_new_conditional:Npnn (or similar), respectively. In each case, grab the name of the function to be defined and its parameters then insert tokens before and/or after the definition.

```

2440 \__kernel_if_debug:TF
2441 {
2442     \cs_set_protected:Npn \__kernel_patch:nnNNpn #1#2#3#4#5#
2443     { \__debug_patch_aux:nnnn {#1} {#2} { #3 #4 #5 } }
2444     \cs_set_protected:Npn \__kernel_patch_conditional:nnNpn #1#2#3#4#
2445     { \__debug_patch_auxii:nnnn {#1} { #2 #3 #4 } }
2446     \cs_set_protected:Npn \__debug_patch_aux:nnnn #1#2#3#4
2447     { #3 { #1 #4 #2 } }
2448     \cs_set_protected:Npn \__debug_patch_auxii:nnnn #1#2#3#4
2449     { #2 {#3} { #1 #4 } }
2450 }
2451 {
2452     \cs_set_protected:Npn \__kernel_patch:nnNNpn #1#2 { }
2453     \cs_set_protected:Npn \__kernel_patch_conditional:nnNpn #1 { }
2454 }

```

(End definition for __kernel_patch:nnNNpn and others.)

__kernel_patch_args:nnNpn See __kernel_patch:nnNNpn. The first argument is something like {#1}{(#2)}. Define a temporary macro using the *parameters* and *code* of the definition that follows, then expand that temporary macro in front of the first argument to obtain new *code*. Then perform the definition as if that new *code* was directly typed in the file.

```

2455 \cs_set_protected:Npn \__kernel_patch_args:nnNpn
2456 { \__kernel_patch_args:nnnNNpn { } { } }
2457 \cs_set_protected:Npn \__kernel_patch_conditional_args:nnNpn
2458 { \__kernel_patch_conditional_args:nnnNNpn { } { } }
2459 \__kernel_if_debug:TF
2460 {
2461     \cs_set_protected:Npn \__kernel_patch_args:nnnNNpn #1#2#3#4#5#6#
2462     { \__debug_patch_args_aux:nnnNNnn {#1} {#2} {#3} #4 #5 {#6} }
2463     \cs_set_protected:Npn \__kernel_patch_conditional_args:nnnNNpn
2464     #1#2#3#4#5#6#
2465     { \__debug_patch_args_aux:nnnNNnn {#1} {#2} {#3} #4 #5 {#6} }
2466     \cs_set_protected:Npn \__debug_patch_args_aux:nnnNNnn #1#2#3#4#5#6#7

```



```

2467 {
2468   \cs_set:Npn \__debug_tmp:w #6 {#7}
2469   \exp_after:wN \__debug_patch_args_aux:nnnn \exp_after:wN
2470   { \__debug_tmp:w #3 } { #4 #5 #6 } {#1} {#2}
2471 }
2472 \cs_set_protected:Npn \__debug_patch_args_aux:nnnNNnnn #1#2#3#4#5#6#7#8
2473 {
2474   \cs_set:Npn \__debug_tmp:w #6 {#8}
2475   \exp_after:wN \__debug_patch_args_aux:nnnn \exp_after:wN
2476   { \__debug_tmp:w #3 } { #4 #5 #6 {#7} } {#1} {#2}
2477 }
2478 \cs_set_protected:Npn \__debug_patch_args_aux:nnnn #1#2#3#4
2479 { #2 { #3 #1 #4 } }
2480 }
2481 {
2482   \cs_set_protected:Npn \__kernel_patch_args:nnnNNpn #1#2#3 { }
2483   \cs_set_protected:Npn \__kernel_patch_conditional_args:nnnNNpnn
2484   #1#2#3 { }
2485 }

```

(End definition for `__kernel_patch_args:nnNpn` and others.)

5.7 Conditional processing and definitions

```

2486 <@@=prg>

```

Underneath any predicate function (`_p`) or other conditional forms (TF, etc.) is a built-in logic saying that it after all of the testing and processing must return the *<state>* this leaves `TEX` in. Therefore, a simple user interface could be something like

```

\if_meaning:w #1#2
\prg_return_true:
\else:
\if_meaning:w #1#3
\prg_return_true:
\else:
\prg_return_false:
\fi:
\fi:

```

Usually, a `TEX` programmer would have to insert a number of `\exp_after:wN`s to ensure the state value is returned at exactly the point where the last conditional is finished. However, that obscures the code and forces the `TEX` programmer to prove that he/she knows the $2^n - 1$ table. We therefore provide the simpler interface.

`\prg_return_true:` The idea here is that `\exp:w` expands fully any `\else:` and `\fi:` that are waiting to be discarded, before reaching the `\exp_end:` which leaves an empty expansion. The code can then leave either the first or second argument in the input stream. This means that all of the branching code has to contain at least two tokens: see how the logical tests are actually implemented to see this.

```

2487 \cs_set:Npn \prg_return_true:
2488 { \exp_after:wN \use_i:nn \exp:w }
2489 \cs_set:Npn \prg_return_false:
2490 { \exp_after:wN \use_ii:nn \exp:w}

```

An extended state space could be implemented by including a more elaborate function in place of `\use_i:nn/\use_ii:nn`. Provided two arguments are absorbed then the code would work.

(End definition for `\prg_return_true:` and `\prg_return_false:`. These functions are documented on page 103.)

```
\prg_set_conditional:Npnn
\prg_new_conditional:Npnn
\prg_set_protected_conditional:Npnn
\prg_new_protected_conditional:Npnn
\_prg_generate_conditional_parm:NNNpnn
```

The user functions for the types using parameter text from the programmer. The various functions only differ by which function is used for the assignment. For those `Npnn` type functions, we must grab the parameter text, reading everything up to a left brace before continuing. Then split the base function into name and signature, and feed $\{\langle name \rangle\}$ $\{\langle signature \rangle\}$ $\langle boolean \rangle$ $\{\langle set \text{ or } new \rangle\}$ $\{\langle maybe \text{ protected} \rangle\}$ $\{\langle parameters \rangle\}$ $\{\text{TF}, \dots\}$ $\{\langle code \rangle\}$ to the auxiliary function responsible for defining all conditionals. Note that `e` stands for expandable and `p` for protected.

```
2491 \cs_set_protected:Npn \prg_set_conditional:Npnn
2492 { \_prg_generate_conditional_parm:NNNpnn \cs_set:Npn e }
2493 \cs_set_protected:Npn \prg_new_conditional:Npnn
2494 { \_prg_generate_conditional_parm:NNNpnn \cs_new:Npn e }
2495 \cs_set_protected:Npn \prg_set_protected_conditional:Npnn
2496 { \_prg_generate_conditional_parm:NNNpnn \cs_set_protected:Npn p }
2497 \cs_set_protected:Npn \prg_new_protected_conditional:Npnn
2498 { \_prg_generate_conditional_parm:NNNpnn \cs_new_protected:Npn p }
2499 \cs_set_protected:Npn \_prg_generate_conditional_parm:NNNpnn #1#2#3#4#
2500 {
2501   \use:x
2502   {
2503     \_prg_generate_conditional:nnNNNnnn
2504     \cs_split_function:N #3
2505   }
2506   #1 #2 {#4}
2507 }
```

(End definition for `\prg_set_conditional:Npnn` and others. These functions are documented on page 101.)

```
\prg_set_conditional:Nnn
\prg_new_conditional:Nnn
\prg_set_protected_conditional:Nnn
\prg_new_protected_conditional:Nnn
\_prg_generate_conditional_count:NNNnnn
\_prg_generate_conditional_count:nnNNNnnn
```

The user functions for the types automatically inserting the correct parameter text based on the signature. The various functions only differ by which function is used for the assignment. Split the base function into name and signature. The second auxiliary generates the parameter text from the number of letters in the signature. Then feed $\{\langle name \rangle\}$ $\{\langle signature \rangle\}$ $\langle boolean \rangle$ $\{\langle set \text{ or } new \rangle\}$ $\{\langle maybe \text{ protected} \rangle\}$ $\{\langle parameters \rangle\}$ $\{\text{TF}, \dots\}$ $\{\langle code \rangle\}$ to the auxiliary function responsible for defining all conditionals. If the $\langle signature \rangle$ has more than 9 letters, the definition is aborted since \TeX macros have at most 9 arguments. The erroneous case where the function name contains no colon is captured later.

```
2508 \cs_set_protected:Npn \prg_set_conditional:Nnn
2509 { \_prg_generate_conditional_count:NNNnnn \cs_set:Npn e }
2510 \cs_set_protected:Npn \prg_new_conditional:Nnn
2511 { \_prg_generate_conditional_count:NNNnnn \cs_new:Npn e }
2512 \cs_set_protected:Npn \prg_set_protected_conditional:Nnn
2513 { \_prg_generate_conditional_count:NNNnnn \cs_set_protected:Npn p }
2514 \cs_set_protected:Npn \prg_new_protected_conditional:Nnn
2515 { \_prg_generate_conditional_count:NNNnnn \cs_new_protected:Npn p }
2516 \cs_set_protected:Npn \_prg_generate_conditional_count:NNNnnn #1#2#3
```

```

2517 {
2518   \use:x
2519   {
2520     \__prg_generate_conditional_count:nnNNNnn
2521     \cs_split_function:N #3
2522   }
2523   #1 #2
2524 }
2525 \cs_set_protected:Npn \__prg_generate_conditional_count:nnNNNnn #1#2#3#4#5
2526 {
2527   \__kernel_cs_parm_from_arg_count:nnF
2528   { \__prg_generate_conditional:nnNNNnnn {#1} {#2} #3 #4 #5 }
2529   { \tl_count:n {#2} }
2530   {
2531     \__kernel_msg_error:nnxx { kernel } { bad-number-of-arguments }
2532     { \token_to_str:c { #1 : #2 } }
2533     { \tl_count:n {#2} }
2534     \use_none:nn
2535   }
2536 }

```

(End definition for \prg_set_conditional:Nnn and others. These functions are documented on page 101.)

__prg_generate_conditional:nnNNNnnn
 __prg_generate_conditional:NNnnnnNw
 __prg_generate_conditional_test:w
 __prg_generate_conditional_fast:nw

The workhorse here is going through a list of desired forms, *i.e.*, p, TF, T and F. The first three arguments come from splitting up the base form of the conditional, which gives the name, signature and a boolean to signal whether or not there was a colon in the name. In the absence of a colon, we throw an error and don't define any conditional. The fourth and fifth arguments build up the defining function. The sixth is the parameters to use (possibly empty), the seventh is the list of forms to define, the eighth is the replacement text which we will augment when defining the forms. The use of \tl_to_str:n makes the later loop more robust.

A large number of our low-level conditionals look like `\prg_return_true:\else:\prg_return_false:\fi:` so we optimize this special case by calling `__prg_generate_conditional_fast:nw {<code>}`. This passes `\use_i:nn` instead of `\use_i_ii:nnn` to functions such as `__prg_generate_p_form:wNNnnnnN`.

```

2537 \cs_set_protected:Npn \__prg_generate_conditional:nnNNNnnn #1#2#3#4#5#6#7#8
2538 {
2539   \if_meaning:w \c_false_bool #3
2540   \__kernel_msg_error:nnx { kernel } { missing-colon }
2541   { \token_to_str:c {#1} }
2542   \exp_after:wN \use_none:nn
2543   \fi:
2544   \use:x
2545   {
2546     \exp_not:N \__prg_generate_conditional:NNnnnnNw
2547     \exp_not:n { #4 #5 {#1} {#2} {#6} }
2548     \__prg_generate_conditional_test:w
2549     #8 \q_mark
2550     \__prg_generate_conditional_fast:nw
2551     \prg_return_true:\else:\prg_return_false:\fi:\q_mark
2552     \use_none:n
2553     \exp_not:n { {#8} \use_i_ii:nnn }

```

```

2554         \tl_to_str:n {#7}
2555         \exp_not:n { , \q_recursion_tail , \q_recursion_stop }
2556     }
2557 }
2558 \cs_set:Npn \__prg_generate_conditional_test:w
2559     #1 \prg_return_true: \else: \prg_return_false: \fi: \q_mark #2
2560     { #2 {#1} }
2561 \cs_set:Npn \__prg_generate_conditional_fast:nw #1#2 \exp_not:n #3
2562     { \exp_not:n { {#1} \use_i:nn } }

```

Looping through the list of desired forms. First are six arguments and seventh is the form. Use the form to call the correct type. If the form does not exist, the `\use:c` construction results in `\relax`, and the error message is displayed (unless the form is empty, to allow for `{T, , F}`), then `\use_none:nnnnnnnn` cleans up. Otherwise, the error message is removed by the variant form.

```

2563 \cs_set_protected:Npn \__prg_generate_conditional:NNnnnnNw #1#2#3#4#5#6#7#8 ,
2564 {
2565     \if_meaning:w \q_recursion_tail #8
2566     \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
2567     \fi:
2568     \use:c { __prg_generate_ #8 _form:wNNnnnnN }
2569     \tl_if_empty:nF {#8}
2570     {
2571         \__kernel_msg_error:nnxx
2572         { kernel } { conditional-form-unknown }
2573         {#8} { \token_to_str:c { #3 : #4 } }
2574     }
2575     \use_none:nnnnnnnn
2576     \q_stop
2577     #1 #2 {#3} {#4} {#5} {#6} #7
2578     \__prg_generate_conditional:NNnnnnNw #1 #2 {#3} {#4} {#5} {#6} #7
2579 }

```

(End definition for `__prg_generate_conditional:nnNNnnnn` and others.)

```

\__prg_generate_p_form:wNNnnnnN
\__prg_generate_TF_form:wNNnnnnN
\__prg_generate_T_form:wNNnnnnN
\__prg_generate_F_form:wNNnnnnN
\__prg_p_true:w

```

How to generate the various forms. Those functions take the following arguments: 1: junk, 2: `\cs_set:Npn` or similar, 3: `p` (for protected conditionals) or `e`, 4: function name, 5: signature, 6: parameter text, 7: replacement (possibly trimmed by `__prg_generate_conditional_fast:nw`), 8: `\use_i_ii:nnn` or `\use_i:nn` (for “fast” conditionals). Remember that the logic-returning functions expect two arguments to be present after `\exp_end::`: notice the construction of the different variants relies on this, and that the `TF` and `F` variants will be slightly faster than the `T` version. The `p` form is only valid for expandable tests, we check for that by making sure that the second argument is empty. For “fast” conditionals, `#7` has an extra `\if_....`. To optimize a bit further we could replace `\exp_after:wN \use_ii:nnn` and similar by a single macro similar to `__prg_p_true:w`. The drawback is that if the `T` or `F` arguments are actually missing, the recovery from the runaway argument would not insert `\fi:` back, messing up nesting of conditionals.

```

2580 \cs_set_protected:Npn \__prg_generate_p_form:wNNnnnnN
2581     #1 \q_stop #2#3#4#5#6#7#8
2582     {
2583         \if_meaning:w e #3
2584         \exp_after:wN \use_i:nn

```

```

2585 \else:
2586   \exp_after:wN \use_ii:nn
2587 \fi:
2588 {
2589   #8
2590   { \exp_args:Nc #2 { #4 _p: #5 } #6 }
2591   { { #7 \exp_end: \c_true_bool \c_false_bool } }
2592   { #7 \_prg_p_true:w \fi: \c_false_bool }
2593 }
2594 {
2595   \_kernel_msg_error:nnx { kernel } { protected-predicate }
2596   { \token_to_str:c { #4 _p: #5 } }
2597 }
2598 }
2599 \cs_set_protected:Npn \_prg_generate_T_form:wNNnnnnN
2600 #1 \q_stop #2#3#4#5#6#7#8
2601 {
2602   #8
2603   { \exp_args:Nc #2 { #4 : #5 T } #6 }
2604   { { #7 \exp_end: \use:n \use_none:n } }
2605   { #7 \exp_after:wN \use_ii:nn \fi: \use_none:n }
2606 }
2607 \cs_set_protected:Npn \_prg_generate_F_form:wNNnnnnN
2608 #1 \q_stop #2#3#4#5#6#7#8
2609 {
2610   #8
2611   { \exp_args:Nc #2 { #4 : #5 F } #6 }
2612   { { #7 \exp_end: { } } }
2613   { #7 \exp_after:wN \use_none:nn \fi: \use:n }
2614 }
2615 \cs_set_protected:Npn \_prg_generate_TF_form:wNNnnnnN
2616 #1 \q_stop #2#3#4#5#6#7#8
2617 {
2618   #8
2619   { \exp_args:Nc #2 { #4 : #5 TF } #6 }
2620   { { #7 \exp_end: { } } }
2621   { #7 \exp_after:wN \use_ii:nnn \fi: \use_ii:nn }
2622 }
2623 \cs_set:Npn \_prg_p_true:w \fi: \c_false_bool { \fi: \c_true_bool }

```

(End definition for _prg_generate_p_form:wNNnnnnN and others.)

\prg_set_eq_conditional:NNn The setting-equal functions. Split both functions and feed $\{\langle name_1 \rangle\}$ $\{\langle signature_1 \rangle\}$ $\langle boolean_1 \rangle$ $\{\langle name_2 \rangle\}$ $\{\langle signature_2 \rangle\}$ $\langle boolean_2 \rangle$ $\langle copying\ function \rangle$ $\langle conditions \rangle$, \q-recursion_tail, \q-recursion_stop to a first auxiliary.

```

2624 \cs_set_protected:Npn \prg_set_eq_conditional:NNn
2625 { \_prg_set_eq_conditional:NNNn \cs_set_eq:cc }
2626 \cs_set_protected:Npn \prg_new_eq_conditional:NNn
2627 { \_prg_set_eq_conditional:NNNn \cs_new_eq:cc }
2628 \cs_set_protected:Npn \_prg_set_eq_conditional:NNNn #1#2#3#4
2629 {
2630   \use:x
2631   {
2632     \exp_not:N \_prg_set_eq_conditional:nnNnnNNw

```

```

2633         \cs_split_function:N #2
2634         \cs_split_function:N #3
2635         \exp_not:N #1
2636         \tl_to_str:n {#4}
2637         \exp_not:n { , \q_recursion_tail , \q_recursion_stop }
2638     }
2639 }

```

(End definition for `\prg_set_eq_conditional:NNn`, `\prg_new_eq_conditional:NNn`, and `__prg_set_eq_conditional:NNNn`. These functions are documented on page 102.)

```

\__prg_set_eq_conditional:nnNnnNw
\__prg_set_eq_conditional_loop:nnnnNw
\__prg_set_eq_conditional_p_form:nnn
\__prg_set_eq_conditional_TF_form:nnn
\__prg_set_eq_conditional_T_form:nnn
\__prg_set_eq_conditional_F_form:nnn

```

Split the function to be defined, and setup a manual clist loop over argument #6 of the first auxiliary. The second auxiliary receives twice three arguments coming from splitting the function to be defined and the function to copy. Make sure that both functions contained a colon, otherwise we don't know how to build conditionals, hence abort. Call the looping macro, with arguments $\{\langle name_1 \rangle\} \{\langle signature_1 \rangle\} \{\langle name_2 \rangle\} \{\langle signature_2 \rangle\}$ $\langle copying\ function \rangle$ and followed by the comma list. At each step in the loop, make sure that the conditional form we copy is defined, and copy it, otherwise abort.

```

2640 \cs_set_protected:Npn \__prg_set_eq_conditional:nnNnnNw #1#2#3#4#5#6
2641 {
2642     \if_meaning:w \c_false_bool #3
2643     \__kernel_msg_error:nnx { kernel } { missing-colon }
2644     { \token_to_str:c {#1} }
2645     \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
2646     \fi:
2647     \if_meaning:w \c_false_bool #6
2648     \__kernel_msg_error:nnx { kernel } { missing-colon }
2649     { \token_to_str:c {#4} }
2650     \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
2651     \fi:
2652     \__prg_set_eq_conditional_loop:nnnnNw {#1} {#2} {#4} {#5}
2653 }
2654 \cs_set_protected:Npn \__prg_set_eq_conditional_loop:nnnnNw #1#2#3#4#5#6 ,
2655 {
2656     \if_meaning:w \q_recursion_tail #6
2657     \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
2658     \fi:
2659     \use:c { __prg_set_eq_conditional_ #6 _form:wNnnnn }
2660     \tl_if_empty:nF {#6}
2661     {
2662         \__kernel_msg_error:nnxx
2663         { kernel } { conditional-form-unknown }
2664         {#6} { \token_to_str:c { #1 : #2 } }
2665     }
2666     \use_none:nnnnnn
2667     \q_stop
2668     #5 {#1} {#2} {#3} {#4}
2669     \__prg_set_eq_conditional_loop:nnnnNw {#1} {#2} {#3} {#4} #5
2670 }
2671 \__kernel_patch:nnNNpn
2672 { \__kernel_chk_cs_exist:c { #5 _p : #6 } } { }
2673 \cs_set:Npn \__prg_set_eq_conditional_p_form:wNnnnn #1 \q_stop #2#3#4#5#6
2674 { #2 { #3 _p : #4 } { #5 _p : #6 } }
2675 \__kernel_patch:nnNNpn

```

```

2676 { \__kernel_chk_cs_exist:c { #5      : #6 TF } } { }
2677 \cs_set:Npn \__prg_set_eq_conditional_TF_form:wNnnnn #1 \q_stop #2#3#4#5#6
2678 { #2 { #3      : #4 TF }      { #5      : #6 TF } }
2679 \__kernel_patch:nnNNpn
2680 { \__kernel_chk_cs_exist:c { #5      : #6 T  } } { }
2681 \cs_set:Npn \__prg_set_eq_conditional_T_form:wNnnnn #1 \q_stop #2#3#4#5#6
2682 { #2 { #3      : #4 T  }      { #5      : #6 T  } }
2683 \__kernel_patch:nnNNpn
2684 { \__kernel_chk_cs_exist:c { #5      : #6 F  } } { }
2685 \cs_set:Npn \__prg_set_eq_conditional_F_form:wNnnnn #1 \q_stop #2#3#4#5#6
2686 { #2 { #3      : #4 F  }      { #5      : #6 F  } }

```

(End definition for __prg_set_eq_conditional:nnNnnNNw and others.)

All that is left is to define the canonical boolean true and false. I think Michael originated the idea of expandable boolean tests. At first these were supposed to expand into either TT or TF to be tested using \if:w but this was later changed to 00 and 01, so they could be used in logical operations. Later again they were changed to being numerical constants with values of 1 for true and 0 for false. We need this from the get-go.

```

\c_true_bool Here are the canonical boolean values.
\c_false_bool
2687 \tex_chardef:D \c_true_bool = 1 ~
2688 \tex_chardef:D \c_false_bool = 0 ~

```

(End definition for \c_true_bool and \c_false_bool. These variables are documented on page 22.)

5.8 Dissecting a control sequence

```

2689 \@@=cs

```

```

\__cs_count_signature:N \__cs_count_signature:N <function>

```

Splits the *<function>* into the *<name>* (i.e. the part before the colon) and the *<signature>* (i.e. after the colon). The *<number>* of tokens in the *<signature>* is then left in the input stream. If there was no *<signature>* then the result is the marker value −1.

```

\__cs_get_function_name:N * \__cs_get_function_name:N <function>

```

Splits the *<function>* into the *<name>* (i.e. the part before the colon) and the *<signature>* (i.e. after the colon). The *<name>* is then left in the input stream without the escape character present made up of tokens with category code 12 (other).

```

\__cs_get_function_signature:N * \__cs_get_function_signature:N <function>

```

Splits the *<function>* into the *<name>* (i.e. the part before the colon) and the *<signature>* (i.e. after the colon). The *<signature>* is then left in the input stream made up of tokens with category code 12 (other).

```

\__cs_tmp:w

```

Function used for various short-term usages, for instance defining functions whose definition involves tokens which are hard to insert normally (spaces, characters with category other).

`\cs_to_str:N` This converts a control sequence into the character string of its name, removing the leading escape character. This turns out to be a non-trivial matter as there are different cases:

- The usual case of a printable escape character;
- the case of a non-printable escape character, e.g., when the value of the `\escapechar` is negative;
- when the escape character is a space.

One approach to solve this is to test how many tokens result from `\token_to_str:N \a`. If there are two tokens, then the escape character is printable, while if it is non-printable then only one is present.

However, there is an additional complication: the control sequence itself may start with a space. Clearly that should *not* be lost in the process of converting to a string. So the approach adopted is a little more intricate still. When the escape character is printable, `\token_to_str:N _` yields the escape character itself and a space. The character codes are different, thus the `\if:w` test is false, and TeX reads `_cs_to_str:N` after turning the following control sequence into a string; this auxiliary removes the escape character, and stops the expansion of the initial `\tex_romannumeral:D`. The second case is that the escape character is not printable. Then the `\if:w` test is unfinished after reading a space from `\token_to_str:N _`, and the auxiliary `_cs_to_str:w` is expanded, feeding – as a second character for the test; the test is false, and TeX skips to `\fi:`, then performs `\token_to_str:N`, and stops the `\tex_romannumeral:D` with `\c_zero_int`. The last case is that the escape character is itself a space. In this case, the `\if:w` test is true, and the auxiliary `_cs_to_str:w` comes into play, inserting `-\int_value:w`, which expands `\c_zero_int` to the character 0. The initial `\tex_romannumeral:D` then sees 0, which is not a terminated number, followed by the escape character, a space, which is removed, terminating the expansion of `\tex_romannumeral:D`. In all three cases, `\cs_to_str:N` takes two expansion steps to be fully expanded.

```
2690 \cs_set:Npn \cs_to_str:N
2691 {
```

We implement the expansion scheme using `\tex_romannumeral:D` terminating it with `\c_zero_int` rather than using `\exp:w` and `\exp_end:` as we normally do. The reason is that the code heavily depends on terminating the expansion with `\c_zero_int` so we make this dependency explicit.

```
2692 \tex_romannumeral:D
2693 \if:w \token_to_str:N \\_cs_to_str:w \fi:
2694 \exp_after:wN \_cs_to_str:N \token_to_str:N
2695 }
2696 \cs_set:Npn \_cs_to_str:N #1 { \c_zero_int }
2697 \cs_set:Npn \_cs_to_str:w #1 \_cs_to_str:N
2698 { - \int_value:w \fi: \exp_after:wN \c_zero_int }
```

If speed is a concern we could use `\csstring` in LuaTeX. For the empty csname that primitive gives an empty result while the current `\cs_to_str:N` gives incorrect results in all engines (this is impossible to fix without huge performance hit).

(End definition for `\cs_to_str:N`, `_cs_to_str:N`, and `_cs_to_str:w`. This function is documented on page 17.)

`\cs_split_function:N` This function takes a function name and splits it into name with the escape char removed and argument specification. In addition to this, a third argument, a boolean $\langle true \rangle$ or $\langle false \rangle$ is returned with $\langle true \rangle$ for when there is a colon in the function and $\langle false \rangle$ if there is not.

We cannot use `:` directly as it has the wrong category code so an `x`-type expansion is used to force the conversion.

First ensure that we actually get a properly evaluated string by expanding `\cs_to_str:N` twice. If the function contained a colon, the auxiliary takes as `#1` the function name, delimited by the first colon, then the signature `#2`, delimited by `\q_mark`, then `\c_true_bool` as `#3`, and `#4` cleans up until `\q_stop`. Otherwise, the `#1` contains the function name and `\q_mark \c_true_bool`, `#2` is empty, `#3` is `\c_false_bool`, and `#4` cleans up. The second auxiliary trims the trailing `\q_mark` from the function name if present (that is, if the original function had no colon).

```

2699 \cs_set_protected:Npn \__cs_tmp:w #1
2700 {
2701   \cs_set:Npn \cs_split_function:N ##1
2702   {
2703     \exp_after:wN \exp_after:wN \exp_after:wN
2704     \__cs_split_function_auxi:w
2705     \cs_to_str:N ##1 \q_mark \c_true_bool
2706     #1 \q_mark \c_false_bool \q_stop
2707   }
2708   \cs_set:Npn \__cs_split_function_auxi:w
2709   ##1 #1 ##2 \q_mark ##3##4 \q_stop
2710   { \__cs_split_function_auxii:w ##1 \q_mark \q_stop {##2} ##3 }
2711   \cs_set:Npn \__cs_split_function_auxii:w ##1 \q_mark ##2 \q_stop
2712   { {##1} }
2713 }
2714 \exp_after:wN \__cs_tmp:w \token_to_str:N :

```

(End definition for `\cs_split_function:N`, `__cs_split_function_auxi:w`, and `__cs_split_function_auxii:w`. This function is documented on page 17.)

5.9 Exist or free

A control sequence is said to *exist* (to be used) if has an entry in the hash table and its meaning is different from the primitive `\relax` token. A control sequence is said to be *free* (to be defined) if it does not already exist.

`\cs_if_exist_p:N` Two versions for checking existence. For the `N` form we firstly check for `\scan_stop:` and then if it is in the hash table. There is no problem when inputting something like `\else:` or `\fi:` as \TeX will only ever skip input in case the token tested against is `\scan_stop:`.

```

\cs_if_exist_p:c
\cs_if_exist:NTF
\cs_if_exist:cTF
2715 \prg_set_conditional:Npnn \cs_if_exist:N #1 { p , T , F , TF }
2716 {
2717   \if_meaning:w #1 \scan_stop:
2718     \prg_return_false:
2719   \else:
2720     \if_cs_exist:N #1
2721       \prg_return_true:
2722     \else:
2723       \prg_return_false:
2724   \fi:

```

```

2725     \fi:
2726 }

```

For the `c` form we firstly check if it is in the hash table and then for `\scan_stop:` so that we do not add it to the hash table unless it was already there. Here we have to be careful as the text to be skipped if the first test is false may contain tokens that disturb the scanner. Therefore, we ensure that the second test is performed after the first one has concluded completely.

```

2727 \prg_set_conditional:Npnn \cs_if_exist:c #1 { p , T , F , TF }
2728 {
2729     \if_cs_exist:w #1 \cs_end:
2730     \exp_after:wN \use_i:nn
2731     \else:
2732     \exp_after:wN \use_ii:nn
2733     \fi:
2734     {
2735         \exp_after:wN \if_meaning:w \cs:w #1 \cs_end: \scan_stop:
2736         \prg_return_false:
2737     \else:
2738         \prg_return_true:
2739     \fi:
2740     }
2741     \prg_return_false:
2742 }

```

(End definition for `\cs_if_exist:NTF`. This function is documented on page 22.)

`\cs_if_free_p:N`
`\cs_if_free_p:c`
`\cs_if_free:NTF`
`\cs_if_free:cTF`

The logical reversal of the above.

```

2743 \prg_set_conditional:Npnn \cs_if_free:N #1 { p , T , F , TF }
2744 {
2745     \if_meaning:w #1 \scan_stop:
2746     \prg_return_true:
2747     \else:
2748     \if_cs_exist:N #1
2749     \prg_return_false:
2750     \else:
2751     \prg_return_true:
2752     \fi:
2753     \fi:
2754 }
2755 \prg_set_conditional:Npnn \cs_if_free:c #1 { p , T , F , TF }
2756 {
2757     \if_cs_exist:w #1 \cs_end:
2758     \exp_after:wN \use_i:nn
2759     \else:
2760     \exp_after:wN \use_ii:nn
2761     \fi:
2762     {
2763         \exp_after:wN \if_meaning:w \cs:w #1 \cs_end: \scan_stop:
2764         \prg_return_true:
2765     \else:
2766         \prg_return_false:
2767     \fi:
2768 }

```

```

2769     { \prg_return_true: }
2770 }

```

(End definition for `\cs_if_free:NTF`. This function is documented on page 22.)

`\cs_if_exist_use:N` The `\cs_if_exist_use:...` functions cannot be implemented as conditionals because the true branch must leave both the control sequence itself and the true code in the input stream. For the `c` variants, we are careful not to put the control sequence in the hash table if it does not exist. In LuaTeX we could use the `\lastnamedcs` primitive.

```

2771 \cs_set:Npn \cs_if_exist_use:NTF #1#2
2772   { \cs_if_exist:NTF #1 { #1 #2 } }
2773 \cs_set:Npn \cs_if_exist_use:NF #1
2774   { \cs_if_exist:NTF #1 { #1 } }
2775 \cs_set:Npn \cs_if_exist_use:NT #1 #2
2776   { \cs_if_exist:NTF #1 { #1 #2 } { } }
2777 \cs_set:Npn \cs_if_exist_use:N #1
2778   { \cs_if_exist:NTF #1 { #1 } { } }
2779 \cs_set:Npn \cs_if_exist_use:cTF #1#2
2780   { \cs_if_exist:cTF {#1} { \use:c {#1} #2 } }
2781 \cs_set:Npn \cs_if_exist_use:cF #1
2782   { \cs_if_exist:cTF {#1} { \use:c {#1} } }
2783 \cs_set:Npn \cs_if_exist_use:cT #1#2
2784   { \cs_if_exist:cTF {#1} { \use:c {#1} #2 } { } }
2785 \cs_set:Npn \cs_if_exist_use:c #1
2786   { \cs_if_exist:cTF {#1} { \use:c {#1} } { } }

```

(End definition for `\cs_if_exist_use:NTF`. This function is documented on page 16.)

5.10 Preliminaries for new functions

We provide two kinds of functions that can be used to define control sequences. On the one hand we have functions that check if their argument doesn't already exist, they are called `\..._new`. The second type of defining functions doesn't check if the argument is already defined.

Before we can define them, we need some auxiliary macros that allow us to generate error messages. The next few definitions here are only temporary, they will be redefined later on.

`_kernel_msg_error:nxxx` If an internal error occurs before L^AT_EX3 has loaded `l3msg` then the code should issue a usable if terse error message and halt. This can only happen if a coding error is made by the team, so this is a reasonable response. Setting the `\newlinechar` is needed, to turn `^^J` into a proper line break in plain T_EX.

```

2787 \cs_set_protected:Npn \_kernel_msg_error:nxxx #1#2#3#4
2788   {
2789     \tex_newlinechar:D = '\^^J \scan_stop:
2790     \tex_errmessage:D
2791       {
2792         !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!~! ^^J
2793         Argh,~internal~LaTeX3~error! ^^J ^^J
2794         Module ~ #1 , ~ message-name~"#2": ^^J
2795         Arguments~'#3'~and~'#4' ^^J ^^J
2796         This-is-one-for-The-LaTeX3-Project:~bailing-out
2797       }

```

```

2798 \tex_end:D
2799 }
2800 \cs_set_protected:Npn \__kernel_msg_error:nnx #1#2#3
2801 { \__kernel_msg_error:nnxx {#1} {#2} {#3} { } }
2802 \cs_set_protected:Npn \__kernel_msg_error:nn #1#2
2803 { \__kernel_msg_error:nnxx {#1} {#2} { } { } }

(End definition for \__kernel_msg_error:nnxx, \__kernel_msg_error:nnx, and \__kernel_msg_error:nn.)

```

\msg_line_context: Another one from l3msg which will be altered later.

```

2804 \cs_set:Npn \msg_line_context:
2805 { on~line~ \tex_the:D \tex_inputlineno:D }

(End definition for \msg_line_context:. This function is documented on page 145.)

```

\iow_log:x We define a routine to write only to the log file. And a similar one for writing to both
\iow_term:x the log file and the terminal. These will be redefined later by l3io.

```

2806 \cs_set_protected:Npn \iow_log:x
2807 { \tex_immediate:D \tex_write:D -1 }
2808 \cs_set_protected:Npn \iow_term:x
2809 { \tex_immediate:D \tex_write:D 16 }

(End definition for \iow_log:n. This function is documented on page 154.)

```

__kernel_chk_if_free_cs:N This command is called by **\cs_new_nopar:Npn** and **\cs_new_eq:NN** etc. to make sure
__kernel_chk_if_free_cs:c that the argument sequence is not already in use. If it is, an error is signalled. It checks
if *<csname>* is undefined or **\scan_stop:..** Otherwise an error message is issued. We have
to make sure we don't put the argument into the conditional processing since it may be
an **\if... type** function!

```

2810 \__kernel_patch:nnNNpn { }
2811 {
2812   \__kernel_debug_log:x
2813   { Defining~\token_to_str:N #1~ \msg_line_context: }
2814 }
2815 \cs_set_protected:Npn \__kernel_chk_if_free_cs:N #1
2816 {
2817   \cs_if_free:NF #1
2818   {
2819     \__kernel_msg_error:nnxx { kernel } { command-already-defined }
2820     { \token_to_str:N #1 } { \token_to_meaning:N #1 }
2821   }
2822 }
2823 \cs_set_protected:Npn \__kernel_chk_if_free_cs:c
2824 { \exp_args:Nc \__kernel_chk_if_free_cs:N }

(End definition for \__kernel_chk_if_free_cs:N.)

```

5.11 Defining new functions

```

2825 <@@=cs>

```

\cs_new_nopar:Npn Function which check that the control sequence is free before defining it.

```

\cs_new_nopar:Npx
\cs_new:Npn
\cs_new:Npx
\cs_new_protected_nopar:Npn
\cs_new_protected_nopar:Npx
\cs_new_protected:Npn
\cs_new_protected:Npx
\__cs_tmp:w

```

```

2829     {
2830         \__kernel_chk_if_free_cs:N ##1
2831         #2 ##1
2832     }
2833 }
2834 \__cs_tmp:w \cs_new_nopar:Npn          \cs_gset_nopar:Npn
2835 \__cs_tmp:w \cs_new_nopar:Npx          \cs_gset_nopar:Npx
2836 \__cs_tmp:w \cs_new:Npn                \cs_gset:Npn
2837 \__cs_tmp:w \cs_new:Npx                \cs_gset:Npx
2838 \__cs_tmp:w \cs_new_protected_nopar:Npn \cs_gset_protected_nopar:Npn
2839 \__cs_tmp:w \cs_new_protected_nopar:Npx \cs_gset_protected_nopar:Npx
2840 \__cs_tmp:w \cs_new_protected:Npn       \cs_gset_protected:Npn
2841 \__cs_tmp:w \cs_new_protected:Npx       \cs_gset_protected:Npx

```

(End definition for `\cs_new_nopar:Npn` and others. These functions are documented on page 11.)

<code>\cs_set_nopar:cpn</code>	Like <code>\cs_set_nopar:Npn</code> and <code>\cs_new_nopar:Npn</code> , except that the first argument consists of the sequence of characters that should be used to form the name of the desired control sequence (the <code>c</code> stands for <code>csname</code> argument, see the expansion module). Global versions are also provided.
<code>\cs_set_nopar:cpx</code>	
<code>\cs_gset_nopar:cpn</code>	
<code>\cs_gset_nopar:cpx</code>	
<code>\cs_new_nopar:cpn</code>	<code>\cs_set_nopar:cpn⟨string⟩⟨rep-text⟩</code> turns <code>⟨string⟩</code> into a <code>csname</code> and then assigns <code>⟨rep-text⟩</code> to it by using <code>\cs_set_nopar:Npn</code> . This means that there might be a parameter string between the two arguments.
<code>\cs_new_nopar:cpx</code>	

```

2842 \cs_set:Npn \__cs_tmp:w #1#2
2843 { \cs_new_protected_nopar:Npn #1 { \exp_args:Nc #2 } }
2844 \__cs_tmp:w \cs_set_nopar:cpn \cs_set_nopar:Npn
2845 \__cs_tmp:w \cs_set_nopar:cpx \cs_set_nopar:Npx
2846 \__cs_tmp:w \cs_gset_nopar:cpn \cs_gset_nopar:Npn
2847 \__cs_tmp:w \cs_gset_nopar:cpx \cs_gset_nopar:Npx
2848 \__cs_tmp:w \cs_new_nopar:cpn \cs_new_nopar:Npn
2849 \__cs_tmp:w \cs_new_nopar:cpx \cs_new_nopar:Npx

```

(End definition for `\cs_set_nopar:Npn`. This function is documented on page 11.)

<code>\cs_set:cpn</code>	Variants of the <code>\cs_set:Npn</code> versions which make a <code>csname</code> out of the first arguments.
<code>\cs_set:cpx</code>	We may also do this globally.

<code>\cs_gset:cpn</code>	2850 <code>__cs_tmp:w \cs_set:cpn \cs_set:Npn</code>
<code>\cs_gset:cpx</code>	2851 <code>__cs_tmp:w \cs_set:cpx \cs_set:Npx</code>
<code>\cs_new:cpn</code>	2852 <code>__cs_tmp:w \cs_gset:cpn \cs_gset:Npn</code>
<code>\cs_new:cpx</code>	2853 <code>__cs_tmp:w \cs_gset:cpx \cs_gset:Npx</code>
	2854 <code>__cs_tmp:w \cs_new:cpn \cs_new:Npn</code>
	2855 <code>__cs_tmp:w \cs_new:cpx \cs_new:Npx</code>

(End definition for `\cs_set:Npn`. This function is documented on page 11.)

<code>\cs_set_protected_nopar:cpn</code>	Variants of the <code>\cs_set_protected_nopar:Npn</code> versions which make a <code>csname</code> out of the first arguments. We may also do this globally.
<code>\cs_set_protected_nopar:cpx</code>	

<code>\cs_gset_protected_nopar:cpn</code>	2856 <code>__cs_tmp:w \cs_set_protected_nopar:cpn \cs_set_protected_nopar:Npn</code>
<code>\cs_gset_protected_nopar:cpx</code>	2857 <code>__cs_tmp:w \cs_set_protected_nopar:cpx \cs_set_protected_nopar:Npx</code>
<code>\cs_new_protected_nopar:cpn</code>	2858 <code>__cs_tmp:w \cs_gset_protected_nopar:cpn \cs_gset_protected_nopar:Npn</code>
<code>\cs_new_protected_nopar:cpx</code>	2859 <code>__cs_tmp:w \cs_gset_protected_nopar:cpx \cs_gset_protected_nopar:Npx</code>
	2860 <code>__cs_tmp:w \cs_new_protected_nopar:cpn \cs_new_protected_nopar:Npn</code>
	2861 <code>__cs_tmp:w \cs_new_protected_nopar:cpx \cs_new_protected_nopar:Npx</code>

(End definition for `\cs_set_protected_nopar:Npn`. This function is documented on page 12.)

<code>\cs_set_protected:cpn</code>	2862	<code>__cs_tmp:w \cs_set_protected:cpn \cs_set_protected:Npn</code>
<code>\cs_set_protected:cpx</code>	2863	<code>__cs_tmp:w \cs_set_protected:cpx \cs_set_protected:Npx</code>
<code>\cs_gset_protected:cpn</code>	2864	<code>__cs_tmp:w \cs_gset_protected:cpn \cs_gset_protected:Npn</code>
<code>\cs_gset_protected:cpx</code>	2865	<code>__cs_tmp:w \cs_gset_protected:cpx \cs_gset_protected:Npx</code>
<code>\cs_new_protected:cpn</code>	2866	<code>__cs_tmp:w \cs_new_protected:cpn \cs_new_protected:Npn</code>
<code>\cs_new_protected:cpx</code>	2867	<code>__cs_tmp:w \cs_new_protected:cpx \cs_new_protected:Npx</code>

(End definition for `\cs_set_protected:Npn`. This function is documented on page 11.)

5.12 Copying definitions

<code>\cs_set_eq:NN</code>	These macros allow us to copy the definition of a control sequence to another control sequence.
<code>\cs_set_eq:cN</code>	The = sign allows us to define funny char tokens like = itself or <code>_</code> with this function.
<code>\cs_set_eq:Nc</code>	For the definition of <code>\c_space_char{~}</code> to work we need the <code>~</code> after the =.
<code>\cs_set_eq:cc</code>	<code>\cs_set_eq:NN</code> is long to avoid problems with a literal argument of <code>\par</code> . While
<code>\cs_gset_eq:NN</code>	<code>\cs_new_eq:NN</code> will probably never be correct with a first argument of <code>\par</code> , define it
<code>\cs_gset_eq:cN</code>	long in order to throw an “already defined” error rather than “runaway argument”.
<code>\cs_gset_eq:Nc</code>	
<code>\cs_gset_eq:cc</code>	2868 <code>\cs_new_protected:Npn \cs_set_eq:NN #1 { \tex_let:D #1 =~ }</code>
<code>\cs_new_eq:NN</code>	2869 <code>\cs_new_protected:Npn \cs_set_eq:cN { \exp_args:Nc \cs_set_eq:NN }</code>
<code>\cs_new_eq:cN</code>	2870 <code>\cs_new_protected:Npn \cs_set_eq:Nc { \exp_args:NNc \cs_set_eq:NN }</code>
<code>\cs_new_eq:Nc</code>	2871 <code>\cs_new_protected:Npn \cs_set_eq:cc { \exp_args:Ncc \cs_set_eq:NN }</code>
<code>\cs_new_eq:cc</code>	2872 <code>\cs_new_protected:Npn \cs_gset_eq:NN { \tex_global:D \cs_set_eq:NN }</code>
	2873 <code>\cs_new_protected:Npn \cs_gset_eq:Nc { \exp_args:NNc \cs_gset_eq:NN }</code>
	2874 <code>\cs_new_protected:Npn \cs_gset_eq:cN { \exp_args:Nc \cs_gset_eq:NN }</code>
	2875 <code>\cs_new_protected:Npn \cs_gset_eq:cc { \exp_args:Ncc \cs_gset_eq:NN }</code>
	2876 <code>\cs_new_protected:Npn \cs_new_eq:NN #1</code>
	2877 <code>{</code>
	2878 <code>__kernel_chk_if_free_cs:N #1</code>
	2879 <code>\tex_global:D \cs_set_eq:NN #1</code>
	2880 <code>}</code>
	2881 <code>\cs_new_protected:Npn \cs_new_eq:cN { \exp_args:Nc \cs_new_eq:NN }</code>
	2882 <code>\cs_new_protected:Npn \cs_new_eq:Nc { \exp_args:NNc \cs_new_eq:NN }</code>
	2883 <code>\cs_new_protected:Npn \cs_new_eq:cc { \exp_args:Ncc \cs_new_eq:NN }</code>

(End definition for `\cs_set_eq:NN`, `\cs_gset_eq:NN`, and `\cs_new_eq:NN`. These functions are documented on page 15.)

5.13 undefining functions

<code>\cs_undefine:N</code>	The following function is used to free the main memory from the definition of some function that isn't in use any longer. The c variant is careful not to add the control sequence to the hash table if it isn't there yet, and it also avoids nesting TeX conditionals in case #1 is unbalanced in this matter.
<code>\cs_undefine:c</code>	

```

2884 \cs_new_protected:Npn \cs_undefine:N #1
2885 { \cs_gset_eq:NN #1 \tex_undefined:D }
2886 \cs_new_protected:Npn \cs_undefine:c #1
2887 {
2888   \if_cs_exist:w #1 \cs_end:

```

```

2889     \exp_after:wN \use:n
2890 \else:
2891     \exp_after:wN \use_none:n
2892 \fi:
2893 { \cs_gset_eq:cN {#1} \tex_undefined:D }
2894 }

```

(End definition for `\cs_undefine:N`. This function is documented on page 15.)

5.14 Generating parameter text from argument count

```

2895 <@@=cs>

```

```

\__kernel_cs_parm_from_arg_count:nnF
\__cs_parm_from_arg_count_test:nnF

```

L^AT_EX3 provides shorthands to define control sequences and conditionals with a simple parameter text, derived directly from the signature, or more generally from knowing the number of arguments, between 0 and 9. This function expands to its first argument, untouched, followed by a brace group containing the parameter text `{#1...#n}`, where n is the result of evaluating the second argument (as described in `\int_eval:n`). If the second argument gives a result outside the range $[0, 9]$, the third argument is returned instead, normally an error message. Some of the functions use here are not defined yet, but will be defined before this function is called.

```

2896 \cs_set_protected:Npn \__kernel_cs_parm_from_arg_count:nnF #1#2
2897 {
2898   \exp_args:Nx \__cs_parm_from_arg_count_test:nnF
2899   {
2900     \exp_after:wN \exp_not:n
2901     \if_case:w \int_eval:n {#2}
2902       { }
2903     \or: { ##1 }
2904     \or: { ##1##2 }
2905     \or: { ##1##2##3 }
2906     \or: { ##1##2##3##4 }
2907     \or: { ##1##2##3##4##5 }
2908     \or: { ##1##2##3##4##5##6 }
2909     \or: { ##1##2##3##4##5##6##7 }
2910     \or: { ##1##2##3##4##5##6##7##8 }
2911     \or: { ##1##2##3##4##5##6##7##8##9 }
2912     \else: { \c_false_bool }
2913   \fi:
2914   }
2915   {#1}
2916 }
2917 \cs_set_protected:Npn \__cs_parm_from_arg_count_test:nnF #1#2
2918 {
2919   \if_meaning:w \c_false_bool #1
2920     \exp_after:wN \use_ii:nn
2921   \else:
2922     \exp_after:wN \use_i:nn
2923   \fi:
2924   { #2 {#1} }
2925 }

```

(End definition for `__kernel_cs_parm_from_arg_count:nnF` and `__cs_parm_from_arg_count_test:nnF`.)

5.15 Defining functions from a given number of arguments

2926 `<@@=cs>`

`_cs_count_signature:N` Counting the number of tokens in the signature, *i.e.*, the number of arguments the function should take. Since this is not used in any time-critical function, we simply use `_cs_count_signature:c` `_cs_count_signature:n` `\tl_count:n` if there is a signature, otherwise `-1` arguments to signal an error. We need a variant form right away.

```
2927 \cs_new:Npn \_cs_count_signature:N #1
2928 { \exp_args:Nf \_cs_count_signature:n { \cs_split_function:N #1 } }
2929 \cs_new:Npn \_cs_count_signature:n #1
2930 { \int_eval:n { \_cs_count_signature:nnN #1 } }
2931 \cs_new:Npn \_cs_count_signature:nnN #1#2#3
2932 {
2933   \if_meaning:w \c_true_bool #3
2934     \tl_count:n {#2}
2935   \else:
2936     -1
2937   \fi:
2938 }
2939 \cs_new:Npn \_cs_count_signature:c
2940 { \exp_args:Nc \_cs_count_signature:N }
```

(End definition for `_cs_count_signature:N`, `_cs_count_signature:n`, and `_cs_count_signature:nnN`.)

`\cs_generate_from_arg_count:NNnn`
`\cs_generate_from_arg_count:cNnn`
`\cs_generate_from_arg_count:Ncnn`

We provide a constructor function for defining functions with a given number of arguments. For this we need to choose the correct parameter text and then use that when defining. Since TeX supports from zero to nine arguments, we use a simple switch to choose the correct parameter text, ensuring the result is returned after finishing the conditional. If it is not between zero and nine, we throw an error.

1: function to define, 2: with what to define it, 3: the number of args it requires and 4: the replacement text

```
2941 \cs_new_protected:Npn \cs_generate_from_arg_count:NNnn #1#2#3#4
2942 {
2943   \_kernel_cs_parm_from_arg_count:nnF { \use:nnn #2 #1 } {#3}
2944   {
2945     \_kernel_msg_error:nxxx { kernel } { bad-number-of-arguments }
2946     { \token_to_str:N #1 } { \int_eval:n {#3} }
2947     \use_none:n
2948   }
2949   {#4}
2950 }
```

A variant form we need right away, plus one which is used elsewhere but which is most logically created here.

```
2951 \cs_new_protected:Npn \cs_generate_from_arg_count:cNnn
2952 { \exp_args:Nc \cs_generate_from_arg_count:NNnn }
2953 \cs_new_protected:Npn \cs_generate_from_arg_count:Ncnn
2954 { \exp_args:NNc \cs_generate_from_arg_count:NNnn }
```

(End definition for `\cs_generate_from_arg_count:NNnn`. This function is documented on page 14.)

5.16 Using the signature to define functions

2955 <@@=cs>

We can now combine some of the tools we have to provide a simple interface for defining functions, where the number of arguments is read from the signature. For instance, `\cs_set:Nn \foo_bar:nn {#1,#2}`.

We want to define `\cs_set:Nn` as

```
\cs_set:Nn
\cs_set:Nx
\cs_set_nopar:Nn
\cs_set_nopar:Nx
\cs_set_protected:Nn
\cs_set_protected:Nx
\cs_set_protected_nopar:Nn
\cs_set_protected_nopar:Nx
\cs_gset:Nn
\cs_gset:Nx
\cs_gset_nopar:Nn
\cs_gset_nopar:Nx
\cs_gset_protected:Nn
\cs_gset_protected:Nx
\cs_new:Nn
\cs_new:Nx
\cs_new_nopar:Nn
\cs_new_nopar:Nx
\cs_new_protected:Nn
\cs_new_protected:Nx
\cs_new_protected_nopar:Nn
\cs_new_protected_nopar:Nx
```

In short, to define `\cs_set:Nn` we need just use `\cs_set:Npn`, everything else is the same for each variant. Therefore, we can make it simpler by temporarily defining a function to do this for us.

```
2956 \cs_set:Npn \__cs_tmp:w #1#2#3
2957 {
2958   \cs_new_protected:cpx { cs_ #1 : #2 }
2959   {
2960     \exp_not:N \__cs_generate_from_signature:NNn
2961     \exp_after:wN \exp_not:N \cs:w cs_ #1 : #3 \cs_end:
2962   }
2963 }
2964 \cs_new_protected:Npn \__cs_generate_from_signature:NNn #1#2
2965 {
2966   \use:x
2967   {
2968     \__cs_generate_from_signature:nnNNNn
2969     \cs_split_function:N #2
2970   }
2971   #1 #2
2972 }
2973 \cs_new_protected:Npn \__cs_generate_from_signature:nnNNNn #1#2#3#4#5#6
2974 {
2975   \bool_if:NTF #3
2976   {
2977     \str_if_eq:eeF { }
2978     { \tl_map_function:nN {#2} \__cs_generate_from_signature:n }
2979     {
2980       \__kernel_msg_error:nnx { kernel } { non-base-function }
2981       { \token_to_str:N #5 }
2982     }
2983     \cs_generate_from_arg_count:NNnn
2984     #5 #4 { \tl_count:n {#2} } {#6}
2985   }
2986   {
2987     \__kernel_msg_error:nnx { kernel } { missing-colon }
2988     { \token_to_str:N #5 }
2989   }
2990 }
2991 \cs_new:Npn \__cs_generate_from_signature:n #1
```

```

2992 {
2993     \if:w n #1 \else: \if:w N #1 \else:
2994     \if:w T #1 \else: \if:w F #1 \else: #1 \fi: \fi: \fi: \fi:
2995 }

```

Then we define the 24 variants beginning with N.

```

2996 \__cs_tmp:w { set } { Nn } { Npn }
2997 \__cs_tmp:w { set } { Nx } { Npx }
2998 \__cs_tmp:w { set_nopar } { Nn } { Npn }
2999 \__cs_tmp:w { set_nopar } { Nx } { Npx }
3000 \__cs_tmp:w { set_protected } { Nn } { Npn }
3001 \__cs_tmp:w { set_protected } { Nx } { Npx }
3002 \__cs_tmp:w { set_protected_nopar } { Nn } { Npn }
3003 \__cs_tmp:w { set_protected_nopar } { Nx } { Npx }
3004 \__cs_tmp:w { gset } { Nn } { Npn }
3005 \__cs_tmp:w { gset } { Nx } { Npx }
3006 \__cs_tmp:w { gset_nopar } { Nn } { Npn }
3007 \__cs_tmp:w { gset_nopar } { Nx } { Npx }
3008 \__cs_tmp:w { gset_protected } { Nn } { Npn }
3009 \__cs_tmp:w { gset_protected } { Nx } { Npx }
3010 \__cs_tmp:w { gset_protected_nopar } { Nn } { Npn }
3011 \__cs_tmp:w { gset_protected_nopar } { Nx } { Npx }
3012 \__cs_tmp:w { new } { Nn } { Npn }
3013 \__cs_tmp:w { new } { Nx } { Npx }
3014 \__cs_tmp:w { new_nopar } { Nn } { Npn }
3015 \__cs_tmp:w { new_nopar } { Nx } { Npx }
3016 \__cs_tmp:w { new_protected } { Nn } { Npn }
3017 \__cs_tmp:w { new_protected } { Nx } { Npx }
3018 \__cs_tmp:w { new_protected_nopar } { Nn } { Npn }
3019 \__cs_tmp:w { new_protected_nopar } { Nx } { Npx }

```

(End definition for \cs_set:Nn and others. These functions are documented on page 13.)

\cs_set:cn The 24 c variants simply use \exp_args:Nc.

\cs_set:cx 3020 \cs_set:Npn __cs_tmp:w #1#2

\cs_set_nopar:cn 3021 {

\cs_set_nopar:cx 3022 \cs_new_protected:cpx { cs_ #1 : c #2 }

\cs_set_protected:cn 3023 {

\cs_set_protected:cx 3024 \exp_not:N \exp_args:Nc

\cs_set_protected_nopar:cn 3025 \exp_after:wN \exp_not:N \cs:w cs_ #1 : N #2 \cs_end:

\cs_set_protected_nopar:cx 3026 }

\cs_gset:cn 3027 }

\cs_gset:cx 3028 __cs_tmp:w { set } { n }

\cs_gset_nopar:cn 3029 __cs_tmp:w { set } { x }

\cs_gset_nopar:cx 3030 __cs_tmp:w { set_nopar } { n }

\cs_gset_protected:cn 3031 __cs_tmp:w { set_nopar } { x }

\cs_gset_protected:cx 3032 __cs_tmp:w { set_protected } { n }

\cs_gset_protected_nopar:cn 3033 __cs_tmp:w { set_protected } { x }

\cs_gset_protected_nopar:cx 3034 __cs_tmp:w { set_protected_nopar } { n }

\cs_gset_protected_nopar:cx 3035 __cs_tmp:w { set_protected_nopar } { x }

\cs_new:cn 3036 __cs_tmp:w { gset } { n }

\cs_new:cx 3037 __cs_tmp:w { gset } { x }

\cs_new_nopar:cn 3038 __cs_tmp:w { gset_nopar } { n }

\cs_new_nopar:cx 3039 __cs_tmp:w { gset_nopar } { x }

\cs_new_protected:cn 3040 __cs_tmp:w { gset_protected } { n }

\cs_new_protected:cx

\cs_new_protected_nopar:cn

\cs_new_protected_nopar:cx

```

3041 \__cs_tmp:w { gset_protected } { x }
3042 \__cs_tmp:w { gset_protected_nopar } { n }
3043 \__cs_tmp:w { gset_protected_nopar } { x }
3044 \__cs_tmp:w { new } { n }
3045 \__cs_tmp:w { new } { x }
3046 \__cs_tmp:w { new_nopar } { n }
3047 \__cs_tmp:w { new_nopar } { x }
3048 \__cs_tmp:w { new_protected } { n }
3049 \__cs_tmp:w { new_protected } { x }
3050 \__cs_tmp:w { new_protected_nopar } { n }
3051 \__cs_tmp:w { new_protected_nopar } { x }

```

(End definition for \cs_set:Nn. This function is documented on page 13.)

5.17 Checking control sequence equality

\cs_if_eq_p:NN Check if two control sequences are identical.

```

\cs_if_eq_p:cN 3052 \prg_new_conditional:Npnn \cs_if_eq:NN #1#2 { p , T , F , TF }
\cs_if_eq_p:Nc 3053 {
\cs_if_eq_p:cc 3054   \if_meaning:w #1#2
\cs_if_eq:NNTF 3055   \prg_return_true: \else: \prg_return_false: \fi:
\cs_if_eq:cNTF 3056 }
\cs_if_eq:NcTF 3057 \cs_new:Npn \cs_if_eq_p:cN { \exp_args:Nc \cs_if_eq_p:NN }
\cs_if_eq:NcTF 3058 \cs_new:Npn \cs_if_eq:cNTF { \exp_args:Nc \cs_if_eq:NNTF }
\cs_if_eq:ccTF 3059 \cs_new:Npn \cs_if_eq:cNT { \exp_args:Nc \cs_if_eq:NNT }
\cs_if_eq:ccTF 3060 \cs_new:Npn \cs_if_eq:cNF { \exp_args:Nc \cs_if_eq:NNF }
\cs_if_eq:NcTF 3061 \cs_new:Npn \cs_if_eq_p:Nc { \exp_args:NNc \cs_if_eq_p:NN }
\cs_if_eq:NcTF 3062 \cs_new:Npn \cs_if_eq:NcTF { \exp_args:NNc \cs_if_eq:NNTF }
\cs_if_eq:NcTF 3063 \cs_new:Npn \cs_if_eq:NcT { \exp_args:NNc \cs_if_eq:NNT }
\cs_if_eq:NcTF 3064 \cs_new:Npn \cs_if_eq:NcF { \exp_args:NNc \cs_if_eq:NNF }
\cs_if_eq:pcc 3065 \cs_new:Npn \cs_if_eq_p:cc { \exp_args:Ncc \cs_if_eq_p:NN }
\cs_if_eq:ccTF 3066 \cs_new:Npn \cs_if_eq:ccTF { \exp_args:Ncc \cs_if_eq:NNTF }
\cs_if_eq:ccTF 3067 \cs_new:Npn \cs_if_eq:ccT { \exp_args:Ncc \cs_if_eq:NNT }
\cs_if_eq:ccTF 3068 \cs_new:Npn \cs_if_eq:ccF { \exp_args:Ncc \cs_if_eq:NNF }

```

(End definition for \cs_if_eq:NNTF. This function is documented on page 22.)

5.18 Diagnostic functions

```

3069 <@@=kernel>
\__kernel_chk_defined:NT Error if the variable #1 is not defined.
3070 \cs_new_protected:Npn \__kernel_chk_defined:NT #1#2
3071 {
3072   \cs_if_exist:NTF #1
3073   {#2}
3074   {
3075     \__kernel_msg_error:nxx { kernel } { variable-not-defined }
3076     { \token_to_str:N #1 }
3077   }
3078 }

```

(End definition for __kernel_chk_defined:NT.)

Simply using the `\show` primitive does not allow for line-wrapping, so instead use `\tl_show:n` and `\tl_log:n` (defined in `l3tl` and that performs line-wrapping). This displays `>~⟨variable⟩=⟨value⟩`. We expand the value before-hand as otherwise some integers (such as `\currentgrouplevel` or `\currentgrouptype`) altered by the line-wrapping code would show wrong values.

```

\__kernel_register_show:N
\__kernel_register_show:c
\__kernel_register_log:N
\__kernel_register_log:c
  \__kernel_register_show_aux:NN
  \__kernel_register_show_aux:nNN
3079 \cs_new_protected:Npn \__kernel_register_show:N
3080   { \__kernel_register_show_aux:NN \tl_show:n }
3081 \cs_new_protected:Npn \__kernel_register_show:c
3082   { \exp_args:Nc \__kernel_register_show:N }
3083 \cs_new_protected:Npn \__kernel_register_log:N
3084   { \__kernel_register_show_aux:NN \tl_log:n }
3085 \cs_new_protected:Npn \__kernel_register_log:c
3086   { \exp_args:Nc \__kernel_register_log:N }
3087 \cs_new_protected:Npn \__kernel_register_show_aux:NN #1#2
3088   {
3089     \__kernel_chk_defined:NT #2
3090     {
3091       \exp_args:No \__kernel_register_show_aux:nNN
3092       { \tex_the:D #2 } #2 #1
3093     }
3094   }
3095 \cs_new_protected:Npn \__kernel_register_show_aux:nNN #1#2#3
3096   { \exp_args:No #3 { \token_to_str:N #2 = #1 } }

```

(End definition for `__kernel_register_show:N` and others.)

Some control sequences have a very long name or meaning. Thus, simply using TeX's primitive `\show` could lead to overlong lines. The output of this primitive is mimicked to some extent, then the re-built string is given to `\tl_show:n` or `\tl_log:n` for line-wrapping. We must expand the meaning before passing it to the wrapping code as otherwise we would wrongly see the definitions that are in place there. To get correct escape characters, set the `\escapechar` in a group; this also localizes the assignment performed by x-expansion. The `\cs_show:c` and `\cs_log:c` commands convert their argument to a control sequence within a group to avoid showing `\relax` for undefined control sequences.

```

3097 \cs_new_protected:Npn \cs_show:N { \__kernel_show:NN \tl_show:n }
3098 \cs_new_protected:Npn \cs_show:c
3099   { \group_begin: \exp_args:NNc \group_end: \cs_show:N }
3100 \cs_new_protected:Npn \cs_log:N { \__kernel_show:NN \tl_log:n }
3101 \cs_new_protected:Npn \cs_log:c
3102   { \group_begin: \exp_args:NNc \group_end: \cs_log:N }
3103 \cs_new_protected:Npn \__kernel_show:NN #1#2
3104   {
3105     \group_begin:
3106     \int_set:Nn \tex_escapechar:D { '\ }
3107     \exp_args:NNx
3108     \group_end:
3109     #1 { \token_to_str:N #2 = \cs_meaning:N #2 }
3110   }

```

(End definition for `\cs_show:N`, `\cs_log:N`, and `__kernel_show:NN`. These functions are documented on page 16.)

5.19 Decomposing a macro definition

`\cs_prefix_spec:N` We sometimes want to test if a control sequence can be expanded to reveal a hidden value.
`\cs_argument_spec:N` However, we cannot just expand the macro blindly as it may have arguments and none
`\cs_replacement_spec:N` might be present. Therefore we define these functions to pick either the prefix(es), the
`__kernel_prefix_arg_replacement:wN` argument specification, or the replacement text from a macro. All of this information is
returned as characters with catcode 12. If the token in question isn't a macro, the token
`\scan_stop:` is returned instead.

```

3111 \use:x
3112 {
3113   \exp_not:n { \cs_new:Npn \__kernel_prefix_arg_replacement:wN #1 }
3114   \tl_to_str:n { macro : } \exp_not:n { #2 -> #3 \q_stop #4 }
3115 }
3116 { #4 {#1} {#2} {#3} }
3117 \cs_new:Npn \cs_prefix_spec:N #1
3118 {
3119   \token_if_macro:NTF #1
3120   {
3121     \exp_after:wN \__kernel_prefix_arg_replacement:wN
3122     \token_to_meaning:N #1 \q_stop \use_i:nnn
3123   }
3124   { \scan_stop: }
3125 }
3126 \cs_new:Npn \cs_argument_spec:N #1
3127 {
3128   \token_if_macro:NTF #1
3129   {
3130     \exp_after:wN \__kernel_prefix_arg_replacement:wN
3131     \token_to_meaning:N #1 \q_stop \use_ii:nnn
3132   }
3133   { \scan_stop: }
3134 }
3135 \cs_new:Npn \cs_replacement_spec:N #1
3136 {
3137   \token_if_macro:NTF #1
3138   {
3139     \exp_after:wN \__kernel_prefix_arg_replacement:wN
3140     \token_to_meaning:N #1 \q_stop \use_iii:nnn
3141   }
3142   { \scan_stop: }
3143 }
```

(End definition for `\cs_prefix_spec:N` and others. These functions are documented on page 18.)

5.20 Doing nothing functions

`\prg_do_nothing:` This does not fit anywhere else!

```

3144 \cs_new:Npn \prg_do_nothing: { }
```

(End definition for `\prg_do_nothing:`. This function is documented on page 9.)

5.21 Breaking out of mapping functions

3145 $\langle @@=\text{prg} \rangle$

$\backslash\text{prg_break_point:Nn}$ In inline mappings, the nesting level must be reset at the end of the mapping, even when
 $\backslash\text{prg_map_break:Nn}$ the user decides to break out. This is done by putting the code that must be performed
as an argument of $\backslash_prg_break_point:Nn$. The breaking functions are then defined to
jump to that point and perform the argument of $\backslash_prg_break_point:Nn$, before the
user’s code (if any). There is a check that we close the correct loop, otherwise we continue
breaking.

```
3146 \cs_new_eq:NN \prg_break_point:Nn \use_ii:nn
3147 \cs_new:Npn \prg_map_break:Nn #1#2#3 \prg_break_point:Nn #4#5
3148 {
3149   #5
3150   \if_meaning:w #1 #4
3151     \exp_after:wN \use_iii:nnn
3152   \fi:
3153   \prg_map_break:Nn #1 {#2}
3154 }
```

(End definition for $\backslash\text{prg_break_point:Nn}$ and $\backslash\text{prg_map_break:Nn}$. These functions are documented on page 109.)

$\backslash\text{prg_break_point:}$ Very simple analogues of $\backslash\text{prg_break_point:Nn}$ and $\backslash\text{prg_map_break:Nn}$, for use in fast
 $\backslash\text{prg_break:}$ short-term recursions which are not mappings, do not need to support nesting, and in
 $\backslash\text{prg_break:n}$ which nothing has to be done at the end of the loop.

```
3155 \cs_new_eq:NN \prg_break_point: \prg_do_nothing:
3156 \cs_new:Npn \prg_break: #1 \prg_break_point: { }
3157 \cs_new:Npn \prg_break:n #1#2 \prg_break_point: {#1}
```

(End definition for $\backslash\text{prg_break_point:}$, $\backslash\text{prg_break:}$, and $\backslash\text{prg_break:n}$. These functions are documented on page 109.)

3158 $\langle /\text{initex} \mid \text{package} \rangle$

6 l3expan implementation

3159 $\langle *\text{initex} \mid \text{package} \rangle$

3160 $\langle @@=\text{exp} \rangle$

$\backslash\text{l_exp_internal_tl}$ The $\backslash\text{exp_}$ module has its private variable to temporarily store the result of x-type argument expansion. This is done to avoid interference with other functions using temporary variables.

(End definition for $\backslash\text{l_exp_internal_tl}$.)

$\backslash\text{exp_after:wN}$ These are defined in l3basics, as they are needed “early”. This is just a reminder of that
 $\backslash\text{exp_not:N}$ fact!

$\backslash\text{exp_not:n}$ (End definition for $\backslash\text{exp_after:wN}$, $\backslash\text{exp_not:N}$, and $\backslash\text{exp_not:n}$. These functions are documented on page 32.)

6.1 General expansion

In this section a general mechanism for defining functions that handle arguments is defined. These general expansion functions are expandable unless `x` is used. (Any version of `x` is going to have to use one of the L^AT_EX3 names for `\cs_set:Npx` at some point, and so is never going to be expandable.)

The definition of expansion functions with this technique happens in section 6.3. In section 6.2 some common cases are coded by a more direct method for efficiency, typically using calls to `\exp_after:wN`.

`\l__exp_internal_tl` This scratch token list variable is defined in `l3basics`.

(End definition for `\l__exp_internal_tl`.)

This code uses internal functions with names that start with `\:` to perform the expansions. All macros are `long` since the tokens undergoing expansion may be arbitrary user input.

An argument manipulator `\:<Z>` always has signature `#1\:::#2#3` where `#1` holds the remaining argument manipulations to be performed, `\:::` serves as an end marker for the list of manipulations, `#2` is the carried over result of the previous expansion steps and `#3` is the argument about to be processed. One exception to this rule is `\:p`, which has to grab an argument delimited by a left brace.

`__exp_arg_next:nnn` `#1` is the result of an expansion step, `#2` is the remaining argument manipulations and
`__exp_arg_next:Nnn` `#3` is the current result of the expansion chain. This auxiliary function moves `#1` back after `#3` in the input stream and checks if any expansion is left to be done by calling `#2`. In by far the most cases we need to add a set of braces to the result of an argument manipulation so it is more effective to do it directly here. Actually, so far only the `c` of the final argument manipulation variants does not require a set of braces.

```
3161 \cs_new:Npn \__exp_arg_next:nnn #1#2#3 { #2 \::: { #3 {#1} } }
3162 \cs_new:Npn \__exp_arg_next:Nnn #1#2#3 { #2 \::: { #3 #1 } }
```

(End definition for `__exp_arg_next:nnn` and `__exp_arg_next:Nnn`.)

`\:::` The end marker is just another name for the identity function.

```
3163 \cs_new:Npn \::: #1 {#1}
```

(End definition for `\:::`. This function is documented on page 36.)

`\:n` This function is used to skip an argument that doesn't need to be expanded.

```
3164 \cs_new:Npn \:n #1 \::: #2#3 { #1 \::: { #2 {#3} } }
```

(End definition for `\:n`. This function is documented on page 36.)

`\:N` This function is used to skip an argument that consists of a single token and doesn't need to be expanded.

```
3165 \cs_new:Npn \:N #1 \::: #2#3 { #1 \::: {#2#3} }
```

(End definition for `\:N`. This function is documented on page 36.)

`\:p` This function is used to skip an argument that is delimited by a left brace and doesn't need to be expanded. It is not wrapped in braces in the result.

```
3166 \cs_new:Npn \:p #1 \::: #2#3# { #1 \::: {#2#3} }
```

(End definition for `\:p`. This function is documented on page 36.)

\::c This function is used to skip an argument that is turned into a control sequence without expansion.

```
3167 \cs_new:Npn \::c #1 \::: #2#3
3168 { \exp_after:wN \__exp_arg_next:Nnn \cs:w #3 \cs_end: {#1} {#2} }
```

(End definition for \::c. This function is documented on page 36.)

\::o This function is used to expand an argument once.

```
3169 \cs_new:Npn \::o #1 \::: #2#3
3170 { \exp_after:wN \__exp_arg_next:nnn \exp_after:wN {#3} {#1} {#2} }
```

(End definition for \::o. This function is documented on page 36.)

\::e With the `\expanded` primitive available, just expand. Otherwise defer to `\exp_args:Ne` implemented later.

```
3171 \cs_if_exist:NTF \tex_expanded:D
3172 {
3173   \cs_new:Npn \::e #1 \::: #2#3
3174   { \tex_expanded:D { \exp_not:n { #1 \::: } { \exp_not:n {#2} {#3} } } }
3175 }
3176 {
3177   \cs_new:Npn \::e #1 \::: #2#3
3178   { \exp_args:Ne \__exp_arg_next:nnn {#3} {#1} {#2} }
3179 }
```

(End definition for \::e. This function is documented on page 36.)

\::f This function is used to expand a token list until the first unexpandable token is found. This is achieved through `\exp:w \exp_end_continue_f:w` that expands everything in its way following it. This scanning procedure is terminated once the expansion hits something non-expandable (if that is a space it is removed). We introduce `\exp_stop_f:` to mark such an end-of-expansion marker. For example, `f`-expanding `\cs_set_eq:Nc \aaa { b \l_tmpa_tl b }` where `\l_tmpa_tl` contains the characters `lur` gives `\tex_let:D \aaa = \blurb` which then turns out to start with the non-expandable token `\tex_let:D`. Since the expansion of `\exp:w \exp_end_continue_f:w` is empty, we wind up with a fully expanded list, only TeX has not tried to execute any of the non-expandable tokens. This is what differentiates this function from the `x` argument type.

```
3180 \cs_new:Npn \::f #1 \::: #2#3
3181 {
3182   \exp_after:wN \__exp_arg_next:nnn
3183   \exp_after:wN { \exp:w \exp_end_continue_f:w #3 }
3184   {#1} {#2}
3185 }
3186 \use:nn { \cs_new_eq:NN \exp_stop_f: } { ~ }
```

(End definition for \::f and \exp_stop_f:. These functions are documented on page 36.)

\::x This function is used to expand an argument fully. We build in the expansion of `__exp_arg_next:nnn`.

```
3187 \cs_new_protected:Npn \::x #1 \::: #2#3
3188 {
3189   \cs_set_nopar:Npx \l__exp_internal_tl
```



```

3190     { \exp_not:n { #1 \::: } { \exp_not:n {#2} {#3} } }
3191     \l__exp_internal_tl
3192   }

```

(End definition for `\::x`. This function is documented on page 36.)

`\::v` These functions return the value of a register, i.e., one of `tl`, `clist`, `int`, `skip`, `dim`, `muskip`, or built-in T_EX register. The **`V`** version expects a single token whereas **`v`** like **`c`** creates a `csname` from its argument given in braces and then evaluates it as if it was a **`V`**. The `\exp:w` sets off an expansion similar to an `f`-type expansion, which we terminate using `\exp_end:.` The argument is returned in braces.

```

3193 \cs_new:Npn \::V #1 \::: #2#3
3194 {
3195   \exp_after:wN \__exp_arg_next:nnn
3196   \exp_after:wN { \exp:w \__exp_eval_register:N #3 }
3197   {#1} {#2}
3198 }
3199 \cs_new:Npn \::v # 1\::: #2#3
3200 {
3201   \exp_after:wN \__exp_arg_next:nnn
3202   \exp_after:wN { \exp:w \__exp_eval_register:c {#3} }
3203   {#1} {#2}
3204 }

```

(End definition for `\::v` and `\::V`. These functions are documented on page 36.)

`__exp_eval_register:N` This function evaluates a register. Now a register might exist as one of two things: A parameter-less macro or a built-in T_EX register such as `\count`. For the T_EX registers we have to utilize a `\the` whereas for the macros we merely have to expand them once. The trick is to find out when to use `\the` and when not to. What we want here is to find out whether the token expands to something else when hit with `\exp_after:wN`. The technique is to compare the meaning of the token in question when it has been prefixed with `\exp_not:N` and the token itself. If it is a macro, the prefixed `\exp_not:N` temporarily turns it into the primitive `\scan_stop:.`

```

3205 \cs_new:Npn \__exp_eval_register:N #1
3206 {
3207   \exp_after:wN \if_meaning:w \exp_not:N #1 #1

```

If the token was not a macro it may be a malformed variable from a `c` expansion in which case it is equal to the primitive `\scan_stop:.` In that case we throw an error. We could let T_EX do it for us but that would result in the rather obscure

! You can't use ‘`\relax`’ after `\the`.

which while quite true doesn't give many hints as to what actually went wrong. We provide something more sensible.

```

3208   \if_meaning:w \scan_stop: #1
3209   \__exp_eval_error_msg:w
3210   \fi:

```

The next bit requires some explanation. The function must be initiated by `\exp:w` and we want to terminate this expansion chain by inserting the `\exp_end:` token. However, we have to expand the register `#1` before we do that. If it is a T_EX register, we need to execute the sequence `\exp_after:wN \exp_end: \tex_the:D #1` and if it is a macro

we need to execute `\exp_after:wN \exp_end: #1`. We therefore issue the longer of the two sequences and if the register is a macro, we remove the `\tex_the:D`.

```

3211 \else:
3212 \exp_after:wN \use_i_ii:nnn
3213 \fi:
3214 \exp_after:wN \exp_end: \tex_the:D #1
3215 }
3216 \cs_new:Npn \__exp_eval_register:c #1
3217 { \exp_after:wN \__exp_eval_register:N \cs:w #1 \cs_end: }

```

Clean up nicely, then call the undefined control sequence. The result is an error message looking like this:

```

! Undefined control sequence.
<argument> \LaTeX3 error:
                               Erroneous variable used!
1.55 \tl_set:Nv \l_tmpa_tl {undefined_tl}

3218 \cs_new:Npn \__exp_eval_error_msg:w #1 \tex_the:D #2
3219 {
3220 \fi:
3221 \fi:
3222 \__kernel_msg_expandable_error:nnn { kernel } { bad-variable } {#2}
3223 \exp_end:
3224 }

```

(End definition for `__exp_eval_register:N` and `__exp_eval_error_msg:w`.)

6.2 Hand-tuned definitions

One of the most important features of these functions is that they are fully expandable.

`\exp_args:Nc` In `l3basics`.

`\exp_args:cc`

(End definition for `\exp_args:Nc` and `\exp_args:cc`. These functions are documented on page 28.)

`\exp_args:NNc`

`\exp_args:Ncc`

`\exp_args:Nccc`

Here are the functions that turn their argument into csnames but are expandable.

```

3225 \cs_new:Npn \exp_args:NNc #1#2#3
3226 { \exp_after:wN #1 \exp_after:wN #2 \cs:w # 3\cs_end: }
3227 \cs_new:Npn \exp_args:Ncc #1#2#3
3228 { \exp_after:wN #1 \cs:w #2 \exp_after:wN \cs_end: \cs:w #3 \cs_end: }
3229 \cs_new:Npn \exp_args:Nccc #1#2#3#4
3230 {
3231 \exp_after:wN #1
3232 \cs:w #2 \exp_after:wN \cs_end:
3233 \cs:w #3 \exp_after:wN \cs_end:
3234 \cs:w #4 \cs_end:
3235 }

```

(End definition for `\exp_args:NNc`, `\exp_args:Ncc`, and `\exp_args:Nccc`. These functions are documented on page 30.)

`\exp_args:No` Those lovely runs of expansion!

`\exp_args:NNo` 3236 `\cs_new:Npn \exp_args:No #1#2 { \exp_after:wN #1 \exp_after:wN {#2} }`

`\exp_args:NNNo` 3237 `\cs_new:Npn \exp_args:NNo #1#2#3`

3238 `{ \exp_after:wN #1 \exp_after:wN #2 \exp_after:wN {#3} }`

3239 `\cs_new:Npn \exp_args:NNNo #1#2#3#4`

3240 `{ \exp_after:wN #1 \exp_after:wN#2 \exp_after:wN #3 \exp_after:wN {#4} }`

(End definition for `\exp_args:No`, `\exp_args:NNo`, and `\exp_args:NNNo`. These functions are documented on page 29.)

`\exp_args:Ne` When the `\expanded` primitive is available, use it. Otherwise use `__exp_e:nn`, defined later, to fully expand tokens.

3241 `\cs_if_exist:NTF \tex_expanded:D`

3242 `{`

3243 `\cs_new:Npn \exp_args:Ne #1#2`

3244 `{ \exp_after:wN #1 \tex_expanded:D { {#2} } }`

3245 `}`

3246 `{`

3247 `\cs_new:Npn \exp_args:Ne #1#2`

3248 `{`

3249 `\exp_after:wN #1 \exp_after:wN`

3250 `{ \exp:w __exp_e:nn {#2} { } }`

3251 `}`

3252 `}`

(End definition for `\exp_args:Ne`. This function is documented on page 29.)

`\exp_args:Nf`

`\exp_args:NV` 3253 `\cs_new:Npn \exp_args:Nf #1#2`

`\exp_args:Nv` 3254 `{ \exp_after:wN #1 \exp_after:wN { \exp:w \exp_end_continue_f:w #2 } }`

3255 `\cs_new:Npn \exp_args:Nv #1#2`

3256 `{`

3257 `\exp_after:wN #1 \exp_after:wN`

3258 `{ \exp:w __exp_eval_register:c {#2} }`

3259 `}`

3260 `\cs_new:Npn \exp_args:NV #1#2`

3261 `{`

3262 `\exp_after:wN #1 \exp_after:wN`

3263 `{ \exp:w __exp_eval_register:N #2 }`

3264 `}`

(End definition for `\exp_args:Nf`, `\exp_args:NV`, and `\exp_args:Nv`. These functions are documented on page 29.)

`\exp_args:NNV` Some more hand-tuned function with three arguments. If we forced that an `o` argument

`\exp_args:NNv` always has braces, we could implement `\exp_args:Nco` with less tokens and only two

`\exp_args:NNe` arguments.

3265 `\cs_new:Npn \exp_args:NNV #1#2#3`

3266 `{`

3267 `\exp_after:wN #1`

3268 `\exp_after:wN #2`

3269 `\exp_after:wN { \exp:w __exp_eval_register:N #3 }`

3270 `}`

3271 `\cs_new:Npn \exp_args:NNv #1#2#3`

```

3272 {
3273   \exp_after:wN #1
3274   \exp_after:wN #2
3275   \exp_after:wN { \exp:w \_\_exp_eval_register:c {#3} }
3276 }
3277 \cs_if_exist:NTF \tex_expanded:D
3278 {
3279   \cs_new:Npn \exp_args:NNe #1#2#3
3280   {
3281     \exp_after:wN #1
3282     \exp_after:wN #2
3283     \tex_expanded:D { {#3} }
3284   }
3285 }
3286 { \cs_new:Npn \exp_args:NNe { \::N \::e \::: } }
3287 \cs_new:Npn \exp_args:NNf #1#2#3
3288 {
3289   \exp_after:wN #1
3290   \exp_after:wN #2
3291   \exp_after:wN { \exp:w \exp_end_continue_f:w #3 }
3292 }
3293 \cs_new:Npn \exp_args:Nco #1#2#3
3294 {
3295   \exp_after:wN #1
3296   \cs:w #2 \exp_after:wN \cs_end:
3297   \exp_after:wN {#3}
3298 }
3299 \cs_new:Npn \exp_args:NcV #1#2#3
3300 {
3301   \exp_after:wN #1
3302   \cs:w #2 \exp_after:wN \cs_end:
3303   \exp_after:wN { \exp:w \_\_exp_eval_register:N #3 }
3304 }
3305 \cs_new:Npn \exp_args:Ncv #1#2#3
3306 {
3307   \exp_after:wN #1
3308   \cs:w #2 \exp_after:wN \cs_end:
3309   \exp_after:wN { \exp:w \_\_exp_eval_register:c {#3} }
3310 }
3311 \cs_new:Npn \exp_args:Ncf #1#2#3
3312 {
3313   \exp_after:wN #1
3314   \cs:w #2 \exp_after:wN \cs_end:
3315   \exp_after:wN { \exp:w \exp_end_continue_f:w #3 }
3316 }
3317 \cs_new:Npn \exp_args:NVV #1#2#3
3318 {
3319   \exp_after:wN #1
3320   \exp_after:wN { \exp:w \exp_after:wN
3321     \_\_exp_eval_register:N \exp_after:wN #2 \exp_after:wN }
3322   \exp_after:wN { \exp:w \_\_exp_eval_register:N #3 }
3323 }

```

(End definition for `\exp_args:NNV` and others. These functions are documented on page 30.)

```

\exp_args:NNNV A few more that we can hand-tune.
\exp_args:NcNc 3324 \cs_new:Npn \exp_args:NNNV #1#2#3#4
\exp_args:NcNo 3325 {
\exp_args:Ncco 3326   \exp_after:wN #1
3327   \exp_after:wN #2
3328   \exp_after:wN #3
3329   \exp_after:wN { \exp:w \__exp_eval_register:N #4 }
3330 }
3331 \cs_new:Npn \exp_args:NcNc #1#2#3#4
3332 {
3333   \exp_after:wN #1
3334   \cs:w #2 \exp_after:wN \cs_end:
3335   \exp_after:wN #3
3336   \cs:w #4 \cs_end:
3337 }
3338 \cs_new:Npn \exp_args:NcNo #1#2#3#4
3339 {
3340   \exp_after:wN #1
3341   \cs:w #2 \exp_after:wN \cs_end:
3342   \exp_after:wN #3
3343   \exp_after:wN {#4}
3344 }
3345 \cs_new:Npn \exp_args:Ncco #1#2#3#4
3346 {
3347   \exp_after:wN #1
3348   \cs:w #2 \exp_after:wN \cs_end:
3349   \cs:w #3 \exp_after:wN \cs_end:
3350   \exp_after:wN {#4}
3351 }

```

(End definition for `\exp_args:NNNV` and others. These functions are documented on page 31.)

6.3 Definitions with the automated technique

Some of these could be done more efficiently, but the complexity of coding then becomes an issue. Notice that the auto-generated functions actually take no arguments themselves.

```

\exp_args:Nx
3352 \cs_new_protected:Npn \exp_args:Nx { \::x \:: }

```

(End definition for `\exp_args:Nx`. This function is documented on page 30.)

Here are the actual function definitions, using the helper functions above.

```

\exp_args:Nnc 3353 \cs_new:Npn \exp_args:Nnc { \::n \::c \:: }
\exp_args:Nno 3354 \cs_new:Npn \exp_args:Nno { \::n \::o \:: }
\exp_args:NnV 3355 \cs_new:Npn \exp_args:NnV { \::n \::V \:: }
\exp_args:Nnv 3356 \cs_new:Npn \exp_args:Nnv { \::n \::v \:: }
\exp_args:Nne 3357 \cs_new:Npn \exp_args:Nne { \::n \::e \:: }
\exp_args:Nnf 3358 \cs_new:Npn \exp_args:Nnf { \::n \::f \:: }
\exp_args:Noc 3359 \cs_new:Npn \exp_args:Noc { \::o \::c \:: }
\exp_args:Noo 3360 \cs_new:Npn \exp_args:Noo { \::o \::o \:: }
\exp_args:Nof 3361 \cs_new:Npn \exp_args:Nof { \::o \::f \:: }
\exp_args:NVo 3362 \cs_new:Npn \exp_args:NVo { \::V \::o \:: }
\exp_args:Nfo 3363 \cs_new:Npn \exp_args:Nfo { \::f \::o \:: }

```

```

3364 \cs_new:Npn \exp_args:Nff { \::f \::f \::: }
3365 \cs_new_protected:Npn \exp_args:NNx { \::N \::x \::: }
3366 \cs_new_protected:Npn \exp_args:Ncx { \::c \::x \::: }
3367 \cs_new_protected:Npn \exp_args:Nnx { \::n \::x \::: }
3368 \cs_new_protected:Npn \exp_args:Nox { \::o \::x \::: }
3369 \cs_new_protected:Npn \exp_args:Nxo { \::x \::o \::: }
3370 \cs_new_protected:Npn \exp_args:Nxx { \::x \::x \::: }

```

(End definition for `\exp_args:Nnc` and others. These functions are documented on page 30.)

```

\exp_args:NNNv
\exp_args:NNcf 3371 \cs_new:Npn \exp_args:NNNv { \::N \::N \::v \::: }
\exp_args:NNno 3372 \cs_new:Npn \exp_args:NNcf { \::N \::c \::f \::: }
\exp_args:NNnV 3373 \cs_new:Npn \exp_args:NNno { \::N \::n \::o \::: }
\exp_args:NNoo 3374 \cs_new:Npn \exp_args:NNnV { \::N \::n \::V \::: }
\exp_args:NNVV 3375 \cs_new:Npn \exp_args:NNoo { \::N \::o \::o \::: }
\exp_args:Ncno 3376 \cs_new:Npn \exp_args:NNVV { \::N \::V \::V \::: }
\exp_args:NcnV 3377 \cs_new:Npn \exp_args:Ncno { \::c \::n \::o \::: }
\exp_args:Ncoo 3378 \cs_new:Npn \exp_args:NcnV { \::c \::n \::V \::: }
\exp_args:NcVV 3379 \cs_new:Npn \exp_args:Ncoo { \::c \::o \::o \::: }
\exp_args:Nnnc 3380 \cs_new:Npn \exp_args:NcVV { \::c \::V \::V \::: }
\exp_args:Nnno 3381 \cs_new:Npn \exp_args:Nnnc { \::n \::n \::c \::: }
\exp_args:Nnnf 3382 \cs_new:Npn \exp_args:Nnno { \::n \::n \::o \::: }
\exp_args:Nnff 3383 \cs_new:Npn \exp_args:Nnnf { \::n \::n \::f \::: }
\exp_args:Nooo 3384 \cs_new:Npn \exp_args:Nnff { \::n \::f \::f \::: }
\exp_args:Noof 3385 \cs_new:Npn \exp_args:Nooo { \::o \::o \::o \::: }
\exp_args:Nffo 3386 \cs_new:Npn \exp_args:Noof { \::o \::o \::f \::: }
\exp_args:NNNx 3387 \cs_new:Npn \exp_args:Nffo { \::f \::f \::o \::: }
\exp_args:NNnx 3388 \cs_new_protected:Npn \exp_args:NNNx { \::N \::N \::x \::: }
\exp_args:NNox 3389 \cs_new_protected:Npn \exp_args:NNnx { \::N \::n \::x \::: }
\exp_args:Nccx 3390 \cs_new_protected:Npn \exp_args:NNox { \::N \::o \::x \::: }
\exp_args:Ncnx 3391 \cs_new_protected:Npn \exp_args:Nnnx { \::n \::n \::x \::: }
\exp_args:Nnnx 3392 \cs_new_protected:Npn \exp_args:Nnox { \::n \::o \::x \::: }
\exp_args:Nnox 3393 \cs_new_protected:Npn \exp_args:Nccx { \::c \::c \::x \::: }
\exp_args:Noox 3394 \cs_new_protected:Npn \exp_args:Ncnx { \::c \::n \::x \::: }
\exp_args:Noox 3395 \cs_new_protected:Npn \exp_args:Noox { \::o \::o \::x \::: }

```

(End definition for `\exp_args:NNNv` and others. These functions are documented on page 31.)

6.4 Last-unbraced versions

`__exp_arg_last_unbraced:nn` There are a few places where the last argument needs to be available unbraced. First some helper macros.

```

\::o_unbraced
\::V_unbraced
\::v_unbraced
\::e_unbraced
\::f_unbraced
\::x_unbraced
3396 \cs_new:Npn \__exp_arg_last_unbraced:nn #1#2 { #2#1 }
3397 \cs_new:Npn \::o_unbraced \::: #1#2
3398 { \exp_after:wN \__exp_arg_last_unbraced:nn \exp_after:wN {#2} {#1} }
3399 \cs_new:Npn \::V_unbraced \::: #1#2
3400 {
3401   \exp_after:wN \__exp_arg_last_unbraced:nn
3402   \exp_after:wN { \exp:w \__exp_eval_register:N #2 } {#1}
3403 }
3404 \cs_new:Npn \::v_unbraced \::: #1#2
3405 {
3406   \exp_after:wN \__exp_arg_last_unbraced:nn

```

```

3407     \exp_after:wN { \exp:w \__exp_eval_register:c {#2} } {#1}
3408   }
3409 \cs_if_exist:NTF \tex_expanded:D
3410 {
3411   \cs_new:Npn \::e_unbraced \::: #1#2
3412   { \tex_expanded:D { \exp_not:n {#1} #2 } }
3413 }
3414 {
3415   \cs_new:Npn \::e_unbraced \::: #1#2
3416   { \exp:w \__exp_e:nn {#2} {#1} }
3417 }
3418 \cs_new:Npn \::f_unbraced \::: #1#2
3419 {
3420   \exp_after:wN \__exp_arg_last_unbraced:nn
3421   \exp_after:wN { \exp:w \exp_end_continue_f:w #2 } {#1}
3422 }
3423 \cs_new_protected:Npn \::x_unbraced \::: #1#2
3424 {
3425   \cs_set_nopar:Npx \l__exp_internal_tl { \exp_not:n {#1} #2 }
3426   \l__exp_internal_tl
3427 }

```

(End definition for `__exp_arg_last_unbraced:nn` and others. These functions are documented on page 36.)

<pre> \exp_last_unbraced:No \exp_last_unbraced:Nv \exp_last_unbraced:Nv \exp_last_unbraced:Nf \exp_last_unbraced:NNo \exp_last_unbraced:NNv \exp_last_unbraced:NNf \exp_last_unbraced:Nco \exp_last_unbraced:NcV \exp_last_unbraced:NNNo \exp_last_unbraced:NNNV \exp_last_unbraced:NNNf \exp_last_unbraced:Nno \exp_last_unbraced:Noo \exp_last_unbraced:Nfo \exp_last_unbraced:NnNo \exp_last_unbraced:NNNNo \exp_last_unbraced:NNNNf \exp_last_unbraced:Nx </pre>	<p>Now the business end: most of these are hand-tuned for speed, but the general system is in place.</p> <pre> 3428 \cs_new:Npn \exp_last_unbraced:No #1#2 { \exp_after:wN #1 #2 } 3429 \cs_new:Npn \exp_last_unbraced:Nv #1#2 3430 { \exp_after:wN #1 \exp:w __exp_eval_register:N #2 } 3431 \cs_new:Npn \exp_last_unbraced:Nv #1#2 3432 { \exp_after:wN #1 \exp:w __exp_eval_register:c {#2} } 3433 \cs_if_exist:NTF \tex_expanded:D 3434 { 3435 \cs_new:Npn \exp_last_unbraced:Ne #1#2 3436 { \exp_after:wN #1 \tex_expanded:D {#2} } 3437 } 3438 { \cs_new:Npn \exp_last_unbraced:Ne { \::e_unbraced \::: } } 3439 \cs_new:Npn \exp_last_unbraced:Nf #1#2 3440 { \exp_after:wN #1 \exp:w \exp_end_continue_f:w #2 } 3441 \cs_new:Npn \exp_last_unbraced:NNo #1#2#3 3442 { \exp_after:wN #1 \exp_after:wN #2 #3 } 3443 \cs_new:Npn \exp_last_unbraced:NNv #1#2#3 3444 { 3445 \exp_after:wN #1 3446 \exp_after:wN #2 3447 \exp:w __exp_eval_register:N #3 3448 } 3449 \cs_new:Npn \exp_last_unbraced:NNf #1#2#3 3450 { 3451 \exp_after:wN #1 3452 \exp_after:wN #2 3453 \exp:w \exp_end_continue_f:w #3 3454 } </pre>
--	--

```

3455 \cs_new:Npn \exp_last_unbraced:Nco #1#2#3
3456 { \exp_after:wN #1 \cs:w #2 \exp_after:wN \cs_end: #3 }
3457 \cs_new:Npn \exp_last_unbraced:NcV #1#2#3
3458 {
3459   \exp_after:wN #1
3460   \cs:w #2 \exp_after:wN \cs_end:
3461   \exp:w \__exp_eval_register:N #3
3462 }
3463 \cs_new:Npn \exp_last_unbraced:NNNo #1#2#3#4
3464 { \exp_after:wN #1 \exp_after:wN #2 \exp_after:wN #3 #4 }
3465 \cs_new:Npn \exp_last_unbraced:NNNV #1#2#3#4
3466 {
3467   \exp_after:wN #1
3468   \exp_after:wN #2
3469   \exp_after:wN #3
3470   \exp:w \__exp_eval_register:N #4
3471 }
3472 \cs_new:Npn \exp_last_unbraced:NNNf #1#2#3#4
3473 {
3474   \exp_after:wN #1
3475   \exp_after:wN #2
3476   \exp_after:wN #3
3477   \exp:w \exp_end_continue_f:w #4
3478 }
3479 \cs_new:Npn \exp_last_unbraced:Nno { \::n \::o_unbraced \::: }
3480 \cs_new:Npn \exp_last_unbraced:Noo { \::o \::o_unbraced \::: }
3481 \cs_new:Npn \exp_last_unbraced:Nfo { \::f \::o_unbraced \::: }
3482 \cs_new:Npn \exp_last_unbraced:NnNo { \::n \::N \::o_unbraced \::: }
3483 \cs_new:Npn \exp_last_unbraced:NNNNo #1#2#3#4#5
3484 { \exp_after:wN #1 \exp_after:wN #2 \exp_after:wN #3 \exp_after:wN #4 #5 }
3485 \cs_new:Npn \exp_last_unbraced:NNNNf #1#2#3#4#5
3486 {
3487   \exp_after:wN #1
3488   \exp_after:wN #2
3489   \exp_after:wN #3
3490   \exp_after:wN #4
3491   \exp:w \exp_end_continue_f:w #5
3492 }
3493 \cs_new_protected:Npn \exp_last_unbraced:Nx { \::x_unbraced \::: }

```

(End definition for `\exp_last_unbraced:No` and others. These functions are documented on page 32.)

`\exp_last_two_unbraced:Noo` If #2 is a single token then this can be implemented as

```

\__exp_last_two_unbraced:noN
\cs_new:Npn \exp_last_two_unbraced:Noo #1 #2 #3
{ \exp_after:wN \exp_after:wN \exp_after:wN #1 \exp_after:wN #2 #3 }

```

However, for robustness this is not suitable. Instead, a bit of a shuffle is used to ensure that #2 can be multiple tokens.

```

3494 \cs_new:Npn \exp_last_two_unbraced:Noo #1#2#3
3495 { \exp_after:wN \__exp_last_two_unbraced:noN \exp_after:wN {#3} {#2} #1 }
3496 \cs_new:Npn \__exp_last_two_unbraced:noN #1#2#3
3497 { \exp_after:wN #3 #2 #1 }

```

(End definition for `\exp_last_two_unbraced:Noo` and `__exp_last_two_unbraced:noN`. This function is documented on page 32.)

6.5 Preventing expansion

`__kernel_exp_not:w` At the kernel level, we need the primitive behaviour to allow expansion *before* the brace group.

```
3498 \cs_new_eq:NN \__kernel_exp_not:w \tex_unexpanded:D
```

(End definition for `__kernel_exp_not:w`.)

`\exp_not:c` All these except `\exp_not:c` call the kernel-internal `__kernel_exp_not:w` namely
`\exp_not:o` `\tex_unexpanded:D`.

```
3499 \cs_new:Npn \exp_not:c #1 { \exp_after:wN \exp_not:N \cs:w #1 \cs_end: }
3500 \cs_new:Npn \exp_not:o #1 { \__kernel_exp_not:w \exp_after:wN {#1} }
3501 \cs_if_exist:NTF \tex_expanded:D
3502 {
3503   \cs_new:Npn \exp_not:e #1
3504     { \__kernel_exp_not:w \tex_expanded:D { {#1} } }
3505 }
3506 {
3507   \cs_new:Npn \exp_not:e
3508     { \__kernel_exp_not:w \exp_args:Ne \prg_do_nothing: }
3509 }
3510 \cs_new:Npn \exp_not:f #1
3511 { \__kernel_exp_not:w \exp_after:wN { \exp:w \exp_end_continue_f:w #1 } }
3512 \cs_new:Npn \exp_not:V #1
3513 {
3514   \__kernel_exp_not:w \exp_after:wN
3515   { \exp:w \__exp_eval_register:N #1 }
3516 }
3517 \cs_new:Npn \exp_not:v #1
3518 {
3519   \__kernel_exp_not:w \exp_after:wN
3520   { \exp:w \__exp_eval_register:c {#1} }
3521 }
```

(End definition for `\exp_not:c` and others. These functions are documented on page 33.)

6.6 Controlled expansion

`\exp:w` To trigger a sequence of “arbitrarily” many expansions we need a method to invoke T_EX’s
`\exp_end:` expansion mechanism in such a way that (a) we are able to stop it in a controlled manner
`\exp_end_continue_f:w` and (b) the result of what triggered the expansion in the first place is null, i.e., that we
`\exp_end_continue_f:nw` do not get any unwanted side effects. There aren’t that many possibilities in T_EX; in fact
the one explained below might well be the only one (as normally the result of expansion
is not null).

The trick here is to make use of the fact that `\tex_romannumeral:D` expands the tokens following it when looking for a number and that its expansion is null if that number turns out to be zero or negative. So we use that to start the expansion sequence: `\exp:w` is set equal to `\tex_romannumeral:D` in `l3basics`. To stop the expansion sequence in a controlled way all we need to provide is a constant integer zero as part of expanded tokens. As this is an integer constant it immediately stops `\tex_romannumeral:D`’s search for a number. Again, the definition of `\exp_end:` as the integer constant zero is in `l3basics`. (Note that according to our specification all tokens we expand initiated by `\exp:w` are supposed to be expandable (as well as their replacement text in the expansion) so we will

not encounter a “number” that actually result in a roman numeral being generated. Or if we do then the programmer made a mistake.)

If on the other hand we want to stop the initial expansion sequence but continue with an f-type expansion we provide the alphabetic constant ‘`^^@`’ that also represents 0 but this time T_EX’s syntax for a *⟨number⟩* continues searching for an optional space (and it continues expansion doing that) — see T_EXbook page 269 for details.

```

3522 \group_begin:
3523   \tex_catcode:D ‘^^@ = 13
3524   \cs_new_protected:Npn \exp_end_continue_f:w { ‘^^@ }

```

If the above definition ever appears outside its proper context the active character `^^@` will be executed so we turn this into an error. The test for existence covers the (unlikely) case that some other code has already defined `^^@`: this is true for example for `xmltex.tex`.

```

3525   \if_cs_exist:N ^^@
3526   \else:
3527     \cs_new:Npn ^^@
3528       { \__kernel_msg_expandable_error:nn { kernel } { bad-exp-end-f } }
3529   \fi:

```

The same but grabbing an argument to remove spaces and braces.

```

3530   \cs_new:Npn \exp_end_continue_f:nw #1 { ‘^^@ #1 }
3531 \group_end:

```

(End definition for `\exp:w` and others. These functions are documented on page 35.)

6.7 Emulating e-type expansion

When the `\expanded` primitive is available it is used to implement e-type expansion; otherwise we emulate it.

```

3532 \cs_if_exist:NF \tex_expanded:D
3533 {

```

`__exp_e:nn` Repeatedly expand tokens, keeping track of fully-expanded tokens in the second argument to `__exp_e:nn`; this function eventually calls `__exp_e_end:nn` to leave `\exp_end:` in the input stream, followed by the result of the expansion. There are many special cases: spaces, brace groups, `\noexpand`, `\unexpanded`, `\the`, `\primitive`. While we use brace tricks `\if_false: { \fi:`, the expansion of this function is always triggered by `\exp:w` so brace balance is eventually restored after that is hit with a single step of expansion. Otherwise we could not nest e-type expansions within each other.

```

3534   \cs_new:Npn \__exp_e:nn #1
3535   {
3536     \if_false: { \fi:
3537       \tl_if_head_is_N_type:nTF {#1}
3538       { \__exp_e:N }
3539       {
3540         \tl_if_head_is_group:nTF {#1}
3541         { \__exp_e_group:n }
3542         {
3543           \tl_if_empty:nTF {#1}
3544           { \exp_after:wN \__exp_e_end:nn }
3545           { \exp_after:wN \__exp_e_space:nn }
3546           \exp_after:wN { \if_false: } \fi:
3547         }
3548       }
3549     }

```

```

3548         }
3549         #1
3550     }
3551 }
3552 \cs_new:Npn \__exp_e_end:nn #1#2 { \exp_end: #2 }

```

(End definition for __exp_e:nn and __exp_e_end:nn.)

__exp_e_space:nn For an explicit space character, remove it by f-expansion and put it in the (future) output.

```

3553 \cs_new:Npn \__exp_e_space:nn #1#2
3554 { \exp_args:Nf \__exp_e:nn {#1} { #2 ~ } }

```

(End definition for __exp_e_space:nn.)

__exp_e_group:n For a group, expand its contents, wrap it in two pairs of braces, and call __exp_e_put:nn. This function places the first item (the double-brace wrapped result) into the output. Importantly, \tl_head:n works even if the input contains quarks.

```

3555 \cs_new:Npn \__exp_e_group:n #1
3556 {
3557     \exp_after:wN \__exp_e_put:nn
3558     \exp_after:wN { \exp_after:wN { \exp_after:wN {
3559         \exp:w \if_false: } \fi: \__exp_e:nn {#1} { } } }
3560 }
3561 \cs_new:Npn \__exp_e_put:nn #1
3562 {
3563     \exp_args:NNo \exp_args:No \__exp_e_put:nnn
3564     { \tl_head:n {#1} } {#1}
3565 }
3566 \cs_new:Npn \__exp_e_put:nnn #1#2#3
3567 { \exp_args:No \__exp_e:nn { \use_none:n #2 } { #3 #1 } }

```

(End definition for __exp_e_group:n, __exp_e_put:nn, and __exp_e_put:nnn.)

__exp_e:N For an N-type token, call __exp_e:Nnn with arguments the *⟨first token⟩*, the remaining tokens to expand and what's already been expanded. If the *⟨first token⟩* is non-expandable, including \protected (\long or not) macros, it is put in the result by __exp_e_protected:Nnn. The four special primitives \unexpanded, \noexpand, \the, \primitive are detected; otherwise the token is expanded by __exp_e_expandable:Nnn.

```

3568 \cs_new:Npn \__exp_e:N #1
3569 {
3570     \exp_after:wN \__exp_e:Nnn
3571     \exp_after:wN #1
3572     \exp_after:wN { \if_false: } \fi:
3573 }
3574 \cs_new:Npn \__exp_e:Nnn #1
3575 {
3576     \if_case:w
3577         \exp_after:wN \if_meaning:w \exp_not:N #1 #1 1 ~ \fi:
3578         \token_if_protected_macro:NT #1 { 1 ~ }
3579         \token_if_protected_long_macro:NT #1 { 1 ~ }
3580         \if_meaning:w \exp_not:n #1 2 ~ \fi:
3581         \if_meaning:w \exp_not:N #1 3 ~ \fi:
3582         \if_meaning:w \tex_the:D #1 4 ~ \fi:

```

```

3583     \if_meaning:w \tex_primitive:D #1 5 ~ \fi:
3584     0 ~
3585     \exp_after:wN \__exp_e_expandable:Nnn
3586     \or: \exp_after:wN \__exp_e_protected:Nnn
3587     \or: \exp_after:wN \__exp_e_unexpanded:Nnn
3588     \or: \exp_after:wN \__exp_e_noexpand:Nnn
3589     \or: \exp_after:wN \__exp_e_the:Nnn
3590     \or: \exp_after:wN \__exp_e_primitive:Nnn
3591     \fi:
3592     #1
3593   }
3594   \cs_new:Npn \__exp_e_protected:Nnn #1#2#3
3595     { \__exp_e:nn {#2} { #3 #1 } }
3596   \cs_new:Npn \__exp_e_expandable:Nnn #1#2
3597     { \exp_args:No \__exp_e:nn { #1 #2 } }

```

(End definition for __exp_e:N and others.)

```

\__exp_e_primitive:Nnn
\__exp_e_primitive_aux:NNw
\__exp_e_primitive_aux:NNnn
  \__exp_e_primitive_other:NNnn
  \__exp_e_primitive_other_aux:nNNnn

```

We don't try hard to make sensible error recovery since the error recovery of `\tex_primitive:D` when followed by something else than a primitive depends on the engine. The only valid case is when what follows is N-type. Then distinguish special primitives `\unexpanded`, `\noexpand`, `\the`, `\primitive` from other primitives. In the “other” case, the only reasonable way to check if the primitive that follows `\tex_primitive:D` is expandable is to expand and compare the before-expansion and after-expansion results. If they coincide then probably the primitive is non-expandable and should be put in the output together with `\tex_primitive:D` (one can cook up contrived counter-examples where the true `\expanded` would have an infinite loop), and otherwise one should continue expanding.

```

3598   \cs_new:Npn \__exp_e_primitive:Nnn #1#2
3599     {
3600       \if_false: { \fi:
3601         \tl_if_head_is_N_type:nTF {#2}
3602           { \__exp_e_primitive_aux:NNw #1 }
3603           {
3604             \__kernel_msg_expandable_error:nnn { kernel } { e-type }
3605             { Missing~primitive~name }
3606             \__exp_e_primitive_aux:NNw #1 \c_empty_tl
3607           }
3608         #2
3609       }
3610     }
3611   \cs_new:Npn \__exp_e_primitive_aux:NNw #1#2
3612     {
3613       \exp_after:wN \__exp_e_primitive_aux:NNnn
3614       \exp_after:wN #1
3615       \exp_after:wN #2
3616       \exp_after:wN { \if_false: } \fi:
3617     }
3618   \cs_new:Npn \__exp_e_primitive_aux:NNnn #1#2
3619     {
3620       \exp_args:Nf \str_case_e:nnTF { \cs_to_str:N #2 }
3621       {
3622         { unexpanded } { \__exp_e_unexpanded:Nnn \exp_not:n }
3623         { noexpand } { \__exp_e_noexpand:Nnn \exp_not:N }

```

```

3624         { the } { \__exp_e_the:Nnn \tex_the:D }
3625         {
3626             \sys_if_engine_xetex:T { pdf }
3627             \sys_if_engine luatex:T { pdf }
3628             primitive
3629         } { \__exp_e_primitive:Nnn #1 }
3630     }
3631     { \__exp_e_primitive_other:NNnn #1 #2 }
3632 }
3633 \cs_new:Npn \__exp_e_primitive_other:NNnn #1#2#3
3634 {
3635     \exp_args:No \__exp_e_primitive_other_aux:nNNnn
3636     { #1 #2 #3 }
3637     #1 #2 {#3}
3638 }
3639 \cs_new:Npn \__exp_e_primitive_other_aux:nNNnn #1#2#3#4#5
3640 {
3641     \str_if_eq:nnTF {#1} { #2 #3 #4 }
3642     { \__exp_e:nn {#4} { #5 #2 #3 } }
3643     { \__exp_e:nn {#1} {#5} }
3644 }

```

(End definition for __exp_e_primitive:Nnn and others.)

`__exp_e_noexpand:Nnn` The `\noexpand` primitive has no effect when followed by a token that is not N-type; otherwise `__exp_e_put:nn` can grab the next token and put it in the result unchanged.

```

3645     \cs_new:Npn \__exp_e_noexpand:Nnn #1#2
3646     {
3647         \tl_if_head_is_N_type:nTF {#2}
3648         { \__exp_e_put:nn } { \__exp_e:nn } {#2}
3649     }

```

(End definition for __exp_e_noexpand:Nnn.)

`__exp_e_unexpanded:Nnn` The `\unexpanded` primitive expands and ignores any space, `\scan_stop:`, or token affected by `\exp_not:N`, then expects a brace group. Since we only support brace-balanced token lists it is impossible to support the case where the argument of `\unexpanded` starts with an implicit brace. Even though we want to expand and ignore spaces we cannot blindly f-expand because tokens affected by `\exp_not:N` should be discarded without being expanded further.

As usual distinguish four cases: brace group (the normal case, where we just put the item in the result), space (just f-expand to remove the space), empty (an error), or N-type *<token>*. In the last case call `__exp_e_unexpanded:nN` triggered by an f-expansion. Having a non-expandable *<token>* after `\unexpanded` is an error (we recover by passing `{}` to `\unexpanded`; this is different from T_EX because the error recovery of `\unexpanded` changes the balance of braces), unless that *<token>* is `\scan_stop:` or a space (recall that we don't implement the case of an implicit begin-group token). An expandable *<token>* is instead expanded, unless it is `\noexpand`. The latter primitive can be followed by an expandable N-type token (removed), by a non-expandable one (kept and later causing an error), by a space (removed by f-expansion), or by a brace group or nothing (later causing an error).

```

3650     \cs_new:Npn \__exp_e_unexpanded:Nnn #1 { \__exp_e_unexpanded:nn }
3651     \cs_new:Npn \__exp_e_unexpanded:nn #1

```

```

3652 {
3653   \tl_if_head_is_N_type:nTF {#1}
3654   {
3655     \exp_args:Nf \__exp_e_unexpanded:nn
3656     { \__exp_e_unexpanded:nN {#1} #1 }
3657   }
3658   {
3659     \tl_if_head_is_group:nTF {#1}
3660     { \__exp_e_put:nn }
3661     {
3662       \tl_if_empty:nTF {#1}
3663       {
3664         \__kernel_msg_expandable_error:nnn
3665         { kernel } { e-type }
3666         { \unexpanded missing~brace }
3667         \__exp_e_end:nn
3668       }
3669       { \exp_args:Nf \__exp_e_unexpanded:nn }
3670     }
3671     {#1}
3672   }
3673 }
3674 \cs_new:Npn \__exp_e_unexpanded:nN #1#2
3675 {
3676   \exp_after:wN \if_meaning:w \exp_not:N #2 #2
3677   \exp_after:wN \use_i:nn
3678   \else:
3679     \exp_after:wN \use_ii:nn
3680   \fi:
3681   {
3682     \token_if_eq_catcode:NNTF #2 \c_space_token
3683     { \exp_stop_f: }
3684     {
3685       \token_if_eq_meaning:NNTF #2 \scan_stop:
3686       { \exp_stop_f: }
3687       {
3688         \__kernel_msg_expandable_error:nnn
3689         { kernel } { e-type }
3690         { \unexpanded missing~brace }
3691         { }
3692       }
3693     }
3694   }
3695   {
3696     \token_if_eq_meaning:NNTF #2 \exp_not:N
3697     {
3698       \exp_args:No \tl_if_head_is_N_type:nT { \use_none:n #1 }
3699       { \__exp_e_unexpanded:N }
3700     }
3701     { \exp_after:wN \exp_stop_f: #2 }
3702   }
3703 }
3704 \cs_new:Npn \__exp_e_unexpanded:N #1
3705 {

```

```

3706     \exp_after:wN \if_meaning:w \exp_not:N #1 #1 \else:
3707     \exp_after:wN \use_i:nn
3708     \fi:
3709     \exp_stop_f: #1
3710 }

```

(End definition for `_exp_e_unexpanded:Nnn` and others.)

```

\_exp_e_the:Nnn
\_exp_e_the:N
\_exp_e_the_toks_reg:N

```

Finally implement `\the`. Followed by anything other than an N-type $\langle token \rangle$ this causes an error (we just let \TeX make one), otherwise we test the $\langle token \rangle$. If the $\langle token \rangle$ is expandable, expand it. Otherwise it could be any kind of register, or things like `\numexpr`, so there is no way to deal with all cases. Thankfully, only `\toks` data needs to be protected from expansion since everything else gives a string of characters. If the $\langle token \rangle$ is `\toks` we find a number and unpack using the `the_toks` functions. If it is a token register we unpack it in a brace group and call `_exp_e_put:nn` to move it to the result. Otherwise we unpack and continue expanding (useless but safe) since it is basically impossible to have a handle on where the result of `\the` ends.

```

3711 \cs_new:Npn \_exp_e_the:Nnn #1#2
3712 {
3713   \tl_if_head_is_N_type:nTF {#2}
3714   { \if_false: { \fi: \_exp_e_the:N #2 } }
3715   { \exp_args:No \_exp_e:nn { \tex_the:D #2 } }
3716 }
3717 \cs_new:Npn \_exp_e_the:N #1
3718 {
3719   \exp_after:wN \if_meaning:w \exp_not:N #1 #1
3720   \exp_after:wN \use_i:nn
3721   \else:
3722   \exp_after:wN \use_ii:nn
3723   \fi:
3724   {
3725     \if_meaning:w \tex_toks:D #1
3726     \exp_after:wN \_exp_e_the_toks:wnn \int_value:w
3727     \exp_after:wN \_exp_e_the_toks:n
3728     \exp_after:wN { \int_value:w \if_false: } \fi:
3729     \else:
3730     \_exp_e_if_toks_register:NTF #1
3731     { \exp_after:wN \_exp_e_the_toks_reg:N }
3732     {
3733       \exp_after:wN \_exp_e:nn \exp_after:wN {
3734         \tex_the:D \if_false: } \fi:
3735     }
3736     \exp_after:wN #1
3737   \fi:
3738 }
3739 {
3740   \exp_after:wN \_exp_e_the:Nnn \exp_after:wN ?
3741   \exp_after:wN { \exp:w \if_false: } \fi:
3742   \exp_after:wN \exp_end: #1
3743 }
3744 }
3745 \cs_new:Npn \_exp_e_the_toks_reg:N #1
3746 {
3747   \exp_after:wN \_exp_e_put:nn \exp_after:wN {

```

```

3748         \exp_after:wN {
3749             \tex_the:D \if_false: } \fi: #1 }
3750     }

```

(End definition for `_exp_e_the:Nnn`, `_exp_e_the:N`, and `_exp_e_the_toks_reg:N`.)

```

\__exp_e_the_toks:wnn The calling function has applied \int_value:w so we collect digits with \__exp_e_the_
\__exp_e_the_toks:n toks:n (which gets the token list as an argument) and \__exp_e_the_toks:N (which
\__exp_e_the_toks:N gets the first token in case it is N-type). The digits are themselves collected into an
\int_value:w argument to \__exp_e_the_toks:wnn. Then that function unpacks the
\toks<number> into the result. We include ? because \__exp_e_put:nnn removes one
item from its second argument. Note that our approach is rather crude: in cases like
\the\toks12~34 the first \int_value:w removes the space and we will incorrectly unpack
the \the\toks1234.

```

```

3751 \cs_new:Npn \__exp_e_the_toks:wnn #1; #2
3752 {
3753   \exp_args:No \__exp_e_put:nnn
3754   { \tex_the:D \tex_toks:D #1 } { ? #2 }
3755 }
3756 \cs_new:Npn \__exp_e_the_toks:n #1
3757 {
3758   \tl_if_head_is_N_type:nTF {#1}
3759   { \exp_after:wN \__exp_e_the_toks:N \if_false: { \fi: #1 } }
3760   { ; {#1} }
3761 }
3762 \cs_new:Npn \__exp_e_the_toks:N #1
3763 {
3764   \if_int_compare:w 10 < 9 \token_to_str:N #1 \exp_stop_f:
3765   \exp_after:wN \use_i:nn
3766   \else:
3767   \exp_after:wN \use_ii:nn
3768   \fi:
3769   {
3770     #1
3771     \exp_after:wN \__exp_e_the_toks:n
3772     \exp_after:wN { \if_false: } \fi:
3773   }
3774   {
3775     \exp_after:wN ;
3776     \exp_after:wN { \if_false: } \fi: #1
3777   }
3778 }

```

(End definition for _exp e the toks:wnn, _exp e the toks:n, and _exp e the toks:N.)

<code>_exp_e_if_toks_register:NTF</code> <code>_exp_e_the_XeTeXinterchartoks:</code> <code>_exp_e_the_errhelp:</code> <code>_exp_e_the_everycr:</code> <code>_exp_e_the_everystyle:</code>	We need to detect both <code>\toks</code> registers like <code>\toks@</code> in L ^A T _E X 2 _ε and parameters such as <code>\everypar</code> , as the result of unpacking the register should not expand further. Registers are found by <code>\token_if_toks_register:NTF</code> by inspecting the meaning. The list of parameters is finite so we just use a <code>\cs_if_exist:cTF</code> test to look up in a table. We abuse <code>\cs</code> to <code>str:N</code> 's ability to remove a leading escape character whatever it is.
---	--

<pre> __exp_e_the_everyeof: __exp_e_the_everyhbox: __exp_e_the_everyjob: __exp_e_the_everymath: __exp_e_the_everypar: __exp_e_the_everyvbox: __exp_e_the_output: __exp_e_the_pdfpageattr: __exp_e_the_pdfpageresources: __exp_e_the_pdfpagesattr: __exp_e_the_pdfpkmode: </pre>	<pre> 3779 3780 3781 3782 </pre>	<pre> \prg_new_conditional:Npnn __exp_e_if_toks_register:N #1 { TF } { \token_if_toks_register:NTF #1 { \prg_return_true: } { </pre>	<pre> 368 </pre>
--	----------------------------------	---	------------------


```

3783 \cs_if_exist:cTF
3784 {
3785   __exp_e_the_
3786   \exp_after:wN \cs_to_str:N
3787   \token_to_meaning:N #1
3788   :
3789   } { \prg_return_true: } { \prg_return_false: }
3790 }
3791 }
3792 \cs_new_eq:NN \__exp_e_the_XeTeXinterchartoks: ?
3793 \cs_new_eq:NN \__exp_e_the_errhelp: ?
3794 \cs_new_eq:NN \__exp_e_the_everycr: ?
3795 \cs_new_eq:NN \__exp_e_the_everydisplay: ?
3796 \cs_new_eq:NN \__exp_e_the_everyeof: ?
3797 \cs_new_eq:NN \__exp_e_the_everyhbox: ?
3798 \cs_new_eq:NN \__exp_e_the_everyjob: ?
3799 \cs_new_eq:NN \__exp_e_the_everymath: ?
3800 \cs_new_eq:NN \__exp_e_the_everypar: ?
3801 \cs_new_eq:NN \__exp_e_the_everyvbox: ?
3802 \cs_new_eq:NN \__exp_e_the_output: ?
3803 \cs_new_eq:NN \__exp_e_the_pdffpageattr: ?
3804 \cs_new_eq:NN \__exp_e_the_pdfpageresources: ?
3805 \cs_new_eq:NN \__exp_e_the_pdfpagesattr: ?
3806 \cs_new_eq:NN \__exp_e_the_pdfpkmode: ?

```

(End definition for __exp_e_if_toks_register:NTF and others.)

We are done emulating e-type argument expansion when \expanded is unavailable.

```

3807 }

```

6.8 Defining function variants

```

3808 <@@=cs>

```

\cs_generate_variant:Nn #1 : Base form of a function; *e.g.*, \tl_set:Nn

\cs_generate_variant:cn #2 : One or more variant argument specifiers; *e.g.*, {Nx,c,cx}

After making sure that the base form exists, test whether it is protected or not and define __cs_tmp:w as either \cs_new:Npx or \cs_new_protected:Npx, which is then used to define all the variants (except those involving x-expansion, always protected). Split up the original base function only once, to grab its name and signature. Then we wish to iterate through the comma list of variant argument specifiers, which we first convert to a string: the reason is explained later.

```

3809 \__kernel_patch:nnNNpn { \__kernel_chk_cs_exist:N #1 } { }
3810 \cs_new_protected:Npn \cs_generate_variant:Nn #1#2
3811 {
3812   \__cs_generate_variant:N #1
3813   \use:x
3814   {
3815     \__cs_generate_variant:nnNN
3816     \cs_split_function:N #1
3817     \exp_not:N #1
3818     \tl_to_str:n {#2} ,
3819     \exp_not:N \scan_stop: ,
3820     \exp_not:N \q_recursion_stop
3821   }

```

```

3822 }
3823 \cs_new_protected:Npn \cs_generate_variant:cn
3824 { \exp_args:Nc \cs_generate_variant:Nn }

```

(End definition for `\cs_generate_variant:Nn`. This function is documented on page 26.)

```

\__cs_generate_variant:N
\__cs_generate_variant:ww
\__cs_generate_variant:wwNw

```

The goal here is to pick up protected parent functions. There are four cases: the parent function can be a primitive or a macro, and can be expandable or not. For non-expandable primitives, all variants should be protected; skipping the `\else:` branch is safe because non-expandable primitives cannot be \TeX conditionals.

The other case where variants should be protected is when the parent function is a protected macro: then `protected` appears in the meaning before the first occurrence of `macro`. The `ww` auxiliary removes everything in the meaning string after the first `ma`. We use `ma` rather than the full `macro` because the meaning of the `\firstmark` primitive (and four others) can contain an arbitrary string after a leading `firstmark:`. Then, look for `pr` in the part we extracted: no need to look for anything longer: the only strings we can have are an empty string, `\long`, `\protected`, `\protected\long`, `\first`, `\top`, `\bot`, `\splittop`, or `\splitbot`, with `\` replaced by the appropriate escape character. If `pr` appears in the part before `ma`, the first `\q_mark` is taken as an argument of the `wwNw` auxiliary, and `#3` is `\cs_new_protected:Npx`, otherwise it is `\cs_new:Npx`.

```

3825 \cs_new_protected:Npx \__cs_generate_variant:N #1
3826 {
3827   \exp_not:N \exp_after:wN \exp_not:N \if_meaning:w
3828   \exp_not:N \exp_not:N #1 #1
3829   \cs_set_eq:NN \exp_not:N \__cs_tmp:w \cs_new_protected:Npx
3830   \exp_not:N \else:
3831   \exp_not:N \exp_after:wN \exp_not:N \__cs_generate_variant:ww
3832   \exp_not:N \token_to_meaning:N #1 \tl_to_str:n { ma }
3833   \exp_not:N \q_mark
3834   \exp_not:N \q_mark \cs_new_protected:Npx
3835   \tl_to_str:n { pr }
3836   \exp_not:N \q_mark \cs_new:Npx
3837   \exp_not:N \q_stop
3838   \exp_not:N \fi:
3839 }
3840 \exp_last_unbraced:NNNNo
3841 \cs_new_protected:Npn \__cs_generate_variant:ww
3842 #1 { \tl_to_str:n { ma } } #2 \q_mark
3843 { \__cs_generate_variant:wwNw #1 }
3844 \exp_last_unbraced:NNNNo
3845 \cs_new_protected:Npn \__cs_generate_variant:wwNw
3846 #1 { \tl_to_str:n { pr } } #2 \q_mark #3 #4 \q_stop
3847 { \cs_set_eq:NN \__cs_tmp:w #3 }

```

(End definition for `__cs_generate_variant:N`, `__cs_generate_variant:ww`, and `__cs_generate_variant:wwNw`.)

```

\__cs_generate_variant:nnNN

```

#1 : Base name.
#2 : Base signature.
#3 : Boolean.
#4 : Base function.

If the boolean is `\c_false_bool`, the base function has no colon and we abort with an error; otherwise, set off a loop through the desired variant forms. The original function is retained as `#4` for efficiency.

```

3848 \cs_new_protected:Npn \__cs_generate_variant:nnNN #1#2#3#4
3849 {
3850   \if_meaning:w \c_false_bool #3
3851     \__kernel_msg_error:nxx { kernel } { missing-colon }
3852     { \token_to_str:c {#1} }
3853     \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
3854   \fi:
3855   \__cs_generate_variant:Nnnw #4 {#1}{#2}
3856 }

```

(End definition for `__cs_generate_variant:nnNN`.)

`__cs_generate_variant:Nnnw` `#1` : Base function.
`#2` : Base name.
`#3` : Base signature.
`#4` : Beginning of variant signature.

First check whether to terminate the loop over variant forms. Then, for each variant form, construct a new function name using the original base name, the variant signature consisting of l letters and the last $k - l$ letters of the base signature (of length k). For example, for a base function `\prop_put:Nnn` which needs a `cV` variant form, we want the new signature to be `cVn`.

There are further subtleties:

- In `\cs_generate_variant:Nn \foo:nnTF {xxTF}`, we must define `\foo:xxTF` using `\exp_args:Nxx`, rather than a hypothetical `\exp_args:NxxTF`. Thus, we wish to trim a common trailing part from the base signature and the variant signature.
- In `\cs_generate_variant:Nn \foo:on {ox}`, the function `\foo:ox` must be defined using `\exp_args:Nnx`, not `\exp_args:Nox`, to avoid double `o` expansion.
- Lastly, `\cs_generate_variant:Nn \foo:on {xn}` must trigger an error, because we do not have a means to replace `o`-expansion by `x`-expansion. More generally, we can only convert `N` to `c`, or convert `n` to `V`, `v`, `o`, `f`, `x`.

All this boils down to a few rules. Only `n` and `N`-type arguments can be replaced by `\cs_generate_variant:Nn`. Other argument types are allowed to be passed unchanged from the base form to the variant: in the process they are changed to `n` except for `N` and `p`-type arguments. A common trailing part is ignored.

We compare the base and variant signatures one character at a time within `x`-expansion. The result is given to `__cs_generate_variant:wwNN` (defined later) in the form `<processed variant signature> \q_mark <errors> \q_stop <base function> <new function>`. If all went well, `<errors>` is empty; otherwise, it is a kernel error message and some clean-up code.

Note the space after `#3` and after the following brace group. Those are ignored by `TEX` when fetching the last argument for `__cs_generate_variant_loop:nNwN`, but can be used as a delimiter for `__cs_generate_variant_loop_end:nwwwNNnn`.

```

3857 \cs_new_protected:Npn \__cs_generate_variant:Nnnw #1#2#3#4 ,
3858 {
3859   \if_meaning:w \scan_stop: #4

```

```

3860 \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
3861 \fi:
3862 \use:x
3863 {
3864 \exp_not:N \__cs_generate_variant:wwNN
3865 \__cs_generate_variant_loop:nNwN { }
3866 #4
3867 \__cs_generate_variant_loop_end:nwwwNNnn
3868 \q_mark
3869 #3 ~
3870 { ~ { } \fi: \__cs_generate_variant_loop_long:wNNnn } ~
3871 { }
3872 \q_stop
3873 \exp_not:N #1 {#2} {#4}
3874 }
3875 \__cs_generate_variant:Nnnw #1 {#2} {#3}
3876 }

```

(End definition for __cs_generate_variant:Nnnw.)

<pre> __cs_generate_variant_loop:nNwN __cs_generate_variant_loop_base:N __cs_generate_variant_loop_same:w __cs_generate_variant_loop_end:nwwwNNnn __cs_generate_variant_loop_long:wNNnn __cs_generate_variant_loop_invalid:NNwNNnn __cs_generate_variant_loop_special:NNwNNnn </pre>	<pre> #1 : Last few consecutive letters common between the base and variant (more precisely, __cs_generate_variant_same:N <letter> for each letter). #2 : Next variant letter. #3 : Remainder of variant form. #4 : Next base letter. </pre>
---	---

The first argument is populated by __cs_generate_variant_loop_same:w when a variant letter and a base letter match. It is flushed into the input stream whenever the two letters are different: if the loop ends before, the argument is dropped, which means that trailing common letters are ignored.

The case where the two letters are different is only allowed if the base is N and the variant is c, or when the base is n and the variant is o, V, v, f or x. Otherwise, call __cs_generate_variant_loop_invalid:NNwNNnn to remove the end of the loop, get arguments at the end of the loop, and place an appropriate error message as a second argument of __cs_generate_variant:wwNN. If the letters are distinct and the base letter is indeed n or N, leave in the input stream whatever argument #1 was collected, and the next variant letter #2, then loop by calling __cs_generate_variant_loop:nNwN.

The loop can stop in three ways.

- If the end of the variant form is encountered first, #2 is __cs_generate_variant_loop_end:nwwwNNnn (expanded by the conditional \if:w), which inserts some tokens to end the conditional; grabs the *<base name>* as #7, the *<variant signature>* #8, the *<next base letter>* #1 and the part #3 of the base signature that wasn't read yet; and combines those into the *<new function>* to be defined.
- If the end of the base form is encountered first, #4 is ~{} \fi: which ends the conditional (with an empty expansion), followed by __cs_generate_variant_loop_long:wNNnn, which places an error as the second argument of __cs_generate_variant:wwNN.
- The loop can be interrupted early if the requested expansion is unavailable, namely when the variant and base letters differ and the base is not the right one (n or N to support the variant). In that case too an error is placed as the second argument of __cs_generate_variant:wwNN.

Note that if the variant form has the same length as the base form, #2 is as described in the first point, and #4 as described in the second point above. The `__cs_generate_variant_loop_end:nwwwNNnn` breaking function takes the empty brace group in #4 as its first argument: this empty brace group produces the correct signature for the full variant.

```

3877 \cs_new:Npn \__cs_generate_variant_loop:nNwN #1#2#3 \q_mark #4
3878 {
3879   \if:w #2 #4
3880     \exp_after:wN \__cs_generate_variant_loop_same:w
3881   \else:
3882     \if:w #4 \__cs_generate_variant_loop_base:N #2 \else:
3883       \if:w 0
3884         \if:w N #4 \else: \if:w n #4 \else: 1 \fi: \fi:
3885         \if:w \scan_stop: \__cs_generate_variant_loop_base:N #2 1 \fi:
3886         0
3887         \__cs_generate_variant_loop_special:NNwNNnn #4#2
3888       \else:
3889         \__cs_generate_variant_loop_invalid:NNwNNnn #4#2
3890       \fi:
3891     \fi:
3892   \fi:
3893   #1
3894   \prg_do_nothing:
3895   #2
3896   \__cs_generate_variant_loop:nNwN { } #3 \q_mark
3897 }
3898 \cs_new:Npn \__cs_generate_variant_loop_base:N #1
3899 {
3900   \if:w c #1 N \else:
3901     \if:w o #1 n \else:
3902       \if:w V #1 n \else:
3903         \if:w v #1 n \else:
3904           \if:w f #1 n \else:
3905             \if:w e #1 n \else:
3906               \if:w x #1 n \else:
3907                 \if:w n #1 n \else:
3908                   \if:w N #1 N \else:
3909                     \scan_stop:
3910                   \fi:
3911                 \fi:
3912               \fi:
3913             \fi:
3914           \fi:
3915         \fi:
3916       \fi:
3917     \fi:
3918   \fi:
3919 }
3920 \cs_new:Npn \__cs_generate_variant_loop_same:w
3921   #1 \prg_do_nothing: #2#3#4
3922   { #3 { #1 \__cs_generate_variant_same:N #2 } }
3923 \cs_new:Npn \__cs_generate_variant_loop_end:nwwwNNnn
3924   #1#2 \q_mark #3 ~ #4 \q_stop #5#6#7#8

```

```

3925 {
3926   \scan_stop: \scan_stop: \fi:
3927   \exp_not:N \q_mark
3928   \exp_not:N \q_stop
3929   \exp_not:N #6
3930   \exp_not:c { #7 : #8 #1 #3 }
3931 }
3932 \cs_new:Npn \__cs_generate_variant_loop_long:wNNnn #1 \q_stop #2#3#4#5
3933 {
3934   \exp_not:n
3935   {
3936     \q_mark
3937     \__kernel_msg_error:nxxx { kernel } { variant-too-long }
3938     {#5} { \token_to_str:N #3 }
3939     \use_none:nnn
3940     \q_stop
3941     #3
3942     #3
3943   }
3944 }
3945 \cs_new:Npn \__cs_generate_variant_loop_invalid:NNwNNnn
3946 #1#2 \fi: \fi: \fi: #3 \q_stop #4#5#6#7
3947 {
3948   \fi: \fi: \fi:
3949   \exp_not:n
3950   {
3951     \q_mark
3952     \__kernel_msg_error:nxxxx { kernel } { invalid-variant }
3953     {#7} { \token_to_str:N #5 } {#1} {#2}
3954     \use_none:nnn
3955     \q_stop
3956     #5
3957     #5
3958   }
3959 }
3960 \cs_new:Npn \__cs_generate_variant_loop_special:NNwNNnn
3961 #1#2#3 \q_stop #4#5#6#7
3962 {
3963   #3 \q_stop #4 #5 {#6} {#7}
3964   \exp_not:n
3965   {
3966     \__kernel_msg_error:nxxxx
3967     { kernel } { deprecated-variant }
3968     {#7} { \token_to_str:N #5 } {#1} {#2}
3969   }
3970 }

```

(End definition for __cs_generate_variant_loop:nNwN and others.)

__cs_generate_variant_same:N When the base and variant letters are identical, don't do any expansion. For most argument types, we can use the n-type no-expansion, but the N and p types require a slightly different behaviour with respect to braces. For V-type this function could output N to avoid adding useless braces but that is not a problem.

```

3971 \cs_new:Npn \__cs_generate_variant_same:N #1

```

```

3972 {
3973   \if:w N #1 N \else:
3974     \if:w p #1 p \else:
3975       n
3976       \if:w n #1 \else:
3977         \__cs_generate_variant_loop_special:NNwNNnn #1#1
3978       \fi:
3979     \fi:
3980   \fi:
3981 }

```

(End definition for __cs_generate_variant_same:N.)

__cs_generate_variant:wwNN If the variant form has already been defined, log its existence (provided log-functions is active). Otherwise, make sure that the \exp_args:N #3 form is defined, and if it contains x, change __cs_tmp:w locally to \cs_new_protected:Npx. Then define the variant by combining the \exp_args:N #3 variant and the base function.

```

3982 \__kernel_patch:nnNNpn
3983 {
3984   \cs_if_free:NF #4
3985   {
3986     \__kernel_debug_log:x
3987     {
3988       Variant~\token_to_str:N #4~%
3989       already-defined;~ not~ changing~ it~ \msg_line_context:
3990     }
3991   }
3992 }
3993 { }
3994 \cs_new_protected:Npn \__cs_generate_variant:wwNN
3995   #1 \q_mark #2 \q_stop #3#4
3996 {
3997   #2
3998   \cs_if_free:NT #4
3999   {
4000     \group_begin:
4001     \__cs_generate_internal_variant:n {#1}
4002     \__cs_tmp:w #4 { \exp_not:c { exp_args:N #1 } \exp_not:N #3 }
4003     \group_end:
4004   }
4005 }

```

(End definition for __cs_generate_variant:wwNN.)

__cs_generate_internal_variant:n Test if \exp_args:N #1 is already defined and if not define it via the \:: commands using the chars in #1. If #1 contains an x (this is the place where having converted the original comma-list argument to a string is very important), the result should be protected, and the next variant to be defined using that internal variant should be protected.

```

4006 \cs_new_protected:Npx \__cs_generate_internal_variant:n #1
4007 {
4008   \exp_not:N \__cs_generate_internal_variant:wwnNwnn
4009   #1 \exp_not:N \q_mark
4010   { \cs_set_eq:NN \exp_not:N \__cs_tmp:w \cs_new_protected:Npx }
4011   \cs_new_protected:cpx

```

```

4012     \token_to_str:N x \exp_not:N \q_mark
4013     { }
4014     \cs_new:cpx
4015     \exp_not:N \q_stop
4016     { \exp_args:N #1 }
4017     {
4018       \exp_not:N \__cs_generate_internal_variant_loop:n #1
4019       { : \exp_not:N \use_i:nn }
4020     }
4021   }
4022 \exp_last_unbraced:NNNNo
4023 \cs_new_protected:Npn \__cs_generate_internal_variant:wwnNwnn #1
4024 { \token_to_str:N x } #2 \q_mark #3#4#5 \q_stop #6#7
4025 {
4026   #3
4027   \cs_if_free:cT {#6} { #4 {#6} {#7} }
4028 }

```

This command grabs char by char outputting \::#1 (not expanded further). We avoid tests by putting a trailing : \use_i:nn, which leaves \cs_end: and removes the looping macro. The colon is in fact also turned into \::: so that the required structure for \exp_args:N... commands is correctly terminated.

```

4029 \cs_new:Npn \__cs_generate_internal_variant_loop:n #1
4030 {
4031   \exp_after:wN \exp_not:N \cs:w :: #1 \cs_end:
4032   \__cs_generate_internal_variant_loop:n
4033 }

```

(End definition for __cs_generate_internal_variant:n, __cs_generate_internal_variant:wwnw, and __cs_generate_internal_variant_loop:n.)

`\prg_generate_conditional_variant:Nnn`

```

\__cs_generate_variant:nnNnn 4034 \cs_new_protected:Npn \prg_generate_conditional_variant:Nnn #1
  \__cs_generate_variant:w 4035 {
  \__cs_generate_variant:n 4036   \use:x
    \cs_generate_variant_p_form:nnn 4037   {
    \cs_generate_variant_T_form:nnn 4038     \__cs_generate_variant:nnNnn
    \cs_generate_variant_F_form:nnn 4039     \cs_split_function:N #1
    \cs_generate_variant_TF_form:nnn 4040   }
  4041 }
4042 \cs_new_protected:Npn \__cs_generate_variant:nnNnn #1#2#3#4#5
4043 {
4044   \if_meaning:w \c_false_bool #3
4045   \__kernel_msg_error:nnx { kernel } { missing-colon }
4046   { \token_to_str:c {#1} }
4047   \use_i_delimit_by_q_stop:nw
4048   \fi:
4049   \exp_after:wN \__cs_generate_variant:w
4050   \tl_to_str:n {#5} , \scan_stop: , \q_recursion_stop
4051   \use_none_delimit_by_q_stop:w \q_mark {#1} {#2} {#4} \q_stop
4052 }
4053 \cs_new_protected:Npn \__cs_generate_variant:w
4054 #1 , #2 \q_mark #3#4#5
4055 {
4056   \if_meaning:w \scan_stop: #1 \scan_stop:

```



```

4057     \if_meaning:w \q_nil #1 \q_nil
4058     \use_i:nnn
4059     \fi:
4060     \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
4061     \else:
4062     \cs_if_exist_use:ctF { __cs_generate_variant_#1_form:nnn }
4063     { {#3} {#4} {#5} }
4064     {
4065         \__kernel_msg_error:nnxx
4066         { kernel } { conditional-form-unknown }
4067         {#1} { \token_to_str:c { #3 : #4 } }
4068     }
4069     \fi:
4070     \__cs_generate_variant:w #2 \q_mark {#3} {#4} {#5}
4071 }
4072 \cs_new_protected:Npn \__cs_generate_variant_p_form:nnn #1#2
4073 { \cs_generate_variant:cn { #1 _p : #2 } }
4074 \cs_new_protected:Npn \__cs_generate_variant_T_form:nnn #1#2
4075 { \cs_generate_variant:cn { #1 : #2 T } }
4076 \cs_new_protected:Npn \__cs_generate_variant_F_form:nnn #1#2
4077 { \cs_generate_variant:cn { #1 : #2 F } }
4078 \cs_new_protected:Npn \__cs_generate_variant_TF_form:nnn #1#2
4079 { \cs_generate_variant:cn { #1 : #2 TF } }

```

(End definition for \prg_generate_conditional_variant:Nnn and others. This function is documented on page 103.)

\exp_args_generate:n
 __cs_args_generate:Nn
 __cs_args_generate:n

This function is not used in the kernel hence we can use functions that are defined in later modules. It also does not need to be fast so use inline mappings. For each requested variant we check that there are no characters besides NnpcofVvx, in particular that there are no spaces. Then we loop through the variant specifier and convert each letter to \::<variant letter>, with a trailing \::.

```

4080 \cs_new_protected:Npn \exp_args_generate:n #1
4081 {
4082     \exp_args:No \clist_map_inline:nn { \tl_to_str:n {#1} }
4083     {
4084         \str_map_inline:nn {##1}
4085         {
4086             \str_if_in:nnF { NnpcofVvx } {####1}
4087             {
4088                 \__kernel_msg_error:nnnn { kernel } { invalid-exp-args }
4089                 {####1} {##1}
4090                 \str_map_break:n { \use_none:nnnn }
4091             }
4092         }
4093     }
4094 }
4095 \exp_args:Nc \__cs_args_generate:Nn { exp_args:N ##1 } {##1}
4096 \cs_new_protected:Npn \__cs_args_generate:Nn #1#2
4097 {
4098     \cs_if_exist:NF #1
4099     {
4100         \str_if_in:nnTF {#2} { x } { \cs_new_protected:Npx } { \cs_new:Npx }
4101         #1 { \tl_map_function:nN { #2 : } \__cs_args_generate:n }

```

```

4102     }
4103   }
4104   \cs_new:Npn \__cs_args_generate:n #1 { \exp_not:c { :: #1 } }

(End definition for \exp_args_generate:n, \__cs_args_generate:Nn, and \__cs_args_generate:n.
This function is documented on page 251.)

4105 \</initex | package>

```

7 l3tl implementation

```

4106 <*initex | package>
4107 <@@=tl>

```

A token list variable is a \TeX macro that holds tokens. By using the $\varepsilon\text{-TeX}$ primitive \unexpanded inside a \TeX \edef it is possible to store any tokens, including $\#$, in this way.

7.1 Functions

\tl_new:N Creating new token list variables is a case of checking for an existing definition and doing the definition.

```

4108 \cs_new_protected:Npn \tl_new:N #1
4109 {
4110   \__kernel_chk_if_free_cs:N #1
4111   \cs_gset_eq:NN #1 \c_empty_tl
4112 }
4113 \cs_generate_variant:Nn \tl_new:N { c }

```

(End definition for \tl_new:N . This function is documented on page 37.)

\tl_const:Nn Constants are also easy to generate.

```

\tl_const:Nx 4114 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
\tl_const:cn 4115 \cs_new_protected:Npn \tl_const:Nn #1#2
\tl_const:cx 4116 {
4117   \__kernel_chk_if_free_cs:N #1
4118   \cs_gset_nopar:Npx #1 { \exp_not:n {#2} }
4119 }
4120 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
4121 \cs_new_protected:Npn \tl_const:Nx #1#2
4122 {
4123   \__kernel_chk_if_free_cs:N #1
4124   \cs_gset_nopar:Npx #1 {#2}
4125 }
4126 \cs_generate_variant:Nn \tl_const:Nn { c }
4127 \cs_generate_variant:Nn \tl_const:Nx { c }

```

(End definition for \tl_const:Nn . This function is documented on page 37.)

\tl_clear:N Clearing a token list variable means setting it to an empty value. Error checking is sorted out by the parent function.

```

\tl_clear:c 4128 \cs_new_protected:Npn \tl_clear:N #1
\tl_gclear:N 4129 { \tl_set_eq:NN #1 \c_empty_tl }
\tl_gclear:c 4130 \cs_new_protected:Npn \tl_gclear:N #1
4131 { \tl_gset_eq:NN #1 \c_empty_tl }
4132 \cs_generate_variant:Nn \tl_clear:N { c }
4133 \cs_generate_variant:Nn \tl_gclear:N { c }

```

(End definition for `\tl_clear:N` and `\tl_gclear:N`. These functions are documented on page 37.)

`\tl_clear_new:N` Clearing a token list variable means setting it to an empty value. Error checking is sorted out by the parent function.

```

\l_clear_new:c
\l_gclear_new:N
\l_gclear_new:c
4134 \cs_new_protected:Npn \tl_clear_new:N #1
4135 { \tl_if_exist:NTF #1 { \tl_clear:N #1 } { \tl_new:N #1 } }
4136 \cs_new_protected:Npn \tl_gclear_new:N #1
4137 { \tl_if_exist:NTF #1 { \tl_gclear:N #1 } { \tl_new:N #1 } }
4138 \cs_generate_variant:Nn \tl_clear_new:N { c }
4139 \cs_generate_variant:Nn \tl_gclear_new:N { c }

```

(End definition for `\tl_clear_new:N` and `\tl_gclear_new:N`. These functions are documented on page 38.)

`\tl_set_eq:NN` For setting token list variables equal to each other. When checking is turned on, make sure both variables exist.

```

\l_set_eq:Nc
\l_set_eq:cN
\l_set_eq:cc
4140 \__kernel_if_debug:TF
4141 {
4142   \cs_new_protected:Npn \tl_set_eq:NN #1#2
4143   {
4144     \__kernel_chk_var_local:N #1
4145     \__kernel_chk_var_exist:N #2
4146     \cs_set_eq:NN #1 #2
4147   }
4148   \cs_new_protected:Npn \tl_gset_eq:NN #1#2
4149   {
4150     \__kernel_chk_var_global:N #1
4151     \__kernel_chk_var_exist:N #2
4152     \cs_gset_eq:NN #1 #2
4153   }
4154 }
4155 {
4156   \cs_new_eq:NN \tl_set_eq:NN \cs_set_eq:NN
4157   \cs_new_eq:NN \tl_gset_eq:NN \cs_gset_eq:NN
4158 }
4159 \cs_generate_variant:Nn \tl_set_eq:NN { cN, Nc, cc }
4160 \cs_generate_variant:Nn \tl_gset_eq:NN { cN, Nc, cc }

```

(End definition for `\tl_set_eq:NN` and `\tl_gset_eq:NN`. These functions are documented on page 38.)

`\tl_concat:NNN` Concatenating token lists is easy. When checking is turned on, all three arguments must be checked: a token list #2 or #3 equal to `\scan_stop:` would lead to problems later on.

```

\l_concat:ccc
\l_gconcat:NNN
\l_gconcat:ccc
4161 \__kernel_patch:nnNNpn
4162 {
4163   \__kernel_chk_var_exist:N #2
4164   \__kernel_chk_var_exist:N #3
4165 }
4166 { }
4167 \cs_new_protected:Npn \tl_concat:NNN #1#2#3
4168 { \tl_set:Nx #1 { \exp_not:o {#2} \exp_not:o {#3} } }
4169 \__kernel_patch:nnNNpn
4170 {
4171   \__kernel_chk_var_exist:N #2
4172   \__kernel_chk_var_exist:N #3

```

```

4173 }
4174 { }
4175 \cs_new_protected:Npn \tl_gconcat:NNN #1#2#3
4176 { \tl_gset:Nx #1 { \exp_not:o {#2} \exp_not:o {#3} } }
4177 \cs_generate_variant:Nn \tl_concat:NNN { ccc }
4178 \cs_generate_variant:Nn \tl_gconcat:NNN { ccc }

```

<code>\tl_if_exist_p:N</code>	Copies of the <code>cs</code> functions defined in <code>l3basics</code> .
<code>\tl_if_exist_p:c</code>	4179 <code>\prg_new_eq_conditional:NNn \tl_if_exist:N \cs_if_exist:N { TF , T , F , p }</code>
<code>\tl_if_exist:N\overline{TF}</code>	4180 <code>\prg_new_eq_conditional:NNn \tl_if_exist:c \cs_if_exist:c { TF , T , F , p }</code>
<code>\tl_if_exist:c\overline{TF}</code>	(End definition for <code>\tl if exist:N\overline{TF}</code> . This function is documented on page 38.)

7.2 Constant token lists

`\c_empty_tl` Never full. We need to define that constant before using `\tl_new:N`.

(End definition for `\c_empty_tl`. This variable is documented on page 51.)

`\c_novalue_tl` A special marker: as we don't have `\char_generate:nn` yet, has to be created the old-fashioned way.

(End definition for \c novalue tl. This variable is documented on page 51.)

`\c_space_tl` A space as a token list (as opposed to as a character).

(End definition for `\c_space_tl`. This variable is documented on page 51.)

7.3 Adding to token list variables

<code>\tl_set:Nn</code>	By using <code>\exp_not:n</code> token list variables can contain <code>#</code> tokens, which makes the token
<code>\tl_set:NV</code>	list registers provided by T _E X more or less redundant. The <code>\tl_set:No</code> version is done
<code>\tl_set:Nv</code>	“by hand” as it is used quite a lot. Each definition is prefixed by a call to <code>__kernel_</code>
<code>\tl_set:No</code>	<code>patch:nnNNpn</code> which adds an existence check to the definition.

\tl_gset:Nn

```
\tl gset:Nv
```

\texttt{gset:Nf}

\url{http://www.elsevier.com/locate/jmr}

```
\tl_gset:cV
```

```

4198 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
4199 \cs_new_protected:Npn \tl_set:Nx #1#2
4200   { \cs_set_nopar:Npx #1 {#2} }
4201 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4202 \cs_new_protected:Npn \tl_gset:Nn #1#2
4203   { \cs_gset_nopar:Npx #1 { \exp_not:n {#2} } }
4204 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4205 \cs_new_protected:Npn \tl_gset:No #1#2
4206   { \cs_gset_nopar:Npx #1 { \exp_not:o {#2} } }
4207 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4208 \cs_new_protected:Npn \tl_gset:Nx #1#2
4209   { \cs_gset_nopar:Npx #1 {#2} }
4210 \cs_generate_variant:Nn \tl_set:Nn { NV , Nv , Nf }
4211 \cs_generate_variant:Nn \tl_set:Nx { c }
4212 \cs_generate_variant:Nn \tl_set:Nn { c , co , cV , cv , cf }
4213 \cs_generate_variant:Nn \tl_gset:Nn { NV , Nv , Nf }
4214 \cs_generate_variant:Nn \tl_gset:Nx { c }
4215 \cs_generate_variant:Nn \tl_gset:Nn { c , co , cV , cv , cf }

```

(End definition for `\tl_set:Nn` and `\tl_gset:Nn`. These functions are documented on page 38.)

\tl_put_left:Nn Adding to the left is done directly to gain a little performance.

```

\tl_put_left:NV 4216 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_put_left:No 4217 \cs_new_protected:Npn \tl_put_left:Nn #1#2
\tl_put_left:Nx 4218   { \cs_set_nopar:Npx #1 { \exp_not:n {#2} \exp_not:o #1 } }
\tl_put_left:cn 4219 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_put_left:cV 4220 \cs_new_protected:Npn \tl_put_left:NV #1#2
\tl_put_left:co 4221   { \cs_set_nopar:Npx #1 { \exp_not:V #2 \exp_not:o #1 } }
\tl_put_left:cx 4222 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_gput_left:Nn 4223 \cs_new_protected:Npn \tl_put_left:No #1#2
\tl_gput_left:NV 4224   { \cs_set_nopar:Npx #1 { \exp_not:o {#2} \exp_not:o #1 } }
\tl_gput_left:No 4225 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_gput_left:Nx 4226 \cs_new_protected:Npn \tl_put_left:Nx #1#2
\tl_gput_left:cn 4227   { \cs_set_nopar:Npx #1 { #2 \exp_not:o #1 } }
\tl_gput_left:cV 4228 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
\tl_gput_left:co 4229 \cs_new_protected:Npn \tl_gput_left:Nn #1#2
\tl_gput_left:cx 4230   { \cs_gset_nopar:Npx #1 { \exp_not:n {#2} \exp_not:o #1 } }
4231 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4232 \cs_new_protected:Npn \tl_gput_left:NV #1#2
4233   { \cs_gset_nopar:Npx #1 { \exp_not:V #2 \exp_not:o #1 } }
4234 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4235 \cs_new_protected:Npn \tl_gput_left:No #1#2
4236   { \cs_gset_nopar:Npx #1 { \exp_not:o {#2} \exp_not:o #1 } }
4237 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4238 \cs_new_protected:Npn \tl_gput_left:Nx #1#2
4239   { \cs_gset_nopar:Npx #1 { #2 \exp_not:o {#1} } }
4240 \cs_generate_variant:Nn \tl_put_left:Nn { c }
4241 \cs_generate_variant:Nn \tl_put_left:NV { c }
4242 \cs_generate_variant:Nn \tl_put_left:No { c }
4243 \cs_generate_variant:Nn \tl_put_left:Nx { c }
4244 \cs_generate_variant:Nn \tl_gput_left:Nn { c }
4245 \cs_generate_variant:Nn \tl_gput_left:NV { c }
4246 \cs_generate_variant:Nn \tl_gput_left:No { c }
4247 \cs_generate_variant:Nn \tl_gput_left:Nx { c }

```

(End definition for `\tl_put_left:Nn` and `\tl_gput_left:Nn`. These functions are documented on page 38.)

```

\tl_put_right:Nn The same on the right.
\tl_put_right:NV 4248 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_put_right:No 4249 \cs_new_protected:Npn \tl_put_right:Nn #1#2
\tl_put_right:Nx 4250 { \cs_set_nopar:Npx #1 { \exp_not:o #1 \exp_not:n {#2} } }
\tl_put_right:cn 4251 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_put_right:cV 4252 \cs_new_protected:Npn \tl_put_right:NV #1#2
\tl_put_right:co 4253 { \cs_set_nopar:Npx #1 { \exp_not:o #1 \exp_not:V #2 } }
\tl_put_right:cx 4254 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_gput_right:Nn 4255 \cs_new_protected:Npn \tl_put_right:No #1#2
\tl_gput_right:NV 4256 { \cs_set_nopar:Npx #1 { \exp_not:o #1 \exp_not:o {#2} } }
\tl_gput_right:No 4257 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\tl_gput_right:Nx 4258 \cs_new_protected:Npn \tl_put_right:Nx #1#2
\tl_gput_right:cn 4259 { \cs_set_nopar:Npx #1 { \exp_not:o #1 #2 } }
\tl_gput_right:cV 4260 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
\tl_gput_right:co 4261 \cs_new_protected:Npn \tl_gput_right:Nn #1#2
\tl_gput_right:cx 4262 { \cs_gset_nopar:Npx #1 { \exp_not:o #1 \exp_not:n {#2} } }
4263 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4264 \cs_new_protected:Npn \tl_gput_right:NV #1#2
4265 { \cs_gset_nopar:Npx #1 { \exp_not:o #1 \exp_not:V #2 } }
4266 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4267 \cs_new_protected:Npn \tl_gput_right:No #1#2
4268 { \cs_gset_nopar:Npx #1 { \exp_not:o #1 \exp_not:o {#2} } }
4269 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
4270 \cs_new_protected:Npn \tl_gput_right:Nx #1#2
4271 { \cs_gset_nopar:Npx #1 { \exp_not:o {#1} #2 } }
4272 \cs_generate_variant:Nn \tl_put_right:Nn { c }
4273 \cs_generate_variant:Nn \tl_put_right:NV { c }
4274 \cs_generate_variant:Nn \tl_put_right:No { c }
4275 \cs_generate_variant:Nn \tl_put_right:Nx { c }
4276 \cs_generate_variant:Nn \tl_gput_right:Nn { c }
4277 \cs_generate_variant:Nn \tl_gput_right:NV { c }
4278 \cs_generate_variant:Nn \tl_gput_right:No { c }
4279 \cs_generate_variant:Nn \tl_gput_right:Nx { c }

```

(End definition for `\tl_put_right:Nn` and `\tl_gput_right:Nn`. These functions are documented on page 38.)

7.4 Reassigning token list category codes

`\c__tl_rescan_marker_tl` The rescanning code needs a special token list containing the same character (chosen here to be a colon) with two different category codes: it cannot appear in the tokens being rescanned since all colons have the same category code.

```
4280 \tl_const:Nx \c__tl_rescan_marker_tl { : \token_to_str:N : }
```

(End definition for `\c__tl_rescan_marker_tl`.)

`\tl_set_rescan:Nnn` In a group, after some initial setup explained below and the user setup #3 (followed by `\scan_stop:` to be safe), there is a call to `__tl_set_rescan:nNN`. This shared auxiliary distinguishes single-line and multi-line files as explained below. In the simplest case of multi-line files it calls (with the same arguments) `__tl_set_rescan_multi:nNN`, whose

```

\tl_set_rescan:Nno
\tl_set_rescan:Nnx
\tl_set_rescan:cn
\tl_set_rescan:cno
\tl_set_rescan:cnx
\tl_gset_rescan:Nnn
\tl_gset_rescan:Nno
\tl_gset_rescan:Nnx
\tl_gset_rescan:cn
\tl_gset_rescan:cno
\tl_gset_rescan:cnx

```

```
\tl_rescan:nn
```

```
\__tl_set_rescan:NNnn
```

```
\__tl_set_rescan_multi:nNN
```

code is included here to help understand the approach: it rescans its argument #1, closes the group, and performs the assignment.

One difficulty when rescanning is that `\scantokens` treats the argument as a file, and without the correct settings a T_EX error occurs:

```
! File ended while scanning definition of ...
```

A related minor issue is a warning due to opening a group before the `\scantokens` and closing it inside that temporary file; we avoid that by setting `\tracingnesting`. The standard solution to the “File ended” error is to grab the rescanned tokens as a delimited argument of an auxiliary, here `__tl_set_rescan:NNw`, that performs the assignment, then let T_EX “execute” the end of file marker. As usual in delimited arguments we use `\prg_do_nothing:` to avoid stripping an outer set braces: this is removed by using o-expanding assignments. The delimiter cannot appear within the rescanned token list because it contains twice the same character, with different catcodes.

For `\tl_rescan:nn` we cannot simply call `__tl_set_rescan:NNnn \prg_do_nothing: \use:n` because that would leave the end-of-file marker *after* the result of rescanning. If that rescanned result is code that looks further in the input stream for arguments, it would break.

The two `\if_false: ... \fi:` are there to prevent alignment tabs to cause a change of tabular cell while rescanning. We put the “opening” one after `\group_begin:` so that if one accidentally f-expands `\tl_set_rescan:Nnn` braces remain balanced. This is essential in e-type arguments when `\expanded` is not available.

```

4281 \cs_new_protected:Npn \tl_set_rescan:Nnn
4282   { \__tl_set_rescan:NNnn \tl_set:No }
4283 \cs_new_protected:Npn \tl_gset_rescan:Nnn
4284   { \__tl_set_rescan:NNnn \tl_gset:No }
4285 \cs_new_protected:Npn \tl_rescan:nn #1#2
4286   {
4287     \tl_set_rescan:Nnn \l__tl_internal_a_tl {#1} {#2}
4288     \exp_after:wN \tl_clear:N \exp_after:wN \l__tl_internal_a_tl
4289     \l__tl_internal_a_tl
4290   }
4291 \cs_new_protected:Npn \__tl_set_rescan:NNnn #1#2#3#4
4292   {
4293     \group_begin:
4294     \if_false: { \fi:
4295       \int_set_eq:NN \tex_tracingnesting:D \c_zero_int
4296       \exp_args:No \tex_everyeof:D { \c__tl_rescan_marker_tl }
4297       \int_compare:nNnT \tex_endlinechar:D = { 32 }
4298         { \int_set:Nn \tex_endlinechar:D { -1 } }
4299       \int_set_eq:NN \tex_newlinechar:D \tex_endlinechar:D
4300       #3 \scan_stop:
4301       \exp_args:No \__tl_set_rescan:nN { \tl_to_str:n {#4} } #1 #2
4302     \if_false: } \fi:
4303   }
4304 \cs_new_protected:Npn \__tl_set_rescan_multi:nNn #1#2#3
4305   {
4306     \exp_after:wN \__tl_rescan:NNw
4307     \exp_after:wN #2
4308     \exp_after:wN #3
4309     \exp_after:wN \prg_do_nothing:
4310     \tex_scantokens:D {#1}

```

```

4311 }
4312 \exp_args:Nno \use:nn
4313 { \cs_new:Npn \__tl_rescan:NNw #1#2#3 } \c__tl_rescan_marker_tl
4314 {
4315   \group_end:
4316   #1 #2 {#3}
4317 }
4318 \cs_generate_variant:Nn \tl_set_rescan:Nnn { Nno , Nnx }
4319 \cs_generate_variant:Nn \tl_set_rescan:Nnn { c , cno , cnx }
4320 \cs_generate_variant:Nn \tl_gset_rescan:Nnn { Nno , Nnx }
4321 \cs_generate_variant:Nn \tl_gset_rescan:Nnn { c , cno }

```

(End definition for `\tl_set_rescan:Nnn` and others. These functions are documented on page 40.)

```

\__tl_set_rescan:nNN This function calls \__tl_set_rescan_multi:nNN or \__tl_set_rescan_single:nNN
\__tl_set_rescan_single:nNN { ' } depending on whether its argument is a single-line fragment of code/data or is
\__tl_set_rescan_single_aux:nNN made of multiple lines by testing for the presence of a \newlinechar character. If
\newlinechar is out of range, the argument is assumed to be a single line.

```

The case of multiple lines is a straightforward application of `\scantokens` as described above. The only subtlety is that `\newlinechar` should be equal to `\endlinechar` because `\newlinechar` characters become new lines and then become `\endlinechar` characters when writing to an abstract file and reading back. This equality is ensured by setting `\newlinechar` equal to `\endlinechar`. Prior to this, `\endlinechar` is set to `-1` if it was `32` (in particular true after `\ExplSyntaxOn`) to avoid unreasonable line-breaks at every space for instance in error messages triggered by the user setup. Another side effect of reading back from the file is that spaces (catcode `10`) are ignored at the beginning of lines, and spaces and tabs (character code `32` and `9`) are ignored at the end of lines.

For a single line, no `\endlinechar` should be added, so it is set to `-1`, and spaces should not be removed. Trailing spaces and tabs are a difficult matter, as `TeX` removes these at a very low level. The only way to preserve them is to rescan not the argument but the argument followed by a character with a reasonable category code. Here, `11` (letter) and `12` (other) are accepted, as these are convenient, suitable for delimiting an argument, and it is very unlikely that none of the ASCII characters are in one of these categories. To avoid selecting one particular character to put at the end, whose category code may have been modified, there is a loop through characters from `'` (ASCII `39`) to `~` (ASCII `127`). The choice of starting point was made because this is the start of a very long range of characters whose standard category is letter or other, thus minimizing the number of steps needed by the loop (most often just a single one). Once a valid character is found, run some code very similar to `__tl_set_rescan_multi:nNN` but with that character put at the start and end. The auxiliary `__tl_rescan:NNw` must be redefined to also remove the additional character (with the appropriate catcode thanks to `\char_generate:nn`). If no valid character is found (very rare), fall-back on `__tl_set_rescan_multi:nNN`.

```

4322 \cs_new_protected:Npn \__tl_set_rescan:nNN #1
4323 {
4324   \int_compare:nNnTF \tex_newlinechar:D < 0
4325   { \use_ii:nn }
4326   {
4327     \exp_args:Nnf \tl_if_in:nNTF {#1}
4328     { \char_generate:nn { \tex_newlinechar:D } { 12 } }
4329   }
4330   { \__tl_set_rescan_multi:nNN }
4331   {

```



```

4332         \int_set:Nn \tex_endlinechar:D { -1 }
4333         \__tl_set_rescan_single:nnNN { ' ' }
4334     }
4335     {#1}
4336 }
4337 \cs_new_protected:Npn \__tl_set_rescan_single:nnNN #1
4338 {
4339     \int_compare:nNnTF
4340     { \char_value_catcode:n {#1} / 2 } = 6
4341     {
4342         \exp_args:Nf \__tl_set_rescan_single_aux:nnNN
4343         { \char_generate:nn {#1} { \char_value_catcode:n {#1} } }
4344     }
4345     {
4346         \int_compare:nNnTF {#1} < { '\~ }
4347         {
4348             \exp_args:Nf \__tl_set_rescan_single:nnNN
4349             { \int_eval:n { #1 + 1 } }
4350         }
4351         { \__tl_set_rescan_multi:nnN }
4352     }
4353 }
4354 \cs_new_protected:Npn \__tl_set_rescan_single_aux:nnNN #1#2#3#4
4355 {
4356     \exp_args:Nno \use:nn
4357     { \cs_set:Npn \__tl_rescan:NNw ##1##2##3 #1 }
4358     \c__tl_rescan_marker_tl
4359     {
4360         \group_end:
4361         ##1 ##2 { \use_none:n ##3 }
4362     }
4363     \exp_after:wN \__tl_rescan:NNw
4364     \exp_after:wN #3
4365     \exp_after:wN #4
4366     \tex_scantokens:D { #1 #2 #1 }
4367 }

```

(End definition for `__tl_set_rescan:nnN`, `__tl_set_rescan_single:nnNN`, and `__tl_set_rescan_single_aux:nnNN`.)

7.5 Modifying token list variables

`\tl_replace_all:Nnn` All of the `replace` functions call `__tl_replace:NnNNnn` with appropriate arguments. `\tl_replace_all:cnn` The first two arguments are explained later. The next controls whether the replacement function calls itself (`__tl_replace_next:w`) or stops (`__tl_replace_wrap:w`) after the first replacement. Next comes an x-type assignment function `\tl_set:Nx` or `\tl_gset:Nx` for local or global replacements. Finally, the three arguments $\langle tl\ var \rangle \{ \langle pattern \rangle \} \{ \langle replacement \rangle \}$ provided by the user. When describing the auxiliary functions below, we denote the contents of the $\langle tl\ var \rangle$ by $\langle token\ list \rangle$.

```

4368 \cs_new_protected:Npn \tl_replace_once:Nnn
4369 { \__tl_replace:NnNNnn \q_mark ? \__tl_replace_wrap:w \tl_set:Nx }
4370 \cs_new_protected:Npn \tl_greplace_once:Nnn
4371 { \__tl_replace:NnNNnn \q_mark ? \__tl_replace_wrap:w \tl_gset:Nx }
4372 \cs_new_protected:Npn \tl_replace_all:Nnn

```

```

4373 { \_tl\_replace:NnNNNnn \q\_mark ? \_tl\_replace\_next:w \tl\_set:Nx }
4374 \cs\_new\_protected:Npn \tl\_greplace\_all:Nnn
4375 { \_tl\_replace:NnNNNnn \q\_mark ? \_tl\_replace\_next:w \tl\_gset:Nx }
4376 \cs\_generate\_variant:Nn \tl\_greplace\_once:Nnn { c }
4377 \cs\_generate\_variant:Nn \tl\_greplace\_once:Nnn { c }
4378 \cs\_generate\_variant:Nn \tl\_replace\_all:Nnn { c }
4379 \cs\_generate\_variant:Nn \tl\_greplace\_all:Nnn { c }

```

(End definition for `\tl_replace_all:Nnn` and others. These functions are documented on page 39.)

```

\_tl\_replace:NnNNNnn
\_tl\_replace\_auxi:NnnNNNnn
\_tl\_replace\_auxii:NnnNNn
  \_tl\_replace\_next:w
  \_tl\_replace\_wrap:w

```

To implement the actual replacement auxiliary `_tl_replace_auxii:NnnNNn` we need a *delimiter* with the following properties:

- all occurrences of the *pattern* #6 in “*token list* *delimiter*” belong to the *token list* and have no overlap with the *delimiter*,
- the first occurrence of the *delimiter* in “*token list* *delimiter*” is the trailing *delimiter*.

We first find the building blocks for the *delimiter*, namely two tokens $\langle A \rangle$ and $\langle B \rangle$ such that $\langle A \rangle$ does not appear in #6 and #6 is not $\langle B \rangle$ (this condition is trivial if #6 has more than one token). Then we consider the delimiters “ $\langle A \rangle$ ” and “ $\langle A \rangle \langle A \rangle^n \langle B \rangle \langle A \rangle^n \langle B \rangle$ ”, for $n \geq 1$, where $\langle A \rangle^n$ denotes n copies of $\langle A \rangle$, and we choose as our *delimiter* the first one which is not in the *token list*.

Every delimiter in the set obeys the first condition: #6 does not contain $\langle A \rangle$ hence cannot be overlapping with the *token list* and the *delimiter*, and it cannot be within the *delimiter* since it would have to be in one of the two $\langle B \rangle$ hence be equal to this single token (or empty, but this is an error case filtered separately). Given the particular form of these delimiters, for which no prefix is also a suffix, the second condition is actually a consequence of the weaker condition that the *delimiter* we choose does not appear in the *token list*. Additionally, the set of delimiters is such that a *token list* of n tokens can contain at most $O(n^{1/2})$ of them, hence we find a *delimiter* with at most $O(n^{1/2})$ tokens in a time at most $O(n^{3/2})$. Bear in mind that these upper bounds are reached only in very contrived scenarios: we include the case “ $\langle A \rangle$ ” in the list of delimiters to try, so that the *delimiter* is simply `\q_mark` in the most common situation where neither the *token list* nor the *pattern* contains `\q_mark`.

Let us now ahead, optimizing for this most common case. First, two special cases: an empty *pattern* #6 is an error, and if #1 is absent from both the *token list* #5 and the *pattern* #6 then we can use it as the *delimiter* through `_tl_replace_auxii:NnnNNn {#1}`. Otherwise, we end up calling `_tl_replace:NnNNNnn` repeatedly with the first two arguments `\q_mark {?}`, `\? {??}`, `\?? {???`, and so on, until #6 does not contain the control sequence #1, which we take as our $\langle A \rangle$. The argument #2 only serves to collect ? characters for #1. Note that the order of the tests means that the first two are done every time, which is wasteful (for instance, we repeatedly test for the emptiness of #6). However, this is rare enough not to matter. Finally, choose $\langle B \rangle$ to be `\q_nil` or `\q_stop` such that it is not equal to #6.

The `_tl_replace_auxi:NnnNNNnn` auxiliary receives $\{\langle A \rangle\}$ and $\{\langle A \rangle^n \langle B \rangle\}$ as its arguments, initially with $n = 1$. If “ $\langle A \rangle \langle A \rangle^n \langle B \rangle \langle A \rangle^n \langle B \rangle$ ” is in the *token list* then increase n and try again. Once it is not anymore in the *token list* we take it as our *delimiter* and pass this to the *auxii* auxiliary.

```

4380 \cs\_new\_protected:Npn \_tl\_replace:NnNNNnn #1#2#3#4#5#6#7
4381 {

```

```

4382 \tl_if_empty:nTF {#6}
4383 {
4384   \__kernel_msg_error:nxx { kernel } { empty-search-pattern }
4385   { \tl_to_str:n {#7} }
4386 }
4387 {
4388   \tl_if_in:ontF { #5 #6 } {#1}
4389   {
4390     \tl_if_in:nnTF {#6} {#1}
4391     { \exp_args:Nc \__tl_replace:NnnNNnn {#2} {#2?} }
4392     {
4393       \quark_if_nil:nTF {#6}
4394       { \__tl_replace_auxi:NnnNNNnn #5 {#1} { #1 \q_stop } }
4395       { \__tl_replace_auxi:NnnNNNnn #5 {#1} { #1 \q_nil } }
4396     }
4397   }
4398   { \__tl_replace_auxii:nNNNnn {#1} }
4399   #3#4#5 {#6} {#7}
4400 }
4401 }
4402 \cs_new_protected:Npn \__tl_replace_auxi:NnnNNNnn #1#2#3
4403 {
4404   \tl_if_in:NnTF #1 { #2 #3 #3 }
4405   { \__tl_replace_auxi:NnnNNNnn #1 { #2 #3 } {#2} }
4406   { \__tl_replace_auxii:nNNNnn { #2 #3 #3 } }
4407 }

```

The auxiliary `__tl_replace_auxii:nNNNnn` receives the following arguments:

```

{<delimiter>} <function> <assignment>
<tl var> {<pattern>} {<replacement>}

```

All of its work is done between `\group_align_safe_begin:` and `\group_align_safe_end:` to avoid issues in alignments. It does the actual replacement within `#3 #4 {...}`, an x-expanding *<assignment>* `#3` to the *<tl var>* `#4`. The auxiliary `__tl_replace_next:w` is called, followed by the *<token list>*, some tokens including the *<delimiter>* `#1`, followed by the *<pattern>* `#5`. This auxiliary finds an argument delimited by `#5` (the presence of a trailing `#5` avoids runaway arguments) and calls `__tl_replace_wrap:w` to test whether this `#5` is found within the *<token list>* or is the trailing one.

If on the one hand it is found within the *<token list>*, then `##1` cannot contain the *<delimiter>* `#1` that we worked so hard to obtain, thus `__tl_replace_wrap:w` gets `##1` as its own argument `##1`, and protects it against the x-expanding assignment. It also finds `\exp_not:n` as `##2` and does nothing to it, thus letting through `\exp_not:n {<replacement>}` into the assignment. Note that `__tl_replace_next:w` and `__tl_replace_wrap:w` are always called followed by two empty brace groups. These are safe because no delimiter can match them. They prevent losing braces when grabbing delimited arguments, but require the use of `\exp_not:o` and `\use_none:nn`, rather than simply `\exp_not:n`. Afterwards, `__tl_replace_next:w` is called to repeat the replacement, or `__tl_replace_wrap:w` if we only want a single replacement. In this second case, `##1` is the *<remaining tokens>* in the *<token list>* and `##2` is some *<ending code>* which ends the assignment and removes the trailing tokens `#5` using some `\if_false: { \fi: }` trickery because `#5` may contain any delimiter.

If on the other hand the argument `##1` of `__tl_replace_next:w` is delimited by the trailing *<pattern>* `#5`, then `##1` is “`{ } { } <token list> <delimiter> {<ending code>}`”,

hence `__tl_replace_wrap:w` finds “`{ } { }` *⟨token list⟩*” as `##1` and the *⟨ending code⟩* as `##2`. It leaves the *⟨token list⟩* into the assignment and unbraces the *⟨ending code⟩* which removes what remains (essentially the *⟨delimiter⟩* and *⟨replacement⟩*).

```

4408 \cs_new_protected:Npn \__tl_replace_auxii:nNNNnn #1#2#3#4#5#6
4409 {
4410   \group_align_safe_begin:
4411   \cs_set:Npn \__tl_replace_wrap:w ##1 #1 ##2
4412     { \exp_not:o { \use_none:nn ##1 } ##2 }
4413   \cs_set:Npx \__tl_replace_next:w ##1 #5
4414   {
4415     \exp_not:N \__tl_replace_wrap:w ##1
4416     \exp_not:n { #1 }
4417     \exp_not:n { \exp_not:n {#6} }
4418     \exp_not:n { #2 { } { } }
4419   }
4420   #3 #4
4421   {
4422     \exp_after:wN \__tl_replace_next:w
4423     \exp_after:wN { \exp_after:wN }
4424     \exp_after:wN { \exp_after:wN }
4425     #4
4426     #1
4427     {
4428       \if_false: { \fi: }
4429       \exp_after:wN \use_none:n \exp_after:wN { \if_false: } \fi:
4430     }
4431     #5
4432   }
4433   \group_align_safe_end:
4434 }
4435 \cs_new_eq:NN \__tl_replace_wrap:w ?
4436 \cs_new_eq:NN \__tl_replace_next:w ?

```

(End definition for `__tl_replace:NnNNNnn` and others.)

```

\tl_remove_once:Nn Removal is just a special case of replacement.
\tl_remove_once:cn 4437 \cs_new_protected:Npn \tl_remove_once:Nn #1#2
\tl_gremove_once:Nn 4438 { \tl_replace_once:Nnn #1 {#2} { } }
\tl_gremove_once:cn 4439 \cs_new_protected:Npn \tl_gremove_once:Nn #1#2
4440 { \tl_greplace_once:Nnn #1 {#2} { } }
4441 \cs_generate_variant:Nn \tl_remove_once:Nn { c }
4442 \cs_generate_variant:Nn \tl_gremove_once:Nn { c }

```

(End definition for `\tl_remove_once:Nn` and `\tl_gremove_once:Nn`. These functions are documented on page 39.)

```

\tl_remove_all:Nn Removal is just a special case of replacement.
\tl_remove_all:cn 4443 \cs_new_protected:Npn \tl_remove_all:Nn #1#2
\tl_gremove_all:Nn 4444 { \tl_replace_all:Nnn #1 {#2} { } }
\tl_gremove_all:cn 4445 \cs_new_protected:Npn \tl_gremove_all:Nn #1#2
4446 { \tl_greplace_all:Nnn #1 {#2} { } }
4447 \cs_generate_variant:Nn \tl_remove_all:Nn { c }
4448 \cs_generate_variant:Nn \tl_gremove_all:Nn { c }

```

(End definition for `\tl_remove_all:Nn` and `\tl_gremove_all:Nn`. These functions are documented on page 39.)

7.6 Token list conditionals

`\tl_if_blank_p:n` TeX skips spaces when reading a non-delimited arguments. Thus, a *token list* is blank if and only if `\use_none:n <token list> ?` is empty after one expansion. The auxiliary `__tl_if_empty_if:o` is a fast emptiness test, converting its argument to a string (after one expansion) and using the test `\if_meaning:w \q_nil ... \q_nil`.

```

\tl_if_blank_p:n 4449 \prg_new_conditional:Npnn \tl_if_blank:n #1 { p , T , F , TF }
\tl_if_blank_p:V 4450 {
\tl_if_blank_p:o 4451   \__tl_if_empty_if:o { \use_none:n #1 ? }
\tl_if_blank:nTF 4452   \prg_return_true:
\tl_if_blank:VTF 4453   \else:
\tl_if_blank:oTF 4454   \prg_return_false:
\tl_if_blank:nTF 4455   \fi:
\tl_if_blank:VTF 4456 }
\tl_if_blank:oTF 4457 \prg_generate_conditional_variant:Nnn \tl_if_blank:n
\tl_if_blank:nTF 4458 { V , o } { p , T , F , TF }
```

(End definition for `\tl_if_blank:nTF` and `__tl_if_blank_p:NNw`. This function is documented on page 40.)

`\tl_if_empty_p:N` These functions check whether the token list in the argument is empty and execute the proper code from their argument(s).

```

\tl_if_empty_p:c 4459 \prg_new_conditional:Npnn \tl_if_empty:N #1 { p , T , F , TF }
\tl_if_empty_p:c 4460 {
\tl_if_empty:NTF 4461   \if_meaning:w #1 \c_empty_tl
\tl_if_empty:cTF 4462   \prg_return_true:
\tl_if_empty:NTF 4463   \else:
\tl_if_empty:cTF 4464   \prg_return_false:
\tl_if_empty:NTF 4465   \fi:
\tl_if_empty:cTF 4466 }
\tl_if_empty:NTF 4467 \prg_generate_conditional_variant:Nnn \tl_if_empty:N
\tl_if_empty:cTF 4468 { c } { p , T , F , TF }
```

(End definition for `\tl_if_empty:NTF`. This function is documented on page 41.)

`\tl_if_empty_p:n` Convert the argument to a string: this is empty if and only if the argument is. Then `\if_meaning:w \q_nil ... \q_nil` is true if and only if the string ... is empty. It could be tempting to use `\if_meaning:w \q_nil #1 \q_nil` directly. This fails on a token list starting with `\q_nil` of course but more troubling is the case where argument is a complete conditional such as `\if_true: a \else: b \fi:` because then `\if_true:` is used by `\if_meaning:w`, the test turns out false, the `\else:` executes the false branch, the `\fi:` ends it and the `\q_nil` at the end starts executing...

```

4469 \prg_new_conditional:Npnn \tl_if_empty:n #1 { p , TF , T , F }
4470 {
4471   \exp_after:wN \if_meaning:w \exp_after:wN \q_nil
4472   \tl_to_str:n {#1} \q_nil
4473   \prg_return_true:
4474   \else:
4475   \prg_return_false:
4476   \fi:
4477 }
4478 \prg_generate_conditional_variant:Nnn \tl_if_empty:n
4479 { V } { p , TF , T , F }
```

(End definition for `\tl_if_empty:nTF`. This function is documented on page 41.)

`\tl_if_empty_p:o` The auxiliary function `__tl_if_empty_if:o` is for use in various token list conditionals which reduce to testing if a given token list is empty after applying a simple function to it.
`\tl_if_empty:oTF` The test for emptiness is based on `\tl_if_empty:nTF`, but the expansion is hard-coded for efficiency, as this auxiliary function is used in several places. We don't put `\prg_return_true:` and so on in the definition of the auxiliary, because that would prevent an optimization applied to conditionals that end with this code.
`__tl_if_empty_if:o`

```

4480 \cs_new:Npn \__tl_if_empty_if:o #1
4481 {
4482   \exp_after:wN \if_meaning:w \exp_after:wN \q_nil
4483   \__kernel_tl_to_str:w \exp_after:wN {#1} \q_nil
4484 }
4485 \prg_new_conditional:Npnn \tl_if_empty:o #1 { p , TF , T , F }
4486 {
4487   \__tl_if_empty_if:o {#1}
4488   \prg_return_true:
4489   \else:
4490   \prg_return_false:
4491   \fi:
4492 }

```

(End definition for `\tl_if_empty:nTF` and `__tl_if_empty_if:o`. This function is documented on page 41.)

`\tl_if_eq_p:NN` Returns `\c_true_bool` if and only if the two token list variables are equal.

```

\tl_if_eq_p:Nc 4493 \prg_new_conditional:Npnn \tl_if_eq:NN #1#2 { p , T , F , TF }
\tl_if_eq_p:cN 4494 {
\tl_if_eq_p:cc 4495   \if_meaning:w #1 #2
\tl_if_eq:NNTF 4496   \prg_return_true:
\tl_if_eq:NcTF 4497   \else:
\tl_if_eq:cNTF 4498   \prg_return_false:
\tl_if_eq:ccTF 4499   \fi:
4500 }
4501 \prg_generate_conditional_variant:Nnn \tl_if_eq:NN
4502 { Nc , c , cc } { p , TF , T , F }

```

(End definition for `\tl_if_eq:NNTF`. This function is documented on page 41.)

`\tl_if_eq:nnTF` A simple store and compare routine.

```

\l__tl_internal_a_tl 4503 \prg_new_protected_conditional:Npnn \tl_if_eq:nn #1#2 { T , F , TF }
\l__tl_internal_b_tl 4504 {
4505   \group_begin:
4506   \tl_set:Nn \l__tl_internal_a_tl {#1}
4507   \tl_set:Nn \l__tl_internal_b_tl {#2}
4508   \exp_after:wN
4509   \group_end:
4510   \if_meaning:w \l__tl_internal_a_tl \l__tl_internal_b_tl
4511   \prg_return_true:
4512   \else:
4513   \prg_return_false:
4514   \fi:
4515 }
4516 \tl_new:N \l__tl_internal_a_tl
4517 \tl_new:N \l__tl_internal_b_tl

```

(End definition for `\tl_if_eq:nnTF`, `\l__tl_internal_a_tl`, and `\l__tl_internal_b_tl`. This function is documented on page 41.)

`\tl_if_in:NnTF` See `\tl_if_in:nnTF` for further comments. Here we simply expand the token list variable `\tl_if_in:cnTF` and pass it to `\tl_if_in:nnTF`.

```

4518 \cs_new_protected:Npn \tl_if_in:NnT { \exp_args:No \tl_if_in:nnT }
4519 \cs_new_protected:Npn \tl_if_in:NnF { \exp_args:No \tl_if_in:nnF }
4520 \cs_new_protected:Npn \tl_if_in:NnTF { \exp_args:No \tl_if_in:nnTF }
4521 \prg_generate_conditional_variant:Nnn \tl_if_in:Nn
4522 { c } { T , F , TF }

```

(End definition for `\tl_if_in:NnTF`. This function is documented on page 41.)

`\tl_if_in:nnTF` Once more, the test relies on the emptiness test for robustness. The function `__tl_tmp:w` removes tokens until the first occurrence of `#2`. If this does not appear in `#1`, then the final `#2` is removed, leaving an empty token list. Otherwise some tokens remain, and the test is `false`. See `\tl_if_empty:nTF` for details on the emptiness test.

Treating correctly cases like `\tl_if_in:nnTF {a state}{states}`, where `#1#2` contains `#2` before the end, requires special care. To cater for this case, we insert `{ }{ }` between the two token lists. This marker may not appear in `#2` because of \TeX limitations on what can delimit a parameter, hence we are safe. Using two brace groups makes the test work also for empty arguments. The `\if_false:` constructions are a faster way to do `\group_align_safe_begin:` and `\group_align_safe_end:`. The `\scan_stop:` ensures that f-expanding `\tl_if_in:nn` does not lead to unbalanced braces.

```

4523 \prg_new_protected_conditional:Npnn \tl_if_in:nn #1#2 { T , F , TF }
4524 {
4525   \scan_stop:
4526   \if_false: { \fi:
4527     \cs_set:Npn \__tl_tmp:w ##1 #2 { }
4528     \tl_if_empty:oTF { \__tl_tmp:w #1 { } { } #2 }
4529     { \prg_return_false: } { \prg_return_true: }
4530     \if_false: } \fi:
4531   }
4532 \prg_generate_conditional_variant:Nnn \tl_if_in:nn
4533 { V , o , no } { T , F , TF }

```

(End definition for `\tl_if_in:nnTF`. This function is documented on page 41.)

`\tl_if_novalue:p:n` Tests for `-NoValue-`: this is similar to `\tl_if_in:nn` but set up to be expandable and to check the value exactly. The question mark prevents the auxiliary from losing braces.

```

\__tl_if_novalue:w
4534 \cs_set_protected:Npn \__tl_tmp:w #1
4535 {
4536   \prg_new_conditional:Npnn \tl_if_novalue:n ##1
4537   { p , T , F , TF }
4538   {
4539     \str_if_eq:onTF
4540     { \__tl_if_novalue:w ? ##1 { } #1 }
4541     { ? { } #1 }
4542     { \prg_return_true: }
4543     { \prg_return_false: }
4544   }
4545   \cs_new:Npn \__tl_if_novalue:w ##1 #1 {##1}
4546 }
4547 \exp_args:No \__tl_tmp:w { \c_novalue_tl }

```

(End definition for `\tl_if_novalue:nTF` and `__tl_if_novalue:w`. This function is documented on page 41.)

```
\tl_if_single_p:N Expand the token list and feed it to \tl_if_single:n.
\tl_if_single:N $\underline{TF}$ 
4548 \cs_new:Npn \tl_if_single_p:N { \exp_args:No \tl_if_single_p:n }
4549 \cs_new:Npn \tl_if_single:N $\underline{TF}$  { \exp_args:No \tl_if_single:n $\underline{TF}$  }
4550 \cs_new:Npn \tl_if_single:N $\underline{F}$  { \exp_args:No \tl_if_single:n $\underline{F}$  }
4551 \cs_new:Npn \tl_if_single:N $\underline{TF}$  { \exp_args:No \tl_if_single:n $\underline{TF}$  }
```

(End definition for `\tl_if_single:N \underline{TF}` . This function is documented on page 42.)

`\tl_if_single_p:n` This test is similar to `\tl_if_empty:nTF`. Expanding `\use_none:nn #1 ??` once yields an empty result if #1 is blank, a single ? if #1 has a single item, and otherwise yields some tokens ending with ??. Then, `\tl_to_str:n` makes sure there are no odd category codes. `__tl_if_single_p:n` An earlier version would compare the result to a single ? using string comparison, but `__tl_if_single:n \underline{TF}` the Lua call is slow in Lua \TeX . Instead, `__tl_if_single:nnw` picks the second token in front of it. If #1 is empty, this token is the trailing ? and the catcode test yields false. If #1 has a single item, the token is ^ and the catcode test yields true. Otherwise, it is one of the characters resulting from `\tl_to_str:n`, and the catcode test yields false. Note that `\if_catcode:w` and `__kernel_tl_to_str:w` are primitives that take care of expansion.

```
4552 \prg_new_conditional:Npnn \tl_if_single:n #1 { p , T , F , TF }
4553 {
4554   \if_catcode:w ^ \exp_after:wN \__tl_if_single:nnw
4555     \__kernel_tl_to_str:w
4556     \exp_after:wN { \use_none:nn #1 ?? } ^ ? \q_stop
4557   \prg_return_true:
4558   \else:
4559     \prg_return_false:
4560   \fi:
4561 }
4562 \cs_new:Npn \__tl_if_single:nnw #1#2#3 \q_stop {#2}
```

(End definition for `\tl_if_single:nTF` and `__tl_if_single:n \underline{TF}` . This function is documented on page 42.)

`\tl_if_single_token_p:n` There are four cases: empty token list, token list starting with a normal token, with a brace group, or with a space token. If the token list starts with a normal token, remove it and check for emptiness. For the next case, an empty token list is not a single token. Finally, we have a non-empty token list starting with a space or a brace group. Applying f-expansion yields an empty result if and only if the token list is a single space.

```
\tl_if_single_token:n $\underline{TF}$ 
4563 \prg_new_conditional:Npnn \tl_if_single_token:n #1 { p , T , F , TF }
4564 {
4565   \tl_if_head_is_N_type:nTF {#1}
4566     { \__tl_if_empty_if:o { \use_none:n #1 } }
4567     {
4568       \tl_if_empty:nTF {#1}
4569         { \if_false: }
4570         { \__tl_if_empty_if:o { \exp:w \exp_end_continue_f:w #1 } }
4571     }
4572   \prg_return_true:
4573   \else:
4574     \prg_return_false:
```



```

4575     \fi:
4576   }

```

(End definition for `\tl_if_single_token:nTF`. This function is documented on page 42.)

<pre> \tl_case:Nn \tl_case:cn \tl_case:NnTF \tl_case:cnTF __tl_case:nnTF __tl_case:Nw __tl_case_end:nw </pre>	<p>The aim here is to allow the case statement to be evaluated using a known number of expansion steps (two), and without needing to use an explicit “end of recursion” marker. That is achieved by using the test input as the final case, as this is always true. The trick is then to tidy up the output such that the appropriate case code plus either the <code>true</code> or <code>false</code> branch code is inserted.</p> <pre> 4577 \cs_new:Npn \tl_case:Nn #1#2 4578 { 4579 \exp:w 4580 __tl_case:NnTF #1 {#2} { } { } 4581 } 4582 \cs_new:Npn \tl_case:NnT #1#2#3 4583 { 4584 \exp:w 4585 __tl_case:NnTF #1 {#2} {#3} { } 4586 } 4587 \cs_new:Npn \tl_case:NnF #1#2#3 4588 { 4589 \exp:w 4590 __tl_case:NnTF #1 {#2} { } {#3} 4591 } 4592 \cs_new:Npn \tl_case:NnTF #1#2 4593 { 4594 \exp:w 4595 __tl_case:NnTF #1 {#2} 4596 } 4597 \cs_new:Npn __tl_case:NnTF #1#2#3#4 4598 { __tl_case:Nw #1 #2 #1 { } \q_mark {#3} \q_mark {#4} \q_stop } 4599 \cs_new:Npn __tl_case:Nw #1#2#3 4600 { 4601 \tl_if_eq:NNTF #1 #2 4602 { __tl_case_end:nw {#3} } 4603 { __tl_case:Nw #1 } 4604 } 4605 \cs_generate_variant:Nn \tl_case:Nn { c } 4606 \prg_generate_conditional_variant:Nnn \tl_case:Nn 4607 { c } { T , F , TF } </pre>
--	---

To tidy up the recursion, there are two outcomes. If there was a hit to one of the cases searched for, then #1 is the code to insert, #2 is the *next* case to check on and #3 is all of the rest of the cases code. That means that #4 is the `true` branch code, and #5 tidies up the spare `\q_mark` and the `false` branch. On the other hand, if none of the cases matched then we arrive here using the “termination” case of comparing the search with itself. That means that #1 is empty, #2 is the first `\q_mark` and so #4 is the `false` code (the `true` code is mopped up by #3).

```

4608 \cs_new:Npn \__tl_case_end:nw #1#2#3 \q_mark #4#5 \q_stop
4609 { \exp_end: #1 #4 }

```

(End definition for `\tl_case:NnTF` and others. This function is documented on page 42.)

7.7 Mapping to token lists

`\tl_map_function:nN` Expandable loop macro for token lists. These have the advantage of not needing to test if the argument is empty, because if it is, the stop marker is read immediately and the loop terminated.

```
\tl_map_function:NN
\tl_map_function:cN
\__tl_map_function:Nn
4610 \cs_new:Npn \tl_map_function:nN #1#2
4611 {
4612     \__tl_map_function:Nn #2 #1
4613     \q_recursion_tail
4614     \prg_break_point:Nn \tl_map_break: { }
4615 }
4616 \cs_new:Npn \tl_map_function:NN
4617 { \exp_args:No \tl_map_function:nN }
4618 \cs_new:Npn \__tl_map_function:Nn #1#2
4619 {
4620     \quark_if_recursion_tail_break:nN {#2} \tl_map_break:
4621     #1 {#2} \__tl_map_function:Nn #1
4622 }
4623 \cs_generate_variant:Nn \tl_map_function:NN { c }
```

(End definition for `\tl_map_function:nN`, `\tl_map_function:NN`, and `__tl_map_function:Nn`. These functions are documented on page 42.)

`\tl_map_inline:nn` The inline functions are straight forward by now. We use a little trick with the counter `\g__kernel_prg_map_int` to make them nestable. We can also make use of `__tl_map_function:Nn` from before.

```
\tl_map_inline:NN
\tl_map_inline:cn
4624 \cs_new_protected:Npn \tl_map_inline:nn #1#2
4625 {
4626     \int_gincr:N \g__kernel_prg_map_int
4627     \cs_gset_protected:cpn
4628     { \__tl_map_ \int_use:N \g__kernel_prg_map_int :w } ##1 {#2}
4629     \exp_args:Nc \__tl_map_function:Nn
4630     { \__tl_map_ \int_use:N \g__kernel_prg_map_int :w }
4631     #1 \q_recursion_tail
4632     \prg_break_point:Nn \tl_map_break:
4633     { \int_gdecr:N \g__kernel_prg_map_int }
4634 }
4635 \cs_new_protected:Npn \tl_map_inline:NN
4636 { \exp_args:No \tl_map_inline:nn }
4637 \cs_generate_variant:Nn \tl_map_inline:NN { c }
```

(End definition for `\tl_map_inline:nn` and `\tl_map_inline:NN`. These functions are documented on page 43.)

`\tl_map_variable:nNn` `\tl_map_variable:nNn` $\langle token\ list \rangle$ $\langle temp \rangle$ $\langle action \rangle$ assigns $\langle temp \rangle$ to each element and executes $\langle action \rangle$.

```
\tl_map_variable:NNn
\tl_map_variable:cNn
\__tl_map_variable:Nnn
4638 \cs_new_protected:Npn \tl_map_variable:nNn #1#2#3
4639 {
4640     \__tl_map_variable:Nnn #2 {#3} #1
4641     \q_recursion_tail
4642     \prg_break_point:Nn \tl_map_break: { }
4643 }
4644 \cs_new_protected:Npn \tl_map_variable:NNn
4645 { \exp_args:No \tl_map_variable:nNn }
```

```

4646 \cs_new_protected:Npn \__tl_map_variable:Nnn #1#2#3
4647 {
4648   \tl_set:Nn #1 {#3}
4649   \quark_if_recursion_tail_break:NN #1 \tl_map_break:
4650   \use:n {#2}
4651   \__tl_map_variable:Nnn #1 {#2}
4652 }
4653 \cs_generate_variant:Nn \tl_map_variable:NNn { c }

```

(End definition for `\tl_map_variable:nnn`, `\tl_map_variable:NNn`, and `__tl_map_variable:Nnn`. These functions are documented on page 43.)

`\tl_map_break:` The break statements use the general `\prg_map_break:Nn`.
`\tl_map_break:n`

```

4654 \cs_new:Npn \tl_map_break:
4655 { \prg_map_break:Nn \tl_map_break: { } }
4656 \cs_new:Npn \tl_map_break:n
4657 { \prg_map_break:Nn \tl_map_break: }

```

(End definition for `\tl_map_break:` and `\tl_map_break:n`. These functions are documented on page 43.)

7.8 Using token lists

`\tl_to_str:n` Another name for a primitive: defined in `l3basics`.

`\tl_to_str:V`

```
4658 \cs_generate_variant:Nn \tl_to_str:n { V }
```

(End definition for `\tl_to_str:n`. This function is documented on page 44.)

`\tl_to_str:N` These functions return the replacement text of a token list as a string.

`\tl_to_str:c`

```
4659 \cs_new:Npn \tl_to_str:N #1 { \__kernel_tl_to_str:w \exp_after:wN {#1} }
4660 \cs_generate_variant:Nn \tl_to_str:N { c }
```

(End definition for `\tl_to_str:N`. This function is documented on page 44.)

`\tl_use:N` Token lists which are simply not defined give a clear T_EX error here. No such luck for
`\tl_use:c` ones equal to `\scan_stop:` so instead a test is made and if there is an issue an error is forced.

```

4661 \cs_new:Npn \tl_use:N #1
4662 {
4663   \tl_if_exist:NTF #1 {#1}
4664   {
4665     \__kernel_msg_expandable_error:nnn
4666     { kernel } { bad-variable } {#1}
4667   }
4668 }
4669 \cs_generate_variant:Nn \tl_use:N { c }

```

(End definition for `\tl_use:N`. This function is documented on page 45.)

7.9 Working with the contents of token lists

\tl_count:n Count number of elements within a token list or token list variable. Brace groups within the list are read as a single element. Spaces are ignored. **__tl_count:n** grabs the element and replaces it by +1. The 0 ensures that it works on an empty list.

```

\tl_count:V
\tl_count:o
\tl_count:N
\tl_count:c
\__tl_count:n
4670 \cs_new:Npn \tl_count:n #1
4671 {
4672   \int_eval:n
4673     { 0 \tl_map_function:nN {#1} \__tl_count:n }
4674 }
4675 \cs_new:Npn \tl_count:N #1
4676 {
4677   \int_eval:n
4678     { 0 \tl_map_function:NN #1 \__tl_count:n }
4679 }
4680 \cs_new:Npn \__tl_count:n #1 { + 1 }
4681 \cs_generate_variant:Nn \tl_count:n { V , o }
4682 \cs_generate_variant:Nn \tl_count:N { c }
```

(End definition for \tl_count:n, \tl_count:N, and __tl_count:n. These functions are documented on page 45.)

\tl_count_tokens:n The token count is computed through an **\int_eval:n** construction. Each 1+ is output to the *left*, into the integer expression, and the sum is ended by the **\exp_end:** inserted by **__tl_act_end:wn** (which is technically implemented as **\c_zero_int**). Somewhat a hack!

```

4683 \cs_new:Npn \tl_count_tokens:n #1
4684 {
4685   \int_eval:n
4686     {
4687       \__tl_act:NNNnn
4688       \__tl_act_count_normal:nN
4689       \__tl_act_count_group:nn
4690       \__tl_act_count_space:n
4691       { }
4692       {#1}
4693     }
4694 }
4695 \cs_new:Npn \__tl_act_count_normal:nN #1 #2 { 1 + }
4696 \cs_new:Npn \__tl_act_count_space:n #1 { 1 + }
4697 \cs_new:Npn \__tl_act_count_group:nn #1 #2
4698 { 2 + \tl_count_tokens:n {#2} + }
```

(End definition for \tl_count_tokens:n and others. This function is documented on page 45.)

\tl_reverse_items:n Reversal of a token list is done by taking one item at a time and putting it after **\q_stop**.

```

\__tl_reverse_items:nwNwn
\__tl_reverse_items:wn
4699 \cs_new:Npn \tl_reverse_items:n #1
4700 {
4701   \__tl_reverse_items:nwNwn #1 ?
4702   \q_mark \__tl_reverse_items:nwNwn
4703   \q_mark \__tl_reverse_items:wn
4704   \q_stop { }
4705 }
4706 \cs_new:Npn \__tl_reverse_items:nwNwn #1 #2 \q_mark #3 #4 \q_stop #5
```

```

4707 {
4708     #3 #2
4709     \q_mark \_tl_reverse_items:nwNwn
4710     \q_mark \_tl_reverse_items:wn
4711     \q_stop { {#1} #5 }
4712 }
4713 \cs_new:Npn \_tl_reverse_items:wn #1 \q_stop #2
4714 { \exp_not:o { \use_none:nn #2 } }

```

(End definition for `\tl_reverse_items:n`, `__tl_reverse_items:nwNwn`, and `__tl_reverse_items:wn`.
This function is documented on page 46.)

<pre> \tl_trim_spaces:n \tl_trim_spaces:o \tl_trim_spaces_apply:nN \tl_trim_spaces_apply:oN \tl_trim_spaces:N </pre>	<p>Trimming spaces from around the input is deferred to an internal function whose first argument is the token list to trim, augmented by an initial <code>\q_mark</code>, and whose second argument is a <i><continuation></i>, which receives as a braced argument <code>\use_none:n \q_mark <trimmed token list></code>. In the case at hand, we take <code>\exp_not:o</code> as our continuation, so that space trimming behaves correctly within an x-type expansion.</p>
--	--

```

\tl_trim_spaces:c
4715 \cs_new:Npn \tl_trim_spaces:n #1
\tl_gtrim_spaces:N
4716 { \__tl_trim_spaces:nn { \q_mark #1 } \exp_not:o }
\tl_gtrim_spaces:c
4717 \cs_generate_variant:Nn \tl_trim_spaces:n { o }
4718 \cs_new:Npn \tl_trim_spaces_apply:nN #1#2
4719 { \__tl_trim_spaces:nn { \q_mark #1 } { \exp_args:No #2 } }
4720 \cs_generate_variant:Nn \tl_trim_spaces_apply:nN { o }
4721 \cs_new_protected:Npn \tl_trim_spaces:N #1
4722 { \tl_set:Nx #1 { \exp_args:No \tl_trim_spaces:n {#1} } }
4723 \cs_new_protected:Npn \tl_gtrim_spaces:N #1
4724 { \tl_gset:Nx #1 { \exp_args:No \tl_trim_spaces:n {#1} } }
4725 \cs_generate_variant:Nn \tl_trim_spaces:N { c }
4726 \cs_generate_variant:Nn \tl_gtrim_spaces:N { c }

```

Trimming spaces from around the input is done using delimited arguments and quarks, and to get spaces at odd places in the definitions, we nest those in `__tl_tmp:w`, which then receives a single space as its argument: `#1` is `␣`. Removing leading spaces is done with `__tl_trim_spaces_auxi:w`, which loops until `\q_mark␣` matches the end of the token list: then `##1` is the token list and `##3` is `__tl_trim_spaces_auxiii:w`. This hands the relevant tokens to the loop `__tl_trim_spaces_auxiii:w`, responsible for trimming trailing spaces. The end is reached when `␣\q_nil` matches the one present in the definition of `\tl_trim_spaces:n`. Then `__tl_trim_spaces_auxiv:w` puts the token list into a group, with `\use_none:n` placed there to gobble a lingering `\q_mark`, and feeds this to the *⟨continuation⟩*.

`__tl_trim_spaces:nn` then receives a single space as its argument: `#1` is
`__tl_trim_spaces_auxi:w` with `__tl_trim_spaces_auxi:w`, which loops until
`__tl_trim_spaces_auxii:w` token list: then `##1` is the token list and `##3` is
`__tl_trim_spaces_auxiii:w` hands the relevant tokens to the loop `__tl_trim`
`__tl_trim_spaces_auxiv:w` trimming trailing spaces. The end is reached when
the definition of `\tl_trim_spaces:n`. Then `__tl_t`
list into a group, with `\use_none:n` placed there to g
this to the *continuation*.

```

4727 \cs_set:Npn __tl_tmp:w #1
4728 {
4729     \cs_new:Npn __tl_trim_spaces:nn ##1
4730     {
4731         __tl_trim_spaces_auxi:w
4732         ##1
4733         \q_nil
4734         \q_mark #1 { }
4735         \q_mark __tl_trim_spaces_auxii:w
4736         __tl_trim_spaces_auxiii:w
4737         #1 \q_nil
4738         __tl_trim_spaces_auxiv:w
4739         \q_stop

```

```

4740     }
4741     \cs_new:Npn \__tl_trim_spaces_auxi:w ##1 \q_mark #1 ##2 \q_mark ##3
4742     {
4743         ##3
4744         \__tl_trim_spaces_auxi:w
4745         \q_mark
4746         ##2
4747         \q_mark #1 {##1}
4748     }
4749     \cs_new:Npn \__tl_trim_spaces_auxii:w
4750     \__tl_trim_spaces_auxi:w \q_mark \q_mark ##1
4751     {
4752         \__tl_trim_spaces_auxiii:w
4753         ##1
4754     }
4755     \cs_new:Npn \__tl_trim_spaces_auxiii:w ##1 #1 \q_nil ##2
4756     {
4757         ##2
4758         ##1 \q_nil
4759         \__tl_trim_spaces_auxiii:w
4760     }
4761     \cs_new:Npn \__tl_trim_spaces_auxiv:w ##1 \q_nil ##2 \q_stop ##3
4762     { ##3 { \use_none:n ##1 } }
4763 }
4764 \__tl_tmp:w { ~ }

```

(End definition for `\tl_trim_spaces:n` and others. These functions are documented on page 46.)

`\tl_sort:Nn` Implemented in `l3sort`.

`\tl_sort:cn`

`\tl_gsort:Nn` (End definition for `\tl_sort:Nn`, `\tl_gsort:Nn`, and `\tl_sort:nN`. These functions are documented on page 46.)

`\tl_gsort:cn`

`\tl_sort:nN`

7.10 Token by token changes

`\q__tl_act_mark`

`\q__tl_act_stop`

The `__tl_act_...` functions may be applied to any token list. Hence, we use two private quarks, to allow any token, even quarks, in the token list. Only `\q__tl_act_mark` and `\q__tl_act_stop` may not appear in the token lists manipulated by `__tl_act:NNNnn` functions. No quark module yet, so do things by hand.

```

4765 \cs_new_nopar:Npn \q__tl_act_mark { \q__tl_act_mark }
4766 \cs_new_nopar:Npn \q__tl_act_stop { \q__tl_act_stop }

```

(End definition for `\q__tl_act_mark` and `\q__tl_act_stop`.)

`__tl_act:NNNnn`

`__tl_act_output:n`

`__tl_act_reverse_output:n`

`__tl_act_loop:w`

`__tl_act_normal:NwnNNN`

`__tl_act_group:nwnNNN`

`__tl_act_space:wwnNNN`

`__tl_act_end:w`

To help control the expansion, `__tl_act:NNNnn` should always be proceeded by `\exp:w` and ends by producing `\exp_end:` once the result has been obtained. Then loop over tokens, groups, and spaces in #5. The marker `\q__tl_act_mark` is used both to avoid losing outer braces and to detect the end of the token list more easily. The result is stored as an argument for the dummy function `__tl_act_result:n`.

```

4767 \cs_new:Npn \__tl_act:NNNnn #1#2#3#4#5
4768 {
4769     \group_align_safe_begin:
4770     \__tl_act_loop:w #5 \q__tl_act_mark \q__tl_act_stop
4771     {#4} #1 #2 #3

```

```

4772   \_tl_act_result:n { }
4773 }

```

In the loop, we check how the token list begins and act accordingly. In the “normal” case, we may have reached `\q_tl_act_mark`, the end of the list. Then leave `\exp_end:` and the result in the input stream, to terminate the expansion of `\exp:w`. Otherwise, apply the relevant function to the “arguments”, #3 and to the head of the token list. Then repeat the loop. The scheme is the same if the token list starts with a group or with a space. Some extra work is needed to make `_tl_act_space:wnnn` gobble the space.

```

4774 \cs_new:Npn \_tl_act_loop:w #1 \q_tl_act_stop
4775 {
4776   \tl_if_head_is_N_type:nTF {#1}
4777   { \_tl_act_normal:Nwnnn }
4778   {
4779     \tl_if_head_is_group:nTF {#1}
4780     { \_tl_act_group:wnnn }
4781     { \_tl_act_space:wnnn }
4782   }
4783   #1 \q_tl_act_stop
4784 }
4785 \cs_new:Npn \_tl_act_normal:Nwnnn #1 #2 \q_tl_act_stop #3#4
4786 {
4787   \if_meaning:w \q_tl_act_mark #1
4788   \exp_after:wN \_tl_act_end:wn
4789   \fi:
4790   #4 {#3} #1
4791   \_tl_act_loop:w #2 \q_tl_act_stop
4792   {#3} #4
4793 }
4794 \cs_new:Npn \_tl_act_end:wn #1 \_tl_act_result:n #2
4795 { \group_align_safe_end: \exp_end: #2 }
4796 \cs_new:Npn \_tl_act_group:wnnn #1 #2 \q_tl_act_stop #3#4#5
4797 {
4798   #5 {#3} {#1}
4799   \_tl_act_loop:w #2 \q_tl_act_stop
4800   {#3} #4 #5
4801 }
4802 \exp_last_unbraced:NNo
4803 \cs_new:Npn \_tl_act_space:wnnn \c_space_tl #1 \q_tl_act_stop #2#3#4#5
4804 {
4805   #5 {#2}
4806   \_tl_act_loop:w #1 \q_tl_act_stop
4807   {#2} #3 #4 #5
4808 }

```

Typically, the output is done to the right of what was already output, using `_tl_act_output:n`, but for the `_tl_act_reverse` functions, it should be done to the left.

```

4809 \cs_new:Npn \_tl_act_output:n #1 #2 \_tl_act_result:n #3
4810 { #2 \_tl_act_result:n { #3 #1 } }
4811 \cs_new:Npn \_tl_act_reverse_output:n #1 #2 \_tl_act_result:n #3
4812 { #2 \_tl_act_result:n { #1 #3 } }

```

(End definition for `_tl_act:nnnn` and others.)

\tl_reverse:n The goal here is to reverse without losing spaces nor braces. This is done using the
\tl_reverse:o general internal function `__tl_act:NNNnn`. Spaces and “normal” tokens are output on
\tl_reverse:V the left of the current output. Grouped tokens are output to the left but without any
__tl_reverse_normal:nN reversal within the group. All of the internal functions here drop one argument: this is
__tl_reverse_group_preserve:nn needed by `__tl_act:NNNnn` when changing case (to record which direction the change
__tl_reverse_space:n is in), but not when reversing the tokens.

```

4813 \cs_new:Npn \tl_reverse:n #1
4814 {
4815   \__kernel_exp_not:w \exp_after:wN
4816   {
4817     \exp:w
4818     \__tl_act:NNNnn
4819     \__tl_reverse_normal:nN
4820     \__tl_reverse_group_preserve:nn
4821     \__tl_reverse_space:n
4822     { }
4823     {#1}
4824   }
4825 }
4826 \cs_generate_variant:Nn \tl_reverse:n { o , V }
4827 \cs_new:Npn \__tl_reverse_normal:nN #1#2
4828 { \__tl_act_reverse_output:n {#2} }
4829 \cs_new:Npn \__tl_reverse_group_preserve:nn #1#2
4830 { \__tl_act_reverse_output:n { {#2} } }
4831 \cs_new:Npn \__tl_reverse_space:n #1
4832 { \__tl_act_reverse_output:n { ~ } }

```

(End definition for `\tl_reverse:n` and others. This function is documented on page 45.)

\tl_reverse:N This reverses the list, leaving `\exp_stop_f:` in front, which stops the f-expansion.
\tl_reverse:c
\tl_greverse:N
\tl_greverse:c

```

4833 \cs_new_protected:Npn \tl_reverse:N #1
4834 { \tl_set:Nx #1 { \exp_args:No \tl_reverse:n { #1 } } }
4835 \cs_new_protected:Npn \tl_greverse:N #1
4836 { \tl_gset:Nx #1 { \exp_args:No \tl_reverse:n { #1 } } }
4837 \cs_generate_variant:Nn \tl_reverse:N { c }
4838 \cs_generate_variant:Nn \tl_greverse:N { c }

```

(End definition for `\tl_reverse:N` and `\tl_greverse:N`. These functions are documented on page 45.)

7.11 The first token from a token list

\tl_head:N Finding the head of a token list expandably always strips braces, which is fine as this
\tl_head:n is consistent with for example mapping to a list. The empty brace groups in `\tl_`
\tl_head:V `head:n` ensure that a blank argument gives an empty result. The result is returned
\tl_head:v within the `\unexpanded` primitive. The approach here is to use `\if_false:` to allow
\tl_head:f us to use `}` as the closing delimiter: this is the only safe choice, as any other token
__tl_head_auxi:nw would not be able to parse it’s own code. Using a marker, we can see if what we are
__tl_head_auxii:n grabbing is exactly the marker, or there is anything else to deal with. Is there is, there
\tl_head:w is a loop. If not, tidy up and leave the item in the output stream. More detail in
\tl_tail:N <http://tex.stackexchange.com/a/70168>.
\tl_tail:n
\tl_tail:V
\tl_tail:v
\tl_tail:f

```

4839 \cs_new:Npn \tl_head:n #1
4840 {
4841   \__kernel_exp_not:w

```



```

4842     \if_false: { \fi: \_tl\_head\_auxi:nw #1 { } \q\_stop }
4843   }
4844 \cs\_new:Npn \_tl\_head\_auxi:nw #1#2 \q\_stop
4845   {
4846     \exp\_after:wN \_tl\_head\_auxii:n \exp\_after:wN {
4847       \if_false: } \fi: {#1}
4848   }
4849 \cs\_new:Npn \_tl\_head\_auxii:n #1
4850   {
4851     \exp\_after:wN \if\_meaning:w \exp\_after:wN \q\_nil
4852     \_kernel\_tl\_to\_str:w \exp\_after:wN { \use\_none:n #1 } \q\_nil
4853     \exp\_after:wN \use\_i:nn
4854     \else:
4855       \exp\_after:wN \use\_ii:nn
4856     \fi:
4857     {#1}
4858     { \if_false: { \fi: \_tl\_head\_auxi:nw #1 } }
4859   }
4860 \cs\_generate\_variant:Nn \tl\_head:n { V , v , f }
4861 \cs\_new:Npn \tl\_head:w #1#2 \q\_stop {#1}
4862 \cs\_new:Npn \tl\_head:N { \exp\_args:No \tl\_head:n }

```

To correctly leave the tail of a token list, it's important *not* to absorb any of the tail part as an argument. For example, the simple definition

```

\_cs\_new:Npn \tl\_tail:n #1 { \tl\_tail:w #1 \q\_stop }
\_cs\_new:Npn \tl\_tail:w #1#2 \q\_stop

```

would give the wrong result for `\tl_tail:n { a { bc } }` (the braces would be stripped). Thus the only safe way to proceed is to first check that there is an item to grab (*i.e.* that the argument is not blank) and assuming there is to dispose of the first item. As with `\tl_head:n`, the result is protected from further expansion by `\unexpanded`. While we could optimise the test here, this would leave some tokens “banned” in the input, which we do not have with this definition.

```

4863 \cs\_new:Npn \tl\_tail:n #1
4864   {
4865     \_kernel\_exp\_not:w
4866     \tl\_if\_blank:nTF {#1}
4867       { { } }
4868       { \exp\_after:wN { \use\_none:n #1 } }
4869   }
4870 \cs\_generate\_variant:Nn \tl\_tail:n { V , v , f }
4871 \cs\_new:Npn \tl\_tail:N { \exp\_args:No \tl\_tail:n }

```

(End definition for `\tl_head:N` and others. These functions are documented on page 47.)

```

\tl\_if\_head\_eq\_meaning\_p:nN
\tl\_if\_head\_eq\_meaning:nNTF
\tl\_if\_head\_eq\_charcode\_p:nN
\tl\_if\_head\_eq\_charcode:nNTF
\tl\_if\_head\_eq\_charcode\_p:fN
\tl\_if\_head\_eq\_charcode:fNTF
\tl\_if\_head\_eq\_catcode\_p:nN
\tl\_if\_head\_eq\_catcode:nNTF

```

Accessing the first token of a token list is tricky in three cases: when it has category code 1 (begin-group token), when it is an explicit space, with category code 10 and character code 32, or when the token list is empty (obviously).

Forgetting temporarily about this issue we would use the following test in `\tl_if_head_eq_charcode:nN`. Here, `\tl_head:w` yields the first token of the token list, then passed to `\exp_not:N`.

```

\if_charcode:w
  \exp_after:wN \exp_not:N \tl_head:w #1 \q_nil \q_stop
  \exp_not:N #2

```

The two first special cases are detected by testing if the token list starts with an N-type token (the extra ? sends empty token lists to the `true` branch of this test). In those cases, the first token is a character, and since we only care about its character code, we can use `\str_head:n` to access it (this works even if it is a space character). An empty argument results in `\tl_head:w` leaving two tokens: ? which is taken in the `\if_charcode:w` test, and `\use_none:nn`, which ensures that `\prg_return_false:` is returned regardless of whether the charcode test was true or false.

```

4872 \prg_new_conditional:Npnn \tl_if_head_eq_charcode:nN #1#2 { p , T , F , TF }
4873 {
4874   \if_charcode:w
4875     \exp_not:N #2
4876     \tl_if_head_is_N_type:nTF { #1 ? }
4877     {
4878       \exp_after:wN \exp_not:N
4879       \tl_head:w #1 { ? \use_none:nn } \q_stop
4880     }
4881     { \str_head:n {#1} }
4882     \prg_return_true:
4883   \else:
4884     \prg_return_false:
4885   \fi:
4886 }
4887 \prg_generate_conditional_variant:Nnn \tl_if_head_eq_charcode:nN
4888 { f } { p , TF , T , F }

```

For `\tl_if_head_eq_catcode:nN`, again we detect special cases with a `\tl_if_head_is_N_type:n`. Then we need to test if the first token is a begin-group token or an explicit space token, and produce the relevant token, either `\c_group_begin_token` or `\c_space_token`. Again, for an empty argument, a hack is used, removing `\prg_return_true:` and `\else:` with `\use_none:nn` in case the catcode test with the (arbitrarily chosen) ? is true.

```

4889 \prg_new_conditional:Npnn \tl_if_head_eq_catcode:nN #1 #2 { p , T , F , TF }
4890 {
4891   \if_catcode:w
4892     \exp_not:N #2
4893     \tl_if_head_is_N_type:nTF { #1 ? }
4894     {
4895       \exp_after:wN \exp_not:N
4896       \tl_head:w #1 { ? \use_none:nn } \q_stop
4897     }
4898     {
4899       \tl_if_head_is_group:nTF {#1}
4900       { \c_group_begin_token }
4901       { \c_space_token }
4902     }
4903     \prg_return_true:
4904   \else:
4905     \prg_return_false:
4906   \fi:
4907 }

```

For `\tl_if_head_eq_meaning:nN`, again, detect special cases. In the normal case, use `\tl_head:w`, with no `\exp_not:N` this time, since `\if_meaning:w` causes no expansion. With an empty argument, the test is true, and `\use_none:nnn` removes #2 and the usual `\prg_return_true:` and `\else:`. In the special cases, we know that the first token is a character, hence `\if_charcode:w` and `\if_catcode:w` together are enough. We combine them in some order, hopefully faster than the reverse. Tests are not nested because the arguments may contain unmatched primitive conditionals.

```

4908 \prg_new_conditional:Npnn \tl_if_head_eq_meaning:nN #1#2 { p , T , F , TF }
4909 {
4910   \tl_if_head_is_N_type:nTF { #1 ? }
4911   { \__tl_if_head_eq_meaning_normal:nN }
4912   { \__tl_if_head_eq_meaning_special:nN }
4913   {#1} #2
4914 }
4915 \cs_new:Npn \__tl_if_head_eq_meaning_normal:nN #1 #2
4916 {
4917   \exp_after:wN \if_meaning:w
4918   \tl_head:w #1 { ?? \use_none:nnn } \q_stop #2
4919   \prg_return_true:
4920   \else:
4921   \prg_return_false:
4922   \fi:
4923 }
4924 \cs_new:Npn \__tl_if_head_eq_meaning_special:nN #1 #2
4925 {
4926   \if_charcode:w \str_head:n {#1} \exp_not:N #2
4927   \exp_after:wN \use:n
4928   \else:
4929   \prg_return_false:
4930   \exp_after:wN \use_none:n
4931   \fi:
4932   {
4933     \if_catcode:w \exp_not:N #2
4934     \tl_if_head_is_group:nTF {#1}
4935     { \c_group_begin_token }
4936     { \c_space_token }
4937     \prg_return_true:
4938     \else:
4939     \prg_return_false:
4940     \fi:
4941   }
4942 }

```

(End definition for `\tl_if_head_eq_meaning:nNTF` and others. These functions are documented on page 48.)

`\tl_if_head_is_N_type_p:n`
`\tl_if_head_is_N_type:nTF`
`__tl_if_head_is_N_type:w`

A token list can be empty, can start with an explicit space character (catcode 10 and charcode 32), can start with a begin-group token (catcode 1), or start with an N-type argument. In the first two cases, the line involving `__tl_if_head_is_N_type:w` produces `~` (and otherwise nothing). In the third case (begin-group token), the lines involving `\exp_after:wN` produce a single closing brace. The category code test is thus true exactly in the fourth case, which is what we want. One cannot optimize by moving one of

the `*` to the beginning: if `#1` contains primitive conditionals, all of its occurrences must be dealt with before the `\if_catcode:w` tries to skip the `true` branch of the conditional.

```

4943 \prg_new_conditional:Npnn \tl_if_head_is_N_type:n #1 { p , T , F , TF }
4944 {
4945   \if_catcode:w
4946     \if_false: { \fi: \__tl_if_head_is_N_type:w ? #1 ~ }
4947     \exp_after:wN \use_none:n
4948     \exp_after:wN { \exp_after:wN { \token_to_str:N #1 ? } }
4949     * *
4950     \prg_return_true:
4951   \else:
4952     \prg_return_false:
4953   \fi:
4954 }
4955 \cs_new:Npn \__tl_if_head_is_N_type:w #1 ~
4956 {
4957   \tl_if_empty:oTF { \use_none:n #1 } { ^ } { }
4958   \exp_after:wN \use_none:n \exp_after:wN { \if_false: } \fi:
4959 }

```

(End definition for `\tl_if_head_is_N_type:nTF` and `__tl_if_head_is_N_type:w`. This function is documented on page 49.)

`\tl_if_head_is_group_p:n` Pass the first token of `#1` through `\token_to_str:N`, then check for the brace balance.
`\tl_if_head_is_group:nTF` The extra `?` caters for an empty argument. This could be made faster, but we need all brace tricks to happen in one step of expansion, keeping the token list brace balanced at all times.

```

4960 \prg_new_conditional:Npnn \tl_if_head_is_group:n #1 { p , T , F , TF }
4961 {
4962   \if_catcode:w
4963     \exp_after:wN \use_none:n
4964     \exp_after:wN { \exp_after:wN { \token_to_str:N #1 ? } }
4965     * *
4966     \prg_return_false:
4967   \else:
4968     \prg_return_true:
4969   \fi:
4970 }

```

(End definition for `\tl_if_head_is_group:nTF`. This function is documented on page 48.)

`\tl_if_head_is_space_p:n` The auxiliary's argument is all that is before the first explicit space in `?#1?~`. If that is a single `?` the test yields `true`. Otherwise, that is more than one token, and the
`\tl_if_head_is_space:nTF` test yields `false`. The work is done within braces (with an `\if_false: { \fi: ... }` construction) both to hide potential alignment tab characters from `TEX` in a table, and to allow for removing what remains of the token list after its first space. The `\exp:w` and `\exp_end:` ensure that the result of a single step of expansion directly yields a balanced token list (no trailing closing brace).

```

4971 \prg_new_conditional:Npnn \tl_if_head_is_space:n #1 { p , T , F , TF }
4972 {
4973   \exp:w \if_false: { \fi:
4974     \__tl_if_head_is_space:w ? #1 ? ~ }
4975 }
4976 \cs_new:Npn \__tl_if_head_is_space:w #1 ~

```

```

4977 {
4978   \tl_if_empty:oTF { \use_none:n #1 }
4979   { \exp_after:wN \exp_end: \exp_after:wN \prg_return_true: }
4980   { \exp_after:wN \exp_end: \exp_after:wN \prg_return_false: }
4981   \exp_after:wN \use_none:n \exp_after:wN { \if_false: } \fi:
4982 }

```

(End definition for `\tl_if_head_is_space:nTF` and `__tl_if_head_is_space:w`. This function is documented on page 49.)

7.12 Using a single item

```

\tl_item:nn The idea here is to find the offset of the item from the left, then use a loop to grab
\tl_item:Nn the correct item. If the resulting offset is too large, then \quark_if_recursion_tail_
\tl_item:cn stop:n terminates the loop, and returns nothing at all.
__tl_item_aux:nn 4983 \cs_new:Npn \tl_item:nn #1#2
__tl_item:nn 4984 {
4985   \exp_args:Nf \__tl_item:nn
4986   { \exp_args:Nf \__tl_item_aux:nn { \int_eval:n {#2} } {#1} }
4987   #1
4988   \q_recursion_tail
4989   \prg_break_point:
4990 }
4991 \cs_new:Npn \__tl_item_aux:nn #1#2
4992 {
4993   \int_compare:nNnTF {#1} < 0
4994   { \int_eval:n { \tl_count:n {#2} + 1 + #1 } }
4995   {#1}
4996 }
4997 \cs_new:Npn \__tl_item:nn #1#2
4998 {
4999   \quark_if_recursion_tail_break:nN {#2} \prg_break:
5000   \int_compare:nNnTF {#1} = 1
5001   { \prg_break:n { \exp_not:n {#2} } }
5002   { \exp_args:Nf \__tl_item:nn { \int_eval:n { #1 - 1 } } }
5003 }
5004 \cs_new:Npn \tl_item:Nn { \exp_args:No \tl_item:nn }
5005 \cs_generate_variant:Nn \tl_item:Nn { c }

```

(End definition for `\tl_item:nn` and others. These functions are documented on page 49.)

```

\tl_rand_item:n Importantly \tl_item:nn only evaluates its argument once.
\tl_rand_item:N 5006 \cs_new:Npn \tl_rand_item:n #1
\tl_rand_item:c 5007 {
5008   \tl_if_blank:nF {#1}
5009   { \tl_item:nn {#1} { \int_rand:nn { 1 } { \tl_count:n {#1} } } }
5010 }
5011 \cs_new:Npn \tl_rand_item:N { \exp_args:No \tl_rand_item:n }
5012 \cs_generate_variant:Nn \tl_rand_item:N { c }

```

(End definition for `\tl_rand_item:n` and `\tl_rand_item:N`. These functions are documented on page 49.)

<pre> \tl_range:Nnn \tl_range:cnn \tl_range:nnn __tl_range:Nnnn __tl_range:nnnNn __tl_range:nnNn __tl_range_skip:w __tl_range:w __tl_range_skip_spaces:n __tl_range_collect:nn __tl_range_collect:ff __tl_range_collect_space:nw __tl_range_collect_N:nN __tl_range_collect_group:nN </pre>	<p>To avoid checking for the end of the token list at every step, start by counting the number l of items and “normalizing” the bounds, namely clamping them to the interval $[0, l]$ and dealing with negative indices. More precisely, <code>__tl_range_items:nnNn</code> receives the number of items to skip at the beginning of the token list, the index of the last item to keep, a function which is either <code>__tl_range:w</code> or the token list itself. If nothing should be kept, leave <code>{}</code>: this stops the <code>f</code>-expansion of <code>\tl_head:f</code> and that function produces an empty result. Otherwise, repeatedly call <code>__tl_range_skip:w</code> to delete #1 items from the input stream (the extra brace group avoids an off-by-one shift). For the braced version <code>__tl_range_braced:w</code> sets up <code>__tl_range_collect_braced:w</code> which stores items one by one in an argument after the semicolon. Depending on the first token of the tail, either just move it (if it is a space) or also decrement the number of items left to find. Eventually, the result is a brace group followed by the rest of the token list, and <code>\tl_head:f</code> cleans up and gives the result in <code>\exp_not:n</code>.</p> <pre> 5013 \cs_new:Npn \tl_range:Nnn { \exp_args:No \tl_range:nnn } 5014 \cs_generate_variant:Nn \tl_range:Nnn { c } 5015 \cs_new:Npn \tl_range:nnn { __tl_range:Nnnn __tl_range:w } 5016 \cs_new:Npn __tl_range:Nnnn #1#2#3#4 5017 { 5018 \tl_head:f 5019 { 5020 \exp_args:Nf __tl_range:nnnNn 5021 { \tl_count:n {#2} } {#3} {#4} #1 {#2} 5022 } 5023 } 5024 \cs_new:Npn __tl_range:nnnNn #1#2#3 5025 { 5026 \exp_args:Nff __tl_range:nnNn 5027 { 5028 \exp_args:Nf __tl_range_normalize:nn 5029 { \int_eval:n { #2 - 1 } } {#1} 5030 } 5031 { 5032 \exp_args:Nf __tl_range_normalize:nn 5033 { \int_eval:n {#3} } {#1} 5034 } 5035 } 5036 \cs_new:Npn __tl_range:nnNn #1#2#3#4 5037 { 5038 \if_int_compare:w #2 > #1 \exp_stop_f: \else: 5039 \exp_after:wN { \exp_after:wN } 5040 \fi: 5041 \exp_after:wN #3 5042 \int_value:w \int_eval:n { #2 - #1 } \exp_after:wN ; 5043 \exp_after:wN { \exp:w __tl_range_skip:w #1 ; { } #4 } 5044 } 5045 \cs_new:Npn __tl_range_skip:w #1 ; #2 5046 { 5047 \if_int_compare:w #1 > 0 \exp_stop_f: 5048 \exp_after:wN __tl_range_skip:w 5049 \int_value:w \int_eval:n { #1 - 1 } \exp_after:wN ; 5050 \else: 5051 \exp_after:wN \exp_end: 5052 \fi: </pre>
---	---

```

5053 }
5054 \cs_new:Npn \__tl_range:w #1 ; #2
5055 {
5056   \exp_args:Nf \__tl_range_collect:nn
5057   { \__tl_range_skip_spaces:n {#2} } {#1}
5058 }
5059 \cs_new:Npn \__tl_range_skip_spaces:n #1
5060 {
5061   \tl_if_head_is_space:nTF {#1}
5062   { \exp_args:Nf \__tl_range_skip_spaces:n {#1} }
5063   { { } #1 }
5064 }
5065 \cs_new:Npn \__tl_range_collect:nn #1#2
5066 {
5067   \int_compare:nNnTF {#2} = 0
5068   {#1}
5069   {
5070     \exp_args:No \tl_if_head_is_space:nTF { \use_none:n #1 }
5071     {
5072       \exp_args:Nf \__tl_range_collect:nn
5073       { \__tl_range_collect_space:nw #1 }
5074       {#2}
5075     }
5076     {
5077       \__tl_range_collect:ff
5078       {
5079         \exp_args:No \tl_if_head_is_N_type:nTF { \use_none:n #1 }
5080         { \__tl_range_collect_N:nN }
5081         { \__tl_range_collect_group:nn }
5082         #1
5083       }
5084       { \int_eval:n { #2 - 1 } }
5085     }
5086   }
5087 }
5088 \cs_new:Npn \__tl_range_collect_space:nw #1 ~ { { #1 ~ } }
5089 \cs_new:Npn \__tl_range_collect_N:nN #1#2 { { #1 #2 } }
5090 \cs_new:Npn \__tl_range_collect_group:nn #1#2 { { #1 {#2} } }
5091 \cs_generate_variant:Nn \__tl_range_collect:nn { ff }

```

(End definition for `\tl_range:Nnn` and others. These functions are documented on page 50.)

`__tl_range_normalize:nn` This function converts an $\langle index \rangle$ argument into an explicit position in the token list (a result of 0 denoting “out of bounds”). Expects two explicit integer arguments: the $\langle index \rangle$ #1 and the string count #2. If #1 is negative, replace it by $\#1 + \#2 + 1$, then limit to the range $[0, \#2]$.

```

5092 \cs_new:Npn \__tl_range_normalize:nn #1#2
5093 {
5094   \int_eval:n
5095   {
5096     \if_int_compare:w #1 < 0 \exp_stop_f:
5097     \if_int_compare:w #1 < -#2 \exp_stop_f:
5098     0
5099     \else:

```

```

5100         #1 + #2 + 1
5101     \fi:
5102 \else:
5103     \if_int_compare:w #1 < #2 \exp_stop_f:
5104         #1
5105     \else:
5106         #2
5107     \fi:
5108 \fi:
5109 }
5110 }

```

(End definition for `_tl_range_normalize:nn`.)

7.13 Viewing token lists

`\tl_show:N` Showing token list variables is done after checking that the variable is defined (see `_kernel_register_show:N`).

`\tl_log:N` `\tl_log:c` `_tl_show:NN`

```

5111 \cs_new_protected:Npn \tl\_show:N { \_tl\_show:NN \tl\_show:n }
5112 \cs_generate_variant:Nn \tl\_show:N { c }
5113 \cs_new_protected:Npn \tl\_log:N { \_tl\_show:NN \tl\_log:n }
5114 \cs_generate_variant:Nn \tl\_log:N { c }
5115 \cs_new_protected:Npn \_tl\_show:NN #1#2
5116 {
5117     \_kernel\_chk_defined:NT #2
5118     { \exp_args:Nx #1 { \token\_to\_str:N #2 = \exp\_not:o {#2} } }
5119 }

```

(End definition for `\tl_show:N`, `\tl_log:N`, and `_tl_show:NN`. These functions are documented on page 51.)

`\tl_show:n` Many `show` functions are based on `\tl_show:n`. The argument of `\tl_show:n` is line-wrapped using `\iow_wrap:nnnN` but with a leading `>~` and trailing period, both removed before passing the wrapped text to the `\showtokens` primitive. This primitive shows the result with a leading `>~` and trailing period.

The token list `\l_tl_internal_a_tl` containing the result of all these manipulations is displayed to the terminal using `\tex_showtokens:D` and an odd `\exp_after:wN` which expand the closing brace to improve the output slightly. The calls to `_kernel_iow_with:Nnn` ensure that the `\newlinechar` is set to 10 so that the `\iow_newline:` inserted by the line-wrapping code are correctly recognized by T_EX, and that `\errorcontextlines` is `-1` to avoid printing irrelevant context.

```

5120 \cs_new_protected:Npn \tl\_show:n #1
5121 { \iow\_wrap:nnnN { >~ \tl\_to\_str:n {#1} . } { } { } \_tl\_show:n }
5122 \cs_new_protected:Npn \_tl\_show:n #1
5123 {
5124     \tl\_set:Nf \l\_tl\_internal\_a\_tl { \_tl\_show:w #1 \q\_stop }
5125     \_kernel\_iow\_with:Nnn \tex\_newlinechar:D { 10 }
5126     {
5127         \_kernel\_iow\_with:Nnn \tex\_errorcontextlines:D { -1 }
5128         {
5129             \tex\_showtokens:D \exp\_after:wN \exp\_after:wN \exp\_after:wN
5130             { \exp\_after:wN \l\_tl\_internal\_a\_tl }
5131         }
5132     }

```



```

5132     }
5133   }
5134   \cs_new:Npn \__tl_show:w #1 > #2 . \q_stop {#2}

```

(End definition for `\tl_show:n`, `__tl_show:n`, and `__tl_show:w`. This function is documented on page 51.)

`\tl_log:n` Logging is much easier, simply line-wrap. The `>~` and trailing period is there to match the output of `\tl_show:n`.

```

5135 \cs_new_protected:Npn \tl_log:n #1
5136 { \iow_wrap:nnnN { > ~ \tl_to_str:n {#1} . } { } { } \iow_log:n }

```

(End definition for `\tl_log:n`. This function is documented on page 51.)

7.14 Scratch token lists

`\g_tmpa_tl` **`\g_tmpb_tl`** Global temporary token list variables. They are supposed to be set and used immediately, with no delay between the definition and the use because you can't count on other macros not to redefine them from under you.

```

5137 \tl_new:N \g_tmpa_tl
5138 \tl_new:N \g_tmpb_tl

```

(End definition for `\g_tmpa_tl` and `\g_tmpb_tl`. These variables are documented on page 52.)

`\l_tmpa_tl` **`\l_tmpb_tl`** These are local temporary token list variables. Be sure not to assume that the value you put into them will survive for long—see discussion above.

```

5139 \tl_new:N \l_tmpa_tl
5140 \tl_new:N \l_tmpb_tl

```

(End definition for `\l_tmpa_tl` and `\l_tmpb_tl`. These variables are documented on page 52.)

```

5141 \</initex | package>

```

8 l3str implementation

```

5142 \<*initex | package>

```

```

5143 \<@@=str>

```

8.1 Creating and setting string variables

`\str_new:N` **`\str_new:c`** A string is simply a token list. The full mapping system isn't set up yet so do things by hand.

```

\str_use:N      5144 \group_begin:
\str_use:c      5145 \cs_set_protected:Npn \__str_tmp:n #1
\str_clear:N    5146 {
\str_clear:c    5147   \tl_if_blank:nF {#1}
\str_gclear:N   5148   {
\str_gclear:c   5149     \cs_new_eq:cc { str_ #1 :N } { tl_ #1 :N }
\str_clear_new:N 5150     \exp_args:Nc \cs_generate_variant:Nn { str_ #1 :N } { c }
\str_clear_new:c 5151     \__str_tmp:n
\str_gclear_new:N 5152   }
\str_gclear_new:c 5153 }
\str_set_eq:NN  5154 \__str_tmp:n
\str_set_eq:cN  5155 { new }
\str_set_eq:Nc
\str_set_eq:cc
\str_gset_eq:NN
\str_gset_eq:cN
\str_gset_eq:Nc
\str_gset_eq:cc
\str_concat:NNN
\str_concat:ccc
\str_gconcat:NNN

```

```

5156     { use }
5157     { clear }
5158     { gclear }
5159     { clear_new }
5160     { gclear_new }
5161     { }
5162 \group_end:
5163 \cs_new_eq:NN \str_set_eq:NN \tl_set_eq:NN
5164 \cs_new_eq:NN \str_gset_eq:NN \tl_gset_eq:NN
5165 \cs_generate_variant:Nn \str_set_eq:NN { c , Nc , cc }
5166 \cs_generate_variant:Nn \str_gset_eq:NN { c , Nc , cc }
5167 \cs_new_eq:NN \str_concat:NNN \tl_concat:NNN
5168 \cs_new_eq:NN \str_gconcat:NNN \tl_gconcat:NNN
5169 \cs_generate_variant:Nn \str_concat:NNN { ccc }
5170 \cs_generate_variant:Nn \str_gconcat:NNN { ccc }

```

```

\str_set:Nn      Simply convert the token list inputs to  $\langle strings \rangle$ .
\str_set:NV      5171 \group_begin:
\str_set:Nx      5172 \cs_set_protected:Npn \__str_tmp:n #1
\str_set:cn      5173 {
\str_set:cV      5174 \tl_if_blank:nF {#1}
\str_set:cx      5175 {
\str_gset:Nn      5176 \cs_new_protected:cpx { str_ #1 :Nn } ##1##2
\str_gset:NV      5177 {
\str_gset:Nx      5178 \exp_not:c { tl_ #1 :Nx } ##1
\str_gset:cn      5179 { \exp_not:N \tl_to_str:n {##2} }
\str_gset:cV      5180 }
\str_gset:cx      5181 \cs_generate_variant:cn { str_ #1 :Nn } { NV , Nx , cn , cV , cx }
\str_gset:cx      5182 \__str_tmp:n
\str_const:Nn     5183 }
\str_const:NV     5184 }
\str_const:Nx     5185 \__str_tmp:n
\str_const:cn     5186 { set }
\str_const:cV     5187 { gset }
\str_const:cx     5188 { const }
\str_const:cx     5189 { put_left }
\str_const:cx     5190 { gput_left }
\str_const:cx     5191 { put_right }
\str_const:cx     5192 { gput_right }
\str_const:cn     5193 { }
\str_const:cV     5194 \group_end:
\str_const:cx

```

Start by applying `\tl_to_str:n` to convert the old and new token lists to strings, and also apply `\tl_to_str:N` to avoid any issues if we are fed a token list variable. Then the code is a much simplified version of the token list code because neither the delimiter nor the replacement can contain macro parameters or braces. The delimiter `\q_mark` cannot appear in the string to edit so it is used in all cases. Some `x-expansion` is unnecessary.

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There is no need to avoid losing braces nor to protect against expansion. The ending code is much simplified and does not need to hide in braces.

```

5195 \cs_new_protected:Npn \str_replace_once:Nnn
5196 { \__str_replace:NNNnn \prg_do_nothing: \tl_set:Nx }
5197 \cs_new_protected:Npn \str_greplace_once:Nnn
5198 { \__str_replace:NNNnn \prg_do_nothing: \tl_gset:Nx }
5199 \cs_new_protected:Npn \str_replace_all:Nnn
5200 { \__str_replace:NNNnn \__str_replace_next:w \tl_set:Nx }
5201 \cs_new_protected:Npn \str_greplace_all:Nnn
5202 { \__str_replace:NNNnn \__str_replace_next:w \tl_gset:Nx }
5203 \cs_generate_variant:Nn \str_replace_once:Nnn { c }
5204 \cs_generate_variant:Nn \str_greplace_once:Nnn { c }
5205 \cs_generate_variant:Nn \str_replace_all:Nnn { c }
5206 \cs_generate_variant:Nn \str_greplace_all:Nnn { c }
5207 \cs_new_protected:Npn \__str_replace:NNNnn #1#2#3#4#5
5208 {
5209     \tl_if_empty:nTF {#4}
5210     {
5211         \__kernel_msg_error:nnx { kernel } { empty-search-pattern } {#5}
5212     }
5213     {
5214         \use:x
5215         {
5216             \exp_not:n { \__str_replace_aux:NNNnnn #1 #2 #3 }
5217             { \tl_to_str:N #3 }
5218             { \tl_to_str:n {#4} } { \tl_to_str:n {#5} }
5219         }
5220     }
5221 }
5222 \cs_new_protected:Npn \__str_replace_aux:NNNnnn #1#2#3#4#5#6
5223 {
5224     \cs_set:Npn \__str_replace_next:w ##1 #5 { ##1 #6 #1 }
5225     #2 #3
5226     {
5227         \__str_replace_next:w
5228         #4
5229         \use_none_delimit_by_q_stop:w
5230         #5
5231         \q_stop
5232     }
5233 }
5234 \cs_new_eq:NN \__str_replace_next:w ?

```

(End definition for `\str_replace_all:Nnn` and others. These functions are documented on page 55.)

```

\str_remove_once:Nn Removal is just a special case of replacement.
\str_remove_once:cn
\str_gremove_once:Nn
\str_gremove_once:cn
5235 \cs_new_protected:Npn \str_remove_once:Nn #1#2
5236 { \str_replace_once:Nnn #1 {#2} { } }
5237 \cs_new_protected:Npn \str_gremove_once:Nn #1#2
5238 { \str_greplace_once:Nnn #1 {#2} { } }
5239 \cs_generate_variant:Nn \str_remove_once:Nn { c }
5240 \cs_generate_variant:Nn \str_gremove_once:Nn { c }

```

(End definition for `\str_remove_once:Nn` and `\str_gremove_once:Nn`. These functions are documented on page 55.)

```

\str_remove_all:Nn Removal is just a special case of replacement.
\str_remove_all:cn 5241 \cs_new_protected:Npn \str_remove_all:Nn #1#2
\str_gremove_all:Nn 5242 { \str_replace_all:Nnn #1 {#2} { } }
\str_gremove_all:cn 5243 \cs_new_protected:Npn \str_gremove_all:Nn #1#2
5244 { \str_greplace_all:Nnn #1 {#2} { } }
5245 \cs_generate_variant:Nn \str_remove_all:Nn { c }
5246 \cs_generate_variant:Nn \str_gremove_all:Nn { c }

```

(End definition for `\str_remove_all:Nn` and `\str_gremove_all:Nn`. These functions are documented on page 55.)

8.3 String comparisons

```

\str_if_empty_p:N More copy-paste!
\str_if_empty_p:c 5247 \prg_new_eq_conditional:Nnn \str_if_exist:N \tl_if_exist:N
\str_if_empty:NTF 5248 { p , T , F , TF }
\str_if_empty:cTF 5249 \prg_new_eq_conditional:Nnn \str_if_exist:c \tl_if_exist:c
\str_if_exist_p:N 5250 { p , T , F , TF }
\str_if_exist_p:c 5251 \prg_new_eq_conditional:Nnn \str_if_empty:N \tl_if_empty:N
\str_if_exist:NTF 5252 { p , T , F , TF }
\str_if_exist:cTF 5253 \prg_new_eq_conditional:Nnn \str_if_empty:c \tl_if_empty:c
5254 { p , T , F , TF }

```

(End definition for `\str_if_empty:NTF` and `\str_if_exist:NTF`. These functions are documented on page 56.)

`__str_if_eq:nn` String comparisons rely on the primitive `\(pdf)strcmp` if available: LuaTeX does not have it, so emulation is required. As the net result is that we do not *always* use the primitive, the correct approach is to wrap up in a function with defined behaviour. That's done by providing a wrapper and then redefining in the LuaTeX case. Note that the necessary Lua code is loaded in `l3bootstrap`. The need to detokenize and force expansion of input arises from the case where a `#` token is used in the input, e.g. `__str_if_eq:nn {#} { \tl_to_str:n {#} }`, which otherwise would fail as `\tex_luaescapestring:D` does not double such tokens.

```

5255 \cs_new:Npn __str_if_eq:nn #1#2 { \tex_strcmp:D {#1} {#2} }
5256 \cs_if_exist:NT \tex_luaescapestring:D
5257 {
5258   \cs_set_eq:NN \lua_escape:e \tex_luaescapestring:D
5259   \cs_set_eq:NN \lua_now:e \tex_directlua:D
5260   \cs_set:Npn __str_if_eq:nn #1#2
5261   {
5262     \lua_now:e
5263     {
5264       l3kernel_strcmp
5265       (
5266         " __str_escape:n {#1} " ,
5267         " __str_escape:n {#2} "
5268       )
5269     }
5270   }
5271   \cs_new:Npn __str_escape:n #1
5272   {
5273     \lua_escape:e
5274     { \__kernel_tl_to_str:w \use:e { {#1} } }

```

```

5275     }
5276 }

```

(End definition for `_str_if_eq:nn` and `_str_escape:n`.)

`\str_if_eq_p:nn` Modern engines provide a direct way of comparing two token lists, but returning a number. This set of conditionals therefore make life a bit clearer. The `nn` and `xx` versions are created directly as this is most efficient.

```

\str_if_eq_p:Vn
\str_if_eq_p:on
\str_if_eq_p:nV
\str_if_eq_p:no
\str_if_eq_p:VV
\str_if_eq:nnTF
\str_if_eq:VnTF
\str_if_eq:onTF
\str_if_eq:nVTF
\str_if_eq:noTF
\str_if_eq:VnTF
\str_if_eq:ee
\str_if_eq:eeTF

```

```

5277 \prg_new_conditional:Npnn \str_if_eq:nn #1#2 { p , T , F , TF }
5278 {
5279     \if_int_compare:w
5280         \_str_if_eq:nn { \exp_not:n {#1} } { \exp_not:n {#2} }
5281         = 0 \exp_stop_f:
5282         \prg_return_true: \else: \prg_return_false: \fi:
5283     }
5284 \prg_generate_conditional_variant:Nnn \str_if_eq:nn
5285 { V , v , o , nV , no , VV , nv } { p , T , F , TF }
5286 \prg_new_conditional:Npnn \str_if_eq:ee #1#2 { p , T , F , TF }
5287 {
5288     \if_int_compare:w \_str_if_eq:nn {#1} {#2} = 0 \exp_stop_f:
5289     \prg_return_true: \else: \prg_return_false: \fi:
5290 }

```

(End definition for `\str_if_eq:nnTF` and `\str_if_eq:eeTF`. These functions are documented on page 56.)

`\str_if_eq_p:NN` Note that `\str_if_eq:NN` is different from `\tl_if_eq:NN` because it needs to ignore category codes.

```

\str_if_eq_p:Nc
\str_if_eq_p:cN
\str_if_eq_p:cc
\str_if_eq:NNTF
\str_if_eq:NcTF
\str_if_eq:cNTF
\str_if_eq:ccTF

```

```

5291 \prg_new_conditional:Npnn \str_if_eq:NN #1#2 { p , TF , T , F }
5292 {
5293     \if_int_compare:w
5294         \_str_if_eq:nn { \tl_to_str:N #1 } { \tl_to_str:N #2 }
5295         = 0 \exp_stop_f: \prg_return_true: \else: \prg_return_false: \fi:
5296     }
5297 \prg_generate_conditional_variant:Nnn \str_if_eq:NN
5298 { c , Nc , cc } { T , F , TF , p }

```

(End definition for `\str_if_eq:NNTF`. This function is documented on page 56.)

`\str_if_in:NnTF` Everything here needs to be detokenized but beyond that it is a simple token list test.
`\str_if_in:cnTF` It would be faster to fine-tune the T, F, TF variants by calling the appropriate variant of
`\str_if_in:nnTF` `\tl_if_in:nnTF` directly but that takes more code.

```

5299 \prg_new_protected_conditional:Npnn \str_if_in:Nn #1#2 { T , F , TF }
5300 {
5301     \use:x
5302     { \tl_if_in:nnTF { \tl_to_str:N #1 } { \tl_to_str:n {#2} } }
5303     { \prg_return_true: } { \prg_return_false: }
5304 }
5305 \prg_generate_conditional_variant:Nnn \str_if_in:Nn
5306 { c } { T , F , TF }
5307 \prg_new_protected_conditional:Npnn \str_if_in:nn #1#2 { T , F , TF }
5308 {
5309     \use:x
5310     { \tl_if_in:nnTF { \tl_to_str:n {#1} } { \tl_to_str:n {#2} } }
5311     { \prg_return_true: } { \prg_return_false: }
5312 }

```

(End definition for `\str_if_in:NnTF` and `\str_if_in:nnTF`. These functions are documented on page 56.)

`\str_case:nn` Much the same as `\tl_case:nn(TF)` here: just a change in the internal comparison.

```

\str_case:on      5313 \cs_new:Npn \str_case:nn #1#2
\str_case:nV      5314 {
\str_case:nv      5315   \exp:w
\str_case:nnTF    5316   \__str_case:nnTF {#1} {#2} { } { }
\str_case:onTF    5317 }
\str_case:nVTF    5318 \cs_new:Npn \str_case:nnT #1#2#3
\str_case:nvTF    5319 {
\str_case_e:nn    5320   \exp:w
\str_case_e:nnTF  5321   \__str_case:nnTF {#1} {#2} {#3} { }
\__str_case:nnTF  5322 }
\__str_case_e:nnTF 5323 \cs_new:Npn \str_case:nnF #1#2
\__str_case:nw    5324 {
\__str_case_e:nw  5325   \exp:w
\__str_case_e:nw  5326   \__str_case:nnTF {#1} {#2} { }
\__str_case_end:nw 5327 }
                    5328 \cs_new:Npn \str_case:nnTF #1#2
                    5329 {
                    5330   \exp:w
                    5331   \__str_case:nnTF {#1} {#2}
                    5332 }
                    5333 \cs_new:Npn \__str_case:nnTF #1#2#3#4
                    5334 { \__str_case:nw {#1} #2 {#1} { } \q_mark {#3} \q_mark {#4} \q_stop }
                    5335 \cs_generate_variant:Nn \str_case:nn { o , nV , nv }
                    5336 \prg_generate_conditional_variant:Nnn \str_case:nn
                    5337 { o , nV , nv } { T , F , TF }
                    5338 \cs_new:Npn \__str_case:nw #1#2#3
                    5339 {
                    5340   \str_if_eq:nnTF {#1} {#2}
                    5341   { \__str_case_end:nw {#3} }
                    5342   { \__str_case:nw {#1} }
                    5343 }
                    5344 \cs_new:Npn \str_case_e:nn #1#2
                    5345 {
                    5346   \exp:w
                    5347   \__str_case_e:nnTF {#1} {#2} { } { }
                    5348 }
                    5349 \cs_new:Npn \str_case_e:nnT #1#2#3
                    5350 {
                    5351   \exp:w
                    5352   \__str_case_e:nnTF {#1} {#2} {#3} { }
                    5353 }
                    5354 \cs_new:Npn \str_case_e:nnF #1#2
                    5355 {
                    5356   \exp:w
                    5357   \__str_case_e:nnTF {#1} {#2} { }
                    5358 }
                    5359 \cs_new:Npn \str_case_e:nnTF #1#2
                    5360 {
                    5361   \exp:w
                    5362   \__str_case_e:nnTF {#1} {#2}

```

```

5363 }
5364 \cs_new:Npn \__str_case_e:nnTF #1#2#3#4
5365 { \__str_case_e:nw {#1} #2 {#1} { } \q_mark {#3} \q_mark {#4} \q_stop }
5366 \cs_new:Npn \__str_case_e:nw #1#2#3
5367 {
5368   \str_if_eq:eeTF {#1} {#2}
5369   { \__str_case_end:nw {#3} }
5370   { \__str_case_e:nw {#1} }
5371 }
5372 \cs_new:Npn \__str_case_end:nw #1#2#3 \q_mark #4#5 \q_stop
5373 { \exp_end: #1 #4 }

```

(End definition for `\str_case:nnTF` and others. These functions are documented on page 57.)

8.4 Mapping to strings

`\str_map_function:Nn` The inline and variable mappings are similar to the usual token list mappings but start out by turning the argument to an “other string”. Doing the same for the expandable function mapping would require `__kernel_str_to_other:n`, quadratic in the string length. To deal with spaces in that case, `__str_map_function:w` replaces the following space by a braced space and a further call to itself. These are received by `__str_map_function:Nn`, which passes the space to #1 and calls `__str_map_function:w` to deal with the next space. The space before the braced space allows to optimize the `\q_recursion_tail` test. Of course we need to include a trailing space (the question mark is needed to avoid losing the space when TeX tokenizes the line). At the cost of about three more auxiliaries this code could get a 9 times speed up by testing only every 9-th character for whether it is `\q_recursion_tail` (also by converting 9 spaces at a time in the `\str_map_function:nN` case).

```

\str_map_function:cN
\str_map_function:nN
  \str_map_inline:Nn
    \str_map_inline:cn
      \str_map_inline:nn
\str_map_variable:NNn
\str_map_variable:cNn
\str_map_variable:nNn
  \str_map_break:
    \str_map_break:n
      \__str_map_function:w
\__str_map_function:Nn
  \__str_map_inline:NN
\__str_map_variable:NnN
5374 \cs_new:Npn \str_map_function:nN #1#2
5375 {
5376   \exp_after:wN \__str_map_function:w
5377   \exp_after:wN \__str_map_function:Nn \exp_after:wN #2
5378   \__kernel_tl_to_str:w {#1}
5379   \q_recursion_tail ? ~
5380   \prg_break_point:Nn \str_map_break: { }
5381 }
5382 \cs_new:Npn \str_map_function:NN
5383 { \exp_args:No \str_map_function:nN }
5384 \cs_new:Npn \__str_map_function:w #1 ~
5385 { #1 { ~ { ~ } \__str_map_function:w } }
5386 \cs_new:Npn \__str_map_function:Nn #1#2
5387 {
5388   \if_meaning:w \q_recursion_tail #2
5389   \exp_after:wN \str_map_break:
5390   \fi:
5391   #1 #2 \__str_map_function:Nn #1
5392 }
5393 \cs_generate_variant:Nn \str_map_function:NN { c }
5394 \cs_new_protected:Npn \str_map_inline:nn #1#2
5395 {
5396   \int_gincr:N \g__kernel_prg_map_int
5397   \cs_gset_protected:cpn
5398   { \__str_map_ \int_use:N \g__kernel_prg_map_int :w } ##1 {#2}

```

```

5399 \use:x
5400 {
5401   \exp_not:N \__str_map_inline:NN
5402   \exp_not:c { \__str_map_ \int_use:N \g__kernel_prg_map_int :w }
5403   \__kernel_str_to_other_fast:n {#1}
5404 }
5405 \q_recursion_tail
5406 \prg_break_point:Nn \str_map_break:
5407 { \int_gdecr:N \g__kernel_prg_map_int }
5408 }
5409 \cs_new_protected:Npn \str_map_inline:Nn
5410 { \exp_args:No \str_map_inline:nn }
5411 \cs_generate_variant:Nn \str_map_inline:Nn { c }
5412 \cs_new:Npn \__str_map_inline:NN #1#2
5413 {
5414   \quark_if_recursion_tail_break:NN #2 \str_map_break:
5415   \exp_args:No #1 { \token_to_str:N #2 }
5416   \__str_map_inline:NN #1
5417 }
5418 \cs_new_protected:Npn \str_map_variable:nNn #1#2#3
5419 {
5420   \use:x
5421   {
5422     \exp_not:n { \__str_map_variable:NnN #2 {#3} }
5423     \__kernel_str_to_other_fast:n {#1}
5424   }
5425   \q_recursion_tail
5426   \prg_break_point:Nn \str_map_break: { }
5427 }
5428 \cs_new_protected:Npn \str_map_variable:NNn
5429 { \exp_args:No \str_map_variable:nNn }
5430 \cs_new_protected:Npn \__str_map_variable:NnN #1#2#3
5431 {
5432   \quark_if_recursion_tail_break:NN #3 \str_map_break:
5433   \str_set:Nn #1 {#3}
5434   \use:n {#2}
5435   \__str_map_variable:NnN #1 {#2}
5436 }
5437 \cs_generate_variant:Nn \str_map_variable:NNn { c }
5438 \cs_new:Npn \str_map_break:
5439 { \prg_map_break:Nn \str_map_break: { } }
5440 \cs_new:Npn \str_map_break:n
5441 { \prg_map_break:Nn \str_map_break: }

```

(End definition for `\str_map_function:NN` and others. These functions are documented on page 57.)

8.5 Accessing specific characters in a string

`__kernel_str_to_other:n` First apply `\tl_to_str:n`, then replace all spaces by “other” spaces, 8 at a time, storing the converted part of the string between the `\q_mark` and `\q_stop` markers. The end is detected when `__str_to_other_loop:w` finds one of the trailing A, distinguished from any contents of the initial token list by their category. Then `__str_to_other_end:w` is called, and finds the result between `\q_mark` and the first A (well, there is also the need to remove a space).


```

5442 \cs_new:Npn \__kernel_str_to_other:n #1
5443 {
5444   \exp_after:wN \__str_to_other_loop:w
5445   \tl_to_str:n {#1} ~ A ~ A ~ A ~ A ~ A ~ A ~ A ~ \q_mark \q_stop
5446 }
5447 \group_begin:
5448 \tex_lccode:D '\* = '\ %
5449 \tex_lccode:D '\A = '\A %
5450 \tex_lowercase:D
5451 {
5452   \group_end:
5453   \cs_new:Npn \__str_to_other_loop:w
5454     #1 ~ #2 ~ #3 ~ #4 ~ #5 ~ #6 ~ #7 ~ #8 ~ #9 \q_stop
5455   {
5456     \if_meaning:w A #8
5457       \__str_to_other_end:w
5458     \fi:
5459     \__str_to_other_loop:w
5460     #9 #1 * #2 * #3 * #4 * #5 * #6 * #7 * #8 * \q_stop
5461   }
5462   \cs_new:Npn \__str_to_other_end:w \fi: #1 \q_mark #2 * A #3 \q_stop
5463   { \fi: #2 }
5464 }

```

(End definition for __kernel_str_to_other:n, __str_to_other_loop:w, and __str_to_other_end:w.)

__kernel_str_to_other_fast:n
 __kernel_str_to_other_fast_loop:w
 __str_to_other_fast_end:w

The difference with __kernel_str_to_other:n is that the converted part is left in the input stream, making these commands only restricted-expandable.

```

5465 \cs_new:Npn \__kernel_str_to_other_fast:n #1
5466 {
5467   \exp_after:wN \__str_to_other_fast_loop:w \tl_to_str:n {#1} ~
5468   A ~ A ~ A ~ A ~ A ~ A ~ A ~ A ~ A ~ \q_stop
5469 }
5470 \group_begin:
5471 \tex_lccode:D '\* = '\ %
5472 \tex_lccode:D '\A = '\A %
5473 \tex_lowercase:D
5474 {
5475   \group_end:
5476   \cs_new:Npn \__str_to_other_fast_loop:w
5477     #1 ~ #2 ~ #3 ~ #4 ~ #5 ~ #6 ~ #7 ~ #8 ~ #9 ~
5478   {
5479     \if_meaning:w A #9
5480       \__str_to_other_fast_end:w
5481     \fi:
5482     #1 * #2 * #3 * #4 * #5 * #6 * #7 * #8 * #9
5483     \__str_to_other_fast_loop:w *
5484   }
5485   \cs_new:Npn \__str_to_other_fast_end:w #1 * A #2 \q_stop {#1}
5486 }

```

(End definition for __kernel_str_to_other_fast:n, __kernel_str_to_other_fast_loop:w, and __str_to_other_fast_end:w.)

`\str_item:Nn` The `\str_item:nn` hands its argument with spaces escaped to `__str_item:nn`, and
`\str_item:cn` makes sure to turn the result back into a proper string (with category code 10 spaces)
`\str_item:nn` eventually. The `\str_item_ignore_spaces:nn` function does not escape spaces, which
`\str_item_ignore_spaces:nn` are thus ignored by `__str_item:nn` since everything else is done with undelimited ar-
`__str_item:nn` guments. Evaluate the $\langle index \rangle$ argument #2 and count characters in the string, passing
`__str_item:w` those two numbers to `__str_item:w` for further analysis. If the $\langle index \rangle$ is negative, shift
it by the $\langle count \rangle$ to know the how many character to discard, and if that is still negative
give an empty result. If the $\langle index \rangle$ is larger than the $\langle count \rangle$, give an empty result, and
otherwise discard $\langle index \rangle - 1$ characters before returning the following one. The shift by
 -1 is obtained by inserting an empty brace group before the string in that case: that
brace group also covers the case where the $\langle index \rangle$ is zero.

```

5487 \cs_new:Npn \str_item:Nn { \exp_args:No \str_item:nn }
5488 \cs_generate_variant:Nn \str_item:Nn { c }
5489 \cs_new:Npn \str_item:nn #1#2
5490 {
5491   \exp_args:Nf \tl_to_str:n
5492   {
5493     \exp_args:Nf \__str_item:nn
5494     { \__kernel_str_to_other:n {#1} } {#2}
5495   }
5496 }
5497 \cs_new:Npn \str_item_ignore_spaces:nn #1
5498 { \exp_args:No \__str_item:nn { \tl_to_str:n {#1} } }
5499 \cs_new:Npn \__str_item:nn #1#2
5500 {
5501   \exp_after:wN \__str_item:w
5502   \int_value:w \int_eval:n {#2} \exp_after:wN ;
5503   \int_value:w \__str_count:n {#1} ;
5504   #1 \q_stop
5505 }
5506 \cs_new:Npn \__str_item:w #1; #2;
5507 {
5508   \int_compare:nNnTF {#1} < 0
5509   {
5510     \int_compare:nNnTF {#1} < {-#2}
5511     { \use_none_delimit_by_q_stop:w }
5512     {
5513       \exp_after:wN \use_i_delimit_by_q_stop:nw
5514       \exp:w \exp_after:wN \__str_skip_exp_end:w
5515       \int_value:w \int_eval:n { #1 + #2 } ;
5516     }
5517   }
5518   {
5519     \int_compare:nNnTF {#1} > {#2}
5520     { \use_none_delimit_by_q_stop:w }
5521     {
5522       \exp_after:wN \use_i_delimit_by_q_stop:nw
5523       \exp:w \__str_skip_exp_end:w #1 ; { }
5524     }
5525   }
5526 }

```

(End definition for `\str_item:Nn` and others. These functions are documented on page 60.)

`__str_skip_exp_end:w` Removes `max(#1,0)` characters from the input stream, and then leaves `\exp_end:`. This should be expanded using `\exp:w`. We remove characters 8 at a time until there are at most 8 to remove. Then we do a dirty trick: the `\if_case:w` construction leaves between 0 and 8 times the `\or:` control sequence, and those `\or:` become arguments of `__str_skip_end:NNNNNNNN`. If the number of characters to remove is 6, say, then there are two `\or:` left, and the 8 arguments of `__str_skip_end:NNNNNNNN` are the two `\or:`, and 6 characters from the input stream, exactly what we wanted to remove. Then close the `\if_case:w` conditional with `\fi:`, and stop the initial expansion with `\exp_end:` (see places where `__str_skip_exp_end:w` is called).

```

5527 \cs_new:Npn \__str_skip_exp_end:w #1;
5528 {
5529     \if_int_compare:w #1 > 8 \exp_stop_f:
5530     \exp_after:wN \__str_skip_loop:wNNNNNNNN
5531     \else:
5532     \exp_after:wN \__str_skip_end:w
5533     \int_value:w \int_eval:w
5534     \fi:
5535     #1 ;
5536 }
5537 \cs_new:Npn \__str_skip_loop:wNNNNNNNN #1; #2#3#4#5#6#7#8#9
5538 {
5539     \exp_after:wN \__str_skip_exp_end:w
5540     \int_value:w \int_eval:n { #1 - 8 } ;
5541 }
5542 \cs_new:Npn \__str_skip_end:w #1 ;
5543 {
5544     \exp_after:wN \__str_skip_end:NNNNNNNN
5545     \if_case:w #1 \exp_stop_f: \or: \or: \or: \or: \or: \or: \or: \or:
5546 }
5547 \cs_new:Npn \__str_skip_end:NNNNNNNN #1#2#3#4#5#6#7#8 { \fi: \exp_end: }

```

(End definition for `__str_skip_exp_end:w` and others.)

`\str_range:Nnn` Sanitize the string. Then evaluate the arguments. At this stage we also decrement the `\str_range:nnn` `<start index>`, since our goal is to know how many characters should be removed. Then `\str_range_ignore_spaces:nnn` limit the range to be non-negative and at most the length of the string (this avoids needing to check for the end of the string when grabbing characters), shifting negative numbers by the appropriate amount. Afterwards, skip characters, then keep some more, and finally drop the end of the string.

```

5548 \cs_new:Npn \str_range:Nnn { \exp_args:No \str_range:nnn }
5549 \cs_generate_variant:Nn \str_range:Nnn { c }
5550 \cs_new:Npn \str_range:nnn #1#2#3
5551 {
5552     \exp_args:Nf \tl_to_str:n
5553     {
5554         \exp_args:Nf \__str_range:nnn
5555         { \__kernel_str_to_other:n {#1} } {#2} {#3}
5556     }
5557 }
5558 \cs_new:Npn \str_range_ignore_spaces:nnn #1
5559 { \exp_args:No \__str_range:nnn { \tl_to_str:n {#1} } }
5560 \cs_new:Npn \__str_range:nnn #1#2#3
5561 {

```

```

5562     \exp_after:wN \_str_range:w
5563     \int_value:w \_str_count:n {#1} \exp_after:wN ;
5564     \int_value:w \int_eval:n { (#2) - 1 } \exp_after:wN ;
5565     \int_value:w \int_eval:n {#3} ;
5566     #1 \q_stop
5567   }
5568 \cs_new:Npn \_str_range:w #1; #2; #3;
5569 {
5570   \exp_args:Nf \_str_range:nnw
5571   { \_str_range_normalize:nn {#2} {#1} }
5572   { \_str_range_normalize:nn {#3} {#1} }
5573 }
5574 \cs_new:Npn \_str_range:nnw #1#2
5575 {
5576   \exp_after:wN \_str_collect_delimit_by_q_stop:w
5577   \int_value:w \int_eval:n { #2 - #1 } \exp_after:wN ;
5578   \exp:w \_str_skip_exp_end:w #1 ;
5579 }

```

(End definition for `\str_range:Nnn` and others. These functions are documented on page 61.)

`_str_range_normalize:nn` This function converts an *⟨index⟩* argument into an explicit position in the string (a result of 0 denoting “out of bounds”). Expects two explicit integer arguments: the *⟨index⟩* #1 and the string count #2. If #1 is negative, replace it by #1 + #2 + 1, then limit to the range [0, #2].

```

5580 \cs_new:Npn \_str_range_normalize:nn #1#2
5581 {
5582   \int_eval:n
5583   {
5584     \if_int_compare:w #1 < 0 \exp_stop_f:
5585     \if_int_compare:w #1 < -#2 \exp_stop_f:
5586     0
5587     \else:
5588     #1 + #2 + 1
5589     \fi:
5590   \else:
5591     \if_int_compare:w #1 < #2 \exp_stop_f:
5592     #1
5593     \else:
5594     #2
5595     \fi:
5596   \fi:
5597 }
5598 }

```

(End definition for `_str_range_normalize:nn`.)

`_str_collect_delimit_by_q_stop:w` Collects $\max(\#1, 0)$ characters, and removes everything else until `\q_stop`. This is somewhat similar to `_str_skip_exp_end:w`, but accepts integer expression arguments. This time we can only grab 7 characters at a time. At the end, we use an `\if_case:w` trick again, so that the 8 first arguments of `_str_collect_end:nnnnnnnnw` are some `\or:`, followed by an `\fi:`, followed by #1 characters from the input stream. Simply leaving this in the input stream closes the conditional properly and the `\or:` disappear.

```

5599 \cs_new:Npn \_str_collect_delimit_by_q_stop:w #1;

```

```

5600 { \__str_collect_loop:wn #1 ; { } }
5601 \cs_new:Npn \__str_collect_loop:wn #1 ;
5602 {
5603   \if_int_compare:w #1 > 7 \exp_stop_f:
5604   \exp_after:wN \__str_collect_loop:wnNNNNNNN
5605   \else:
5606   \exp_after:wN \__str_collect_end:wn
5607   \fi:
5608   #1 ;
5609 }
5610 \cs_new:Npn \__str_collect_loop:wnNNNNNNN #1; #2 #3#4#5#6#7#8#9
5611 {
5612   \exp_after:wN \__str_collect_loop:wn
5613   \int_value:w \int_eval:n { #1 - 7 } ;
5614   { #2 #3#4#5#6#7#8#9 }
5615 }
5616 \cs_new:Npn \__str_collect_end:wn #1 ;
5617 {
5618   \exp_after:wN \__str_collect_end:nnnnnnnnw
5619   \if_case:w \if_int_compare:w #1 > 0 \exp_stop_f:
5620   #1 \else: 0 \fi: \exp_stop_f:
5621   \or: \or: \or: \or: \or: \or: \or: \fi:
5622 }
5623 \cs_new:Npn \__str_collect_end:nnnnnnnnw #1#2#3#4#5#6#7#8 #9 \q_stop
5624 { #1#2#3#4#5#6#7#8 }

```

(End definition for __str_collect_delimit_by_q_stop:w and others.)

8.6 Counting characters

\str_count_spaces:N To speed up this function, we grab and discard 9 space-delimited arguments in each iteration of the loop. The loop stops when the last argument is one of the trailing $X\langle number \rangle$, and that $\langle number \rangle$ is added to the sum of 9 that precedes, to adjust the result.

```

\str_count_spaces:c
\str_count_spaces:n
\__str_count_spaces_loop:w
5625 \cs_new:Npn \str_count_spaces:N
5626 { \exp_args:No \str_count_spaces:n }
5627 \cs_generate_variant:Nn \str_count_spaces:N { c }
5628 \cs_new:Npn \str_count_spaces:n #1
5629 {
5630   \int_eval:n
5631   {
5632     \exp_after:wN \__str_count_spaces_loop:w
5633     \tl_to_str:n {#1} ~
5634     X 7 ~ X 6 ~ X 5 ~ X 4 ~ X 3 ~ X 2 ~ X 1 ~ X 0 ~ X -1 ~
5635     \q_stop
5636   }
5637 }
5638 \cs_new:Npn \__str_count_spaces_loop:w #1~#2~#3~#4~#5~#6~#7~#8~#9~
5639 {
5640   \if_meaning:w X #9
5641   \use_i_delimit_by_q_stop:nw
5642   \fi:
5643   9 + \__str_count_spaces_loop:w
5644 }

```

(End definition for `\str_count_spaces:N`, `\str_count_spaces:n`, and `__str_count_spaces_loop:w`. These functions are documented on page 59.)

`\str_count:N` To count characters in a string we could first escape all spaces using `__kernel_str_to_other:n`, then pass the result to `\tl_count:n`. However, the escaping step would be quadratic in the number of characters in the string, and we can do better. Namely, sum the number of spaces (`\str_count_spaces:n`) and the result of `\tl_count:n`, which ignores spaces. Since strings tend to be longer than token lists, we use specialized functions to count characters ignoring spaces. Namely, `loop`, grabbing 9 non-space characters at each step, and end as soon as we reach one of the 9 trailing items. The internal function `__str_count:n`, used in `\str_item:nn` and `\str_range:nnn`, is similar to `\str_count_ignore_spaces:n` but expects its argument to already be a string or a string with spaces escaped.

```

5645 \cs_new:Npn \str_count:N { \exp_args:No \str_count:n }
5646 \cs_generate_variant:Nn \str_count:N { c }
5647 \cs_new:Npn \str_count:n #1
5648 {
5649   \__str_count_aux:n
5650   {
5651     \str_count_spaces:n {#1}
5652     + \exp_after:wN \__str_count_loop:NNNNNNNN \tl_to_str:n {#1}
5653   }
5654 }
5655 \cs_new:Npn \__str_count:n #1
5656 {
5657   \__str_count_aux:n
5658   { \__str_count_loop:NNNNNNNN #1 }
5659 }
5660 \cs_new:Npn \str_count_ignore_spaces:n #1
5661 {
5662   \__str_count_aux:n
5663   { \exp_after:wN \__str_count_loop:NNNNNNNN \tl_to_str:n {#1} }
5664 }
5665 \cs_new:Npn \__str_count_loop:NNNNNNNN #1#2#3#4#5#6#7#8#9
5666 {
5667   \int_eval:n
5668   {
5669     #1
5670     { X 8 } { X 7 } { X 6 }
5671     { X 5 } { X 4 } { X 3 }
5672     { X 2 } { X 1 } { X 0 }
5673     \q_stop
5674   }
5675 }
5676 \cs_new:Npn \__str_count_loop:NNNNNNNN #1#2#3#4#5#6#7#8#9
5677 {
5678   \if_meaning:w X #9
5679     \exp_after:wN \use_none_delimit_by_q_stop:w
5680   \fi:
5681   9 + \__str_count_loop:NNNNNNNN
5682 }
```

(End definition for `\str_count:N` and others. These functions are documented on page 59.)

8.7 The first character in a string

`\str_head:N` The `_ignore_spaces` variant applies `\tl_to_str:n` then grabs the first item, thus skipping spaces. As usual, `\str_head:N` expands its argument and hands it to `\str_head:n`.
`\str_head:c` To circumvent the fact that \TeX skips spaces when grabbing undelimited macro parameters, `__str_head:w` takes an argument delimited by a space. If `#1` starts with a non-space character, `\use_i_delimit_by_q_stop:nw` leaves that in the input stream. On the other hand, if `#1` starts with a space, the `__str_head:w` takes an empty argument, and the single (initially braced) space in the definition of `__str_head:w` makes its way to the output. Finally, for an empty argument, the (braced) empty brace group in the definition of `\str_head:n` gives an empty result after passing through `\use_i_delimit_by_q_stop:nw`.

```

5683 \cs_new:Npn \str_head:N { \exp_args:No \str_head:n }
5684 \cs_generate_variant:Nn \str_head:N { c }
5685 \cs_new:Npn \str_head:n #1
5686 {
5687     \exp_after:wN \__str_head:w
5688     \tl_to_str:n {#1}
5689     { { } } ~ \q_stop
5690 }
5691 \cs_new:Npn \__str_head:w #1 ~ %
5692 { \use_i_delimit_by_q_stop:nw #1 { ~ } }
5693 \cs_new:Npn \str_head_ignore_spaces:n #1
5694 {
5695     \exp_after:wN \use_i_delimit_by_q_stop:nw
5696     \tl_to_str:n {#1} { } \q_stop
5697 }
```

(End definition for `\str_head:N` and others. These functions are documented on page 60.)

`\str_tail:N` Getting the tail is a little bit more convoluted than the head of a string. We hit the front of the string with `\reverse_if:N` `\if_charcode:w` `\scan_stop:.` This removes the first character, and necessarily makes the test true, since the character cannot match `\scan_stop:.` The auxiliary function then inserts the required `\fi:` to close the conditional, and leaves the tail of the string in the input stream. The details are such that an empty string has an empty tail (this requires in particular that the end-marker `X` be unexpandable and not a control sequence). The `_ignore_spaces` is rather simpler: after converting the input to a string, `__str_tail_auxii:w` removes one undelimited argument and leaves everything else until an end-marker `\q_mark`. One can check that an empty (or blank) string yields an empty tail.

```

5698 \cs_new:Npn \str_tail:N { \exp_args:No \str_tail:n }
5699 \cs_generate_variant:Nn \str_tail:N { c }
5700 \cs_new:Npn \str_tail:n #1
5701 {
5702     \exp_after:wN \__str_tail_auxi:w
5703     \reverse_if:N \if_charcode:w
5704     \scan_stop: \tl_to_str:n {#1} X X \q_stop
5705 }
5706 \cs_new:Npn \__str_tail_auxi:w #1 X #2 \q_stop { \fi: #1 }
5707 \cs_new:Npn \str_tail_ignore_spaces:n #1
5708 {
5709     \exp_after:wN \__str_tail_auxii:w
5710     \tl_to_str:n {#1} \q_mark \q_mark \q_stop
```

```

5711 }
5712 \cs_new:Npn \__str_tail_auxii:w #1 #2 \q_mark #3 \q_stop { #2 }

```

(End definition for `\str_tail:N` and others. These functions are documented on page 60.)

8.8 String manipulation

`\str_fold_case:n` Case changing for programmatic reasons is done by first detokenizing input then doing a simple loop that only has to worry about spaces and everything else. The output is detokenized to allow data sharing with text-based case changing.

```

\str_fold_case:V
\str_lower_case:n
\str_lower_case:f
\str_upper_case:n
\str_upper_case:f
__str_change_case:nn
__str_change_case_aux:nn
__str_change_case_result:n
__str_change_case_output:nw
__str_change_case_output:fw
__str_change_case_end:nw
__str_change_case_loop:nw
__str_change_case_space:n
__str_change_case_char:nN
5713 \cs_new:Npn \str_fold_case:n #1 { __str_change_case:nn {#1} { fold } }
5714 \cs_new:Npn \str_lower_case:n #1 { __str_change_case:nn {#1} { lower } }
5715 \cs_new:Npn \str_upper_case:n #1 { __str_change_case:nn {#1} { upper } }
5716 \cs_generate_variant:Nn \str_fold_case:n { V }
5717 \cs_generate_variant:Nn \str_lower_case:n { f }
5718 \cs_generate_variant:Nn \str_upper_case:n { f }
5719 \cs_new:Npn \__str_change_case:nn #1
5720 {
5721   \exp_after:wN \__str_change_case_aux:nn \exp_after:wN
5722   { \tl_to_str:n {#1} }
5723 }
5724 \cs_new:Npn \__str_change_case_aux:nn #1#2
5725 {
5726   __str_change_case_loop:nw {#2} #1 \q_recursion_tail \q_recursion_stop
5727   __str_change_case_result:n { }
5728 }
5729 \cs_new:Npn \__str_change_case_output:nw #1#2 \__str_change_case_result:n #3
5730 { #2 \__str_change_case_result:n { #3 #1 } }
5731 \cs_generate_variant:Nn \__str_change_case_output:nw { f }
5732 \cs_new:Npn \__str_change_case_end:wn #1 \__str_change_case_result:n #2
5733 { \tl_to_str:n {#2} }
5734 \cs_new:Npn \__str_change_case_loop:nw #1#2 \q_recursion_stop
5735 {
5736   \tl_if_head_is_space:nTF {#2}
5737   { __str_change_case_space:n }
5738   { __str_change_case_char:nN }
5739   {#1} #2 \q_recursion_stop
5740 }
5741 \exp_last_unbraced:NNNN
5742 \cs_new:Npn \__str_change_case_space:n #1 \c_space_tl
5743 {
5744   __str_change_case_output:nw { ~ }
5745   __str_change_case_loop:nw {#1}
5746 }
5747 \cs_new:Npn \__str_change_case_char:nN #1#2
5748 {
5749   \quark_if_recursion_tail_stop_do:Nn #2
5750   { __str_change_case_end:wn }
5751   __str_change_case_output:fw
5752   { \use:c { char_str_ #1 _case:N } #2 }
5753   __str_change_case_loop:nw {#1}
5754 }

```

(End definition for `\str_fold_case:n` and others. These functions are documented on page 63.)


```

\c_ampersand_str For all of those strings, use \cs_to_str:N to get characters with the correct category
\c_atsign_str   code without worries
\c_backslash_str 5755 \str_const:Nx \c_ampersand_str { \cs_to_str:N \& }
\c_left_brace_str 5756 \str_const:Nx \c_atsign_str { \cs_to_str:N \@ }
\c_right_brace_str 5757 \str_const:Nx \c_backslash_str { \cs_to_str:N \\ }
\c_circumflex_str 5758 \str_const:Nx \c_left_brace_str { \cs_to_str:N \{ }
\c_colon_str      5759 \str_const:Nx \c_right_brace_str { \cs_to_str:N \} }
\c_dollar_str     5760 \str_const:Nx \c_circumflex_str { \cs_to_str:N \^ }
\c_hash_str       5761 \str_const:Nx \c_colon_str { \cs_to_str:N \: }
\c_percent_str    5762 \str_const:Nx \c_dollar_str { \cs_to_str:N \$ }
\c_tilde_str      5763 \str_const:Nx \c_hash_str { \cs_to_str:N \# }
\c_underscore_str 5764 \str_const:Nx \c_percent_str { \cs_to_str:N \% }
                  5765 \str_const:Nx \c_tilde_str { \cs_to_str:N \~ }
                  5766 \str_const:Nx \c_underscore_str { \cs_to_str:N \_ }

```

(End definition for \c_ampersand_str and others. These variables are documented on page 64.)

```

\l_tmpa_str Scratch strings.
\l_tmpb_str 5767 \str_new:N \l_tmpa_str
\g_tmpa_str 5768 \str_new:N \l_tmpb_str
\g_tmpb_str 5769 \str_new:N \g_tmpa_str
          5770 \str_new:N \g_tmpb_str

```

(End definition for \l_tmpa_str and others. These variables are documented on page 64.)

8.9 Viewing strings

```

\str_show:n Displays a string on the terminal.
\str_show:N 5771 \cs_new_eq:NN \str_show:n \tl_show:n
\str_show:c 5772 \cs_new_eq:NN \str_show:N \tl_show:N
\str_log:n   5773 \cs_generate_variant:Nn \str_show:N { c }
\str_log:N   5774 \cs_new_eq:NN \str_log:n \tl_log:n
\str_log:c   5775 \cs_new_eq:NN \str_log:N \tl_log:N
          5776 \cs_generate_variant:Nn \str_log:N { c }

```

(End definition for \str_show:n and others. These functions are documented on page 63.)

```
5777 </initex | package>
```

9 l3str-convert implementation

```
5778 <*initex | package>
```

```
5779 <@@=str>
```

9.1 Helpers

9.1.1 Variables and constants

```

\__str_tmp:w Internal scratch space for some functions.
\l__str_internal_int 5780 \cs_new_protected:Npn \__str_tmp:w { }
\l__str_internal_tl  5781 \tl_new:N \l__str_internal_tl
                    5782 \int_new:N \l__str_internal_int

```

(End definition for __str_tmp:w, \l__str_internal_int, and \l__str_internal_tl.)

`\g__str_result_tl` The `\g__str_result_tl` variable is used to hold the result of various internal string operations (mostly conversions) which are typically performed in a group. The variable is global so that it remains defined outside the group, to be assigned to a user-provided variable.

```
5783 \tl_new:N \g__str_result_tl
```

(End definition for `\g__str_result_tl`.)

`\c__str_replacement_char_int` When converting, invalid bytes are replaced by the Unicode replacement character "FFFD.

```
5784 \int_const:Nn \c__str_replacement_char_int { "FFFD }
```

(End definition for `\c__str_replacement_char_int`.)

`\c__str_max_byte_int` The maximal byte number.

```
5785 \int_const:Nn \c__str_max_byte_int { 255 }
```

(End definition for `\c__str_max_byte_int`.)

`\g__str_alias_prop` To avoid needing one file per encoding/escaping alias, we keep track of those in a property list.

```
5786 \prop_new:N \g__str_alias_prop
5787 \prop_gput:Nnn \g__str_alias_prop { latin1 } { iso88591 }
5788 \prop_gput:Nnn \g__str_alias_prop { latin2 } { iso88592 }
5789 \prop_gput:Nnn \g__str_alias_prop { latin3 } { iso88593 }
5790 \prop_gput:Nnn \g__str_alias_prop { latin4 } { iso88594 }
5791 \prop_gput:Nnn \g__str_alias_prop { latin5 } { iso88599 }
5792 \prop_gput:Nnn \g__str_alias_prop { latin6 } { iso885910 }
5793 \prop_gput:Nnn \g__str_alias_prop { latin7 } { iso885913 }
5794 \prop_gput:Nnn \g__str_alias_prop { latin8 } { iso885914 }
5795 \prop_gput:Nnn \g__str_alias_prop { latin9 } { iso885915 }
5796 \prop_gput:Nnn \g__str_alias_prop { latin10 } { iso885916 }
5797 \prop_gput:Nnn \g__str_alias_prop { utf16le } { utf16 }
5798 \prop_gput:Nnn \g__str_alias_prop { utf16be } { utf16 }
5799 \prop_gput:Nnn \g__str_alias_prop { utf32le } { utf32 }
5800 \prop_gput:Nnn \g__str_alias_prop { utf32be } { utf32 }
5801 \prop_gput:Nnn \g__str_alias_prop { hexadecimal } { hex }
```

(End definition for `\g__str_alias_prop`.)

`\g__str_error_bool` In conversion functions with a built-in conditional, errors are not reported directly to the user, but the information is collected in this boolean, used at the end to decide on which branch of the conditional to take.

```
5802 \bool_new:N \g__str_error_bool
```

(End definition for `\g__str_error_bool`.)

str_byte Conversions from one *<encoding>*/*<escaping>* pair to another are done within x-expanding assignments. Errors are signalled by raising the relevant flag.

```
5803 \flag_new:n { str_byte }
```

```
5804 \flag_new:n { str_error }
```

(End definition for `str_byte` and `str_error`. These variables are documented on page ??.)

9.2 String conditionals

`_str_if_contains_char:NNT` `_str_if_contains_char:nNTF {⟨token list⟩} ⟨char⟩`
`_str_if_contains_char:NNTF` Expects the *⟨token list⟩* to be an *⟨other string⟩*: the caller is responsible for ensuring
`_str_if_contains_char:nNTF` that no (too-)special catcodes remain. Spaces with catcode 10 are ignored. Loop over
`_str_if_contains_char_aux:NN` the characters of the string, comparing character codes. The loop is broken if character
`_str_if_contains_char_true:` codes match. Otherwise we return “false”.

```

5805 \prg_new_conditional:Npnn \_str_if_contains_char:NN #1#2 { T , TF }
5806 {
5807   \exp_after:wN \_str_if_contains_char_aux:NN \exp_after:wN #2
5808   #1 { \prg_break:n { ? \fi: } }
5809   \prg_break_point:
5810   \prg_return_false:
5811 }
5812 \prg_new_conditional:Npnn \_str_if_contains_char:nN #1#2 { TF }
5813 {
5814   \_str_if_contains_char_aux:NN #2 #1 { \prg_break:n { ? \fi: } }
5815   \prg_break_point:
5816   \prg_return_false:
5817 }
5818 \cs_new:Npn \_str_if_contains_char_aux:NN #1#2
5819 {
5820   \if_charcode:w #1 #2
5821   \exp_after:wN \_str_if_contains_char_true:
5822   \fi:
5823   \_str_if_contains_char_aux:NN #1
5824 }
5825 \cs_new:Npn \_str_if_contains_char_true:
5826 { \prg_break:n { \prg_return_true: \use_none:n } }

```

(End definition for `_str_if_contains_char:NNT` and others.)

`_str_octal_use:NTF` `_str_octal_use:NTF {⟨token⟩} {⟨true code⟩} {⟨false code⟩}`
 If the *⟨token⟩* is an octal digit, it is left in the input stream, *followed* by the *⟨true code⟩*. Otherwise, the *⟨false code⟩* is left in the input stream.

T_EXhackers note: This function will fail if the escape character is an octal digit. We are thus careful to set the escape character to a known value before using it. T_EX dutifully detects

octal digits for us: if #1 is an octal digit, then the right-hand side of the comparison is '1#1, greater than 1. Otherwise, the right-hand side stops as '1, and the conditional takes the false branch.

```

5827 \prg_new_conditional:Npnn \_str_octal_use:N #1 { TF }
5828 {
5829   \if_int_compare:w 1 < '1 \token_to_str:N #1 \exp_stop_f:
5830   #1 \prg_return_true:
5831   \else:
5832   \prg_return_false:
5833   \fi:
5834 }

```

(End definition for `_str_octal_use:NTF`.)

`__str_hexadecimal_use:N`TF TeX detects uppercase hexadecimal digits for us (see `__str_octal_use:N`TF), but not the lowercase letters, which we need to detect and replace by their uppercase counterpart.

```

5835 \prg_new_conditional:Npnn \__str_hexadecimal_use:N #1 { TF }
5836 {
5837   \if_int_compare:w 1 < "1 \token_to_str:N #1 \exp_stop_f:
5838     #1 \prg_return_true:
5839   \else:
5840     \if_case:w \int_eval:n { \exp_after:wN ' \token_to_str:N #1 - 'a }
5841       A
5842     \or: B
5843     \or: C
5844     \or: D
5845     \or: E
5846     \or: F
5847     \else:
5848       \prg_return_false:
5849       \exp_after:wN \use_none:n
5850     \fi:
5851     \prg_return_true:
5852   \fi:
5853 }

```

(End definition for `__str_hexadecimal_use:N`TF.)

9.3 Conversions

9.3.1 Producing one byte or character

`\c__str_byte_0_tl` For each integer N in the range $[0, 255]$, we create a constant token list which holds three character tokens with category code other: the character with character code N , followed by the representation of N as two hexadecimal digits. The value -1 is given a default token list which ensures that later functions give an empty result for the input -1 .

```

5854 \group_begin:
5855   \tl_set:Nx \l__str_internal_tl { \tl_to_str:n { 0123456789ABCDEF } }
5856   \tl_map_inline:Nn \l__str_internal_tl
5857     {
5858       \tl_map_inline:Nn \l__str_internal_tl
5859         {
5860           \tl_const:cx { c__str_byte_ \int_eval:n {"#1##1} _tl }
5861             { \char_generate:nn { "#1##1 } { 12 } #1 ##1 }
5862         }
5863     }
5864 \group_end:
5865 \tl_const:cn { c__str_byte_-1_tl } { { } \use_none:n { } }

```

(End definition for `\c__str_byte_0_tl` and others.)

`__str_output_byte:n` Those functions must be used carefully: feeding them a value outside the range $[-1, 255]$ will attempt to use the undefined token list variable `\c__str_byte_⟨number⟩_tl`. Assuming that the argument is in the right range, we expand the corresponding token list, and pick either the byte (first token) or the hexadecimal representations (second and third tokens). The value -1 produces an empty result in both cases.

```

5866 \cs_new:Npn \__str_output_byte:n #1

```

```

5867 { \__str_output_byte:w #1 \__str_output_end: }
5868 \cs_new:Npn \__str_output_byte:w
5869 {
5870   \exp_after:wN \exp_after:wN
5871   \exp_after:wN \use_i:nnn
5872   \cs:w c__str_byte_ \int_eval:w
5873 }
5874 \cs_new:Npn \__str_output_hexadecimal:n #1
5875 {
5876   \exp_after:wN \exp_after:wN
5877   \exp_after:wN \use_none:n
5878   \cs:w c__str_byte_ \int_eval:n {#1} _tl \cs_end:
5879 }
5880 \cs_new:Npn \__str_output_end:
5881 { \scan_stop: _tl \cs_end: }

```

(End definition for __str_output_byte:n and others.)

__str_output_byte_pair_be:n Convert a number in the range [0,65535] to a pair of bytes, either big-endian or little-endian.

```

\__str_output_byte_pair_le:n
\__str_output_byte_pair:nnN
5882 \cs_new:Npn \__str_output_byte_pair_be:n #1
5883 {
5884   \exp_args:Nf \__str_output_byte_pair:nnN
5885   { \int_div_truncate:nn { #1 } { "100 } } {#1} \use:nn
5886 }
5887 \cs_new:Npn \__str_output_byte_pair_le:n #1
5888 {
5889   \exp_args:Nf \__str_output_byte_pair:nnN
5890   { \int_div_truncate:nn { #1 } { "100 } } {#1} \use_ii_i:nn
5891 }
5892 \cs_new:Npn \__str_output_byte_pair:nnN #1#2#3
5893 {
5894   #3
5895   { \__str_output_byte:n { #1 } }
5896   { \__str_output_byte:n { #2 - #1 * "100 } }
5897 }

```

(End definition for __str_output_byte_pair_be:n, __str_output_byte_pair_le:n, and __str_output_byte_pair:nnN.)

9.3.2 Mapping functions for conversions

__str_convert_gmap:N This maps the function #1 over all characters in \g__str_result_tl, which should be a byte string in most cases, sometimes a native string.

```

\__str_convert_gmap_loop:NN
5898 \cs_new_protected:Npn \__str_convert_gmap:N #1
5899 {
5900   \tl_gset:Nx \g__str_result_tl
5901   {
5902     \exp_after:wN \__str_convert_gmap_loop:NN
5903     \exp_after:wN #1
5904     \g__str_result_tl { ? \prg_break: }
5905     \prg_break_point:
5906   }
5907 }

```

```

5908 \cs_new:Npn \__str_convert_gmap_loop:NN #1#2
5909 {
5910     \use_none:n #2
5911     #1#2
5912     \__str_convert_gmap_loop:NN #1
5913 }

```

(End definition for __str_convert_gmap:N and __str_convert_gmap_loop:NN.)

__str_convert_gmap_internal:N
__str_convert_gmap_internal_loop:Nw

This maps the function #1 over all character codes in \g__str_result_tl, which must be in the internal representation.

```

5914 \cs_new_protected:Npn \__str_convert_gmap_internal:N #1
5915 {
5916     \tl_gset:Nx \g__str_result_tl
5917     {
5918         \exp_after:wN \__str_convert_gmap_internal_loop:Nww
5919         \exp_after:wN #1
5920         \g__str_result_tl \s__tl \q_stop \prg_break: \s__tl
5921         \prg_break_point:
5922     }
5923 }
5924 \cs_new:Npn \__str_convert_gmap_internal_loop:Nww #1 #2 \s__tl #3 \s__tl
5925 {
5926     \use_none_delimit_by_q_stop:w #3 \q_stop
5927     #1 {#3}
5928     \__str_convert_gmap_internal_loop:Nww #1
5929 }

```

(End definition for __str_convert_gmap_internal:N and __str_convert_gmap_internal_loop:Nw.)

9.3.3 Error-reporting during conversion

__str_if_flag_error:nnx
__str_if_flag_no_error:nnx

When converting using the function \str_set_convert:Nnnn, errors should be reported to the user after each step in the conversion. Errors are signalled by raising some flag (typically @@_error), so here we test that flag: if it is raised, give the user an error, otherwise remove the arguments. On the other hand, in the conditional functions \str_set_convert:NnnnTF, errors should be suppressed. This is done by changing __str_if_flag_error:nnx into __str_if_flag_no_error:nnx locally.

```

5930 \cs_new_protected:Npn \__str_if_flag_error:nnx #1
5931 {
5932     \flag_if_raised:nTF {#1}
5933     { \__kernel_msg_error:nnx { str } }
5934     { \use_none:nn }
5935 }
5936 \cs_new_protected:Npn \__str_if_flag_no_error:nnx #1#2#3
5937 { \flag_if_raised:nT {#1} { \bool_gset_true:N \g__str_error_bool } }

```

(End definition for __str_if_flag_error:nnx and __str_if_flag_no_error:nnx.)

__str_if_flag_times:nT

At the end of each conversion step, we raise all relevant errors as one error message, built on the fly. The height of each flag indicates how many times a given error was encountered. This function prints #2 followed by the number of occurrences of an error if it occurred, nothing otherwise.

```

5938 \cs_new:Npn \__str_if_flag_times:nT #1#2
5939 { \flag_if_raised:nT {#1} { #2~(x \flag_height:n {#1} ) } }

```

(End definition for `_str_if_flag_times:nT`.)

9.3.4 Framework for conversions

Most functions in this module expect to be working with “native” strings. Strings can also be stored as bytes, in one of many encodings, for instance UTF8. The bytes themselves can be expressed in various ways in terms of \TeX tokens, for instance as pairs of hexadecimal digits. The questions of going from arbitrary Unicode code points to bytes, and from bytes to tokens are mostly independent.

Conversions are done in four steps:

- “unescape” produces a string of bytes;
- “decode” takes in a string of bytes, and converts it to a list of Unicode characters in an internal representation, with items of the form

$\langle bytes \rangle \backslash s_tl \langle Unicode\ code\ point \rangle \backslash s_tl$

where we have collected the $\langle bytes \rangle$ which combined to form this particular Unicode character, and the $\langle Unicode\ code\ point \rangle$ is in the range $[0, "10FFFF]$.

- “encode” encodes the internal list of code points as a byte string in the new encoding;
- “escape” escapes bytes as requested.

The process is modified in case one of the encoding is empty (or the conversion function has been set equal to the empty encoding because it was not found): then the unescape or escape step is ignored, and the decode or encode steps work on tokens instead of bytes. Otherwise, each step must ensure that it passes a correct byte string or internal string to the next step.

The input string is stored in `\g__str_result_tl`, then we: unescape and decode; encode and escape; exit the group and store the result in the user’s variable. The various conversion functions all act on `\g__str_result_tl`. Errors are silenced for the conditional functions by redefining `_str_if_flag_error:nxx` locally.

```

\str_set_convert:Nnnn
\str_gset_convert:Nnnn
\str_set_convert:NnnnTF
\str_gset_convert:NnnnTF
\_str_convert:nNNnnn
5940 \cs_new_protected:Npn \str_set_convert:Nnnn
5941 { \_str_convert:nNNnnn { } \tl_set_eq:NN }
5942 \cs_new_protected:Npn \str_gset_convert:Nnnn
5943 { \_str_convert:nNNnnn { } \tl_gset_eq:NN }
5944 \prg_new_protected_conditional:Npnn
5945 \str_set_convert:Nnnn #1#2#3#4 { T , F , TF }
5946 {
5947   \bool_gset_false:N \g__str_error_bool
5948   \_str_convert:nNNnnn
5949   { \cs_set_eq:NN \_str_if_flag_error:nxx \_str_if_flag_no_error:nxx }
5950   \tl_set_eq:NN #1 {#2} {#3} {#4}
5951   \bool_if:NTF \g__str_error_bool \prg_return_false: \prg_return_true:
5952 }
5953 \prg_new_protected_conditional:Npnn
5954 \str_gset_convert:Nnnn #1#2#3#4 { T , F , TF }
5955 {
5956   \bool_gset_false:N \g__str_error_bool
5957   \_str_convert:nNNnnn

```

```

5958     { \cs_set_eq:NN \__str_if_flag_error:nxx \__str_if_flag_no_error:nxx }
5959     \tl_gset_eq:NN #1 {#2} {#3} {#4}
5960     \bool_if:NTF \g__str_error_bool \prg_return_false: \prg_return_true:
5961   }
5962 \cs_new_protected:Npn \__str_convert:nNNnnn #1#2#3#4#5#6
5963 {
5964   \group_begin:
5965   #1
5966   \tl_gset:Nx \g__str_result_tl { \__kernel_str_to_other_fast:n {#4} }
5967   \exp_after:wN \__str_convert:wwwnn
5968   \tl_to_str:n {#5} /// \q_stop
5969   { decode } { unescape }
5970   \prg_do_nothing:
5971   \__str_convert_decode_:
5972   \exp_after:wN \__str_convert:wwwnn
5973   \tl_to_str:n {#6} /// \q_stop
5974   { encode } { escape }
5975   \use_ii_i:nn
5976   \__str_convert_encode_:
5977   \group_end:
5978   #2 #3 \g__str_result_tl
5979 }

```

(End definition for `\str_set_convert:Nnnn` and others. These functions are documented on page 65.)

`__str_convert:wwwnn` The task of `__str_convert:wwwnn` is to split $\langle encoding \rangle / \langle escaping \rangle$ pairs into their components, #1 and #2. Calls to `__str_convert:nnn` ensure that the corresponding conversion functions are defined. The third auxiliary does the main work.

`__str_convert:NNnNN`

- #1 is the encoding conversion function;
- #2 is the escaping function;
- #3 is the escaping name for use in an error message;
- #4 is `\prg_do_nothing:` for unescaping/decoding, and `\use_ii_i:nn` for encoding/escaping;
- #5 is the default encoding function (either “decode” or “encode”), for which there should be no escaping.

Let us ignore the native encoding for a second. In the unescaping/decoding phase, we want to do #2#1 in this order, and in the encoding/escaping phase, the order should be reversed: #4#2#1 does exactly that. If one of the encodings is the default (native), then the escaping should be ignored, with an error if any was given, and only the encoding, #1, should be performed.

```

5980 \cs_new_protected:Npn \__str_convert:wwwnn
5981   #1 / #2 // #3 \q_stop #4#5
5982 {
5983   \__str_convert:nnn {enc} {#4} {#1}
5984   \__str_convert:nnn {esc} {#5} {#2}
5985   \exp_args:Ncc \__str_convert:NNnNN
5986   { __str_convert_#4_#1: } { __str_convert_#5_#2: } {#2}
5987 }
5988 \cs_new_protected:Npn \__str_convert:NNnNN #1#2#3#4#5

```



```

5989 {
5990   \if_meaning:w #1 #5
5991   \tl_if_empty:nF {#3}
5992   { \__kernel_msg_error:nxx { str } { native-escaping } {#3} }
5993   #1
5994   \else:
5995     #4 #2 #1
5996   \fi:
5997 }

```

(End definition for __str_convert:wwwnn and __str_convert:NNnnN.)

__str_convert:nnn
__str_convert:nnnn

The arguments of __str_convert:nnn are: `enc` or `esc`, used to build filenames, the type of the conversion (unescape, decode, encode, escape), and the encoding or escaping name. If the function is already defined, no need to do anything. Otherwise, filter out all non-alphanumerics in the name, and lowercase it. Feed that, and the same three arguments, to __str_convert:nnnn. The task is then to make sure that the conversion function `#3_#1` corresponding to the type `#3` and filtered name `#1` is defined, then set our initial conversion function `#3_#4` equal to that.

How do we get the `#3_#1` conversion to be defined if it isn't? Two main cases.

First, if `#1` is a key in `\g__str_alias_prop`, then the value `\l__str_internal_tl` tells us what file to load. Loading is skipped if the file was already read, *i.e.*, if the conversion command based on `\l__str_internal_tl` already exists. Otherwise, try to load the file; if that fails, there is an error, use the default empty name instead.

Second, `#1` may be absent from the property list. The `\cs_if_exist:cF` test is automatically false, and we search for a file defining the encoding or escaping `#1` (this should allow third-party `.def` files). If the file is not found, there is an error, use the default empty name instead.

In all cases, the conversion based on `\l__str_internal_tl` is defined, so we can set the `#3_#1` function equal to that. In some cases (*e.g.*, `utf16be`), the `#3_#1` function is actually defined within the file we just loaded, and it is different from the `\l__str_internal_tl`-based function: we mustn't clobber that different definition.

```

5998 \cs_new_protected:Npn \__str_convert:nnn #1#2#3
5999 {
6000   \cs_if_exist:cF { __str_convert_#2_#3: }
6001   {
6002     \exp_args:Nx \__str_convert:nnnn
6003     { \__str_convert_lowercase_alphanum:n {#3} }
6004     {#1} {#2} {#3}
6005   }
6006 }
6007 \cs_new_protected:Npn \__str_convert:nnnn #1#2#3#4
6008 {
6009   \cs_if_exist:cF { __str_convert_#3_#1: }
6010   {
6011     \prop_get:NnNF \g__str_alias_prop {#1} \l__str_internal_tl
6012     { \tl_set:Nn \l__str_internal_tl {#1} }
6013     \cs_if_exist:cF { __str_convert_#3_ \l__str_internal_tl : }
6014     {
6015       \file_if_exist:nTF { l3str-#2- \l__str_internal_tl .def }
6016       {
6017         \group_begin:
6018         \__str_load_catcodes:

```

```

6019         \file_input:n { l3str-#2- \l__str_internal_tl .def }
6020     \group_end:
6021 }
6022 {
6023     \tl_clear:N \l__str_internal_tl
6024     \__kernel_msg_error:nxxx { str } { unknown-#2 } {#4} {#1}
6025 }
6026 }
6027 \cs_if_exist:cF { __str_convert_#3_#1: }
6028 {
6029     \cs_gset_eq:cc { __str_convert_#3_#1: }
6030     { __str_convert_#3_ \l__str_internal_tl : }
6031 }
6032 }
6033 \cs_gset_eq:cc { __str_convert_#3_#4: } { __str_convert_#3_#1: }
6034 }

```

(End definition for `__str_convert:nnn` and `__str_convert:nnnn`.)

`__str_convert_lowercase_alphanum:n` This function keeps only letters and digits, with upper case letters converted to lower case.

```

6035 \cs_new:Npn \__str_convert_lowercase_alphanum:n #1
6036 {
6037     \exp_after:wN \__str_convert_lowercase_alphanum_loop:N
6038     \tl_to_str:n {#1} { ? \prg_break: }
6039     \prg_break_point:
6040 }
6041 \cs_new:Npn \__str_convert_lowercase_alphanum_loop:N #1
6042 {
6043     \use_none:n #1
6044     \if_int_compare:w '#1 > 'Z \exp_stop_f:
6045     \if_int_compare:w '#1 > 'z \exp_stop_f: \else:
6046     \if_int_compare:w '#1 < 'a \exp_stop_f: \else:
6047         #1
6048     \fi:
6049     \fi:
6050 \else:
6051     \if_int_compare:w '#1 < 'A \exp_stop_f:
6052     \if_int_compare:w 1 < 1#1 \exp_stop_f:
6053         #1
6054     \fi:
6055     \else:
6056     \__str_output_byte:n { '#1 + 'a - 'A }
6057     \fi:
6058     \fi:
6059     \__str_convert_lowercase_alphanum_loop:N
6060 }

```

(End definition for `__str_convert_lowercase_alphanum:n` and `__str_convert_lowercase_alphanum_loop:N`.)

`__str_load_catcodes:` Since encoding files may be loaded at arbitrary places in a T_EX document, including within verbatim mode, we set the catcodes of all characters appearing in any encoding definition file.

```

6061 \cs_new_protected:Npn \__str_load_catcodes:
6062 {
6063   \char_set_catcode_escape:N \
6064   \char_set_catcode_group_begin:N \{
6065   \char_set_catcode_group_end:N \}
6066   \char_set_catcode_math_toggle:N \$
6067   \char_set_catcode_alignment:N \&
6068   \char_set_catcode_parameter:N \#
6069   \char_set_catcode_math_superscript:N ^
6070   \char_set_catcode_ignore:N \%
6071   \char_set_catcode_space:N ~
6072   \tl_map_function:nN { abcdefghijklmnopqrstuvwxyz_ABCDEFILNPSTUX }
6073   \char_set_catcode_letter:N
6074   \tl_map_function:nN { 0123456789"?'*+-.(),'!/<>[];= }
6075   \char_set_catcode_other:N
6076   \char_set_catcode_comment:N \%
6077   \int_set:Nn \tex_endlinechar:D {32}
6078 }

```

(End definition for __str_load_catcodes:.)

9.3.5 Byte unescape and escape

Strings of bytes may need to be stored in auxiliary files in safe “escaping” formats. Each such escaping is only loaded as needed. By default, on input any non-byte is filtered out, while the output simply consists in letting bytes through.

```

\__str_filter_bytes:n
\__str_filter_bytes_aux:N

```

In the case of 8-bit engines, every character is a byte. For Unicode-aware engines, test the character code; non-bytes cause us to raise the flag `str_byte`. Spaces have already been given the correct category code when this function is called.

```

6079 \bool_lazy_any:nTF
6080 {
6081   \sys_if_engine luatex_p:
6082   \sys_if_engine xetex_p:
6083 }
6084 {
6085   \cs_new:Npn \__str_filter_bytes:n #1
6086   {
6087     \__str_filter_bytes_aux:N #1
6088     { ? \prg_break: }
6089     \prg_break_point:
6090   }
6091   \cs_new:Npn \__str_filter_bytes_aux:N #1
6092   {
6093     \use_none:n #1
6094     \if_int_compare:w '#1 < 256 \exp_stop_f:
6095     #1
6096     \else:
6097       \flag_raise:n { str_byte }
6098     \fi:
6099     \__str_filter_bytes_aux:N
6100   }
6101 }
6102 { \cs_new_eq:NN \__str_filter_bytes:n \use:n }

```

(End definition for `_str_filter_bytes:n` and `_str_filter_bytes_aux:N`.)

`_str_convert_unescape_:` The simplest unescaping method removes non-bytes from `\g_str_result_tl`.
`_str_convert_unescape_bytes:`

```

6103 \bool_lazy_any:nTF
6104 {
6105   \sys_if_engine luatex_p:
6106   \sys_if_engine xetex_p:
6107 }
6108 {
6109   \cs_new_protected:Npn \_str_convert_unescape_:
6110   {
6111     \flag_clear:n { str_byte }
6112     \tl_gset:Nx \g_str_result_tl
6113     { \exp_args:No \_str_filter_bytes:n \g_str_result_tl }
6114     \\_str_if_flag_error:nmx { str_byte } { non-byte } { bytes }
6115   }
6116 }
6117 { \cs_new_protected:Npn \_str_convert_unescape_: { } }
6118 \cs_new_eq:NN \_str_convert_unescape_bytes: \_str_convert_unescape_:

```

(End definition for `_str_convert_unescape_:` and `_str_convert_unescape_bytes:.`)

`_str_convert_escape_:` The simplest form of escape leaves the bytes from the previous step of the conversion
`_str_convert_escape_bytes:` unchanged.

```

6119 \cs_new_protected:Npn \_str_convert_escape_: { }
6120 \cs_new_eq:NN \_str_convert_escape_bytes: \_str_convert_escape_:

```

(End definition for `_str_convert_escape_:` and `_str_convert_escape_bytes:.`)

9.3.6 Native strings

`_str_convert_decode_:` Convert each character to its character code, one at a time.
`_str_decode_native_char:N`

```

6121 \cs_new_protected:Npn \_str_convert_decode_:
6122 { \_str_convert_gmap:N \_str_decode_native_char:N }
6123 \cs_new:Npn \_str_decode_native_char:N #1
6124 { #1 \s_tl \int_value:w '#1 \s_tl }

```

(End definition for `_str_convert_decode_:` and `_str_decode_native_char:N`.)

`_str_convert_encode_:` The conversion from an internal string to native character tokens basically maps `\char_generate:nn`
`_str_encode_native_char:n` through the code-points, but in non-Unicode-aware engines we use a fall-back character ? rather than nothing when given a character code outside [0,255]. We detect the presence of bad characters using a flag and only produce a single error after the x-expanding assignment.

```

6125 \bool_lazy_any:nTF
6126 {
6127   \sys_if_engine luatex_p:
6128   \sys_if_engine xetex_p:
6129 }
6130 {
6131   \cs_new_protected:Npn \_str_convert_encode_:
6132   { \_str_convert_gmap_internal:N \_str_encode_native_char:n }
6133   \cs_new:Npn \_str_encode_native_char:n #1
6134   { \char_generate:nn {#1} {12} }

```

```

6135 }
6136 {
6137   \cs_new_protected:Npn \__str_convert_encode_
6138   {
6139     \flag_clear:n { str_error }
6140     \__str_convert_gmap_internal:N \__str_encode_native_char:n
6141     \__str_if_flag_error:nnx { str_error }
6142     { native-overflow } { }
6143   }
6144   \cs_new:Npn \__str_encode_native_char:n #1
6145   {
6146     \if_int_compare:w #1 > \c__str_max_byte_int
6147     \flag_raise:n { str_error }
6148     ?
6149     \else:
6150     \char_generate:nn {#1} {12}
6151     \fi:
6152   }
6153   \__kernel_msg_new:nnnn { str } { native-overflow }
6154   { Character-code-too-large-for-this-engine. }
6155   {
6156     This-engine-only-support-8-bit-characters:~
6157     valid-character-codes-are-in-the-range-[0,255].~
6158     To-manipulate-arbitrary-Unicode,~use~LuaTeX-or~XeTeX.
6159   }
6160 }

```

(End definition for __str_convert_encode_ and __str_encode_native_char:n.)

9.3.7 clist

__str_convert_decode_clist: Convert each integer to the internal form. We first turn \g__str_result_tl into a clist variable, as this avoids problems with leading or trailing commas.

```

6161 \cs_new_protected:Npn \__str_convert_decode_clist:
6162 {
6163   \clist_gset:No \g__str_result_tl \g__str_result_tl
6164   \tl_gset:Nx \g__str_result_tl
6165   {
6166     \exp_args:No \clist_map_function:nN
6167     \g__str_result_tl \__str_decode_clist_char:n
6168   }
6169 }
6170 \cs_new:Npn \__str_decode_clist_char:n #1
6171 { #1 \s_tl \int_eval:n {#1} \s_tl }

```

(End definition for __str_convert_decode_clist: and __str_decode_clist_char:n.)

__str_convert_encode_clist: Convert the internal list of character codes to a comma-list of character codes. The first line produces a comma-list with a leading comma, removed in the next step (this also works in the empty case, since \tl_tail:N does not trigger an error in this case).

```

6172 \cs_new_protected:Npn \__str_convert_encode_clist:
6173 {
6174   \__str_convert_gmap_internal:N \__str_encode_clist_char:n
6175   \tl_gset:Nx \g__str_result_tl { \tl_tail:N \g__str_result_tl }

```

```

6176     }
6177 \cs_new:Npn \__str_encode_clist_char:n #1 { , #1 }

(End definition for \__str_convert_encode_clist: and \__str_encode_clist_char:n.)

```

9.3.8 8-bit encodings

This section will be entirely rewritten: it is not yet clear in what situations 8-bit encodings are used, hence I don't know what exactly should be optimized. The current approach is reasonably efficient to convert long strings, and it scales well when using many different encodings. An approach based on csnames would have a smaller constant load time for each individual conversion, but has a large hash table cost. Using a range of \count registers works for decoding, but not for encoding; one possibility there would be to use a binary tree for the mapping of Unicode characters to bytes, stored as a box, one per encoding.

Since the section is going to be rewritten, documentation lacks.

All the 8-bit encodings which l3str supports rely on the same internal functions.

`\str_declare_eight_bit_encoding:nnn` All the 8-bit encoding definition file start with `\str_declare_eight_bit_encoding:nnn` $\{\langle encoding\ name\rangle\} \{\langle mapping\rangle\} \{\langle missing\ bytes\rangle\}$. The $\langle mapping\rangle$ argument is a token list of pairs $\{\langle byte\rangle\} \{\langle Unicode\rangle\}$ expressed in uppercase hexadecimal notation. The $\langle missing\rangle$ argument is a token list of $\{\langle byte\rangle\}$. Every $\langle byte\rangle$ which does not appear in the $\langle mapping\rangle$ nor the $\langle missing\rangle$ lists maps to the same code point in Unicode.

```

6178 \cs_new_protected:Npn \str_declare_eight_bit_encoding:nnn #1#2#3
6179 {
6180   \tl_set:Nn \l__str_internal_tl {#1}
6181   \cs_new_protected:cpn { __str_convert_decode_#1: }
6182     { \__str_convert_decode_eight_bit:n {#1} }
6183   \cs_new_protected:cpn { __str_convert_encode_#1: }
6184     { \__str_convert_encode_eight_bit:n {#1} }
6185   \tl_const:cn { c__str_encoding_#1_tl } {#2}
6186   \tl_const:cn { c__str_encoding_#1_missing_tl } {#3}
6187 }

```

(End definition for `\str_declare_eight_bit_encoding:nnn`. This function is documented on page 67.)

```

\__str_convert_decode_eight_bit:n
\__str_decode_eight_bit_load:nn
\__str_decode_eight_bit_load_missing:n
\__str_decode_eight_bit_char:N
6188 \cs_new_protected:Npn \__str_convert_decode_eight_bit:n #1
6189 {
6190   \group_begin:
6191     \int_zero:N \l__str_internal_int
6192     \exp_last_unbraced:Nx \__str_decode_eight_bit_load:nn
6193       { \tl_use:c { c__str_encoding_#1_tl } }
6194     { \q_stop \prg_break: } { }
6195     \prg_break_point:
6196     \exp_last_unbraced:Nx \__str_decode_eight_bit_load_missing:n
6197       { \tl_use:c { c__str_encoding_#1_missing_tl } }
6198     { \q_stop \prg_break: }
6199     \prg_break_point:
6200     \flag_clear:n { str_error }
6201     \__str_convert_gmap:N \__str_decode_eight_bit_char:N
6202     \__str_if_flag_error:nnx { str_error } { decode-8-bit } {#1}
6203   \group_end:

```

```

6204 }
6205 \cs_new_protected:Npn \__str_decode_eight_bit_load:nn #1#2
6206 {
6207   \use_none_delimit_by_q_stop:w #1 \q_stop
6208   \tex_dimen:D "#1 = \l__str_internal_int sp \scan_stop:
6209   \tex_skip:D \l__str_internal_int = "#1 sp \scan_stop:
6210   \tex_toks:D \l__str_internal_int \exp_after:wN { \int_value:w "#2 }
6211   \int_incr:N \l__str_internal_int
6212   \__str_decode_eight_bit_load:nn
6213 }
6214 \cs_new_protected:Npn \__str_decode_eight_bit_load_missing:n #1
6215 {
6216   \use_none_delimit_by_q_stop:w #1 \q_stop
6217   \tex_dimen:D "#1 = \l__str_internal_int sp \scan_stop:
6218   \tex_skip:D \l__str_internal_int = "#1 sp \scan_stop:
6219   \tex_toks:D \l__str_internal_int \exp_after:wN
6220   { \int_use:N \c__str_replacement_char_int }
6221   \int_incr:N \l__str_internal_int
6222   \__str_decode_eight_bit_load_missing:n
6223 }
6224 \cs_new:Npn \__str_decode_eight_bit_char:N #1
6225 {
6226   #1 \s_tl
6227   \if_int_compare:w \tex_dimen:D '#1 < \l__str_internal_int
6228   \if_int_compare:w \tex_skip:D \tex_dimen:D '#1 = '#1 \exp_stop_f:
6229   \tex_the:D \tex_toks:D \tex_dimen:D
6230   \fi:
6231   \fi:
6232   \int_value:w '#1 \s_tl
6233 }

```

(End definition for __str_convert_decode_eight_bit:n and others.)

```

\__str_convert_encode_eight_bit:n
\__str_encode_eight_bit_load:nn
\__str_encode_eight_bit_char:n
\__str_encode_eight_bit_char_aux:n
6234 \cs_new_protected:Npn \__str_convert_encode_eight_bit:n #1
6235 {
6236   \group_begin:
6237   \int_zero:N \l__str_internal_int
6238   \exp_last_unbraced:Nx \__str_encode_eight_bit_load:nn
6239   { \tl_use:c { c__str_encoding_#1_tl } }
6240   { \q_stop \prg_break: } { }
6241   \prg_break_point:
6242   \flag_clear:n { str_error }
6243   \__str_convert_gmap_internal:N \__str_encode_eight_bit_char:n
6244   \__str_if_flag_error:nnx { str_error } { encode-8-bit } {#1}
6245   \group_end:
6246 }
6247 \cs_new_protected:Npn \__str_encode_eight_bit_load:nn #1#2
6248 {
6249   \use_none_delimit_by_q_stop:w #1 \q_stop
6250   \tex_dimen:D "#2 = \l__str_internal_int sp \scan_stop:
6251   \tex_skip:D \l__str_internal_int = "#2 sp \scan_stop:
6252   \exp_args:NNf \tex_toks:D \l__str_internal_int
6253   { \__str_output_byte:n { "#1 } }

```

```

6254     \int_incr:N \l__str_internal_int
6255     \__str_encode_eight_bit_load:nn
6256   }
6257 \cs_new:Npn \__str_encode_eight_bit_char:n #1
6258 {
6259   \if_int_compare:w #1 > \c_max_register_int
6260     \flag_raise:n { str_error }
6261   \else:
6262     \if_int_compare:w \tex_dimen:D #1 < \l__str_internal_int
6263       \if_int_compare:w \tex_skip:D \tex_dimen:D #1 = #1 \exp_stop_f:
6264         \tex_the:D \tex_toks:D \tex_dimen:D #1 \exp_stop_f:
6265         \exp_after:wN \exp_after:wN \exp_after:wN \use_none:nn
6266       \fi:
6267     \fi:
6268     \__str_encode_eight_bit_char_aux:n {#1}
6269   \fi:
6270 }
6271 \cs_new:Npn \__str_encode_eight_bit_char_aux:n #1
6272 {
6273   \if_int_compare:w #1 > \c__str_max_byte_int
6274     \flag_raise:n { str_error }
6275   \else:
6276     \__str_output_byte:n {#1}
6277   \fi:
6278 }

```

(End definition for `__str_convert_encode_eight_bit:n` and others.)

9.4 Messages

General messages, and messages for the encodings and escapings loaded by default (“native”, and “bytes”).

```

6279 \__kernel_msg_new:nnn { str } { unknown-esc }
6280 { Escaping~scheme~'#1'~(filtered:~'#2')~unknown. }
6281 \__kernel_msg_new:nnn { str } { unknown-enc }
6282 { Encoding~scheme~'#1'~(filtered:~'#2')~unknown. }
6283 \__kernel_msg_new:nnnn { str } { native-escaping }
6284 { The~'native'~encoding~scheme~does~not~support~any~escaping. }
6285 {
6286   Since~native~strings~do~not~consist~in~bytes,~
6287   none~of~the~escaping~methods~make~sense.~
6288   The~specified~escaping,~'#1',~will be ignored.
6289 }
6290 \__kernel_msg_new:nnn { str } { file-not-found }
6291 { File~'l3str-#1.def'~not~found. }

```

Message used when the “bytes” unescaping fails because the string given to `\str_set_convert:Nnnn` contains a non-byte. This cannot happen for the -8-bit engines. Messages used for other escapings and encodings are defined in each definition file.

```

6292 \bool_lazy_any:nT
6293 {
6294   \sys_if_engine luatex_p:
6295   \sys_if_engine xetex_p:
6296 }

```



```

6297 {
6298   \_kernel_msg_new:nnnn { str } { non-byte }
6299   { String~invalid~in~escaping~'#1':~it~may~only~contain~bytes. }
6300   {
6301     Some~characters~in~the~string~you~asked~to~convert~are~not~
6302     8-bit~characters.~Perhaps~the~string~is~a~'native'~Unicode~string?~
6303     If~it~is,~try~using\\
6304     \\
6305     \iow_indent:n
6306     {
6307       \iow_char:N\\str_set_convert:Nnnn \\
6308       \ \ <str-var>~\{<string>~\}~\{~native~\}~\{<target-encoding>~\}
6309     }
6310   }
6311 }

```

Those messages are used when converting to and from 8-bit encodings.

```

6312 \_kernel_msg_new:nnnn { str } { decode-8-bit }
6313 { Invalid~string~in~encoding~'#1'. }
6314 {
6315   LaTeX~came~across~a~byte~which~is~not~defined~to~represent~
6316   any~character~in~the~encoding~'#1'.
6317 }
6318 \_kernel_msg_new:nnnn { str } { encode-8-bit }
6319 { Unicode~string~cannot~be~converted~to~encoding~'#1'. }
6320 {
6321   The~encoding~'#1'~only~contains~a~subset~of~all~Unicode~characters.~
6322   LaTeX~was~asked~to~convert~a~string~to~that~encoding,~but~that~
6323   string~contains~a~character~that~'#1'~does~not~support.
6324 }

```

9.5 Escaping definitions

Several of those encodings are defined by the pdf file format. The following byte storage methods are defined:

- **bytes** (default), non-bytes are filtered out, and bytes are left untouched (this is defined by default);
- **hex** or **hexadecimal**, as per the pdfTeX primitive `\pdfescapehex`
- **name**, as per the pdfTeX primitive `\pdfescapename`
- **string**, as per the pdfTeX primitive `\pdfescapestring`
- **url**, as per the percent encoding of urls.

9.5.1 Unescape methods

`_str_convert_unescape_hex:` Take chars two by two, and interpret each pair as the hexadecimal code for a byte.
`_str_unescape_hex_auxi:N` Anything else than hexadecimal digits is ignored, raising the flag. A string which contains
`_str_unescape_hex_auxii:N` an odd number of hexadecimal digits gets 0 appended to it: this is equivalent to appending
 a 0 in all cases, and dropping it if it is alone.

```

6325 \cs_new_protected:Npn \_str_convert_unescape_hex:

```

```

6326 {
6327   \group_begin:
6328     \flag_clear:n { str_error }
6329     \int_set:Nn \tex_escapechar:D { 92 }
6330     \tl_gset:Nx \g__str_result_tl
6331       {
6332         \__str_output_byte:w "
6333         \exp_last_unbraced:Nf \__str_unescape_hex_auxi:N
6334         { \tl_to_str:N \g__str_result_tl }
6335         0 { ? 0 - 1 \prg_break: }
6336         \prg_break_point:
6337         \__str_output_end:
6338       }
6339     \__str_if_flag_error:nxn { str_error } { unescape-hex } { }
6340   \group_end:
6341 }
6342 \cs_new:Npn \__str_unescape_hex_auxi:N #1
6343 {
6344   \use_none:n #1
6345   \__str_hexadecimal_use:NTF #1
6346   { \__str_unescape_hex_auxii:N }
6347   {
6348     \flag_raise:n { str_error }
6349     \__str_unescape_hex_auxi:N
6350   }
6351 }
6352 \cs_new:Npn \__str_unescape_hex_auxii:N #1
6353 {
6354   \use_none:n #1
6355   \__str_hexadecimal_use:NTF #1
6356   {
6357     \__str_output_end:
6358     \__str_output_byte:w " \__str_unescape_hex_auxi:N
6359   }
6360   {
6361     \flag_raise:n { str_error }
6362     \__str_unescape_hex_auxii:N
6363   }
6364 }
6365 \__kernel_msg_new:nnnn { str } { unescape-hex }
6366 { String~invalid~in~escaping~'hex':~only~hexadecimal~digits~allowed. }
6367 {
6368   Some~characters~in~the~string~you~asked~to~convert~are~not~
6369   hexadecimal~digits~(0-9,~A-F,~a-f)~nor~spaces.
6370 }

```

(End definition for `__str_convert_unescape_hex:`, `__str_unescape_hex_auxi:N`, and `__str_unescape_hex_auxii:N`.)

```

\__str_convert_unescape_name:
\__str_unescape_name_loop:wNN
\__str_convert_unescape_url:
\__str_unescape_url_loop:wNN

```

The `__str_convert_unescape_name:` function replaces each occurrence of # followed by two hexadecimal digits in `\g__str_result_tl` by the corresponding byte. The `url` function is identical, with escape character % instead of #. Thus we define the two together. The arguments of `__str_tmp:w` are the character code of # or % in hexadecimal, the name of the main function to define, and the name of the auxiliary which performs the loop.

The looping auxiliary #3 finds the next escape character, reads the following two characters, and tests them. The test `__str_hexadecimal_use:NTF` leaves the upper-case digit in the input stream, hence we surround the test with `__str_output_byte:w "` and `__str_output_end:.` If both characters are hexadecimal digits, they should be removed before looping: this is done by `\use_i:nnn`. If one of the characters is not a hexadecimal digit, then feed "#1 to `__str_output_byte:w` to produce the escape character, raise the flag, and call the looping function followed by the two characters (remove `\use_i:nnn`).

```

6371 \cs_set_protected:Npn \__str_tmp:w #1#2#3
6372 {
6373   \cs_new_protected:cpn { __str_convert_unescape_#2: }
6374   {
6375     \group_begin:
6376     \flag_clear:n { str_byte }
6377     \flag_clear:n { str_error }
6378     \int_set:Nn \tex_escapechar:D { 92 }
6379     \tl_gset:Nx \g__str_result_tl
6380     {
6381       \exp_after:wN #3 \g__str_result_tl
6382       #1 ? { ? \prg_break: }
6383       \prg_break_point:
6384     }
6385     \__str_if_flag_error:nnx { str_byte } { non-byte } { #2 }
6386     \__str_if_flag_error:nnx { str_error } { unescape-#2 } { }
6387   \group_end:
6388 }
6389 \cs_new:Npn #3 ##1#1##2##3
6390 {
6391   \__str_filter_bytes:n {##1}
6392   \use_none:n ##3
6393   \__str_output_byte:w "
6394   \__str_hexadecimal_use:NTF ##2
6395   {
6396     \__str_hexadecimal_use:NTF ##3
6397     { }
6398     {
6399       \flag_raise:n { str_error }
6400       * 0 + '#1 \use_i:nn
6401     }
6402   }
6403   {
6404     \flag_raise:n { str_error }
6405     0 + '#1 \use_i:nn
6406   }
6407   \__str_output_end:
6408   \use_i:nnn #3 ##2##3
6409 }
6410 \__kernel_msg_new:nnnn { str } { unescape-#2 }
6411 { String~invalid~in~escaping~'#2'. }
6412 {
6413   LaTeX~came~across~the~escape~character~'#1'~not~followed~by~
6414   two~hexadecimal~digits.~This~is~invalid~in~the~escaping~'#2'.
6415 }

```

```

6416     }
6417 \exp_after:wN \_str_tmp:w \c_hash_str { name }
6418 \_str_unescape_name_loop:wNN
6419 \exp_after:wN \_str_tmp:w \c_percent_str { url }
6420 \_str_unescape_url_loop:wNN

```

(End definition for `_str_convert_unescape_name`: and others.)

```

\_str_convert_unescape_string:
\_str_unescape_string_newlines:wN
\_str_unescape_string_loop:wNNN
\_str_unescape_string_repeat:NNNNNN

```

The **string** escaping is somewhat similar to the **name** and **url** escapings, with escape character `\`. The first step is to convert all three line endings, `^^J`, `^^M`, and `^^M^^J` to the common `^^J`, as per the PDF specification. This step cannot raise the flag.

Then the following escape sequences are decoded.

```

\n Line feed (10)
\r Carriage return (13)
\t Horizontal tab (9)
\b Backspace (8)
\f Form feed (12)
\( Left parenthesis
\) Right parenthesis
\\ Backslash

```

`\ddd` (backslash followed by 1 to 3 octal digits) Byte `ddd` (octal), subtracting 256 in case of overflow.

If followed by an end-of-line character, the backslash and the end-of-line are ignored. If followed by anything else, the backslash is ignored, raising the error flag.

```

6421 \group_begin:
6422 \char_set_catcode_other:N \^^J
6423 \char_set_catcode_other:N \^^M
6424 \cs_set_protected:Npn \_str_tmp:w #1
6425 {
6426   \cs_new_protected:Npn \_str_convert_unescape_string:
6427   {
6428     \group_begin:
6429     \flag_clear:n { str_byte }
6430     \flag_clear:n { str_error }
6431     \int_set:Nn \tex_escapechar:D { 92 }
6432     \tl_gset:Nx \g__str_result_tl
6433     {
6434       \exp_after:wN \_str_unescape_string_newlines:wN
6435       \g__str_result_tl \prg_break: ^^M ?
6436       \prg_break_point:
6437     }
6438     \tl_gset:Nx \g__str_result_tl
6439     {
6440       \exp_after:wN \_str_unescape_string_loop:wNNN
6441       \g__str_result_tl #1 ?? { ? \prg_break: }
6442       \prg_break_point:

```

```

6443     }
6444     \__str_if_flag_error:nmx { str_byte } { non-byte } { string }
6445     \__str_if_flag_error:nmx { str_error } { unescape-string } { }
6446 \group_end:
6447 }
6448 }
6449 \exp_args:No \__str_tmp:w { \c_backslash_str }
6450 \exp_last_unbraced:NNNNo
6451 \cs_new:Npn \__str_unescape_string_loop:wNNN #1 \c_backslash_str #2#3#4
6452 {
6453     \__str_filter_bytes:n {#1}
6454     \use_none:n #4
6455     \__str_output_byte:w '
6456     \__str_octal_use:NTF #2
6457     {
6458         \__str_octal_use:NTF #3
6459         {
6460             \__str_octal_use:NTF #4
6461             {
6462                 \if_int_compare:w #2 > 3 \exp_stop_f:
6463                 - 256
6464                 \fi:
6465                 \__str_unescape_string_repeat:NNNNNN
6466             }
6467             { \__str_unescape_string_repeat:NNNNNN ? }
6468         }
6469         { \__str_unescape_string_repeat:NNNNNN ?? }
6470     }
6471     {
6472         \str_case:e:nnF {#2}
6473         {
6474             { \c_backslash_str } { 134 }
6475             { ( ) } { 50 }
6476             { ) } { 51 }
6477             { r } { 15 }
6478             { f } { 14 }
6479             { n } { 12 }
6480             { t } { 11 }
6481             { b } { 10 }
6482             { ^~J } { 0 - 1 }
6483         }
6484         {
6485             \flag_raise:n { str_error }
6486             0 - 1 \use_i:nn
6487         }
6488     }
6489     \__str_output_end:
6490     \use_i:nn \__str_unescape_string_loop:wNNN #2#3#4
6491 }
6492 \cs_new:Npn \__str_unescape_string_repeat:NNNNNN #1#2#3#4#5#6
6493 { \__str_output_end: \__str_unescape_string_loop:wNNN }
6494 \cs_new:Npn \__str_unescape_string_newlines:wN #1 ^~M #2
6495 {
6496     #1

```

```

6497     \if_charcode:w ^^J #2 \else: ^^J \fi:
6498     \__str_unescape_string_newlines:wN #2
6499   }
6500   \__kernel_msg_new:nnnn { str } { unescape-string }
6501   { String~invalid~in~escaping~'string'. }
6502   {
6503     LaTeX~came~across~an~escape~character~'\c_backslash_str'~
6504     not~followed~by~any~of:~'n',~'r',~'t',~'b',~'f',~'(',~')',~
6505     '\c_backslash_str',~one~to~three~octal~digits,~or~the~end~
6506     of~a~line.
6507   }
6508   \group_end:

```

(End definition for `__str_convert_unescape_string`: and others.)

9.5.2 Escape methods

Currently, none of the escape methods can lead to errors, assuming that their input is made out of bytes.

```

\__str_convert_escape_hex: Loop and convert each byte to hexadecimal.
  \__str_escape_hex_char:N
6509   \cs_new_protected:Npn \__str_convert_escape_hex:
6510   { \__str_convert_gmap:N \__str_escape_hex_char:N }
6511   \cs_new:Npn \__str_escape_hex_char:N #1
6512   { \__str_output_hexadecimal:n { '#1' } }

(End definition for \__str_convert_escape_hex: and \__str_escape_hex_char:N.)

\__str_convert_escape_name: For each byte, test whether it should be output as is, or be “hash-encoded”. Roughly,
  \__str_escape_name_char:N bytes outside the range ["2A,"7E] are hash-encoded. We keep two lists of exceptions:
  \__str_if_escape_name:NNTF characters in \c__str_escape_name_not_str are not hash-encoded, and characters in
  \c__str_escape_name_str the \c__str_escape_name_str are encoded.
\c__str_escape_name_not_str
6513   \str_const:Nn \c__str_escape_name_not_str { ! " $ & ' } %$
6514   \str_const:Nn \c__str_escape_name_str { {}/<>[] }
6515   \cs_new_protected:Npn \__str_convert_escape_name:
6516   { \__str_convert_gmap:N \__str_escape_name_char:N }
6517   \cs_new:Npn \__str_escape_name_char:N #1
6518   {
6519     \__str_if_escape_name:NNTF #1 {#1}
6520     { \c_hash_str \__str_output_hexadecimal:n { '#1' } }
6521   }
6522   \prg_new_conditional:Npnn \__str_if_escape_name:N #1 { TF }
6523   {
6524     \if_int_compare:w '#1 < "2A \exp_stop_f:
6525     \__str_if_contains_char:NNTF \c__str_escape_name_not_str #1
6526     \prg_return_true: \prg_return_false:
6527   \else:
6528     \if_int_compare:w '#1 > "7E \exp_stop_f:
6529     \prg_return_false:
6530   \else:
6531     \__str_if_contains_char:NNTF \c__str_escape_name_str #1
6532     \prg_return_false: \prg_return_true:
6533   \fi:
6534   \fi:
6535   }

```

(End definition for `_str_convert_escape_name:` and others.)

`_str_convert_escape_string:` Any character below (and including) space, and any character above (and including) `del`,
`_str_escape_string_char:N` are converted to octal. One backslash is added before each parenthesis and backslash.
`_str_if_escape_string:NTF`
`\c_str_escape_string_str`

```

6536 \str_const:Nx \c\_str_escape_string_str
6537 { \c_backslash_str ( ) }
6538 \cs_new_protected:Npn \_str_convert_escape_string:
6539 { \_str_convert_gmap:N \_str_escape_string_char:N }
6540 \cs_new:Npn \_str_escape_string_char:N #1
6541 {
6542   \_str_if_escape_string:NTF #1
6543   {
6544     \_str_if_contains_char:NNT
6545       \c\_str_escape_string_str #1
6546       { \c_backslash_str }
6547     #1
6548   }
6549   {
6550     \c_backslash_str
6551     \int_div_truncate:nn {'#1} {64}
6552     \int_mod:nn { \int_div_truncate:nn {'#1} { 8 } } { 8 }
6553     \int_mod:nn {'#1} { 8 }
6554   }
6555 }
6556 \prg_new_conditional:Npnn \_str_if_escape_string:N #1 { TF }
6557 {
6558   \if_int_compare:w '#1 < "21 \exp_stop_f:
6559   \prg_return_false:
6560   \else:
6561     \if_int_compare:w '#1 > "7E \exp_stop_f:
6562     \prg_return_false:
6563     \else:
6564       \prg_return_true:
6565     \fi:
6566   \fi:
6567 }
```

(End definition for `_str_convert_escape_string:` and others.)

`_str_convert_escape_url:` This function is similar to `_str_convert_escape_name:`, escaping different characters.

```

\__str_escape_url_char:N
\__str_if_escape_url:NTF
6568 \cs_new_protected:Npn \_str_convert_escape_url:
6569 { \_str_convert_gmap:N \_str_escape_url_char:N }
6570 \cs_new:Npn \_str_escape_url_char:N #1
6571 {
6572   \_str_if_escape_url:NTF #1 {'#1}
6573   { \c_percent_str \_str_output_hexadecimal:n { '#1 } }
6574 }
6575 \prg_new_conditional:Npnn \_str_if_escape_url:N #1 { TF }
6576 {
6577   \if_int_compare:w '#1 < "41 \exp_stop_f:
6578   \_str_if_contains_char:nNTF { "-.<> } #1
6579   \prg_return_true: \prg_return_false:
6580   \else:
6581     \if_int_compare:w '#1 > "7E \exp_stop_f:
```

```

6582         \prg_return_false:
6583     \else:
6584         \__str_if_contains_char:nNTF { [ ] } #1
6585         \prg_return_false: \prg_return_true:
6586     \fi:
6587 \fi:
6588 }

```

(End definition for `__str_convert_escape_url:`, `__str_escape_url_char:N`, and `__str_if_escape_url:N`.)

9.6 Encoding definitions

The `native` encoding is automatically defined. Other encodings are loaded as needed. The following encodings are supported:

- UTF-8;
- UTF-16, big-, little-endian, or with byte order mark;
- UTF-32, big-, little-endian, or with byte order mark;
- the ISO 8859 code pages, numbered from 1 to 16, skipping the inexistent ISO 8859-12.

9.6.1 utf-8 support

`__str_convert_encode_utf8:` Loop through the internal string, and convert each character to its UTF-8 representation.
`__str_encode_utf_viii_char:n` The representation is built from the right-most (least significant) byte to the left-most (most significant) byte. Continuation bytes are in the range [128, 191], taking 64 different values, hence we roughly want to express the character code in base 64, shifting the first digit in the representation by some number depending on how many continuation bytes there are. In the range [0, 127], output the corresponding byte directly. In the range [128, 2047], output the remainder modulo 64, plus 128 as a continuation byte, then output the quotient (which is in the range [0, 31]), shifted by 192. In the next range, [2048, 65535], split the character code into residue and quotient modulo 64, output the residue as a first continuation byte, then repeat; this leaves us with a quotient in the range [0, 15], which we output shifted by 224. The last range, [65536, 1114111], follows the same pattern: once we realize that dividing twice by 64 leaves us with a number larger than 15, we repeat, producing a last continuation byte, and offset the quotient by 240 for the leading byte.

How is that implemented? `__str_encode_utf_vii_loop:wnnnw` takes successive quotients as its first argument, the quotient from the previous step as its second argument (except in step 1), the bound for quotients that trigger one more step or not, and finally the offset used if this step should produce the leading byte. Leading bytes can be in the ranges [0, 127], [192, 223], [224, 239], and [240, 247] (really, that last limit should be 244 because Unicode stops at the code point 1114111). At each step, if the quotient #1 is less than the limit #3 for that range, output the leading byte (#1 shifted by #4) and stop. Otherwise, we need one more step: use the quotient of #1 by 64, and #1 as arguments for the looping auxiliary, and output the continuation byte corresponding to the remainder #2 - 64#1 + 128. The bizarre construction `- 1 + 0 *` removes the spurious initial continuation byte (better methods welcome).


```

6589 \cs_new_protected:cpn { __str_convert_encode_utf8: }
6590 { \__str_convert_gmap_internal:N \__str_encode_utf_viii_char:n }
6591 \cs_new:Npn \__str_encode_utf_viii_char:n #1
6592 {
6593   \__str_encode_utf_viii_loop:wwnnw #1 ; - 1 + 0 * ;
6594   { 128 } { 0 }
6595   { 32 } { 192 }
6596   { 16 } { 224 }
6597   { 8 } { 240 }
6598   \q_stop
6599 }
6600 \cs_new:Npn \__str_encode_utf_viii_loop:wwnnw #1; #2; #3#4 #5 \q_stop
6601 {
6602   \if_int_compare:w #1 < #3 \exp_stop_f:
6603     \__str_output_byte:n { #1 + #4 }
6604     \exp_after:wN \use_none_delimit_by_q_stop:w
6605   \fi:
6606   \exp_after:wN \__str_encode_utf_viii_loop:wwnnw
6607     \int_value:w \int_div_truncate:nn {#1} {64} ; #1 ;
6608   #5 \q_stop
6609   \__str_output_byte:n { #2 - 64 * ( #1 - 2 ) }
6610 }

```

(End definition for `__str_convert_encode_utf8:`, `__str_encode_utf_viii_char:n`, and `__str_encode_utf_viii_loop:wwnnw`.)

`\l__str_missing_flag`
`\l__str_extra_flag`
`\l__str_overlong_flag`
`\l__str_overflow_flag`

When decoding a string that is purportedly in the UTF-8 encoding, four different errors can occur, signalled by a specific flag for each (we define those flags using `\flag_clear_new:n` rather than `\flag_new:n`, because they are shared with other encoding definition files).

- “Missing continuation byte”: a leading byte is not followed by the right number of continuation bytes.
- “Extra continuation byte”: a continuation byte appears where it was not expected, *i.e.*, not after an appropriate leading byte.
- “Overlong”: a Unicode character is expressed using more bytes than necessary, for instance, “C0”80 for the code point 0, instead of a single null byte.
- “Overflow”: this occurs when decoding produces Unicode code points greater than 1114111.

We only raise one L^AT_EX3 error message, combining all the errors which occurred. In the short message, the leading comma must be removed to get a grammatically correct sentence. In the long text, first remind the user what a correct UTF-8 string should look like, then add error-specific information.

```

6611 \flag_clear_new:n { str_missing }
6612 \flag_clear_new:n { str_extra }
6613 \flag_clear_new:n { str_overlong }
6614 \flag_clear_new:n { str_overflow }
6615 \__kernel_msg_new:nnnn { str } { utf8-decode }
6616 {
6617   Invalid~UTF-8~string:
6618   \exp_last_unbraced:Nf \use_none:n

```

```

6619     {
6620         \_str_if_flag_times:nT { str_missing } { ,~missing~continuation~byte }
6621         \_str_if_flag_times:nT { str_extra } { ,~extra~continuation~byte }
6622         \_str_if_flag_times:nT { str_overlong } { ,~overlong~form }
6623         \_str_if_flag_times:nT { str_overflow } { ,~code~point~too~large }
6624     }
6625 .
6626 }
6627 {
6628     In~the~UTF-8~encoding,~each~Unicode~character~consists~in~
6629     1~to~4~bytes,~with~the~following~bit~pattern: \
6630     \iow_indent:n
6631     {
6632         Code~point~\ \ \ \ <~128:~0xxxxxxx \
6633         Code~point~\ \ \ \ <~2048:~110xxxxx~10xxxxxx \
6634         Code~point~\ \ \ \ <~65536:~1110xxxx~10xxxxxx~10xxxxxx \
6635         Code~point~\ \ \ \ <~1114112:~11110xxx~10xxxxxx~10xxxxxx~10xxxxxx \
6636     }
6637     Bytes~of~the~form~10xxxxxx~are~called~continuation~bytes.
6638     \flag_if_raised:nT { str_missing }
6639     {
6640         \\\
6641         A~leading~byte~(in~the~range~[192,255])~was~not~followed~by~
6642         the~appropriate~number~of~continuation~bytes.
6643     }
6644     \flag_if_raised:nT { str_extra }
6645     {
6646         \\\
6647         LaTeX~came~across~a~continuation~byte~when~it~was~not~expected.
6648     }
6649     \flag_if_raised:nT { str_overlong }
6650     {
6651         \\\
6652         Every~Unicode~code~point~must~be~expressed~in~the~shortest~
6653         possible~form.~For~instance,~'0xC0'~'0x83'~is~not~a~valid~
6654         representation~for~the~code~point~3.
6655     }
6656     \flag_if_raised:nT { str_overflow }
6657     {
6658         \\\
6659         Unicode~limits~code~points~to~the~range~[0,1114111].
6660     }
6661 }

```

(End definition for \l__str_missing_flag and others.)

_str_convert_decode_utf8: Decoding is significantly harder than encoding. As before, lower some flags, which are tested at the end (in bulk, to trigger at most one L^AT_EX3 error, as explained above). We expect successive multi-byte sequences of the form *⟨start byte⟩ ⟨continuation bytes⟩*. The *_start* auxiliary tests the first byte:

- [0, "7F]: the byte stands alone, and is converted to its own character code;
- ["80, "BF]: unexpected continuation byte, raise the appropriate flag, and convert that byte to the replacement character "FFFD;

- ["C0, "FF]: this byte should be followed by some continuation byte(s).

In the first two cases, `\use_none_delimit_by_q_stop:w` removes data that only the third case requires, namely the limits of ranges of Unicode characters which can be expressed with 1, 2, 3, or 4 bytes.

We can now concentrate on the multi-byte case and the `_continuation` auxiliary. We expect `#3` to be in the range ["80, "BF]. The test for this goes as follows: if the character code is less than "80, we compare it to `-"C0`, yielding `false`; otherwise to `"C0`, yielding `true` in the range ["80, "BF] and `false` otherwise. If we find that the byte is not a continuation range, stop the current slew of bytes, output the replacement character, and continue parsing with the `_start` auxiliary, starting at the byte we just tested. Once we know that the byte is a continuation byte, leave it behind us in the input stream, compute what code point the bytes read so far would produce, and feed that number to the `_aux` function.

The `_aux` function tests whether we should look for more continuation bytes or not. If the number it receives as `#1` is less than the maximum `#4` for the current range, then we are done: check for an overlong representation by comparing `#1` with the maximum `#3` for the previous range. Otherwise, we call the `_continuation` auxiliary again, after shifting the “current code point” by `#4` (maximum from the range we just checked).

Two additional tests are needed: if we reach the end of the list of range maxima and we are still not done, then we are faced with an overflow. Clean up, and again insert the code point "FFFD for the replacement character. Also, every time we read a byte, we need to check whether we reached the end of the string. In a correct UTF-8 string, this happens automatically when the `_start` auxiliary leaves its first argument in the input stream: the end-marker begins with `\prg_break:`, which ends the loop. On the other hand, if the end is reached when looking for a continuation byte, the `\use_none:n #3` construction removes the first token from the end-marker, and leaves the `_end` auxiliary, which raises the appropriate error flag before ending the mapping.

```

6662 \cs_new_protected:cpn { __str_convert_decode_utf8: }
6663 {
6664   \flag_clear:n { str_error }
6665   \flag_clear:n { str_missing }
6666   \flag_clear:n { str_extra }
6667   \flag_clear:n { str_overlong }
6668   \flag_clear:n { str_overflow }
6669   \tl_gset:Nx \g__str_result_tl
6670   {
6671     \exp_after:wN \__str_decode_utf_viii_start:N \g__str_result_tl
6672     { \prg_break: \__str_decode_utf_viii_end: }
6673     \prg_break_point:
6674   }
6675   \__str_if_flag_error:nxx { str_error } { utf8-decode } { }
6676 }
6677 \cs_new:Npn \__str_decode_utf_viii_start:N #1
6678 {
6679   #1
6680   \if_int_compare:w '#1 < "C0 \exp_stop_f:
6681     \s_tl
6682     \if_int_compare:w '#1 < "80 \exp_stop_f:
6683       \int_value:w '#1
6684     \else:
6685       \flag_raise:n { str_extra }

```

```

6686         \flag_raise:n { str_error }
6687         \int_use:N \c__str_replacement_char_int
6688         \fi:
6689     \else:
6690         \exp_after:wN \__str_decode_utf_viii_continuation:wwN
6691         \int_value:w \int_eval:n { '#1 - "C0 } \exp_after:wN
6692     \fi:
6693     \s__tl
6694     \use_none_delimit_by_q_stop:w {"80} {"800} {"10000} {"110000} \q_stop
6695     \__str_decode_utf_viii_start:N
6696 }
6697 \cs_new:Npn \__str_decode_utf_viii_continuation:wwN
6698 #1 \s__tl #2 \__str_decode_utf_viii_start:N #3
6699 {
6700     \use_none:n #3
6701     \if_int_compare:w '#3 <
6702         \if_int_compare:w '#3 < "80 \exp_stop_f: - \fi:
6703         "C0 \exp_stop_f:
6704         #3
6705         \exp_after:wN \__str_decode_utf_viii_aux:wNnnwN
6706         \int_value:w \int_eval:n { #1 * "40 + '#3 - "80 } \exp_after:wN
6707     \else:
6708         \s__tl
6709         \flag_raise:n { str_missing }
6710         \flag_raise:n { str_error }
6711         \int_use:N \c__str_replacement_char_int
6712     \fi:
6713     \s__tl
6714     #2
6715     \__str_decode_utf_viii_start:N #3
6716 }
6717 \cs_new:Npn \__str_decode_utf_viii_aux:wNnnwN
6718 #1 \s__tl #2#3#4 #5 \__str_decode_utf_viii_start:N #6
6719 {
6720     \if_int_compare:w #1 < #4 \exp_stop_f:
6721         \s__tl
6722         \if_int_compare:w #1 < #3 \exp_stop_f:
6723             \flag_raise:n { str_overlong }
6724             \flag_raise:n { str_error }
6725             \int_use:N \c__str_replacement_char_int
6726         \else:
6727             #1
6728         \fi:
6729     \else:
6730         \if_meaning:w \q_stop #5
6731             \__str_decode_utf_viii_overflow:w #1
6732         \fi:
6733         \exp_after:wN \__str_decode_utf_viii_continuation:wwN
6734         \int_value:w \int_eval:n { #1 - #4 } \exp_after:wN
6735     \fi:
6736     \s__tl
6737     #2 {#4} #5
6738     \__str_decode_utf_viii_start:N
6739 }

```

```

6740 \cs_new:Npn \__str_decode_utf_viii_overflow:w #1 \fi: #2 \fi:
6741 {
6742   \fi: \fi:
6743   \flag_raise:n { str_overflow }
6744   \flag_raise:n { str_error }
6745   \int_use:N \c__str_replacement_char_int
6746 }
6747 \cs_new:Npn \__str_decode_utf_viii_end:
6748 {
6749   \s_tl
6750   \flag_raise:n { str_missing }
6751   \flag_raise:n { str_error }
6752   \int_use:N \c__str_replacement_char_int \s_tl
6753   \prg_break:
6754 }

```

(End definition for `__str_convert_decode_utf8:` and others.)

9.6.2 utf-16 support

The definitions are done in a category code regime where the bytes 254 and 255 used by the byte order mark have catcode 12.

```

6755 \group_begin:
6756   \char_set_catcode_other:N ^^fe
6757   \char_set_catcode_other:N ^^ff

```

`__str_convert_encode_utf16:` When the endianness is not specified, it is big-endian by default, and we add a byte-order mark. Convert characters one by one in a loop, with different behaviours depending on the character code.

`__str_encode_utf_xvi_aux:N`
`__str_encode_utf_xvi_char:n`

- [0, "D7FF]: converted to two bytes;
- ["D800, "DFFF] are used as surrogates: they cannot be converted and are replaced by the replacement character;
- ["E000, "FFFF]: converted to two bytes;
- ["10000, "10FFFF]: converted to a pair of surrogates, each two bytes. The magic "D7C0 is "D800 – "10000/"400.

For the duration of this operation, `__str_tmp:w` is defined as a function to convert a number in the range [0, "FFFF] to a pair of bytes (either big endian or little endian), by feeding the quotient of the division of #1 by "100, followed by #1 to `__str_encode_utf_xvi_be:nn` or its `le` analog: those compute the remainder, and output two bytes for the quotient and remainder.

```

6758 \cs_new_protected:cpn { __str_convert_encode_utf16: }
6759 {
6760   \__str_encode_utf_xvi_aux:N \__str_output_byte_pair_be:n
6761   \tl_gput_left:Nx \g__str_result_tl { ^^fe ^^ff }
6762 }
6763 \cs_new_protected:cpn { __str_convert_encode_utf16be: }
6764 { \__str_encode_utf_xvi_aux:N \__str_output_byte_pair_be:n }
6765 \cs_new_protected:cpn { __str_convert_encode_utf16le: }
6766 { \__str_encode_utf_xvi_aux:N \__str_output_byte_pair_le:n }

```

```

6767 \cs_new_protected:Npn \__str_encode_utf_xvi_aux:N #1
6768 {
6769   \flag_clear:n { str_error }
6770   \cs_set_eq:NN \__str_tmp:w #1
6771   \__str_convert_gmap_internal:N \__str_encode_utf_xvi_char:n
6772   \__str_if_flag_error:nnx { str_error } { utf16-encode } { }
6773 }
6774 \cs_new:Npn \__str_encode_utf_xvi_char:n #1
6775 {
6776   \if_int_compare:w #1 < "D800 \exp_stop_f:
6777   \__str_tmp:w {#1}
6778   \else:
6779     \if_int_compare:w #1 < "10000 \exp_stop_f:
6780     \if_int_compare:w #1 < "E000 \exp_stop_f:
6781     \flag_raise:n { str_error }
6782     \__str_tmp:w { \c__str_replacement_char_int }
6783     \else:
6784       \__str_tmp:w {#1}
6785     \fi:
6786   \else:
6787     \exp_args:Nf \__str_tmp:w { \int_div_truncate:nn {#1} {"400} + "D7C0 }
6788     \exp_args:Nf \__str_tmp:w { \int_mod:nn {#1} {"400} + "DC00 }
6789   \fi:
6790   \fi:
6791 }

```

(End definition for __str_convert_encode_utf16: and others.)

\l__str_missing_flag When encoding a Unicode string to UTF-16, only one error can occur: code points in the range ["D800,"DFFF], corresponding to surrogates, cannot be encoded. We use the
 \l__str_extra_flag all-purpose flag @@_error to signal that error.
 \l__str_end_flag

When decoding a Unicode string which is purportedly in UTF-16, three errors can occur: a missing trail surrogate, an unexpected trail surrogate, and a string containing an odd number of bytes.

```

6792 \flag_clear_new:n { str_missing }
6793 \flag_clear_new:n { str_extra }
6794 \flag_clear_new:n { str_end }
6795 \__kernel_msg_new:nnnn { str } { utf16-encode }
6796 { Unicode-string-cannot-be-expressed-in-UTF-16:-surrogate. }
6797 {
6798   Surrogate-code-points~(in-the-range~[U+D800,-U+DFFF])~
6799   can-be-expressed-in-the~UTF-8-and-UTF-32-encodings,~
6800   but-not-in-the~UTF-16-encoding.
6801 }
6802 \__kernel_msg_new:nnnn { str } { utf16-decode }
6803 {
6804   Invalid-UTF-16-string:
6805   \exp_last_unbraced:Nf \use_none:n
6806   {
6807     \__str_if_flag_times:nT { str_missing } { ,~missing-trail-surrogate }
6808     \__str_if_flag_times:nT { str_extra } { ,~extra-trail-surrogate }
6809     \__str_if_flag_times:nT { str_end } { ,~odd-number-of-bytes }
6810   }
6811 .

```

```

6812     }
6813     {
6814         In-the-UTF-16-encoding,~each~Unicode~character~is~encoded~as~
6815         2~or~4~bytes: \\
6816         \iow_indent:n
6817         {
6818             Code~point~in~[U+0000,~U+D7FF]:~two~bytes \\
6819             Code~point~in~[U+D800,~U+DFFF]:~illegal \\
6820             Code~point~in~[U+E000,~U+FFFF]:~two~bytes \\
6821             Code~point~in~[U+10000,~U+10FFFF]:~
6822             a~lead~surrogate~and~a~trail~surrogate \\
6823         }
6824         Lead-surrogates~are~pairs~of~bytes~in~the~range~[0xD800,~0xDBFF],~
6825         and~trail~surrogates~are~in~the~range~[0xDC00,~0xDFFF].
6826         \flag_if_raised:nT { str_missing }
6827         {
6828             \\ \\
6829             A~lead~surrogate~was~not~followed~by~a~trail~surrogate.
6830         }
6831         \flag_if_raised:nT { str_extra }
6832         {
6833             \\ \\
6834             LaTeX~came~across~a~trail~surrogate~when~it~was~not~expected.
6835         }
6836         \flag_if_raised:nT { str_end }
6837         {
6838             \\ \\
6839             The~string~contained~an~odd~number~of~bytes.~This~is~invalid:~
6840             the~basic~code~unit~for~UTF-16~is~16~bits~(2~bytes).
6841         }
6842     }

```

(End definition for \l__str_missing_flag, \l__str_extra_flag, and \l__str_end_flag.)

__str_convert_decode_utf16: As for UTF-8, decoding UTF-16 is harder than encoding it. If the endianness is unknown, check the first two bytes: if those are "FE and "FF in either order, remove them and use the corresponding endianness, otherwise assume big-endianness. The three endianness cases are based on a common auxiliary whose first argument is 1 for big-endian and 2 for little-endian, and whose second argument, delimited by the scan mark \s_stop, is expanded once (the string may be long; passing \g__str_result_tl as an argument before expansion is cheaper).

The __str_decode_utf_xvi:Nw function defines __str_tmp:w to take two arguments and return the character code of the first one if the string is big-endian, and the second one if the string is little-endian, then loops over the string using __str_decode_utf_xvi_pair:NN described below.

```

6843     \cs_new_protected:cpn { __str_convert_decode_utf16be: }
6844     { \__str_decode_utf_xvi:Nw 1 \g__str_result_tl \s_stop }
6845     \cs_new_protected:cpn { __str_convert_decode_utf16le: }
6846     { \__str_decode_utf_xvi:Nw 2 \g__str_result_tl \s_stop }
6847     \cs_new_protected:cpn { __str_convert_decode_utf16: }
6848     {
6849         \exp_after:wN \__str_decode_utf_xvi_bom:NN
6850         \g__str_result_tl \s_stop \s_stop \s_stop

```

```

6851     }
6852     \cs_new_protected:Npn \__str_decode_utf_xvi_bom:NN #1#2
6853     {
6854         \str_if_eq:nnTF { #1#2 } { ^^ff ^^fe }
6855         { \__str_decode_utf_xvi:Nw 2 }
6856         {
6857             \str_if_eq:nnTF { #1#2 } { ^^fe ^^ff }
6858             { \__str_decode_utf_xvi:Nw 1 }
6859             { \__str_decode_utf_xvi:Nw 1 #1#2 }
6860         }
6861     }
6862     \cs_new_protected:Npn \__str_decode_utf_xvi:Nw #1#2 \s_stop
6863     {
6864         \flag_clear:n { str_error }
6865         \flag_clear:n { str_missing }
6866         \flag_clear:n { str_extra }
6867         \flag_clear:n { str_end }
6868         \cs_set:Npn \__str_tmp:w ##1 ##2 { ' ## #1 }
6869         \tl_gset:Nx \g__str_result_tl
6870         {
6871             \exp_after:wN \__str_decode_utf_xvi_pair:NN
6872             #2 \q_nil \q_nil
6873             \prg_break_point:
6874         }
6875         \__str_if_flag_error:nmx { str_error } { utf16-decode } { }
6876     }

```

(End definition for `__str_convert_decode_utf16:` and others.)

```

\__str_decode_utf_xvi_pair:NN
\__str_decode_utf_xvi_quad:NNwNN
\__str_decode_utf_xvi_pair_end:Nw
\__str_decode_utf_xvi_error:nnN
\__str_decode_utf_xvi_extra:NNw

```

Bytes are read two at a time. At this stage, `\@@_tmp:w #1#2` expands to the character code of the most significant byte, and we distinguish cases depending on which range it lies in:

- ["D8, "DB] signals a lead surrogate, and the integer expression yields 1 (ε -TEX rounds ties away from zero);
- ["DC, "DF] signals a trail surrogate, unexpected here, and the integer expression yields 2;
- any other value signals a code point in the Basic Multilingual Plane, which stands for itself, and the `\if_case:w` construction expands to nothing (cases other than 1 or 2), leaving the relevant material in the input stream, followed by another call to the `_pair` auxiliary.

The case of a lead surrogate is treated by the `_quad` auxiliary, whose arguments `#1`, `#2`, `#4` and `#5` are the four bytes. We expect the most significant byte of `#4#5` to be in the range ["DC, "DF] (trail surrogate). The test is similar to the test used for continuation bytes in the UTF-8 decoding functions. In the case where `#4#5` is indeed a trail surrogate, leave `#1#2#4#5 \s__tl <code point> \s__tl`, and remove the pair `#4#5` before looping with `__str_decode_utf_xvi_pair:NN`. Otherwise, of course, complain about the missing surrogate.

The magic number "D7F7 is such that `"D7F7*"400 = "D800*"400+"DC00—"10000`.

Every time we read a pair of bytes, we test for the end-marker `\q_nil`. When reaching the end, we additionally check that the string had an even length. Also, if the end is reached when expecting a trail surrogate, we treat that as a missing surrogate.

```

6877 \cs_new:Npn \__str_decode_utf_xvi_pair:NN #1#2
6878 {
6879   \if_meaning:w \q_nil #2
6880   \__str_decode_utf_xvi_pair_end:Nw #1
6881   \fi:
6882   \if_case:w
6883     \int_eval:n { ( \__str_tmp:w #1#2 - "D6 ) / 4 } \scan_stop:
6884   \or: \exp_after:wN \__str_decode_utf_xvi_quad:NNwNN
6885   \or: \exp_after:wN \__str_decode_utf_xvi_extra:NNw
6886   \fi:
6887   #1#2 \s__tl
6888   \int_eval:n { "100 * \__str_tmp:w #1#2 + \__str_tmp:w #2#1 } \s__tl
6889   \__str_decode_utf_xvi_pair:NN
6890 }
6891 \cs_new:Npn \__str_decode_utf_xvi_quad:NNwNN
6892   #1#2 #3 \__str_decode_utf_xvi_pair:NN #4#5
6893 {
6894   \if_meaning:w \q_nil #5
6895   \__str_decode_utf_xvi_error:nNN { missing } #1#2
6896   \__str_decode_utf_xvi_pair_end:Nw #4
6897   \fi:
6898   \if_int_compare:w
6899     \if_int_compare:w \__str_tmp:w #4#5 < "DC \exp_stop_f:
6900       0 = 1
6901     \else:
6902       \__str_tmp:w #4#5 < "E0
6903     \fi:
6904     \exp_stop_f:
6905     #1 #2 #4 #5 \s__tl
6906     \int_eval:n
6907     {
6908       ( "100 * \__str_tmp:w #1#2 + \__str_tmp:w #2#1 - "D7F7 ) * "400
6909       + "100 * \__str_tmp:w #4#5 + \__str_tmp:w #5#4
6910     }
6911     \s__tl
6912     \exp_after:wN \use_i:nnn
6913   \else:
6914     \__str_decode_utf_xvi_error:nNN { missing } #1#2
6915   \fi:
6916   \__str_decode_utf_xvi_pair:NN #4#5
6917 }
6918 \cs_new:Npn \__str_decode_utf_xvi_pair_end:Nw #1 \fi:
6919 {
6920   \fi:
6921   \if_meaning:w \q_nil #1
6922   \else:
6923     \__str_decode_utf_xvi_error:nNN { end } #1 \prg_do_nothing:
6924   \fi:
6925   \prg_break:
6926 }
6927 \cs_new:Npn \__str_decode_utf_xvi_extra:NNw #1#2 \s__tl #3 \s__tl

```

```

6928     { \__str_decode_utf_xvi_error:nn { extra } #1#2 }
6929 \cs_new:Npn \__str_decode_utf_xvi_error:nn #1#2#3
6930 {
6931     \flag_raise:n { str_error }
6932     \flag_raise:n { str_#1 }
6933     #2 #3 \s_tl
6934     \int_use:N \c__str_replacement_char_int \s_tl
6935 }

```

(End definition for __str_decode_utf_xvi_pair:nn and others.)

Restore the original catcodes of bytes 254 and 255.

```

6936 \group_end:

```

9.6.3 utf-32 support

The definitions are done in a category code regime where the bytes 0, 254 and 255 used by the byte order mark have catcode “other”.

```

6937 \group_begin:
6938 \char_set_catcode_other:N ^^00
6939 \char_set_catcode_other:N ^^fe
6940 \char_set_catcode_other:N ^^ff

```

__str_convert_encode_utf32: Convert each integer in the comma-list \g__str_result_tl to a sequence of four bytes. The functions for big-endian and little-endian encodings are very similar, but the __str_output_byte:n instructions are reversed.

```

\__str_convert_encode_utf32be:
\__str_convert_encode_utf32le:
\__str_encode_utf_xxxii_be:n
\__str_encode_utf_xxxii_be_aux:nn
\__str_encode_utf_xxxii_le:n
\__str_encode_utf_xxxii_le_aux:nn
6941 \cs_new_protected:cpn { __str_convert_encode_utf32: }
6942 {
6943     \__str_convert_gmap_internal:N \__str_encode_utf_xxxii_be:n
6944     \tl_gput_left:Nx \g__str_result_tl { ^^00 ^^00 ^^fe ^^ff }
6945 }
6946 \cs_new_protected:cpn { __str_convert_encode_utf32be: }
6947 { \__str_convert_gmap_internal:N \__str_encode_utf_xxxii_be:n }
6948 \cs_new_protected:cpn { __str_convert_encode_utf32le: }
6949 { \__str_convert_gmap_internal:N \__str_encode_utf_xxxii_le:n }
6950 \cs_new:Npn \__str_encode_utf_xxxii_be:n #1
6951 {
6952     \exp_args:Nf \__str_encode_utf_xxxii_be_aux:nn
6953     { \int_div_truncate:nn {#1} { "100 } } {#1}
6954 }
6955 \cs_new:Npn \__str_encode_utf_xxxii_be_aux:nn #1#2
6956 {
6957     ^^00
6958     \__str_output_byte_pair_be:n {#1}
6959     \__str_output_byte:n { #2 - #1 * "100 }
6960 }
6961 \cs_new:Npn \__str_encode_utf_xxxii_le:n #1
6962 {
6963     \exp_args:Nf \__str_encode_utf_xxxii_le_aux:nn
6964     { \int_div_truncate:nn {#1} { "100 } } {#1}
6965 }
6966 \cs_new:Npn \__str_encode_utf_xxxii_le_aux:nn #1#2
6967 {
6968     \__str_output_byte:n { #2 - #1 * "100 }

```

```

6969     \__str_output_byte_pair_le:n {#1}
6970     ^^00
6971 }

```

(End definition for `__str_convert_encode_utf32:` and others.)

str_overflow There can be no error when encoding in UTF-32. When decoding, the string may not
str_end have length $4n$, or it may contain code points larger than "10FFFF". The latter case often happens if the encoding was in fact not UTF-32, because most arbitrary strings are not valid in UTF-32.

```

6972 \flag_clear_new:n { str_overflow }
6973 \flag_clear_new:n { str_end }
6974 \__kernel_msg_new:nnnn { str } { utf32-decode }
6975 {
6976   Invalid-UTF-32-string:
6977   \exp_last_unbraced:Nf \use_none:n
6978   {
6979     \__str_if_flag_times:nT { str_overflow } { ,~code-point-too-large }
6980     \__str_if_flag_times:nT { str_end }      { ,~truncated-string }
6981   }
6982   .
6983 }
6984 {
6985   In~the~UTF-32~encoding,~every~Unicode~character~
6986   (in~the~range~[U+0000,~U+10FFFF])~is~encoded~as~4~bytes.
6987   \flag_if_raised:nT { str_overflow }
6988   {
6989     \\\
6990     LaTeX~came~across~a~code~point~larger~than~1114111,~
6991     the~maximum~code~point~defined~by~Unicode.~
6992     Perhaps~the~string~was~not~encoded~in~the~UTF-32~encoding?
6993   }
6994   \flag_if_raised:nT { str_end }
6995   {
6996     \\\
6997     The~length~of~the~string~is~not~a~multiple~of~4.~
6998     Perhaps~the~string~was~truncated?
6999   }
7000 }

```

(End definition for `str_overflow` and `str_end`. These variables are documented on page ??.)

`__str_convert_decode_utf32:` The structure is similar to UTF-16 decoding functions. If the endianness is not given, test the first 4 bytes of the string (possibly `\s_stop` if the string is too short) for the presence of a byte-order mark. If there is a byte-order mark, use that endianness, and remove the 4 bytes, otherwise default to big-endian, and leave the 4 bytes in place. The
`__str_decode_utf_xxxii_bom:NNNN` auxiliary receives 1 or 2 as its first argument indicating endianness, and the string to convert as its second argument (expanded or not). It sets
`__str_decode_utf_xxxii_loop:NNNN` `__str_tmp:w` to expand to the character code of either of its two arguments depending on endianness, then triggers the `_loop` auxiliary inside an x-expanding assignment to
`\g__str_result_tl`.

The `_loop` auxiliary first checks for the end-of-string marker `\s_stop`, calling the `_end` auxiliary if appropriate. Otherwise, leave the $\langle 4 \text{ bytes} \rangle$ `\s_tl` behind, then check

that the code point is not overflowing: the leading byte must be 0, and the following byte at most 16.

In the ending code, we check that there remains no byte: there should be nothing left until the first `\s_stop`. Break the map.

```

7001 \cs_new_protected:cpn { __str_convert_decode_utf32be: }
7002 { \__str_decode_utf_xxxii:Nw 1 \g__str_result_tl \s_stop }
7003 \cs_new_protected:cpn { __str_convert_decode_utf32le: }
7004 { \__str_decode_utf_xxxii:Nw 2 \g__str_result_tl \s_stop }
7005 \cs_new_protected:cpn { __str_convert_decode_utf32: }
7006 {
7007   \exp_after:wN \__str_decode_utf_xxxii_bom:NNNN \g__str_result_tl
7008   \s_stop \s_stop \s_stop \s_stop \s_stop
7009 }
7010 \cs_new_protected:Npn \__str_decode_utf_xxxii_bom:NNNN #1#2#3#4
7011 {
7012   \str_if_eq:nnTF { #1#2#3#4 } { ^^ff ^^fe ^^00 ^^00 }
7013   { \__str_decode_utf_xxxii:Nw 2 }
7014   {
7015     \str_if_eq:nnTF { #1#2#3#4 } { ^^00 ^^00 ^^fe ^^ff }
7016     { \__str_decode_utf_xxxii:Nw 1 }
7017     { \__str_decode_utf_xxxii:Nw 1 #1#2#3#4 }
7018   }
7019 }
7020 \cs_new_protected:Npn \__str_decode_utf_xxxii:Nw #1#2 \s_stop
7021 {
7022   \flag_clear:n { str_overflow }
7023   \flag_clear:n { str_end }
7024   \flag_clear:n { str_error }
7025   \cs_set:Npn \__str_tmp:w ##1 ##2 { ' ## #1 }
7026   \tl_gset:Nx \g__str_result_tl
7027   {
7028     \exp_after:wN \__str_decode_utf_xxxii_loop:NNNN
7029     #2 \s_stop \s_stop \s_stop \s_stop
7030     \prg_break_point:
7031   }
7032   \__str_if_flag_error:nnx { str_error } { utf32-decode } { }
7033 }
7034 \cs_new:Npn \__str_decode_utf_xxxii_loop:NNNN #1#2#3#4
7035 {
7036   \if_meaning:w \s_stop #4
7037   \exp_after:wN \__str_decode_utf_xxxii_end:w
7038   \fi:
7039   #1#2#3#4 \s_tl
7040   \if_int_compare:w \__str_tmp:w #1#4 > 0 \exp_stop_f:
7041     \flag_raise:n { str_overflow }
7042     \flag_raise:n { str_error }
7043     \int_use:N \c__str_replacement_char_int
7044   \else:
7045     \if_int_compare:w \__str_tmp:w #2#3 > 16 \exp_stop_f:
7046       \flag_raise:n { str_overflow }
7047       \flag_raise:n { str_error }
7048       \int_use:N \c__str_replacement_char_int
7049     \else:
7050       \int_eval:n

```

```

7051         { \_str_tmp:w #2#3*"10000 + \_str_tmp:w #3#2*"100 + \_str_tmp:w #4#1 }
7052         \fi:
7053         \fi:
7054         \s__tl
7055         \_str_decode_utf_xxxii_loop:NNNN
7056     }
7057     \cs_new:Npn \_str_decode_utf_xxxii_end:w #1 \s_stop
7058     {
7059         \tl_if_empty:nF {#1}
7060         {
7061             \flag_raise:n { str_end }
7062             \flag_raise:n { str_error }
7063             #1 \s__tl
7064             \int_use:N \c__str_replacement_char_int \s__tl
7065         }
7066         \prg_break:
7067     }

```

(End definition for _str_convert_decode_utf32: and others.)

Restore the original catcodes of bytes 0, 254 and 255.

```

7068 \group_end:
7069 </initex | package>

```

9.6.4 iso 8859 support

The ISO-8859-1 encoding exactly matches with the 256 first Unicode characters. For other 8-bit encodings of the ISO-8859 family, we keep track only of differences, and of unassigned bytes.

```

7070 <*iso88591>
7071 \str_declare_eight_bit_encoding:nnn { iso88591 }
7072 {
7073 }
7074 {
7075 }
7076 </iso88591>
7077 <*iso88592>
7078 \str_declare_eight_bit_encoding:nnn { iso88592 }
7079 {
7080     { A1 } { 0104 }
7081     { A2 } { 02D8 }
7082     { A3 } { 0141 }
7083     { A5 } { 013D }
7084     { A6 } { 015A }
7085     { A9 } { 0160 }
7086     { AA } { 015E }
7087     { AB } { 0164 }
7088     { AC } { 0179 }
7089     { AE } { 017D }
7090     { AF } { 017B }
7091     { B1 } { 0105 }
7092     { B2 } { 02DB }
7093     { B3 } { 0142 }
7094     { B5 } { 013E }

```

```

7095     { B6 } { 015B }
7096     { B7 } { 02C7 }
7097     { B9 } { 0161 }
7098     { BA } { 015F }
7099     { BB } { 0165 }
7100     { BC } { 017A }
7101     { BD } { 02DD }
7102     { BE } { 017E }
7103     { BF } { 017C }
7104     { C0 } { 0154 }
7105     { C3 } { 0102 }
7106     { C5 } { 0139 }
7107     { C6 } { 0106 }
7108     { C8 } { 010C }
7109     { CA } { 0118 }
7110     { CC } { 011A }
7111     { CF } { 010E }
7112     { D0 } { 0110 }
7113     { D1 } { 0143 }
7114     { D2 } { 0147 }
7115     { D5 } { 0150 }
7116     { D8 } { 0158 }
7117     { D9 } { 016E }
7118     { DB } { 0170 }
7119     { DE } { 0162 }
7120     { E0 } { 0155 }
7121     { E3 } { 0103 }
7122     { E5 } { 013A }
7123     { E6 } { 0107 }
7124     { E8 } { 010D }
7125     { EA } { 0119 }
7126     { EC } { 011B }
7127     { EF } { 010F }
7128     { F0 } { 0111 }
7129     { F1 } { 0144 }
7130     { F2 } { 0148 }
7131     { F5 } { 0151 }
7132     { F8 } { 0159 }
7133     { F9 } { 016F }
7134     { FB } { 0171 }
7135     { FE } { 0163 }
7136     { FF } { 02D9 }
7137 }
7138 {
7139 }
7140 </iso88592>
7141 <*iso88593>
7142 \str_declare_eight_bit_encoding:nmn { iso88593 }
7143 {
7144     { A1 } { 0126 }
7145     { A2 } { 02D8 }
7146     { A6 } { 0124 }
7147     { A9 } { 0130 }
7148     { AA } { 015E }

```

```

7149     { AB } { 011E }
7150     { AC } { 0134 }
7151     { AF } { 017B }
7152     { B1 } { 0127 }
7153     { B6 } { 0125 }
7154     { B9 } { 0131 }
7155     { BA } { 015F }
7156     { BB } { 011F }
7157     { BC } { 0135 }
7158     { BF } { 017C }
7159     { C5 } { 010A }
7160     { C6 } { 0108 }
7161     { D5 } { 0120 }
7162     { D8 } { 011C }
7163     { DD } { 016C }
7164     { DE } { 015C }
7165     { E5 } { 010B }
7166     { E6 } { 0109 }
7167     { F5 } { 0121 }
7168     { F8 } { 011D }
7169     { FD } { 016D }
7170     { FE } { 015D }
7171     { FF } { 02D9 }
7172 }
7173 {
7174     { A5 }
7175     { AE }
7176     { BE }
7177     { C3 }
7178     { D0 }
7179     { E3 }
7180     { F0 }
7181 }
7182 </iso88593>
7183 <*:iso88594>
7184 \str_declare_eight_bit_encoding:nnn { iso88594 }
7185 {
7186     { A1 } { 0104 }
7187     { A2 } { 0138 }
7188     { A3 } { 0156 }
7189     { A5 } { 0128 }
7190     { A6 } { 013B }
7191     { A9 } { 0160 }
7192     { AA } { 0112 }
7193     { AB } { 0122 }
7194     { AC } { 0166 }
7195     { AE } { 017D }
7196     { B1 } { 0105 }
7197     { B2 } { 02DB }
7198     { B3 } { 0157 }
7199     { B5 } { 0129 }
7200     { B6 } { 013C }
7201     { B7 } { 02C7 }
7202     { B9 } { 0161 }

```

```

7203     { BA } { 0113 }
7204     { BB } { 0123 }
7205     { BC } { 0167 }
7206     { BD } { 014A }
7207     { BE } { 017E }
7208     { BF } { 014B }
7209     { C0 } { 0100 }
7210     { C7 } { 012E }
7211     { C8 } { 010C }
7212     { CA } { 0118 }
7213     { CC } { 0116 }
7214     { CF } { 012A }
7215     { D0 } { 0110 }
7216     { D1 } { 0145 }
7217     { D2 } { 014C }
7218     { D3 } { 0136 }
7219     { D9 } { 0172 }
7220     { DD } { 0168 }
7221     { DE } { 016A }
7222     { E0 } { 0101 }
7223     { E7 } { 012F }
7224     { E8 } { 010D }
7225     { EA } { 0119 }
7226     { EC } { 0117 }
7227     { EF } { 012B }
7228     { F0 } { 0111 }
7229     { F1 } { 0146 }
7230     { F2 } { 014D }
7231     { F3 } { 0137 }
7232     { F9 } { 0173 }
7233     { FD } { 0169 }
7234     { FE } { 016B }
7235     { FF } { 02D9 }
7236 }
7237 {
7238 }
7239 </iso88594>
7240 <(*iso88595>
7241 \str_declare_eight_bit_encoding:nnn { iso88595 }
7242 {
7243     { A1 } { 0401 }
7244     { A2 } { 0402 }
7245     { A3 } { 0403 }
7246     { A4 } { 0404 }
7247     { A5 } { 0405 }
7248     { A6 } { 0406 }
7249     { A7 } { 0407 }
7250     { A8 } { 0408 }
7251     { A9 } { 0409 }
7252     { AA } { 040A }
7253     { AB } { 040B }
7254     { AC } { 040C }
7255     { AE } { 040E }
7256     { AF } { 040F }

```


7257	{ B0 }	{ 0410 }
7258	{ B1 }	{ 0411 }
7259	{ B2 }	{ 0412 }
7260	{ B3 }	{ 0413 }
7261	{ B4 }	{ 0414 }
7262	{ B5 }	{ 0415 }
7263	{ B6 }	{ 0416 }
7264	{ B7 }	{ 0417 }
7265	{ B8 }	{ 0418 }
7266	{ B9 }	{ 0419 }
7267	{ BA }	{ 041A }
7268	{ BB }	{ 041B }
7269	{ BC }	{ 041C }
7270	{ BD }	{ 041D }
7271	{ BE }	{ 041E }
7272	{ BF }	{ 041F }
7273	{ C0 }	{ 0420 }
7274	{ C1 }	{ 0421 }
7275	{ C2 }	{ 0422 }
7276	{ C3 }	{ 0423 }
7277	{ C4 }	{ 0424 }
7278	{ C5 }	{ 0425 }
7279	{ C6 }	{ 0426 }
7280	{ C7 }	{ 0427 }
7281	{ C8 }	{ 0428 }
7282	{ C9 }	{ 0429 }
7283	{ CA }	{ 042A }
7284	{ CB }	{ 042B }
7285	{ CC }	{ 042C }
7286	{ CD }	{ 042D }
7287	{ CE }	{ 042E }
7288	{ CF }	{ 042F }
7289	{ D0 }	{ 0430 }
7290	{ D1 }	{ 0431 }
7291	{ D2 }	{ 0432 }
7292	{ D3 }	{ 0433 }
7293	{ D4 }	{ 0434 }
7294	{ D5 }	{ 0435 }
7295	{ D6 }	{ 0436 }
7296	{ D7 }	{ 0437 }
7297	{ D8 }	{ 0438 }
7298	{ D9 }	{ 0439 }
7299	{ DA }	{ 043A }
7300	{ DB }	{ 043B }
7301	{ DC }	{ 043C }
7302	{ DD }	{ 043D }
7303	{ DE }	{ 043E }
7304	{ DF }	{ 043F }
7305	{ E0 }	{ 0440 }
7306	{ E1 }	{ 0441 }
7307	{ E2 }	{ 0442 }
7308	{ E3 }	{ 0443 }
7309	{ E4 }	{ 0444 }
7310	{ E5 }	{ 0445 }

```

7311     { E6 } { 0446 }
7312     { E7 } { 0447 }
7313     { E8 } { 0448 }
7314     { E9 } { 0449 }
7315     { EA } { 044A }
7316     { EB } { 044B }
7317     { EC } { 044C }
7318     { ED } { 044D }
7319     { EE } { 044E }
7320     { EF } { 044F }
7321     { F0 } { 2116 }
7322     { F1 } { 0451 }
7323     { F2 } { 0452 }
7324     { F3 } { 0453 }
7325     { F4 } { 0454 }
7326     { F5 } { 0455 }
7327     { F6 } { 0456 }
7328     { F7 } { 0457 }
7329     { F8 } { 0458 }
7330     { F9 } { 0459 }
7331     { FA } { 045A }
7332     { FB } { 045B }
7333     { FC } { 045C }
7334     { FD } { 00A7 }
7335     { FE } { 045E }
7336     { FF } { 045F }
7337 }
7338 {
7339 }
7340 </iso88595>
7341 <*iso88596>
7342 \str_declare_eight_bit_encoding:nnn { iso88596 }
7343 {
7344     { AC } { 060C }
7345     { BB } { 061B }
7346     { BF } { 061F }
7347     { C1 } { 0621 }
7348     { C2 } { 0622 }
7349     { C3 } { 0623 }
7350     { C4 } { 0624 }
7351     { C5 } { 0625 }
7352     { C6 } { 0626 }
7353     { C7 } { 0627 }
7354     { C8 } { 0628 }
7355     { C9 } { 0629 }
7356     { CA } { 062A }
7357     { CB } { 062B }
7358     { CC } { 062C }
7359     { CD } { 062D }
7360     { CE } { 062E }
7361     { CF } { 062F }
7362     { D0 } { 0630 }
7363     { D1 } { 0631 }
7364     { D2 } { 0632 }

```

```

7365      { D3 } { 0633 }
7366      { D4 } { 0634 }
7367      { D5 } { 0635 }
7368      { D6 } { 0636 }
7369      { D7 } { 0637 }
7370      { D8 } { 0638 }
7371      { D9 } { 0639 }
7372      { DA } { 063A }
7373      { E0 } { 0640 }
7374      { E1 } { 0641 }
7375      { E2 } { 0642 }
7376      { E3 } { 0643 }
7377      { E4 } { 0644 }
7378      { E5 } { 0645 }
7379      { E6 } { 0646 }
7380      { E7 } { 0647 }
7381      { E8 } { 0648 }
7382      { E9 } { 0649 }
7383      { EA } { 064A }
7384      { EB } { 064B }
7385      { EC } { 064C }
7386      { ED } { 064D }
7387      { EE } { 064E }
7388      { EF } { 064F }
7389      { F0 } { 0650 }
7390      { F1 } { 0651 }
7391      { F2 } { 0652 }
7392    }
7393    {
7394      { A1 }
7395      { A2 }
7396      { A3 }
7397      { A5 }
7398      { A6 }
7399      { A7 }
7400      { A8 }
7401      { A9 }
7402      { AA }
7403      { AB }
7404      { AE }
7405      { AF }
7406      { B0 }
7407      { B1 }
7408      { B2 }
7409      { B3 }
7410      { B4 }
7411      { B5 }
7412      { B6 }
7413      { B7 }
7414      { B8 }
7415      { B9 }
7416      { BA }
7417      { BC }
7418      { BD }

```

```

7419     { BE }
7420     { CO }
7421     { DB }
7422     { DC }
7423     { DD }
7424     { DE }
7425     { DF }
7426 }
7427 </iso88596>
7428 <*iso88597>
7429 \str_declare_eight_bit_encoding:nnn { iso88597 }
7430 {
7431     { A1 } { 2018 }
7432     { A2 } { 2019 }
7433     { A4 } { 20AC }
7434     { A5 } { 20AF }
7435     { AA } { 037A }
7436     { AF } { 2015 }
7437     { B4 } { 0384 }
7438     { B5 } { 0385 }
7439     { B6 } { 0386 }
7440     { B8 } { 0388 }
7441     { B9 } { 0389 }
7442     { BA } { 038A }
7443     { BC } { 038C }
7444     { BE } { 038E }
7445     { BF } { 038F }
7446     { C0 } { 0390 }
7447     { C1 } { 0391 }
7448     { C2 } { 0392 }
7449     { C3 } { 0393 }
7450     { C4 } { 0394 }
7451     { C5 } { 0395 }
7452     { C6 } { 0396 }
7453     { C7 } { 0397 }
7454     { C8 } { 0398 }
7455     { C9 } { 0399 }
7456     { CA } { 039A }
7457     { CB } { 039B }
7458     { CC } { 039C }
7459     { CD } { 039D }
7460     { CE } { 039E }
7461     { CF } { 039F }
7462     { D0 } { 03A0 }
7463     { D1 } { 03A1 }
7464     { D3 } { 03A3 }
7465     { D4 } { 03A4 }
7466     { D5 } { 03A5 }
7467     { D6 } { 03A6 }
7468     { D7 } { 03A7 }
7469     { D8 } { 03A8 }
7470     { D9 } { 03A9 }
7471     { DA } { 03AA }
7472     { DB } { 03AB }

```

```

7473     { DC } { 03AC }
7474     { DD } { 03AD }
7475     { DE } { 03AE }
7476     { DF } { 03AF }
7477     { E0 } { 03B0 }
7478     { E1 } { 03B1 }
7479     { E2 } { 03B2 }
7480     { E3 } { 03B3 }
7481     { E4 } { 03B4 }
7482     { E5 } { 03B5 }
7483     { E6 } { 03B6 }
7484     { E7 } { 03B7 }
7485     { E8 } { 03B8 }
7486     { E9 } { 03B9 }
7487     { EA } { 03BA }
7488     { EB } { 03BB }
7489     { EC } { 03BC }
7490     { ED } { 03BD }
7491     { EE } { 03BE }
7492     { EF } { 03BF }
7493     { F0 } { 03C0 }
7494     { F1 } { 03C1 }
7495     { F2 } { 03C2 }
7496     { F3 } { 03C3 }
7497     { F4 } { 03C4 }
7498     { F5 } { 03C5 }
7499     { F6 } { 03C6 }
7500     { F7 } { 03C7 }
7501     { F8 } { 03C8 }
7502     { F9 } { 03C9 }
7503     { FA } { 03CA }
7504     { FB } { 03CB }
7505     { FC } { 03CC }
7506     { FD } { 03CD }
7507     { FE } { 03CE }
7508 }
7509 {
7510     { AE }
7511     { D2 }
7512 }
7513 </iso88597>
7514 <*iso88598>
7515 \str_declare_eight_bit_encoding:nnn { iso88598 }
7516 {
7517     { AA } { 00D7 }
7518     { BA } { 00F7 }
7519     { DF } { 2017 }
7520     { E0 } { 05D0 }
7521     { E1 } { 05D1 }
7522     { E2 } { 05D2 }
7523     { E3 } { 05D3 }
7524     { E4 } { 05D4 }
7525     { E5 } { 05D5 }
7526     { E6 } { 05D6 }

```

```

7527      { E7 } { 05D7 }
7528      { E8 } { 05D8 }
7529      { E9 } { 05D9 }
7530      { EA } { 05DA }
7531      { EB } { 05DB }
7532      { EC } { 05DC }
7533      { ED } { 05DD }
7534      { EE } { 05DE }
7535      { EF } { 05DF }
7536      { F0 } { 05E0 }
7537      { F1 } { 05E1 }
7538      { F2 } { 05E2 }
7539      { F3 } { 05E3 }
7540      { F4 } { 05E4 }
7541      { F5 } { 05E5 }
7542      { F6 } { 05E6 }
7543      { F7 } { 05E7 }
7544      { F8 } { 05E8 }
7545      { F9 } { 05E9 }
7546      { FA } { 05EA }
7547      { FD } { 200E }
7548      { FE } { 200F }
7549      }
7550      {
7551          { A1 }
7552          { BF }
7553          { C0 }
7554          { C1 }
7555          { C2 }
7556          { C3 }
7557          { C4 }
7558          { C5 }
7559          { C6 }
7560          { C7 }
7561          { C8 }
7562          { C9 }
7563          { CA }
7564          { CB }
7565          { CC }
7566          { CD }
7567          { CE }
7568          { CF }
7569          { D0 }
7570          { D1 }
7571          { D2 }
7572          { D3 }
7573          { D4 }
7574          { D5 }
7575          { D6 }
7576          { D7 }
7577          { D8 }
7578          { D9 }
7579          { DA }
7580          { DB }

```

```

7581     { DC }
7582     { DD }
7583     { DE }
7584     { FB }
7585     { FC }
7586 }
7587 </iso88598>
7588 < *iso88599>
7589 \str_declare_eight_bit_encoding:nnn { iso88599 }
7590 {
7591     { DO } { 011E }
7592     { DD } { 0130 }
7593     { DE } { 015E }
7594     { FO } { 011F }
7595     { FD } { 0131 }
7596     { FE } { 015F }
7597 }
7598 {
7599 }
7600 </iso88599>
7601 < *iso885910>
7602 \str_declare_eight_bit_encoding:nnn { iso885910 }
7603 {
7604     { A1 } { 0104 }
7605     { A2 } { 0112 }
7606     { A3 } { 0122 }
7607     { A4 } { 012A }
7608     { A5 } { 0128 }
7609     { A6 } { 0136 }
7610     { A8 } { 013B }
7611     { A9 } { 0110 }
7612     { AA } { 0160 }
7613     { AB } { 0166 }
7614     { AC } { 017D }
7615     { AE } { 016A }
7616     { AF } { 014A }
7617     { B1 } { 0105 }
7618     { B2 } { 0113 }
7619     { B3 } { 0123 }
7620     { B4 } { 012B }
7621     { B5 } { 0129 }
7622     { B6 } { 0137 }
7623     { B8 } { 013C }
7624     { B9 } { 0111 }
7625     { BA } { 0161 }
7626     { BB } { 0167 }
7627     { BC } { 017E }
7628     { BD } { 2015 }
7629     { BE } { 016B }
7630     { BF } { 014B }
7631     { C0 } { 0100 }
7632     { C7 } { 012E }
7633     { C8 } { 010C }

```

```

7634     { CA } { 0118 }
7635     { CC } { 0116 }
7636     { D1 } { 0145 }
7637     { D2 } { 014C }
7638     { D7 } { 0168 }
7639     { D9 } { 0172 }
7640     { E0 } { 0101 }
7641     { E7 } { 012F }
7642     { E8 } { 010D }
7643     { EA } { 0119 }
7644     { EC } { 0117 }
7645     { F1 } { 0146 }
7646     { F2 } { 014D }
7647     { F7 } { 0169 }
7648     { F9 } { 0173 }
7649     { FF } { 0138 }
7650 }
7651 {
7652 }
7653 </iso885910>
7654 <iso885911>
7655 \str_declare_eight_bit_encoding:nnn { iso885911 }
7656 {
7657     { A1 } { OE01 }
7658     { A2 } { OE02 }
7659     { A3 } { OE03 }
7660     { A4 } { OE04 }
7661     { A5 } { OE05 }
7662     { A6 } { OE06 }
7663     { A7 } { OE07 }
7664     { A8 } { OE08 }
7665     { A9 } { OE09 }
7666     { AA } { OE0A }
7667     { AB } { OE0B }
7668     { AC } { OE0C }
7669     { AD } { OE0D }
7670     { AE } { OE0E }
7671     { AF } { OE0F }
7672     { B0 } { OE10 }
7673     { B1 } { OE11 }
7674     { B2 } { OE12 }
7675     { B3 } { OE13 }
7676     { B4 } { OE14 }
7677     { B5 } { OE15 }
7678     { B6 } { OE16 }
7679     { B7 } { OE17 }
7680     { B8 } { OE18 }
7681     { B9 } { OE19 }
7682     { BA } { OE1A }
7683     { BB } { OE1B }
7684     { BC } { OE1C }
7685     { BD } { OE1D }
7686     { BE } { OE1E }
7687     { BF } { OE1F }

```


7688	{ C0 }	{ 0E20 }
7689	{ C1 }	{ 0E21 }
7690	{ C2 }	{ 0E22 }
7691	{ C3 }	{ 0E23 }
7692	{ C4 }	{ 0E24 }
7693	{ C5 }	{ 0E25 }
7694	{ C6 }	{ 0E26 }
7695	{ C7 }	{ 0E27 }
7696	{ C8 }	{ 0E28 }
7697	{ C9 }	{ 0E29 }
7698	{ CA }	{ 0E2A }
7699	{ CB }	{ 0E2B }
7700	{ CC }	{ 0E2C }
7701	{ CD }	{ 0E2D }
7702	{ CE }	{ 0E2E }
7703	{ CF }	{ 0E2F }
7704	{ D0 }	{ 0E30 }
7705	{ D1 }	{ 0E31 }
7706	{ D2 }	{ 0E32 }
7707	{ D3 }	{ 0E33 }
7708	{ D4 }	{ 0E34 }
7709	{ D5 }	{ 0E35 }
7710	{ D6 }	{ 0E36 }
7711	{ D7 }	{ 0E37 }
7712	{ D8 }	{ 0E38 }
7713	{ D9 }	{ 0E39 }
7714	{ DA }	{ 0E3A }
7715	{ DF }	{ 0E3F }
7716	{ E0 }	{ 0E40 }
7717	{ E1 }	{ 0E41 }
7718	{ E2 }	{ 0E42 }
7719	{ E3 }	{ 0E43 }
7720	{ E4 }	{ 0E44 }
7721	{ E5 }	{ 0E45 }
7722	{ E6 }	{ 0E46 }
7723	{ E7 }	{ 0E47 }
7724	{ E8 }	{ 0E48 }
7725	{ E9 }	{ 0E49 }
7726	{ EA }	{ 0E4A }
7727	{ EB }	{ 0E4B }
7728	{ EC }	{ 0E4C }
7729	{ ED }	{ 0E4D }
7730	{ EE }	{ 0E4E }
7731	{ EF }	{ 0E4F }
7732	{ F0 }	{ 0E50 }
7733	{ F1 }	{ 0E51 }
7734	{ F2 }	{ 0E52 }
7735	{ F3 }	{ 0E53 }
7736	{ F4 }	{ 0E54 }
7737	{ F5 }	{ 0E55 }
7738	{ F6 }	{ 0E56 }
7739	{ F7 }	{ 0E57 }
7740	{ F8 }	{ 0E58 }
7741	{ F9 }	{ 0E59 }

```

7742     { FA } { OE5A }
7743     { FB } { OE5B }
7744 }
7745 {
7746     { DB }
7747     { DC }
7748     { DD }
7749     { DE }
7750 }
7751 </iso885911>
7752 <*iso885913>
7753 \str_declare_eight_bit_encoding:nmn { iso885913 }
7754 {
7755     { A1 } { 201D }
7756     { A5 } { 201E }
7757     { A8 } { 00D8 }
7758     { AA } { 0156 }
7759     { AF } { 00C6 }
7760     { B4 } { 201C }
7761     { B8 } { 00F8 }
7762     { BA } { 0157 }
7763     { BF } { 00E6 }
7764     { C0 } { 0104 }
7765     { C1 } { 012E }
7766     { C2 } { 0100 }
7767     { C3 } { 0106 }
7768     { C6 } { 0118 }
7769     { C7 } { 0112 }
7770     { C8 } { 010C }
7771     { CA } { 0179 }
7772     { CB } { 0116 }
7773     { CC } { 0122 }
7774     { CD } { 0136 }
7775     { CE } { 012A }
7776     { CF } { 013B }
7777     { D0 } { 0160 }
7778     { D1 } { 0143 }
7779     { D2 } { 0145 }
7780     { D4 } { 014C }
7781     { D8 } { 0172 }
7782     { D9 } { 0141 }
7783     { DA } { 015A }
7784     { DB } { 016A }
7785     { DD } { 017B }
7786     { DE } { 017D }
7787     { E0 } { 0105 }
7788     { E1 } { 012F }
7789     { E2 } { 0101 }
7790     { E3 } { 0107 }
7791     { E6 } { 0119 }
7792     { E7 } { 0113 }
7793     { E8 } { 010D }
7794     { EA } { 017A }
7795     { EB } { 0117 }

```

```

7796     { EC } { 0123 }
7797     { ED } { 0137 }
7798     { EE } { 012B }
7799     { EF } { 013C }
7800     { F0 } { 0161 }
7801     { F1 } { 0144 }
7802     { F2 } { 0146 }
7803     { F4 } { 014D }
7804     { F8 } { 0173 }
7805     { F9 } { 0142 }
7806     { FA } { 015B }
7807     { FB } { 016B }
7808     { FD } { 017C }
7809     { FE } { 017E }
7810     { FF } { 2019 }
7811 }
7812 {
7813 }
7814 </iso885913>
7815 <*iso885914>
7816 \str_declare_eight_bit_encoding:mn { iso885914 }
7817 {
7818     { A1 } { 1E02 }
7819     { A2 } { 1E03 }
7820     { A4 } { 010A }
7821     { A5 } { 010B }
7822     { A6 } { 1E0A }
7823     { A8 } { 1E80 }
7824     { AA } { 1E82 }
7825     { AB } { 1E0B }
7826     { AC } { 1EF2 }
7827     { AF } { 0178 }
7828     { B0 } { 1E1E }
7829     { B1 } { 1E1F }
7830     { B2 } { 0120 }
7831     { B3 } { 0121 }
7832     { B4 } { 1E40 }
7833     { B5 } { 1E41 }
7834     { B7 } { 1E56 }
7835     { B8 } { 1E81 }
7836     { B9 } { 1E57 }
7837     { BA } { 1E83 }
7838     { BB } { 1E60 }
7839     { BC } { 1EF3 }
7840     { BD } { 1E84 }
7841     { BE } { 1E85 }
7842     { BF } { 1E61 }
7843     { D0 } { 0174 }
7844     { D7 } { 1E6A }
7845     { DE } { 0176 }
7846     { F0 } { 0175 }
7847     { F7 } { 1E6B }
7848     { FE } { 0177 }
7849 }

```

```

7850     {
7851     }
7852 </iso885914>
7853 <iso885915>
7854 \str_declare_eight_bit_encoding:nnn { iso885915 }
7855 {
7856     { A4 } { 20AC }
7857     { A6 } { 0160 }
7858     { A8 } { 0161 }
7859     { B4 } { 017D }
7860     { B8 } { 017E }
7861     { BC } { 0152 }
7862     { BD } { 0153 }
7863     { BE } { 0178 }
7864 }
7865 {
7866 }
7867 </iso885915>
7868 <iso885916>
7869 \str_declare_eight_bit_encoding:nnn { iso885916 }
7870 {
7871     { A1 } { 0104 }
7872     { A2 } { 0105 }
7873     { A3 } { 0141 }
7874     { A4 } { 20AC }
7875     { A5 } { 201E }
7876     { A6 } { 0160 }
7877     { A8 } { 0161 }
7878     { AA } { 0218 }
7879     { AC } { 0179 }
7880     { AE } { 017A }
7881     { AF } { 017B }
7882     { B2 } { 010C }
7883     { B3 } { 0142 }
7884     { B4 } { 017D }
7885     { B5 } { 201D }
7886     { B8 } { 017E }
7887     { B9 } { 010D }
7888     { BA } { 0219 }
7889     { BC } { 0152 }
7890     { BD } { 0153 }
7891     { BE } { 0178 }
7892     { BF } { 017C }
7893     { C3 } { 0102 }
7894     { C5 } { 0106 }
7895     { D0 } { 0110 }
7896     { D1 } { 0143 }
7897     { D5 } { 0150 }
7898     { D7 } { 015A }
7899     { D8 } { 0170 }
7900     { DD } { 0118 }
7901     { DE } { 021A }
7902     { E3 } { 0103 }

```

```

7903     { E5 } { 0107 }
7904     { F0 } { 0111 }
7905     { F1 } { 0144 }
7906     { F5 } { 0151 }
7907     { F7 } { 015B }
7908     { F8 } { 0171 }
7909     { FD } { 0119 }
7910     { FE } { 021B }
7911   }
7912   {
7913   }
7914   </iso885916>

```

10 l3quark implementation

The following test files are used for this code: *m3quark001.lvt*.

```

7915 <*initex | package>

```

10.1 Quarks

```

7916 <@@=quark>

```

\quark_new:N Allocate a new quark.

```

7917 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN q #1 } { }
7918 \cs_new_protected:Npn \quark_new:N #1
7919 {
7920   \__kernel_chk_if_free_cs:N #1
7921   \cs_gset_nopar:Npn #1 {#1}
7922 }

```

(End definition for `\quark_new:N`. This function is documented on page 68.)

\q_nil Some “public” quarks. `\q_stop` is an “end of argument” marker, `\q_nil` is a empty value
\q_mark and `\q_no_value` marks an empty argument.
\q_no_value
\q_stop

```

7923 \quark_new:N \q_nil
7924 \quark_new:N \q_mark
7925 \quark_new:N \q_no_value
7926 \quark_new:N \q_stop

```

(End definition for `\q_nil` and others. These variables are documented on page 69.)

\q_recursion_tail Quarks for ending recursions. Only ever used there! `\q_recursion_tail` is appended to
\q_recursion_stop whatever list structure we are doing recursion on, meaning it is added as a proper list
 item with whatever list separator is in use. `\q_recursion_stop` is placed directly after
 the list.

```

7927 \quark_new:N \q_recursion_tail
7928 \quark_new:N \q_recursion_stop

```

(End definition for `\q_recursion_tail` and `\q_recursion_stop`. These variables are documented on page 69.)

`\quark_if_recursion_tail_stop:N`
`\quark_if_recursion_tail_stop_do:Nn`

When doing recursions, it is easy to spend a lot of time testing if the end marker has been found. To avoid this, a dedicated end marker is used each time a recursion is set up. Thus if the marker is found everything can be wrapper up and finished off. The simple case is when the test can guarantee that only a single token is being tested. In this case, there is just a dedicated copy of the standard quark test. Both a gobbling version and one inserting end code are provided.

```

7929 \cs_new:Npn \quark_if_recursion_tail_stop:N #1
7930 {
7931   \if_meaning:w \q_recursion_tail #1
7932   \exp_after:wN \use_none_delimit_by_q_recursion_stop:w
7933   \fi:
7934 }
7935 \cs_new:Npn \quark_if_recursion_tail_stop_do:Nn #1
7936 {
7937   \if_meaning:w \q_recursion_tail #1
7938   \exp_after:wN \use_i_delimit_by_q_recursion_stop:nw
7939   \else:
7940   \exp_after:wN \use_none:n
7941   \fi:
7942 }
```

(End definition for \quark_if_recursion_tail_stop:N and \quark_if_recursion_tail_stop_do:Nn. These functions are documented on page 70.)

`\quark_if_recursion_tail_stop:n`
`\quark_if_recursion_tail_stop:o`
`\quark_if_recursion_tail_stop_do:nn`
`\quark_if_recursion_tail_stop_do:nn`
`__quark_if_recursion_tail:w`

See `\quark_if_nil:nTF` for the details. Expanding `__quark_if_recursion_tail:w` once in front of the tokens chosen here gives an empty result if and only if #1 is exactly `\q_recursion_tail`.

```

7943 \cs_new:Npn \quark_if_recursion_tail_stop:n #1
7944 {
7945   \tl_if_empty:oTF
7946   { \__quark_if_recursion_tail:w {} #1 {} ?! \q_recursion_tail ??? }
7947   { \use_none_delimit_by_q_recursion_stop:w }
7948   { }
7949 }
7950 \cs_new:Npn \quark_if_recursion_tail_stop_do:nn #1
7951 {
7952   \tl_if_empty:oTF
7953   { \__quark_if_recursion_tail:w {} #1 {} ?! \q_recursion_tail ??? }
7954   { \use_i_delimit_by_q_recursion_stop:nw }
7955   { \use_none:n }
7956 }
7957 \cs_new:Npn \__quark_if_recursion_tail:w
7958   #1 \q_recursion_tail #2 ? #3 ?! { #1 #2 }
7959 \cs_generate_variant:Nn \quark_if_recursion_tail_stop:n { o }
7960 \cs_generate_variant:Nn \quark_if_recursion_tail_stop_do:nn { o }
```

(End definition for \quark_if_recursion_tail_stop:n, \quark_if_recursion_tail_stop_do:nn, and __quark_if_recursion_tail:w. These functions are documented on page 70.)

`\quark_if_recursion_tail_break:NN`
`\quark_if_recursion_tail_break:nN`

Analogues of the `\quark_if_recursion_tail_stop...` functions. Break the mapping using #2.

```

7961 \cs_new:Npn \quark_if_recursion_tail_break:NN #1#2
7962 {
7963   \if_meaning:w \q_recursion_tail #1
```

```

7964     \exp_after:wN #2
7965     \fi:
7966   }
7967 \cs_new:Npn \quark_if_recursion_tail_break:nN #1#2
7968 {
7969     \tl_if_empty:oT
7970     { \_quark_if_recursion_tail:w {} #1 {} ?! \q_recursion_tail ??? }
7971     {#2}
7972 }

```

(End definition for `\quark_if_recursion_tail_break:NN` and `\quark_if_recursion_tail_break:nN`. These functions are documented on page 70.)

`\quark_if_nil_p:N` Here we test if we found a special quark as the first argument. We better start with `\quark_if_nil:N \underline{TF}` `\q_no_value` as the first argument since the whole thing may otherwise loop if #1 is wrongly given a string like `aabc` instead of a single token.⁹

```

\quark_if_no_value_p:N \quark_if_no_value_p:c
\quark_if_no_value:N $\underline{TF}$ 
\quark_if_no_value:c $\underline{TF}$ 
7973 \prg_new_conditional:Npnn \quark_if_nil:N #1 { p , T , F , TF }
7974 {
7975     \if_meaning:w \q_nil #1
7976     \prg_return_true:
7977     \else:
7978     \prg_return_false:
7979     \fi:
7980 }
7981 \prg_new_conditional:Npnn \quark_if_no_value:N #1 { p , T , F , TF }
7982 {
7983     \if_meaning:w \q_no_value #1
7984     \prg_return_true:
7985     \else:
7986     \prg_return_false:
7987     \fi:
7988 }
7989 \prg_generate_conditional_variant:Nnn \quark_if_no_value:N
7990 { c } { p , T , F , TF }

```

(End definition for `\quark_if_nil:N \underline{TF}` and `\quark_if_no_value:N \underline{TF}` . These functions are documented on page 69.)

`\quark_if_nil_p:N` Let us explain `\quark_if_nil:n(TF)`. Expanding `_quark_if_nil:w` once is safe thanks to the trailing `\q_nil ?!`. The result of expanding once is empty if and only if both delimited arguments #1 and #2 are empty and #3 is delimited by the last tokens `?!.` Thanks to the leading `{}`, the argument #1 is empty if and only if the argument of `\quark_if_nil:n` starts with `\q_nil`. The argument #2 is empty if and only if this `\q_nil` is followed immediately by `?` or by `{}`?, coming either from the trailing tokens in the definition of `\quark_if_nil:n`, or from its argument. In the first case, `_quark_if_nil:w` is followed by `{}\q_nil {}? !\q_nil ?!`, hence #3 is delimited by the final `?!.`, and the test returns `true` as wanted. In the second case, the result is not empty since the first `?!.` in the definition of `\quark_if_nil:n` stop #3. The auxiliary here is the same as `_tl_if_empty_if:o`, with the same comments applying.

```

7991 \prg_new_conditional:Npnn \quark_if_nil:n #1 { p , T , F , TF }
7992 {
7993     \_quark_if_empty_if:o

```

⁹It may still loop in special circumstances however!

```

7994     { \_quark_if_nil:w {} #1 {} ? ! \q_nil ? ? ! }
7995     \prg_return_true:
7996   \else:
7997     \prg_return_false:
7998   \fi:
7999 }
8000 \cs_new:Npn \_quark_if_nil:w #1 \q_nil #2 ? #3 ? ! { #1 #2 }
8001 \prg_new_conditional:Npnn \quark_if_no_value:n #1 { p, T, F, TF }
8002 {
8003   \_quark_if_empty_if:o
8004   { \_quark_if_no_value:w {} #1 {} ? ! \q_no_value ? ? ! }
8005   \prg_return_true:
8006   \else:
8007     \prg_return_false:
8008   \fi:
8009 }
8010 \cs_new:Npn \_quark_if_no_value:w #1 \q_no_value #2 ? #3 ? ! { #1 #2 }
8011 \prg_generate_conditional_variant:Nnn \quark_if_nil:n
8012 { V, o } { p, TF, T, F }
8013 \cs_new:Npn \_quark_if_empty_if:o #1
8014 {
8015   \exp_after:wN \if_meaning:w \exp_after:wN \q_nil
8016   \__kernel_tl_to_str:w \exp_after:wN {#1} \q_nil
8017 }

```

(End definition for \quark_if_nil:nTF and others. These functions are documented on page 69.)

10.2 Scan marks

```
8018 <@@=scan>
```

\g__scan_marks_tl The list of all scan marks currently declared.

```
8019 \tl_new:N \g__scan_marks_tl
```

(End definition for \g__scan_marks_tl.)

\scan_new:N Check whether the variable is already a scan mark, then declare it to be equal to \scan_stop: globally.

```

8020 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN s #1 } { }
8021 \cs_new_protected:Npn \scan_new:N #1
8022 {
8023   \tl_if_in:NnTF \g__scan_marks_tl { #1 }
8024   {
8025     \__kernel_msg_error:nxx { kernel } { scanmark-already-defined }
8026     { \token_to_str:N #1 }
8027   }
8028   {
8029     \tl_gput_right:Nn \g__scan_marks_tl {#1}
8030     \cs_new_eq:NN #1 \scan_stop:
8031   }
8032 }

```

(End definition for \scan_new:N. This function is documented on page 71.)

`\s_stop` We only declare one scan mark here, more can be defined by specific modules.

```
8033 \scan_new:N \s_stop
```

(End definition for `\s_stop`. This variable is documented on page 72.)

`\use_none_delimit_by_s_stop:w` Similar to `\use_none_delimit_by_q_stop:w`.

```
8034 \cs_new:Npn \use_none_delimit_by_s_stop:w #1 \s_stop { }
```

(End definition for `\use_none_delimit_by_s_stop:w`. This function is documented on page 72.)

```
8035 </initex | package>
```

11 l3seq implementation

The following test files are used for this code: `m3seq002,m3seq003`.

```
8036 <*initex | package>
```

```
8037 <@@=seq>
```

A sequence is a control sequence whose top-level expansion is of the form “`\s__seq __seq_item:n {<item1>} ... __seq_item:n {<itemn>}`”, with a leading scan mark followed by n items of the same form. An earlier implementation used the structure “`\seq_elt:w <item1> \seq_elt_end: ... \seq_elt:w <itemn> \seq_elt_end:`”. This allowed rapid searching using a delimited function, but was not suitable for items containing `{`, `}` and `#` tokens, and also lead to the loss of surrounding braces around items

`__seq_item:n *` `__seq_item:n {<item>}`

The internal token used to begin each sequence entry. If expanded outside of a mapping or manipulation function, an error is raised. The definition should always be set globally.

`__seq_push_item_def:n` `__seq_push_item_def:n {<code>}`

`__seq_push_item_def:x`

Saves the definition of `__seq_item:n` and redefines it to accept one parameter and expand to `<code>`. This function should always be balanced by use of `__seq_pop_item_def:`.

`__seq_pop_item_def:` `__seq_pop_item_def:`

Restores the definition of `__seq_item:n` most recently saved by `__seq_push_item_def:n`. This function should always be used in a balanced pair with `__seq_push_item_def:n`.

`\s__seq` This private scan mark.

```
8038 \scan_new:N \s__seq
```

(End definition for `\s__seq`.)

`__seq_item:n` The delimiter is always defined, but when used incorrectly simply removes its argument and hits an undefined control sequence to raise an error.

```
8039 \cs_new:Npn \__seq_item:n
```

```
8040 {
```

```
8041   \__kernel_msg_expandable_error:nn { kernel } { misused-sequence }
```

```
8042   \use_none:n
```

```
8043 }
```

(End definition for _seq_item:n.)

\l__seq_internal_a_tl Scratch space for various internal uses.

\l__seq_internal_b_tl 8044 \tl_new:N \l__seq_internal_a_tl
8045 \tl_new:N \l__seq_internal_b_tl

(End definition for \l__seq_internal_a_tl and \l__seq_internal_b_tl.)

__seq_tmp:w Scratch function for internal use.

8046 \cs_new_eq:NN __seq_tmp:w ?

(End definition for __seq_tmp:w.)

\c_empty_seq A sequence with no item, following the structure mentioned above.

8047 \tl_const:Nn \c_empty_seq { \s__seq }

(End definition for \c_empty_seq. This variable is documented on page 82.)

11.1 Allocation and initialisation

\seq_new:N Sequences are initialized to \c_empty_seq.

\seq_new:c 8048 \cs_new_protected:Npn \seq_new:N #1
8049 {
8050 __kernel_chk_if_free_cs:N #1
8051 \cs_gset_eq:NN #1 \c_empty_seq
8052 }
8053 \cs_generate_variant:Nn \seq_new:N { c }

(End definition for \seq_new:N. This function is documented on page 73.)

\seq_clear:N Clearing a sequence is similar to setting it equal to the empty one.

\seq_clear:c 8054 \cs_new_protected:Npn \seq_clear:N #1
\seq_gclear:N 8055 { \seq_set_eq:NN #1 \c_empty_seq }
\seq_gclear:c 8056 \cs_generate_variant:Nn \seq_clear:N { c }
8057 \cs_new_protected:Npn \seq_gclear:N #1
8058 { \seq_gset_eq:NN #1 \c_empty_seq }
8059 \cs_generate_variant:Nn \seq_gclear:N { c }

(End definition for \seq_clear:N and \seq_gclear:N. These functions are documented on page 73.)

\seq_clear_new:N Once again we copy code from the token list functions.

\seq_clear_new:c 8060 \cs_new_protected:Npn \seq_clear_new:N #1
\seq_gclear_new:N 8061 { \seq_if_exist:NTF #1 { \seq_clear:N #1 } { \seq_new:N #1 } }
\seq_gclear_new:c 8062 \cs_generate_variant:Nn \seq_clear_new:N { c }
8063 \cs_new_protected:Npn \seq_gclear_new:N #1
8064 { \seq_if_exist:NTF #1 { \seq_gclear:N #1 } { \seq_new:N #1 } }
8065 \cs_generate_variant:Nn \seq_gclear_new:N { c }

(End definition for \seq_clear_new:N and \seq_gclear_new:N. These functions are documented on page 73.)

\seq_set_eq:NN Copying a sequence is the same as copying the underlying token list.

```

\seq_set_eq:cN 8066 \cs_new_eq:NN \seq_set_eq:NN \tl_set_eq:NN
\seq_set_eq:Nc 8067 \cs_new_eq:NN \seq_set_eq:Nc \tl_set_eq:Nc
\seq_set_eq:cc 8068 \cs_new_eq:NN \seq_set_eq:cN \tl_set_eq:cN
\seq_gset_eq:NN 8069 \cs_new_eq:NN \seq_gset_eq:NN \tl_gset_eq:NN
\seq_gset_eq:cN 8070 \cs_new_eq:NN \seq_gset_eq:Nc \tl_gset_eq:Nc
\seq_gset_eq:Nc 8071 \cs_new_eq:NN \seq_gset_eq:cN \tl_gset_eq:cN
\seq_gset_eq:cc 8072 \cs_new_eq:NN \seq_gset_eq:cc \tl_gset_eq:cc
8073 \cs_new_eq:NN \seq_gset_eq:cc \tl_gset_eq:cc

```

(End definition for `\seq_set_eq:NN` and `\seq_gset_eq:NN`. These functions are documented on page 73.)

\seq_set_from_clist:NN Setting a sequence from a comma-separated list is done using a simple mapping.

```

\seq_set_from_clist:cN 8074 \cs_new_protected:Npn \seq_set_from_clist:NN #1#2
\seq_set_from_clist:Nc 8075 {
\seq_set_from_clist:cc 8076   \tl_set:Nx #1
\seq_set_from_clist:Nn 8077   { \s__seq \clist_map_function:NN #2 \__seq_wrap_item:n }
\seq_set_from_clist:cn 8078 }
\seq_gset_from_clist:NN 8079 \cs_new_protected:Npn \seq_gset_from_clist:NN #1#2
\seq_gset_from_clist:cN 8080 {
\seq_gset_from_clist:Nc 8081   \tl_set:Nx #1
\seq_gset_from_clist:cc 8082   { \s__seq \clist_map_function:nN {#2} \__seq_wrap_item:n }
8083 }
\seq_gset_from_clist:Nn 8084 \cs_new_protected:Npn \seq_gset_from_clist:NN #1#2
\seq_gset_from_clist:cn 8085 {
8086   \tl_gset:Nx #1
8087   { \s__seq \clist_map_function:NN #2 \__seq_wrap_item:n }
8088 }
8089 \cs_new_protected:Npn \seq_gset_from_clist:Nn #1#2
8090 {
8091   \tl_gset:Nx #1
8092   { \s__seq \clist_map_function:nN {#2} \__seq_wrap_item:n }
8093 }
8094 \cs_generate_variant:Nn \seq_set_from_clist:NN { c , cc }
8095 \cs_generate_variant:Nn \seq_set_from_clist:NN { c , cc }
8096 \cs_generate_variant:Nn \seq_set_from_clist:Nn { c , cc }
8097 \cs_generate_variant:Nn \seq_gset_from_clist:NN { c , cc }
8098 \cs_generate_variant:Nn \seq_gset_from_clist:NN { c , cc }
8099 \cs_generate_variant:Nn \seq_gset_from_clist:Nn { c , cc }

```

(End definition for `\seq_set_from_clist:NN` and others. These functions are documented on page 73.)

\seq_set_split:Nnn When the separator is empty, everything is very simple, just map `__seq_wrap_item:n` through the items of the last argument. For non-trivial separators, the goal is to split a given token list at the marker, strip spaces from each item, and remove one set of outer braces if after removing leading and trailing spaces the item is enclosed within braces. After `\tl_replace_all:Nnn`, the token list `\l__seq_internal_a_tl` is a repetition of the pattern `__seq_set_split_auxi:w \prg_do_nothing: <item with spaces> __seq_set_split_end:.` Then, x-expansion causes `__seq_set_split_auxi:w` to trim spaces, and leaves its result as `__seq_set_split_auxii:w <trimmed item> __seq_set_split_end:.` This is then converted to the `l3seq` internal structure by another x-expansion. In the first step, we insert `\prg_do_nothing:` to avoid losing braces too early:

that would cause space trimming to act within those lost braces. The second step is solely there to strip braces which are outermost after space trimming.

```

8100 \cs_new_protected:Npn \seq_set_split:Nnn
8101   { \__seq_set_split:NNnn \tl_set:Nx }
8102 \cs_new_protected:Npn \seq_gset_split:Nnn
8103   { \__seq_set_split:NNnn \tl_gset:Nx }
8104 \cs_new_protected:Npn \__seq_set_split:NNnn #1#2#3#4
8105   {
8106     \tl_if_empty:nTF {#3}
8107     {
8108       \tl_set:Nn \l__seq_internal_a_tl
8109       { \tl_map_function:nN {#4} \__seq_wrap_item:n }
8110     }
8111     {
8112       \tl_set:Nn \l__seq_internal_a_tl
8113       {
8114         \__seq_set_split_auxi:w \prg_do_nothing:
8115         #4
8116         \__seq_set_split_end:
8117       }
8118       \tl_replace_all:Nnn \l__seq_internal_a_tl { #3 }
8119       {
8120         \__seq_set_split_end:
8121         \__seq_set_split_auxi:w \prg_do_nothing:
8122       }
8123       \tl_set:Nx \l__seq_internal_a_tl { \l__seq_internal_a_tl }
8124     }
8125     #1 #2 { \s__seq \l__seq_internal_a_tl }
8126   }
8127 \cs_new:Npn \__seq_set_split_auxi:w #1 \__seq_set_split_end:
8128   {
8129     \exp_not:N \__seq_set_split_auxii:w
8130     \exp_args:No \tl_trim_spaces:n {#1}
8131     \exp_not:N \__seq_set_split_end:
8132   }
8133 \cs_new:Npn \__seq_set_split_auxii:w #1 \__seq_set_split_end:
8134   { \__seq_wrap_item:n {#1} }
8135 \cs_generate_variant:Nn \seq_set_split:Nnn { NnV }
8136 \cs_generate_variant:Nn \seq_gset_split:Nnn { NnV }

```

(End definition for `\seq_set_split:Nnn` and others. These functions are documented on page 74.)

`\seq_concat:NNN` When concatenating sequences, one must remove the leading `\s__seq` of the second sequence. The result starts with `\s__seq` (of the first sequence), which stops `f`-expansion.

`\seq_gconcat:NNN`

```

8137 \cs_new_protected:Npn \seq_concat:NNN #1#2#3
8138   { \tl_set:Nf #1 { \exp_after:wN \use_i:nn \exp_after:wN #2 #3 } }
8139 \cs_new_protected:Npn \seq_gconcat:NNN #1#2#3
8140   { \tl_gset:Nf #1 { \exp_after:wN \use_i:nn \exp_after:wN #2 #3 } }
8141 \cs_generate_variant:Nn \seq_concat:NNN { ccc }
8142 \cs_generate_variant:Nn \seq_gconcat:NNN { ccc }

```

(End definition for `\seq_concat:NNN` and `\seq_gconcat:NNN`. These functions are documented on page 74.)

```

\seq_if_exist_p:N Copies of the cs functions defined in l3basics.
\seq_if_exist_p:c 8143 \prg_new_eq_conditional:NNn \seq_if_exist:N \cs_if_exist:N
\seq_if_exist:NTF 8144 { TF , T , F , p }
\seq_if_exist:cTF 8145 \prg_new_eq_conditional:NNn \seq_if_exist:c \cs_if_exist:c
8146 { TF , T , F , p }

```

(End definition for `\seq_if_exist:N`. This function is documented on page 74.)

11.2 Appending data to either end

`\seq_put_left:Nn` When adding to the left of a sequence, remove `\s__seq`. This is done by `__seq_put_left_aux:w`, which also stops f-expansion.

```

\seq_put_left:NV 8147 \cs_new_protected:Npn \seq_put_left:Nn #1#2
\seq_put_left:Nv 8148 {
\seq_put_left:No 8149   \tl_set:Nx #1
\seq_put_left:Nx 8150   {
\seq_put_left:cn 8151     \exp_not:n { \s__seq \__seq_item:n {#2} }
\seq_put_left:cV 8152     \exp_not:f { \exp_after:wN \__seq_put_left_aux:w #1 }
\seq_put_left:cv 8153   }
\seq_put_left:co 8154 }
\seq_put_left:cx 8155 \cs_new_protected:Npn \seq_gput_left:Nn #1#2
\seq_gput_left:Nn 8156 {
\seq_gput_left:Nv 8157   \tl_gset:Nx #1
\seq_gput_left:Nv 8158   {
\seq_gput_left:No 8159     \exp_not:n { \s__seq \__seq_item:n {#2} }
\seq_gput_left:Nx 8160     \exp_not:f { \exp_after:wN \__seq_put_left_aux:w #1 }
\seq_gput_left:cn 8161   }
\seq_gput_left:cV 8162 }
\seq_gput_left:cv 8163 \cs_new:Npn \__seq_put_left_aux:w \s__seq { \exp_stop_f: }
\seq_gput_left:co 8164 \cs_generate_variant:Nn \seq_put_left:Nn { NV , Nv , No , Nx }
\seq_gput_left:cx 8165 \cs_generate_variant:Nn \seq_put_left:Nn { c , cV , cv , co , cx }
\__seq_put_left_aux:w 8166 \cs_generate_variant:Nn \seq_gput_left:Nn { NV , Nv , No , Nx }
8167 \cs_generate_variant:Nn \seq_gput_left:Nn { c , cV , cv , co , cx }

```

(End definition for `\seq_put_left:Nn`, `\seq_gput_left:Nn`, and `__seq_put_left_aux:w`. These functions are documented on page 74.)

`\seq_put_right:Nn` Since there is no trailing marker, adding an item to the right of a sequence simply means wrapping it in `__seq_item:n`.

```

\seq_put_right:NV 8168 \cs_new_protected:Npn \seq_put_right:Nn #1#2
\seq_put_right:Nv 8169 { \tl_put_right:Nn #1 { \__seq_item:n {#2} } }
\seq_put_right:No 8170 \cs_new_protected:Npn \seq_gput_right:Nn #1#2
\seq_put_right:Nx 8171 { \tl_gput_right:Nn #1 { \__seq_item:n {#2} } }
\seq_put_right:cn 8172 \cs_generate_variant:Nn \seq_gput_right:Nn { NV , Nv , No , Nx }
\seq_put_right:cV 8173 \cs_generate_variant:Nn \seq_gput_right:Nn { c , cV , cv , co , cx }
\seq_put_right:cv 8174 \cs_generate_variant:Nn \seq_put_right:Nn { NV , Nv , No , Nx }
\seq_put_right:co 8175 \cs_generate_variant:Nn \seq_put_right:Nn { c , cV , cv , co , cx }
\seq_put_right:cx
\seq_gput_right:Nn (End definition for \seq_put_right:Nn and \seq_gput_right:Nn. These functions are documented on
\seq_gput_right:Nv page 74.)
\seq_gput_right:Nv
\seq_gput_right:No
\seq_gput_right:Nx
\seq_gput_right:cn
\seq_gput_right:cV
\seq_gput_right:cv
\seq_gput_right:co
\seq_gput_right:cx

```

11.3 Modifying sequences

`__seq_wrap_item:n` This function converts its argument to a proper sequence item in an x-expansion context.

```
8176 \cs_new:Npn \__seq_wrap_item:n #1 { \exp_not:n { \__seq_item:n {#1} } }
```

(End definition for __seq_wrap_item:n.)

`\l__seq_remove_seq` An internal sequence for the removal routines.

```
8177 \seq_new:N \l__seq_remove_seq
```

(End definition for \l__seq_remove_seq.)

`\seq_remove_duplicates:N` Removing duplicates means making a new list then copying it.

`\seq_remove_duplicates:c`

```
8178 \cs_new_protected:Npn \seq_remove_duplicates:N
```

```
8179 { \__seq_remove_duplicates:NN \seq_set_eq:NN }
```

`\seq_gremove_duplicates:N`

```
8180 \cs_new_protected:Npn \seq_gremove_duplicates:N
```

`\seq_gremove_duplicates:c`

```
8181 { \__seq_remove_duplicates:NN \seq_gset_eq:NN }
```

`__seq_remove_duplicates:NN`

```
8182 \cs_new_protected:Npn \__seq_remove_duplicates:NN #1#2
```

```
8183 {
```

```
8184   \seq_clear:N \l__seq_remove_seq
```

```
8185   \seq_map_inline:Nn #2
```

```
8186   {
```

```
8187     \seq_if_in:NnF \l__seq_remove_seq {##1}
```

```
8188     { \seq_put_right:Nn \l__seq_remove_seq {##1} }
```

```
8189   }
```

```
8190   #1 #2 \l__seq_remove_seq
```

```
8191 }
```

```
8192 \cs_generate_variant:Nn \seq_remove_duplicates:N { c }
```

```
8193 \cs_generate_variant:Nn \seq_gremove_duplicates:N { c }
```

(End definition for \seq_remove_duplicates:N, \seq_gremove_duplicates:N, and __seq_remove_duplicates:NN. These functions are documented on page 77.)

`\seq_remove_all:Nn` The idea of the code here is to avoid a relatively expensive addition of items one at a time

`\seq_remove_all:cn` to an intermediate sequence. The approach taken is therefore similar to that in `__seq_`

`\seq_gremove_all:Nn` `pop_right:NNN`, using a “flexible” x-type expansion to do most of the work. As `\tl_`

`\seq_gremove_all:cn` `if_eq:nnT` is not expandable, a two-part strategy is needed. First, the x-type expansion

`__seq_remove_all_aux:NNn` uses `\str_if_eq:nnT` to find potential matches. If one is found, the expansion is halted

and the necessary set up takes place to use the `\tl_if_eq:NNT` test. The x-type is started

again, including all of the items copied already. This happens repeatedly until the entire

sequence has been scanned. The code is set up to avoid needing and intermediate scratch

list: the lead-off x-type expansion (`#1 #2 {#2}`) ensures that nothing is lost.

```
8194 \cs_new_protected:Npn \seq_remove_all:Nn
```

```
8195 { \__seq_remove_all_aux:NNn \tl_set:Nx }
```

```
8196 \cs_new_protected:Npn \seq_gremove_all:Nn
```

```
8197 { \__seq_remove_all_aux:NNn \tl_gset:Nx }
```

```
8198 \cs_new_protected:Npn \__seq_remove_all_aux:NNn #1#2#3
```

```
8199 {
```

```
8200   \__seq_push_item_def:n
```

```
8201   {
```

```
8202     \str_if_eq:nnT {##1} {#3}
```

```
8203     {
```

```
8204       \if_false: { \fi: }
```

```
8205       \tl_set:Nn \l__seq_internal_b_tl {##1}
```

```

8206         #1 #2
8207         { \if_false: } \fi:
8208         \exp_not:o {#2}
8209         \tl_if_eq:NNT \l__seq_internal_a_tl \l__seq_internal_b_tl
8210         { \use_none:nn }
8211     }
8212     \__seq_wrap_item:n {##1}
8213 }
8214 \tl_set:Nn \l__seq_internal_a_tl {#3}
8215 #1 #2 {#2}
8216 \__seq_pop_item_def:
8217 }
8218 \cs_generate_variant:Nn \seq_remove_all:Nn { c }
8219 \cs_generate_variant:Nn \seq_gremove_all:Nn { c }

```

(End definition for `\seq_remove_all:Nn`, `\seq_gremove_all:Nn`, and `__seq_remove_all_aux:NNn`. These functions are documented on page 77.)

```

\seq_reverse:N Previously, \seq_reverse:N was coded by collecting the items in reverse order after an
\seq_reverse:c \exp_stop_f: marker.
\seq_greverse:N
\seq_greverse:c
\__seq_reverse:NN
\__seq_reverse_item:nwn
\cs_new_protected:Npn \seq_reverse:N #1
{
  \cs_set_eq:NN \@@_item:n \@@_reverse_item:nw
  \tl_set:Nf #2 { #2 \exp_stop_f: }
}
\cs_new:Npn \@@_reverse_item:nw #1 #2 \exp_stop_f:
{
  #2 \exp_stop_f:
  \@@_item:n {#1}
}

```

At first, this seems optimal, since we can forget about each item as soon as it is placed after `\exp_stop_f:`. Unfortunately, \TeX 's usual tail recursion does not take place in this case: since the following `__seq_reverse_item:nw` only reads tokens until `\exp_stop_f:`, and never reads the `\@@_item:n {#1}` left by the previous call, \TeX cannot remove that previous call from the stack, and in particular must retain the various macro parameters in memory, until the end of the replacement text is reached. The stack is thus only flushed after all the `__seq_reverse_item:nw` are expanded. Keeping track of the arguments of all those calls uses up a memory quadratic in the length of the sequence. \TeX can then not cope with more than a few thousand items.

Instead, we collect the items in the argument of `\exp_not:n`. The previous calls are cleanly removed from the stack, and the memory consumption becomes linear.

```

8220 \cs_new_protected:Npn \seq_reverse:N
8221 { \__seq_reverse:NN \tl_set:Nx }
8222 \cs_new_protected:Npn \seq_greverse:N
8223 { \__seq_reverse:NN \tl_gset:Nx }
8224 \cs_new_protected:Npn \__seq_reverse:NN #1 #2
8225 {
8226   \cs_set_eq:NN \__seq_tmp:w \__seq_item:n
8227   \cs_set_eq:NN \__seq_item:n \__seq_reverse_item:nwn
8228   #1 #2 { #2 \exp_not:n { } }
8229   \cs_set_eq:NN \__seq_item:n \__seq_tmp:w

```

```

8230 }
8231 \cs_new:Npn \__seq_reverse_item:nwn #1 #2 \exp_not:n #3
8232 {
8233     #2
8234     \exp_not:n { \__seq_item:n {#1} #3 }
8235 }
8236 \cs_generate_variant:Nn \seq_reverse:N { c }
8237 \cs_generate_variant:Nn \seq_greverse:N { c }

```

(End definition for `\seq_reverse:N` and others. These functions are documented on page 77.)

`\seq_sort:Nn` Implemented in `l3sort`.

`\seq_sort:cn`

`\seq_gsort:Nn` (End definition for `\seq_sort:Nn` and `\seq_gsort:Nn`. These functions are documented on page 77.)

`\seq_gsort:cn`

11.4 Sequence conditionals

`\seq_if_empty_p:N` Similar to token lists, we compare with the empty sequence.

```

\seq_if_empty_p:c 8238 \prg_new_conditional:Npnn \seq_if_empty:N #1 { p , T , F , TF }
\seq_if_empty:NTF 8239 {
\seq_if_empty:cTF 8240     \if_meaning:w #1 \c_empty_seq
8241     \prg_return_true:
8242     \else:
8243     \prg_return_false:
8244     \fi:
8245 }
8246 \prg_generate_conditional_variant:Nnn \seq_if_empty:N
8247 { c } { p , T , F , TF }

```

(End definition for `\seq_if_empty:N`. This function is documented on page 77.)

`\seq_if_in:NnTF` The approach here is to define `__seq_item:n` to compare its argument with the test sequence. If the two items are equal, the mapping is terminated and `\group_end: \prg_return_true:` is inserted after skipping over the rest of the recursion. On the other hand, if there is no match then the loop breaks, returning `\prg_return_false:`. Everything is inside a group so that `__seq_item:n` is preserved in nested situations.

```

\seq_if_in:NnTF 8248 \prg_new_protected_conditional:Npnn \seq_if_in:Nn #1#2
\seq_if_in:NvTF 8249 { T , F , TF }
\seq_if_in:NvTF 8250 {
\seq_if_in:NoTF 8251     \group_begin:
\seq_if_in:NxTF 8252     \tl_set:Nn \l__seq_internal_a_tl {#2}
\seq_if_in:cnTF 8253     \cs_set_protected:Npn \__seq_item:n ##1
\seq_if_in:cVTF 8254     {
\seq_if_in:cvTF 8255         \tl_set:Nn \l__seq_internal_b_tl {##1}
\seq_if_in:coTF 8256         \if_meaning:w \l__seq_internal_a_tl \l__seq_internal_b_tl
\seq_if_in:cxTF 8257         \exp_after:wN \__seq_if_in:
8258         \fi:
8259     }
8260     #1
8261     \group_end:
8262     \prg_return_false:
8263     \prg_break_point:
8264 }
8265 \cs_new:Npn \__seq_if_in:

```



```

8266 { \prg_break:n { \group_end: \prg_return_true: } }
8267 \prg_generate_conditional_variant:Nnn \seq_if_in:Nn
8268 { NV , Nv , No , Nx , c , cV , cv , co , cx } { T , F , TF }

```

(End definition for `\seq_if_in:NnTF` and `__seq_if_in:..` This function is documented on page 78.)

11.5 Recovering data from sequences

`__seq_pop:NNNN` The two pop functions share their emptiness tests. We also use a common emptiness test
`__seq_pop_TF:NNNN` for all branching get and pop functions.

```

8269 \cs_new_protected:Npn \__seq_pop:NNNN #1#2#3#4
8270 {
8271   \if_meaning:w #3 \c_empty_seq
8272   \tl_set:Nn #4 { \q_no_value }
8273   \else:
8274     #1#2#3#4
8275   \fi:
8276 }
8277 \cs_new_protected:Npn \__seq_pop_TF:NNNN #1#2#3#4
8278 {
8279   \if_meaning:w #3 \c_empty_seq
8280   % \tl_set:Nn #4 { \q_no_value }
8281   \prg_return_false:
8282   \else:
8283     #1#2#3#4
8284   \prg_return_true:
8285   \fi:
8286 }

```

(End definition for `__seq_pop:NNNN` and `__seq_pop_TF:NNNN`.)

`\seq_get_left:NN` Getting an item from the left of a sequence is pretty easy: just trim off the first item
`\seq_get_left:cN` after `__seq_item:n` at the start. We append a `\q_no_value` item to cover the case of
`__seq_get_left:wnw` an empty sequence

```

8287 \cs_new_protected:Npn \seq_get_left:NN #1#2
8288 {
8289   \tl_set:Nx #2
8290   {
8291     \exp_after:wN \__seq_get_left:wnw
8292     #1 \__seq_item:n { \q_no_value } \q_stop
8293   }
8294 }
8295 \cs_new:Npn \__seq_get_left:wnw #1 \__seq_item:n #2#3 \q_stop
8296 { \exp_not:n {#2} }
8297 \cs_generate_variant:Nn \seq_get_left:NN { c }

```

(End definition for `\seq_get_left:NN` and `__seq_get_left:wnw`. This function is documented on page 74.)

`\seq_pop_left:NN` The approach to popping an item is pretty similar to that to get an item, with the only
`\seq_pop_left:cN` difference being that the sequence itself has to be redefined. This makes it more sensible
`\seq_gpop_left:NN` to use an auxiliary function for the local and global cases.
`\seq_gpop_left:cN` `\cs_new_protected:Npn \seq_pop_left:NN`
`__seq_pop_left:NNN` `__seq_pop:NNNN __seq_pop_left:NNN \tl_set:Nn }`
`__seq_pop_left:wnwNNN`

```

8300 \cs_new_protected:Npn \seq_gpop_left:NN
8301 { \__seq_pop:NNNN \__seq_pop_left:NNN \tl_gset:Nn }
8302 \cs_new_protected:Npn \__seq_pop_left:NNN #1#2#3
8303 { \exp_after:wN \__seq_pop_left:wnwNNN #2 \q_stop #1#2#3 }
8304 \cs_new_protected:Npn \__seq_pop_left:wnwNNN
8305 #1 \__seq_item:n #2#3 \q_stop #4#5#6
8306 {
8307 #4 #5 { #1 #3 }
8308 \tl_set:Nn #6 {#2}
8309 }
8310 \cs_generate_variant:Nn \seq_pop_left:NN { c }
8311 \cs_generate_variant:Nn \seq_gpop_left:NN { c }

```

(End definition for `\seq_pop_left:NN` and others. These functions are documented on page 75.)

`\seq_get_right:NN` First remove `\s__seq` and prepend `\q_no_value`. The first argument of `__seq_get_right_loop:nw` is the last item found, and the second argument is empty until the end of the loop, where it is code that applies `\exp_not:n` to the last item and ends the loop.

```

\seq_get_right:cN
\__seq_get_right_loop:nw
\__seq_get_right_end:NnN
8312 \cs_new_protected:Npn \seq_get_right:NN #1#2
8313 {
8314 \tl_set:Nx #2
8315 {
8316 \exp_after:wN \use_i_ii:nnn
8317 \exp_after:wN \__seq_get_right_loop:nw
8318 \exp_after:wN \q_no_value
8319 #1
8320 \__seq_get_right_end:NnN \__seq_item:n
8321 }
8322 }
8323 \cs_new:Npn \__seq_get_right_loop:nw #1#2 \__seq_item:n
8324 {
8325 #2 \use_none:n {#1}
8326 \__seq_get_right_loop:nw
8327 }
8328 \cs_new:Npn \__seq_get_right_end:NnN #1#2#3 { \exp_not:n {#2} }
8329 \cs_generate_variant:Nn \seq_get_right:NN { c }

```

(End definition for `\seq_get_right:NN`, `__seq_get_right_loop:nw`, and `__seq_get_right_end:NnN`. This function is documented on page 75.)

`\seq_pop_right:NN` The approach to popping from the right is a bit more involved, but does use some of the same ideas as getting from the right. What is needed is a “flexible length” way to set a token list variable. This is supplied by the `{ \if_false: } \fi: ... \if_false: { \fi: }` construct. Using an x-type expansion and a “non-expanding” definition for `__seq_item:n`, the left-most $n - 1$ entries in a sequence of n items are stored back in the sequence. That needs a loop of unknown length, hence using the strange `\if_false:` way of including braces. When the last item of the sequence is reached, the closing brace for the assignment is inserted, and `\tl_set:Nn #3` is inserted in front of the final entry. This therefore does the pop assignment. One more iteration is performed, with an empty argument and `\use_none:nn`, which finally stops the loop.

```

8330 \cs_new_protected:Npn \seq_pop_right:NN
8331 { \__seq_pop:NNNN \__seq_pop_right:NNN \tl_set:Nx }
8332 \cs_new_protected:Npn \seq_gpop_right:NN
8333 { \__seq_pop:NNNN \__seq_pop_right:NNN \tl_gset:Nx }

```

```

8334 \cs_new_protected:Npn \__seq_pop_right:NNN #1#2#3
8335 {
8336   \cs_set_eq:NN \__seq_tmp:w \__seq_item:n
8337   \cs_set_eq:NN \__seq_item:n \scan_stop:
8338   #1 #2
8339   { \if_false: } \fi: \s__seq
8340     \exp_after:wN \use_i:nnn
8341     \exp_after:wN \__seq_pop_right_loop:nn
8342     #2
8343     {
8344       \if_false: { \fi: }
8345       \tl_set:Nx #3
8346     }
8347     { } \use_none:nn
8348     \cs_set_eq:NN \__seq_item:n \__seq_tmp:w
8349   }
8350 \cs_new:Npn \__seq_pop_right_loop:nn #1#2
8351 {
8352   #2 { \exp_not:n {#1} }
8353   \__seq_pop_right_loop:nn
8354 }
8355 \cs_generate_variant:Nn \seq_pop_right:NN { c }
8356 \cs_generate_variant:Nn \seq_gpop_right:NN { c }

```

(End definition for \seq_pop_right:NN and others. These functions are documented on page 75.)

\seq_get_left:NNTF Getting from the left or right with a check on the results. The first argument to __seq_pop_TF:NNNN is left unused.

```

\seq_get_left:cNTF
\seq_get_right:NNTF
8357 \prg_new_protected_conditional:Npnn \seq_get_left:NN #1#2 { T , F , TF }
8358 { \__seq_pop_TF:NNNN \prg_do_nothing: \seq_get_left:NN #1#2 }
8359 \prg_new_protected_conditional:Npnn \seq_get_right:NN #1#2 { T , F , TF }
8360 { \__seq_pop_TF:NNNN \prg_do_nothing: \seq_get_right:NN #1#2 }
8361 \prg_generate_conditional_variant:Nnn \seq_get_left:NN
8362 { c } { T , F , TF }
8363 \prg_generate_conditional_variant:Nnn \seq_get_right:NN
8364 { c } { T , F , TF }

```

(End definition for \seq_get_left:NNTF and \seq_get_right:NNTF. These functions are documented on page 76.)

\seq_pop_left:NNTF More or less the same for popping.

```

\seq_pop_left:cNTF
\seq_gpop_left:NNTF
8365 \prg_new_protected_conditional:Npnn \seq_pop_left:NN #1#2
8366 { T , F , TF }
\seq_gpop_left:cNTF
8367 { \__seq_pop_TF:NNNN \__seq_pop_left:NNN \tl_set:Nn #1 #2 }
\seq_pop_right:NNTF
8368 \prg_new_protected_conditional:Npnn \seq_gpop_left:NN #1#2
8369 { T , F , TF }
\seq_pop_right:cNTF
8370 { \__seq_pop_TF:NNNN \__seq_pop_left:NNN \tl_gset:Nn #1 #2 }
\seq_gpop_right:NNTF
8371 \prg_new_protected_conditional:Npnn \seq_pop_right:NN #1#2
8372 { T , F , TF }
8373 { \__seq_pop_TF:NNNN \__seq_pop_right:NNN \tl_set:Nx #1 #2 }
8374 \prg_new_protected_conditional:Npnn \seq_gpop_right:NN #1#2
8375 { T , F , TF }
8376 { \__seq_pop_TF:NNNN \__seq_pop_right:NNN \tl_gset:Nx #1 #2 }
8377 \prg_generate_conditional_variant:Nnn \seq_pop_left:NN { c }
8378 { T , F , TF }

```

```

8379 \prg_generate_conditional_variant:Nnn \seq_gpop_left:NN { c }
8380 { T , F , TF }
8381 \prg_generate_conditional_variant:Nnn \seq_gpop_right:NN { c }
8382 { T , F , TF }
8383 \prg_generate_conditional_variant:Nnn \seq_gpop_right:NN { c }
8384 { T , F , TF }

```

(End definition for `\seq_pop_left:NNTF` and others. These functions are documented on page 76.)

`\seq_item:Nn` The idea here is to find the offset of the item from the left, then use a loop to grab the correct item. If the resulting offset is too large, then the argument delimited by `__seq_item:wNn` is `\prg_break:` instead of being empty, terminating the loop and returning nothing at all.

```

\__seq_item:wNn
\__seq_item:nN
\__seq_item:nwn
8385 \cs_new:Npn \seq_item:Nn #1
8386 { \exp_after:wN \__seq_item:wNn #1 \q_stop #1 }
8387 \cs_new:Npn \__seq_item:wNn \s_seq #1 \q_stop #2#3
8388 {
8389   \exp_args:Nf \__seq_item:nwn
8390   { \exp_args:Nf \__seq_item:nN { \int_eval:n {#3} } #2 }
8391   #1
8392   \prg_break: \__seq_item:n { }
8393   \prg_break_point:
8394 }
8395 \cs_new:Npn \__seq_item:nN #1#2
8396 {
8397   \int_compare:nNnTF {#1} < 0
8398   { \int_eval:n { \seq_count:N #2 + 1 + #1 } }
8399   {#1}
8400 }
8401 \cs_new:Npn \__seq_item:nwn #1#2 \__seq_item:n #3
8402 {
8403   #2
8404   \int_compare:nNnTF {#1} = 1
8405   { \prg_break:n { \exp_not:n {#3} } }
8406   { \exp_args:Nf \__seq_item:nwn { \int_eval:n { #1 - 1 } } }
8407 }
8408 \cs_generate_variant:Nn \seq_item:Nn { c }

```

(End definition for `\seq_item:Nn` and others. This function is documented on page 75.)

`\seq_rand_item:N` Importantly, `\seq_item:Nn` only evaluates its argument once.

```

\seq_rand_item:c
8409 \cs_new:Npn \seq_rand_item:N #1
8410 {
8411   \seq_if_empty:NF #1
8412   { \seq_item:Nn #1 { \int_rand:nn { 1 } { \seq_count:N #1 } } }
8413 }
8414 \cs_generate_variant:Nn \seq_rand_item:N { c }

```

(End definition for `\seq_rand_item:N`. This function is documented on page 75.)

11.6 Mapping to sequences

`\seq_map_break:` To break a function, the special token `\prg_break_point:Nn` is used to find the end of the code. Any ending code is then inserted before the return value of `\seq_map_break:n` is inserted.

```
8415 \cs_new:Npn \seq_map_break:
8416   { \prg_map_break:Nn \seq_map_break: { } }
8417 \cs_new:Npn \seq_map_break:n
8418   { \prg_map_break:Nn \seq_map_break: }
```

(End definition for `\seq_map_break:` and `\seq_map_break:n`. These functions are documented on page 78.)

`\seq_map_function:NN` The idea here is to apply the code of #2 to each item in the sequence without altering the definition of `__seq_item:n`. The argument delimited by `__seq_item:n` is almost always empty, except at the end of the loop where it is `\prg_break:.` This allows to break the loop without needing to do a (relatively-expensive) quark test.

```
8419 \cs_new:Npn \seq_map_function:NN #1#2
8420   {
8421     \exp_after:wN \use_i_ii:nnn
8422     \exp_after:wN \__seq_map_function:Nw
8423     \exp_after:wN #2
8424     #1
8425     \prg_break: \__seq_item:n { } \prg_break_point:
8426     \prg_break_point:Nn \seq_map_break: { }
8427   }
8428 \cs_new:Npn \__seq_map_function:Nw #1#2 \__seq_item:n #3
8429   {
8430     #2
8431     #1 {#3}
8432     \__seq_map_function:Nw #1
8433   }
8434 \cs_generate_variant:Nn \seq_map_function:NN { c }
```

(End definition for `\seq_map_function:NN` and `__seq_map_function:Nw`. This function is documented on page 78.)

`__seq_push_item_def:n` The definition of `__seq_item:n` needs to be saved and restored at various points within the mapping and manipulation code. That is handled here: as always, this approach uses global assignments.

```
\__seq_push_item_def:x
\__seq_push_item_def:
\__seq_pop_item_def:
8435 \cs_new_protected:Npn \__seq_push_item_def:n
8436   {
8437     \__seq_push_item_def:
8438     \cs_gset:Npn \__seq_item:n ##1
8439   }
8440 \cs_new_protected:Npn \__seq_push_item_def:x
8441   {
8442     \__seq_push_item_def:
8443     \cs_gset:Npx \__seq_item:n ##1
8444   }
8445 \cs_new_protected:Npn \__seq_push_item_def:
8446   {
8447     \int_gincr:N \g__kernel_prg_map_int
8448     \cs_gset_eq:cN { __seq_map_ \int_use:N \g__kernel_prg_map_int :w }
```

```

8449     \__seq_item:n
8450   }
8451 \cs_new_protected:Npn \__seq_pop_item_def:
8452 {
8453   \cs_gset_eq:Nc \__seq_item:n
8454   { \__seq_map_ \int_use:N \g__kernel_prg_map_int :w }
8455   \int_gdecr:N \g__kernel_prg_map_int
8456 }

```

(End definition for __seq_push_item_def:n, __seq_push_item_def:, and __seq_pop_item_def:.)

\seq_map_inline:Nn The idea here is that __seq_item:n is already “applied” to each item in a sequence, and so an in-line mapping is just a case of redefining __seq_item:n.

\seq_map_inline:cn

```

8457 \cs_new_protected:Npn \seq_map_inline:Nn #1#2
8458 {
8459   \__seq_push_item_def:n {#2}
8460   #1
8461   \prg_break_point:Nn \seq_map_break: { \__seq_pop_item_def: }
8462 }
8463 \cs_generate_variant:Nn \seq_map_inline:Nn { c }

```

(End definition for \seq_map_inline:Nn. This function is documented on page 78.)

\seq_map_variable:NNn This is just a specialised version of the in-line mapping function, using an x-type expansion for the code set up so that the number of # tokens required is as expected.

\seq_map_variable:Ncn

\seq_map_variable:cNn

\seq_map_variable:ccn

```

8464 \cs_new_protected:Npn \seq_map_variable:NNn #1#2#3
8465 {
8466   \__seq_push_item_def:x
8467   {
8468     \tl_set:Nn \exp_not:N #2 {##1}
8469     \exp_not:n {#3}
8470   }
8471   #1
8472   \prg_break_point:Nn \seq_map_break: { \__seq_pop_item_def: }
8473 }
8474 \cs_generate_variant:Nn \seq_map_variable:NNn { Nc }
8475 \cs_generate_variant:Nn \seq_map_variable:NNn { c , cc }

```

(End definition for \seq_map_variable:NNn. This function is documented on page 78.)

\seq_count:N Since counting the items in a sequence is quite common, we optimize it by grabbing 8 items at a time and correspondingly adding 8 to an integer expression. At the end of the loop, #9 is __seq_count_end:w instead of being empty. It removes 8+ and instead places the number of __seq_item:n that __seq_count:w grabbed before reaching the end of the sequence.

\seq_count:c

__seq_count:w

__seq_count_end:w

```

8476 \cs_new:Npn \seq_count:N #1
8477 {
8478   \int_eval:n
8479   {
8480     \exp_after:wN \use_i:nn
8481     \exp_after:wN \__seq_count:w
8482     #1
8483     \__seq_count_end:w \__seq_item:n 7
8484     \__seq_count_end:w \__seq_item:n 6

```

```

8485     \_seq_count_end:w \_seq_item:n 5
8486     \_seq_count_end:w \_seq_item:n 4
8487     \_seq_count_end:w \_seq_item:n 3
8488     \_seq_count_end:w \_seq_item:n 2
8489     \_seq_count_end:w \_seq_item:n 1
8490     \_seq_count_end:w \_seq_item:n 0
8491     \prg_break_point:
8492 }
8493 }
8494 \cs_new:Npn \_seq_count:w
8495     #1 \_seq_item:n #2 \_seq_item:n #3 \_seq_item:n #4 \_seq_item:n
8496     #5 \_seq_item:n #6 \_seq_item:n #7 \_seq_item:n #8 #9 \_seq_item:n
8497     { #9 8 + \_seq_count:w }
8498 \cs_new:Npn \_seq_count_end:w 8 + \_seq_count:w #1#2 \prg_break_point: {#1}
8499 \cs_generate_variant:Nn \seq_count:N { c }

```

(End definition for `\seq_count:N`, `_seq_count:w`, and `_seq_count_end:w`. This function is documented on page 79.)

11.7 Using sequences

```

\seq_use:Nnnn See \clist_use:Nnnn for a general explanation. The main difference is that we use \_seq_
\seq_use:cnnn \seq_item:n as a delimiter rather than commas. We also need to add \_seq_item:n at
\_seq_use:NNnNnn various places, and \s__seq.
\_seq_use_setup:w 8500 \cs_new:Npn \seq_use:Nnnn #1#2#3#4
\_seq_use:nwwwnwn 8501 {
\_seq_use:nwnn 8502     \seq_if_exist:NTF #1
\seq_use:Nn 8503     {
\seq_use:cn 8504         \int_case:nnF { \seq_count:N #1 }
8505         {
8506             { 0 } { }
8507             { 1 } { \exp_after:wN \_seq_use:NNnNnn #1 ? { } { } }
8508             { 2 } { \exp_after:wN \_seq_use:NNnNnn #1 {#2} }
8509         }
8510         {
8511             \exp_after:wN \_seq_use_setup:w #1 \_seq_item:n
8512             \q_mark { \_seq_use:nwwwnwn {#3} }
8513             \q_mark { \_seq_use:nwnn {#4} }
8514             \q_stop { }
8515         }
8516     }
8517     {
8518         \_kernel_msg_expandable_error:nnn
8519         { kernel } { bad-variable } {#1}
8520     }
8521 }
8522 \cs_generate_variant:Nn \seq_use:Nnnn { c }
8523 \cs_new:Npn \_seq_use:NNnNnn #1#2#3#4#5#6 { \exp_not:n { #3 #6 #5 } }
8524 \cs_new:Npn \_seq_use_setup:w \s__seq { \_seq_use:nwwwnwn { } }
8525 \cs_new:Npn \_seq_use:nwwwnwn
8526     #1 \_seq_item:n #2 \_seq_item:n #3 \_seq_item:n #4#5
8527     \q_mark #6#7 \q_stop #8
8528 {
8529     #6 \_seq_item:n {#3} \_seq_item:n {#4} #5

```

```

8530     \q_mark {#6} #7 \q_stop { #8 #1 #2 }
8531   }
8532 \cs_new:Npn \__seq_use:nwwn #1 \__seq_item:n #2 #3 \q_stop #4
8533   { \exp_not:n { #4 #1 #2 } }
8534 \cs_new:Npn \seq_use:Nn #1#2
8535   { \seq_use:Nnnn #1 {#2} {#2} {#2} }
8536 \cs_generate_variant:Nn \seq_use:Nn { c }

```

(End definition for `\seq_use:Nnnn` and others. These functions are documented on page 79.)

11.8 Sequence stacks

The same functions as for sequences, but with the correct naming.

`\seq_push:Nn` Pushing to a sequence is the same as adding on the left.

```

\seq_push:NV 8537 \cs_new_eq:NN \seq_push:Nn \seq_put_left:Nn
\seq_push:Nv 8538 \cs_new_eq:NN \seq_push:Nv \seq_put_left:Nv
\seq_push:No 8539 \cs_new_eq:NN \seq_push:Nv \seq_put_left:Nv
\seq_push:Nx 8540 \cs_new_eq:NN \seq_push:No \seq_put_left:No
\seq_push:cn 8541 \cs_new_eq:NN \seq_push:Nx \seq_put_left:Nx
\seq_push:cV 8542 \cs_new_eq:NN \seq_push:cn \seq_put_left:cn
\seq_push:cV 8543 \cs_new_eq:NN \seq_push:cV \seq_put_left:cV
\seq_push:cv 8544 \cs_new_eq:NN \seq_push:cv \seq_put_left:cv
\seq_push:co 8545 \cs_new_eq:NN \seq_push:co \seq_put_left:co
\seq_push:cx 8546 \cs_new_eq:NN \seq_push:cx \seq_put_left:cx
\seq_gpush:Nn 8547 \cs_new_eq:NN \seq_gpush:Nn \seq_gput_left:Nn
\seq_gpush:NV 8548 \cs_new_eq:NN \seq_gpush:Nv \seq_gput_left:Nv
\seq_gpush:Nv 8549 \cs_new_eq:NN \seq_gpush:Nv \seq_gput_left:Nv
\seq_gpush:No 8550 \cs_new_eq:NN \seq_gpush:No \seq_gput_left:No
\seq_gpush:Nx 8551 \cs_new_eq:NN \seq_gpush:Nx \seq_gput_left:Nx
\seq_gpush:cn 8552 \cs_new_eq:NN \seq_gpush:cn \seq_gput_left:cn
\seq_gpush:cV 8553 \cs_new_eq:NN \seq_gpush:cV \seq_gput_left:cV
\seq_gpush:cv 8554 \cs_new_eq:NN \seq_gpush:cv \seq_gput_left:cv
\seq_gpush:co 8555 \cs_new_eq:NN \seq_gpush:co \seq_gput_left:co
\seq_gpush:cx 8556 \cs_new_eq:NN \seq_gpush:cx \seq_gput_left:cx

```

(End definition for `\seq_push:Nn` and `\seq_gpush:Nn`. These functions are documented on page 81.)

`\seq_get:NN` In most cases, getting items from the stack does not need to specify that this is from the left. So alias are provided.

```

\seq_get:cN 8557 \cs_new_eq:NN \seq_get:NN \seq_get_left:NN
\seq_pop:NN 8558 \cs_new_eq:NN \seq_get:cN \seq_get_left:cN
\seq_pop:cN 8559 \cs_new_eq:NN \seq_pop:NN \seq_pop_left:NN
\seq_gpop:NN 8560 \cs_new_eq:NN \seq_pop:cN \seq_pop_left:cN
\seq_gpop:cN 8561 \cs_new_eq:NN \seq_gpop:NN \seq_gpop_left:NN
8562 \cs_new_eq:NN \seq_gpop:cN \seq_gpop_left:cN

```

(End definition for `\seq_get:NN`, `\seq_pop:NN`, and `\seq_gpop:NN`. These functions are documented on page 80.)

`\seq_get:NNTF` More copies.

```

\seq_get:cNTF 8563 \prg_new_eq_conditional:NNn \seq_get:NN \seq_get_left:NN { T , F , TF }
\seq_pop:NNTF 8564 \prg_new_eq_conditional:NNn \seq_get:cN \seq_get_left:cN { T , F , TF }
\seq_pop:cNTF 8565 \prg_new_eq_conditional:NNn \seq_pop:NN \seq_pop_left:NN { T , F , TF }
\seq_gpop:NNTF 8566 \prg_new_eq_conditional:NNn \seq_pop:cN \seq_pop_left:cN { T , F , TF }
\seq_gpop:cNTF

```



```

8567 \prg_new_eq_conditional:NNn \seq_gpop:NN \seq_gpop_left:NN { T , F , TF }
8568 \prg_new_eq_conditional:NNn \seq_gpop:cN \seq_gpop_left:cN { T , F , TF }

```

(End definition for `\seq_get:NNTF`, `\seq_pop:NNTF`, and `\seq_gpop:NNTF`. These functions are documented on page 80.)

11.9 Viewing sequences

```

\seq_show:N Apply the general \msg_show:nnnnnn.
\seq_show:c 8569 \cs_new_protected:Npn \seq_show:N { \__seq_show:NN \msg_show:nnxxxx }
\seq_log:N   8570 \cs_generate_variant:Nn \seq_show:N { c }
\seq_log:c   8571 \cs_new_protected:Npn \seq_log:N { \__seq_show:NN \msg_log:nnxxxx }
\__seq_show:NN 8572 \cs_generate_variant:Nn \seq_log:N { c }
               8573 \cs_new_protected:Npn \__seq_show:NN #1#2
               8574 {
               8575   \__kernel_chk_defined:NT #2
               8576   {
               8577     #1 { LaTeX/kernel } { show-seq }
               8578     { \token_to_str:N #2 }
               8579     { \seq_map_function:NN #2 \msg_show_item:n }
               8580     { } { }
               8581   }
               8582 }

```

(End definition for `\seq_show:N`, `\seq_log:N`, and `__seq_show:NN`. These functions are documented on page 83.)

11.10 Scratch sequences

```

\l_tmpa_seq Temporary comma list variables.
\l_tmpb_seq
\g_tmpa_seq 8583 \seq_new:N \l_tmpa_seq
\g_tmpb_seq 8584 \seq_new:N \l_tmpb_seq
            8585 \seq_new:N \g_tmpa_seq
            8586 \seq_new:N \g_tmpb_seq

```

(End definition for `\l_tmpa_seq` and others. These variables are documented on page 83.)

```

8587 </initex | package>

```

12 l3int implementation

```

8588 <*initex | package>
8589 <@@=int>

```

The following test files are used for this code: `m3int001`, `m3int002`, `m3int03`.

```

\c_max_register_int Done in l3basics.

```

(End definition for `\c_max_register_int`. This variable is documented on page 96.)

```

\__int_to_roman:w Done in l3basics.
\if_int_compare:w

```

(End definition for `__int_to_roman:w` and `\if_int_compare:w`. This function is documented on page 97.)

```

\or: Done in l3basics.

```

(End definition for `\or:`. This function is documented on page 97.)

`\int_value:w` Here are the remaining primitives for number comparisons and expressions.

```

\__int_eval:w      8590 \cs_new_eq:NN \int_value:w      \tex_number:D
\__int_eval_end:   8591 \cs_new_eq:NN \__int_eval:w      \tex_numexpr:D
\if_int_odd:w      8592 \cs_new_eq:NN \if_int_odd:w      \tex_relax:D
\if_case:w         8593 \cs_new_eq:NN \if_int_odd:w      \tex_ifodd:D
                   8594 \cs_new_eq:NN \if_case:w      \tex_ifcase:D

```

(End definition for `\int_value:w` and others. These functions are documented on page 97.)

12.1 Integer expressions

`\int_eval:n` Wrapper for `__int_eval:w`: can be used in an integer expression or directly in the input stream. When debugging, use parentheses to catch early termination.

```

8595 \__kernel_patch_args:nNNpn
8596 { { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_eval:n } }
8597 \cs_new:Npn \int_eval:n #1
8598 { \int_value:w \__int_eval:w #1 \__int_eval_end: }
8599 \cs_new:Npn \int_eval:w { \int_value:w \__int_eval:w }

```

(End definition for `\int_eval:n` and `\int_eval:w`. These functions are documented on page 85.)

`\int_abs:n` Functions for min, max, and absolute value with only one evaluation. The absolute value is obtained by removing a leading sign if any. All three functions expand in two steps.

```

\__int_abs:N
\int_max:nn      8600 \__kernel_patch_args:nNNpn
\int_min:nn      8601 { { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_abs:n } }
\__int_maxmin:wwN 8602 \cs_new:Npn \int_abs:n #1
                   8603 {
                   8604   \int_value:w \exp_after:wN \__int_abs:N
                   8605   \int_value:w \__int_eval:w #1 \__int_eval_end:
                   8606   \exp_stop_f:
                   8607 }
                   8608 \cs_new:Npn \__int_abs:N #1
                   8609 { \if_meaning:w - #1 \else: \exp_after:wN #1 \fi: }
                   8610 \__kernel_patch_args:nNNpn
                   8611 {
                   8612   { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_max:nn }
                   8613   { \__kernel_chk_expr:nNnN {#2} \__int_eval:w { } \int_max:nn }
                   8614 }
                   8615 \cs_set:Npn \int_max:nn #1#2
                   8616 {
                   8617   \int_value:w \exp_after:wN \__int_maxmin:wwN
                   8618   \int_value:w \__int_eval:w #1 \exp_after:wN ;
                   8619   \int_value:w \__int_eval:w #2 ;
                   8620   >
                   8621   \exp_stop_f:
                   8622 }
                   8623 \__kernel_patch_args:nNNpn
                   8624 {
                   8625   { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_min:nn }
                   8626   { \__kernel_chk_expr:nNnN {#2} \__int_eval:w { } \int_min:nn }
                   8627 }
                   8628 \cs_set:Npn \int_min:nn #1#2

```

```

8629 {
8630   \int_value:w \exp_after:wN \__int_maxmin:wwN
8631   \int_value:w \__int_eval:w #1 \exp_after:wN ;
8632   \int_value:w \__int_eval:w #2 ;
8633   <
8634   \exp_stop_f:
8635 }
8636 \cs_new:Npn \__int_maxmin:wwN #1 ; #2 ; #3
8637 {
8638   \if_int_compare:w #1 #3 #2 ~
8639     #1
8640   \else:
8641     #2
8642   \fi:
8643 }

```

(End definition for `\int_abs:n` and others. These functions are documented on page 86.)

`\int_div_truncate:nn` As `__int_eval:w` rounds the result of a division we also provide a version that truncates the result. We use an auxiliary to make sure numerator and denominator are only evaluated once: this comes in handy when those are more expressions are expensive to evaluate (e.g., `\tl_count:n`). If the numerator `#1#2` is 0, then we divide 0 by the denominator (this ensures that 0/0 is correctly reported as an error). Otherwise, shift the numerator `#1#2` towards 0 by $(| \#3\#4 | - 1)/2$, which we round away from zero. It turns out that this quantity exactly compensates the difference between ε -TeX's rounding and the truncating behaviour that we want. The details are thanks to Heiko Oberdiek: getting things right in all cases is not so easy.

```

8644 \__kernel_patch_args:nNNpn
8645 {
8646   { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_div_truncate:nn }
8647   { \__kernel_chk_expr:nNnN {#2} \__int_eval:w { } \int_div_truncate:nn }
8648 }
8649 \cs_new:Npn \int_div_truncate:nn #1#2
8650 {
8651   \int_value:w \__int_eval:w
8652   \exp_after:wN \__int_div_truncate:NwNw
8653   \int_value:w \__int_eval:w #1 \exp_after:wN ;
8654   \int_value:w \__int_eval:w #2 ;
8655   \__int_eval_end:
8656 }
8657 \cs_new:Npn \__int_div_truncate:NwNw #1#2; #3#4;
8658 {
8659   \if_meaning:w 0 #1
8660     0
8661   \else:
8662     (
8663       #1#2
8664       \if_meaning:w - #1 + \else: - \fi:
8665       ( \if_meaning:w - #3 - \fi: #3#4 - 1 ) / 2
8666     )
8667   \fi:
8668   / #3#4
8669 }

```

For the sake of completeness:

```
8670 \cs_new:Npn \int_div_round:nn #1#2
8671 { \int_value:w \__int_eval:w ( #1 ) / ( #2 ) \__int_eval_end: }
```

Finally there's the modulus operation.

```
8672 \__kernel_patch_args:nNnNpn
8673 {
8674   { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_mod:nn }
8675   { \__kernel_chk_expr:nNnN {#2} \__int_eval:w { } \int_mod:nn }
8676 }
8677 \cs_new:Npn \int_mod:nn #1#2
8678 {
8679   \int_value:w \__int_eval:w \exp_after:wN \__int_mod:ww
8680   \int_value:w \__int_eval:w #1 \exp_after:wN ;
8681   \int_value:w \__int_eval:w #2 ;
8682   \__int_eval_end:
8683 }
8684 \cs_new:Npn \__int_mod:ww #1; #2;
8685 { #1 - ( \__int_div_truncate:NwNw #1 ; #2 ; ) * #2 }
```

(End definition for `\int_div_truncate:nn` and others. These functions are documented on page 86.)

`__kernel_int_add:nnn`

Equivalent to `\int_eval:n {#1+#2+#3}` except that overflow only occurs if the final result overflows $[-2^{31} + 1, 2^{31} - 1]$. The idea is to choose the order in which the three numbers are added together. If `#1` and `#2` have opposite signs (one is in $[-2^{31} + 1, -1]$ and the other in $[0, 2^{31} - 1]$) then `#1+#2` cannot overflow so we compute the result as `#1+#2+#3`. If they have the same sign, then either `#3` has the same sign and the order does not matter, or `#3` has the opposite sign and any order in which `#3` is not last will work. We use `#1+#3+#2`.

```
8686 \cs_new:Npn \__kernel_int_add:nnn #1#2#3
8687 {
8688   \int_value:w \__int_eval:w #1
8689   \if_int_compare:w #2 < \c_zero_int \exp_after:wN \reverse_if:N \fi:
8690   \if_int_compare:w #1 < \c_zero_int + #2 + #3 \else: + #3 + #2 \fi:
8691   \__int_eval_end:
8692 }
```

(End definition for `__kernel_int_add:nnn`.)

12.2 Creating and initialising integers

`\int_new:N`
`\int_new:c`

Two ways to do this: one for the format and one for the L^AT_EX 2_ε package. In plain T_EX, `\newcount` (and other allocators) are `\outer:` to allow the code here to work in “generic” mode this is therefore accessed by name. (The same applies to `\newbox`, `\newdimen` and so on.)

```
8693 \*package>
8694 \cs_new_protected:Npn \int_new:N #1
8695 {
8696   \__kernel_chk_if_free_cs:N #1
8697   \cs:w newcount \cs_end: #1
8698 }
8699 </package>
8700 \cs_generate_variant:Nn \int_new:N { c }
```

(End definition for `\int_new:N`. This function is documented on page 86.)

`\int_const:Nn` As stated, most constants can be defined as `\chardef` or `\mathchardef` but that's engine dependent. As a result, there is some set up code to determine what can be done. No full engine testing just yet so everything is a little awkward. We cannot use `\int_gset:Nn` because (when `check-declarations` is enabled) this runs some checks that constants would fail.

```

8701 \__kernel_patch_args:nnnNNpn
8702 { \__kernel_chk_var_scope:NN c #1 }
8703 { }
8704 { {#1} { \__kernel_chk_expr:nNnN {#2} \__int_eval:w { } \int_const:Nn } }
8705 \cs_new_protected:Npn \int_const:Nn #1#2
8706 {
8707   \int_compare:nNnTF {#2} < \c_zero_int
8708   {
8709     \int_new:N #1
8710     \tex_global:D
8711   }
8712   {
8713     \int_compare:nNnTF {#2} > \c__int_max_constdef_int
8714     {
8715       \int_new:N #1
8716       \tex_global:D
8717     }
8718     {
8719       \__kernel_chk_if_free_cs:N #1
8720       \tex_global:D \__int_constdef:Nw
8721     }
8722   }
8723   #1 = \__int_eval:w #2 \__int_eval_end:
8724 }
8725 \cs_generate_variant:Nn \int_const:Nn { c }
8726 \if_int_odd:w 0
8727   \cs_if_exist:NT \tex_luatexversion:D { 1 }
8728   \cs_if_exist:NT \tex_disablecjktoken:D
8729   { \if_int_compare:w \tex_jis:D "2121 = "3000 ~ 1 \fi: }
8730   \cs_if_exist:NT \tex_XeTeXversion:D { 1 } ~
8731   \cs_if_exist:NTF \tex_disablecjktoken:D
8732   { \cs_new_eq:NN \__int_constdef:Nw \tex_kchardef:D }
8733   { \cs_new_eq:NN \__int_constdef:Nw \tex_chardef:D }
8734   \__int_constdef:Nw \c__int_max_constdef_int 1114111 ~
8735 \else:
8736   \cs_new_eq:NN \__int_constdef:Nw \tex_mathchardef:D
8737   \tex_mathchardef:D \c__int_max_constdef_int 32767 ~
8738 \fi:

```

(End definition for `\int_const:Nn`, `__int_constdef:Nw`, and `\c__int_max_constdef_int`. This function is documented on page 87.)

`\int_zero:N` Functions that reset an *integer* register to zero.

`\int_zero:c` 8739 __kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }

`\int_gzero:N` 8740 \cs_new_protected:Npn \int_zero:N #1 { #1 = \c_zero_int }

`\int_gzero:c` 8741 __kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }

8742 \cs_new_protected:Npn \int_gzero:N #1 { \tex_global:D #1 = \c_zero_int }

```

8743 \cs_generate_variant:Nn \int_zero:N { c }
8744 \cs_generate_variant:Nn \int_gzero:N { c }

```

(End definition for `\int_zero:N` and `\int_gzero:N`. These functions are documented on page 87.)

```

\int_zero_new:N Create a register if needed, otherwise clear it.
\int_zero_new:c 8745 \cs_new_protected:Npn \int_zero_new:N #1
\int_gzero_new:N 8746 { \int_if_exist:NTF #1 { \int_zero:N #1 } { \int_new:N #1 } }
\int_gzero_new:c 8747 \cs_new_protected:Npn \int_gzero_new:N #1
8748 { \int_if_exist:NTF #1 { \int_gzero:N #1 } { \int_new:N #1 } }
8749 \cs_generate_variant:Nn \int_zero_new:N { c }
8750 \cs_generate_variant:Nn \int_gzero_new:N { c }

```

(End definition for `\int_zero_new:N` and `\int_gzero_new:N`. These functions are documented on page 87.)

```

\int_set_eq:NN Setting equal means using one integer inside the set function of another. Check that
\int_set_eq:cN assigned integer is local/global. No need to check that the other one is defined as TEX
\int_set_eq:Nc does it for us.
\int_set_eq:cc 8751 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\int_gset_eq:NN 8752 \cs_new_protected:Npn \int_set_eq:NN #1#2 { #1 = #2 }
\int_gset_eq:cN 8753 \cs_generate_variant:Nn \int_set_eq:NN { c , Nc , cc }
\int_gset_eq:Nc 8754 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
\int_gset_eq:cc 8755 \cs_new_protected:Npn \int_gset_eq:NN #1#2 { \tex_global:D #1 = #2 }
8756 \cs_generate_variant:Nn \int_gset_eq:NN { c , Nc , cc }

```

(End definition for `\int_set_eq:NN` and `\int_gset_eq:NN`. These functions are documented on page 87.)

```

\int_if_exist_p:N Copies of the cs functions defined in l3basics.
\int_if_exist_p:c 8757 \prg_new_eq_conditional:NNn \int_if_exist:N \cs_if_exist:N
\int_if_exist:NTF 8758 { TF , T , F , p }
\int_if_exist:cTF 8759 \prg_new_eq_conditional:NNn \int_if_exist:c \cs_if_exist:c
8760 { TF , T , F , p }

```

(End definition for `\int_if_exist:NTF`. This function is documented on page 87.)

12.3 Setting and incrementing integers

Several functions here have a signature `:Nn` and are such that when debugging, the first argument should be checked to be a local/global variable and the second should be wrapped in code for an expression. The temporary function `__int_tmp:w` finds the name `#3` of the function being redefined and writes the appropriate patch.

```

8761 \cs_set_protected:Npn \__int_tmp:w #1#2#3
8762 {
8763   \__kernel_patch_args:nnnNNpn
8764     { #1 ##1 }
8765     { }
8766     { {##1} { \__kernel_chk_expr:nNn {##2} \__int_eval:w { } #3 } }
8767   #2 #3
8768 }

```

\int_add:Nn Adding and subtracting to and from a counter. For each function, the debugging code produced by `__int_tmp:w` checks that the assigned variable is correctly local/global and wraps the expression in some checking code.

\int_add:cn

\int_gadd:Nn

\int_gadd:cn

\int_sub:Nn

\int_sub:cn

\int_gsub:Nn

\int_gsub:cn

```

8769 \__int_tmp:w \__kernel_chk_var_local:N
8770 \cs_new_protected:Npn \int_add:Nn #1#2
8771 { \tex_advance:D #1 by \__int_eval:w #2 \__int_eval_end: }
8772 \__int_tmp:w \__kernel_chk_var_local:N
8773 \cs_new_protected:Npn \int_sub:Nn #1#2
8774 { \tex_advance:D #1 by - \__int_eval:w #2 \__int_eval_end: }
8775 \__int_tmp:w \__kernel_chk_var_global:N
8776 \cs_new_protected:Npn \int_gadd:Nn #1#2
8777 { \tex_global:D \tex_advance:D #1 by \__int_eval:w #2 \__int_eval_end: }
8778 \__int_tmp:w \__kernel_chk_var_global:N
8779 \cs_new_protected:Npn \int_gsub:Nn #1#2
8780 { \tex_global:D \tex_advance:D #1 by - \__int_eval:w #2 \__int_eval_end: }
8781 \cs_generate_variant:Nn \int_add:Nn { c }
8782 \cs_generate_variant:Nn \int_gadd:Nn { c }
8783 \cs_generate_variant:Nn \int_sub:Nn { c }
8784 \cs_generate_variant:Nn \int_gsub:Nn { c }

```

(End definition for `\int_add:Nn` and others. These functions are documented on page 87.)

\int_incr:N Incrementing and decrementing of integer registers is done with the following functions.

\int_incr:c

\int_gincr:N

\int_gincr:c

\int_decr:N

\int_decr:c

\int_gdecr:N

\int_gdecr:c

```

8785 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
8786 \cs_new_protected:Npn \int_incr:N #1
8787 { \tex_advance:D #1 \c_one_int }
8788 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
8789 \cs_new_protected:Npn \int_decr:N #1
8790 { \tex_advance:D #1 - \c_one_int }
8791 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
8792 \cs_new_protected:Npn \int_gincr:N #1
8793 { \tex_global:D \tex_advance:D #1 \c_one_int }
8794 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
8795 \cs_new_protected:Npn \int_gdecr:N #1
8796 { \tex_global:D \tex_advance:D #1 - \c_one_int }
8797 \cs_generate_variant:Nn \int_incr:N { c }
8798 \cs_generate_variant:Nn \int_decr:N { c }
8799 \cs_generate_variant:Nn \int_gincr:N { c }
8800 \cs_generate_variant:Nn \int_gdecr:N { c }

```

(End definition for `\int_incr:N` and others. These functions are documented on page 87.)

\int_set:Nn As integers are register-based TeX issues an error if they are not defined. Thus there is no need to check their existence as for token list variables. However, the code that checks whether the assignment is local or global is still needed.

\int_set:cn

\int_gset:Nn

\int_gset:cn

```

8801 \__int_tmp:w \__kernel_chk_var_local:N
8802 \cs_new_protected:Npn \int_set:Nn #1#2
8803 { #1 ~ \__int_eval:w #2 \__int_eval_end: }
8804 \__int_tmp:w \__kernel_chk_var_global:N
8805 \cs_new_protected:Npn \int_gset:Nn #1#2
8806 { \tex_global:D #1 ~ \__int_eval:w #2 \__int_eval_end: }
8807 \cs_generate_variant:Nn \int_set:Nn { c }
8808 \cs_generate_variant:Nn \int_gset:Nn { c }

```

(End definition for `\int_set:Nn` and `\int_gset:Nn`. These functions are documented on page 88.)

12.4 Using integers

`\int_use:N` Here is how counters are accessed:

`\int_use:c` 8809 `\cs_new_eq:NN \int_use:N \tex_the:D`

We hand-code this for some speed gain:

```
8810 %\cs_generate_variant:Nn \int_use:N { c }
8811 \cs_new:Npn \int_use:c #1 { \tex_the:D \cs:w #1 \cs_end: }
```

(End definition for `\int_use:N`. This function is documented on page 88.)

12.5 Integer expression conditionals

`__int_compare_error:`
`__int_compare_error:Nw`

Those functions are used for comparison tests which use a simple syntax where only one set of braces is required and additional operators such as `!=` and `>=` are supported. The tests first evaluate their left-hand side, with a trailing `__int_compare_error:`. This marker is normally not expanded, but if the relation symbol is missing from the test's argument, then the marker inserts `=` (and itself) after triggering the relevant TeX error. If the first token which appears after evaluating and removing the left-hand side is not a known relation symbol, then a judiciously placed `__int_compare_error:Nw` gets expanded, cleaning up the end of the test and telling the user what the problem was.

```
8812 \cs_new_protected:Npn \__int_compare_error:
8813 {
8814   \if_int_compare:w \c_zero_int \c_zero_int \fi:
8815   =
8816   \__int_compare_error:
8817 }
8818 \cs_new:Npn \__int_compare_error:Nw
8819   #1#2 \q_stop
8820 {
8821   { }
8822   \c_zero_int \fi:
8823   \__kernel_msg_expandable_error:nnn
8824     { kernel } { unknown-comparison } {#1}
8825   \prg_return_false:
8826 }
```

(End definition for `__int_compare_error:` and `__int_compare_error:Nw`.)

`\int_compare_p:n`
`\int_compare:nTF`
`__int_compare:w`
`__int_compare:Nw`
`__int_compare:NNw`
`__int_compare:nnN`
`__int_compare_end=:NNw`
`__int_compare=:NNw`
`__int_compare<:NNw`
`__int_compare>:NNw`
`__int_compare=:NNw`
`__int_compare!=:NNw`
`__int_compare<=:NNw`
`__int_compare>=:NNw`

Comparison tests using a simple syntax where only one set of braces is required, additional operators such as `!=` and `>=` are supported, and multiple comparisons can be performed at once, for instance `0 < 5 <= 1`. The idea is to loop through the argument, finding one operand at a time, and comparing it to the previous one. The looping auxiliary `__int_compare:Nw` reads one *operand* and one *comparison* symbol, and leaves roughly

```
<operand> \prg_return_false: \fi:
\reverse_if:N \if_int_compare:w <operand> <comparison>
\__int_compare:Nw
```

in the input stream. Each call to this auxiliary provides the second operand of the last call's `\if_int_compare:w`. If one of the *comparisons* is `false`, the `true` branch of the TeX conditional is taken (because of `\reverse_if:N`), immediately returning `false` as the result of the test. There is no TeX conditional waiting the first operand, so we add

an `\if_false:` and expand by hand with `\int_value:w`, thus skipping `\prg_return_-false:` on the first iteration.

Before starting the loop, the first step is to make sure that there is at least one relation symbol. We first let `TEX` evaluate this left hand side of the (in)equality using `__int_eval:w`. Since the relation symbols `<`, `>`, `=` and `!` are not allowed in integer expressions, they would terminate the expression. If the argument contains no relation symbol, `__int_compare_error:` is expanded, inserting `=` and itself after an error. In all cases, `__int_compare:w` receives as its argument an integer, a relation symbol, and some more tokens. We then setup the loop, which is ended by the two odd-looking items `e` and `{=nd_}`, with a trailing `\q_stop` used to grab the entire argument when necessary.

```

8827 \prg_new_conditional:Npnn \int_compare:n #1 { p , T , F , TF }
8828 {
8829     \exp_after:wN \__int_compare:w
8830     \int_value:w \__int_eval:w #1 \__int_compare_error:
8831 }
8832 \cs_new:Npn \__int_compare:w #1 \__int_compare_error:
8833 {
8834     \exp_after:wN \if_false: \int_value:w
8835     \__int_compare:Nw #1 e { = nd_ } \q_stop
8836 }

```

The goal here is to find an *operand* and a *comparison*. The *operand* is already evaluated, but we cannot yet grab it as an argument. To access the following relation symbol, we remove the number by applying `__int_to_roman:w`, after making sure that the argument becomes non-positive: its roman numeral representation is then empty. Then probe the first two tokens with `__int_compare:NNw` to determine the relation symbol, building a control sequence from it (`\token_to_str:N` gives better errors if `#1` is not a character). All the extended forms have an extra `=` hence the test for that as a second token. If the relation symbol is unknown, then the control sequence is turned by `TEX` into `\scan_stop:`, ignored thanks to `\unexpanded`, and `__int_compare_error:Nw` raises an error.

```

8837 \cs_new:Npn \__int_compare:Nw #1#2 \q_stop
8838 {
8839     \exp_after:wN \__int_compare:NNw
8840     \__int_to_roman:w - 0 #2 \q_mark
8841     #1#2 \q_stop
8842 }
8843 \cs_new:Npn \__int_compare:NNw #1#2#3 \q_mark
8844 {
8845     \__kernel_exp_not:w
8846     \use:c
8847     {
8848         __int_compare_ \token_to_str:N #1
8849         \if_meaning:w = #2 = \fi:
8850         :NNw
8851     }
8852     \__int_compare_error:Nw #1
8853 }

```

When the last *operand* is seen, `__int_compare:NNw` receives `e` and `=nd_` as arguments, hence calling `__int_compare_end=:NNw` to end the loop: return the result of the last comparison (involving the operand that we just found). When a normal relation is found, the appropriate auxiliary calls `__int_compare:nnN` where `#1` is `\if_int_compare:w` or

\reverse_if:N \if_int_compare:w, #2 is the *<operand>*, and #3 is one of <, =, or >. As announced earlier, we leave the *<operand>* for the previous conditional. If this conditional is true the result of the test is known, so we remove all tokens and return false. Otherwise, we apply the conditional #1 to the *<operand>* #2 and the comparison #3, and call __int_compare:Nw to look for additional operands, after evaluating the following expression.

```

8854 \cs_new:cpn { __int_compare_end=:NNw } #1#2#3 e #4 \q_stop
8855 {
8856   {#3} \exp_stop_f:
8857   \prg_return_false: \else: \prg_return_true: \fi:
8858 }
8859 \cs_new:Npn \__int_compare:nnN #1#2#3
8860 {
8861   {#2} \exp_stop_f:
8862   \prg_return_false: \exp_after:wN \use_none_delimit_by_q_stop:w
8863   \fi:
8864   #1 #2 #3 \exp_after:wN \__int_compare:Nw \int_value:w \__int_eval:w
8865 }

```

The actual comparisons are then simple function calls, using the relation as delimiter for a delimited argument and discarding __int_compare_error:Nw *<token>* responsible for error detection.

```

8866 \cs_new:cpn { __int_compare=:NNw } #1#2#3 =
8867 { \__int_compare:nnN { \reverse_if:N \if_int_compare:w } {#3} = }
8868 \cs_new:cpn { __int_compare:<:NNw } #1#2#3 <
8869 { \__int_compare:nnN { \reverse_if:N \if_int_compare:w } {#3} < }
8870 \cs_new:cpn { __int_compare:>:NNw } #1#2#3 >
8871 { \__int_compare:nnN { \reverse_if:N \if_int_compare:w } {#3} > }
8872 \cs_new:cpn { __int_compare:=:NNw } #1#2#3 ==
8873 { \__int_compare:nnN { \reverse_if:N \if_int_compare:w } {#3} = }
8874 \cs_new:cpn { __int_compare!=:NNw } #1#2#3 !=
8875 { \__int_compare:nnN { \if_int_compare:w } {#3} = }
8876 \cs_new:cpn { __int_compare<=:NNw } #1#2#3 <=
8877 { \__int_compare:nnN { \if_int_compare:w } {#3} > }
8878 \cs_new:cpn { __int_compare>=:NNw } #1#2#3 >=
8879 { \__int_compare:nnN { \if_int_compare:w } {#3} < }

```

(End definition for \int_compare:nTF and others. This function is documented on page 89.)

\int_compare_p:nNn More efficient but less natural in typing.

\int_compare:nNnTF

```

8880 \__kernel_patch_conditional_args:nNnpnn
8881 {
8882   { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_compare:nNn }
8883   { \__int_eval_end: #2 }
8884   { \__kernel_chk_expr:nNnN {#3} \__int_eval:w { } \int_compare:nNn }
8885 }
8886 \prg_new_conditional:Npnn \int_compare:nNn #1#2#3 { p , T , F , TF }
8887 {
8888   \if_int_compare:w \__int_eval:w #1 #2 \__int_eval:w #3 \__int_eval_end:
8889   \prg_return_true:
8890   \else:
8891   \prg_return_false:
8892   \fi:
8893 }

```

(End definition for `\int_compare:nNnTF`. This function is documented on page 88.)

`\int_case:nn` For integer cases, the first task to fully expand the check condition. The over all idea is
`\int_case:nnTF` then much the same as for `\tl_case:nn(TF)` as described in l3tl.
`__int_case:nnTF`
`__int_case:nw`
`__int_case_end:nw`

```

8894 \cs_new:Npn \int_case:nnTF #1
8895 {
8896   \exp:w
8897   \exp_args:Nf \__int_case:nnTF { \int_eval:n {#1} }
8898 }
8899 \cs_new:Npn \int_case:nnT #1#2#3
8900 {
8901   \exp:w
8902   \exp_args:Nf \__int_case:nnTF { \int_eval:n {#1} } {#2} {#3} { }
8903 }
8904 \cs_new:Npn \int_case:nnF #1#2
8905 {
8906   \exp:w
8907   \exp_args:Nf \__int_case:nnTF { \int_eval:n {#1} } {#2} { }
8908 }
8909 \cs_new:Npn \int_case:nn #1#2
8910 {
8911   \exp:w
8912   \exp_args:Nf \__int_case:nnTF { \int_eval:n {#1} } {#2} { } { }
8913 }
8914 \cs_new:Npn \__int_case:nnTF #1#2#3#4
8915 { \__int_case:nw {#1} #2 {#1} { } \q_mark {#3} \q_mark {#4} \q_stop }
8916 \cs_new:Npn \__int_case:nw #1#2#3
8917 {
8918   \int_compare:nNnTF {#1} = {#2}
8919   { \__int_case_end:nw {#3} }
8920   { \__int_case:nw {#1} }
8921 }
8922 \cs_new:Npn \__int_case_end:nw #1#2#3 \q_mark #4#5 \q_stop
8923 { \exp_end: #1 #4 }

```

(End definition for `\int_case:nnTF` and others. This function is documented on page 90.)

`\int_if_odd_p:n` A predicate function.
`\int_if_odd:nTF`
`\int_if_even_p:n`
`\int_if_even:nTF`

```

8924 \__kernel_patch_conditional_args:nNnpnn
8925 { { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_if_odd:n } }
8926 \prg_new_conditional:Npnn \int_if_odd:n #1 { p , T , F , TF }
8927 {
8928   \if_int_odd:w \__int_eval:w #1 \__int_eval_end:
8929   \prg_return_true:
8930   \else:
8931   \prg_return_false:
8932   \fi:
8933 }
8934 \__kernel_patch_conditional_args:nNnpnn
8935 { { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_if_even:n } }
8936 \prg_new_conditional:Npnn \int_if_even:n #1 { p , T , F , TF }
8937 {
8938   \reverse_if:N \if_int_odd:w \__int_eval:w #1 \__int_eval_end:
8939   \prg_return_true:

```

```

8940     \else:
8941         \prg_return_false:
8942     \fi:
8943 }

```

(End definition for `\int_if_odd:nTF` and `\int_if_even:nTF`. These functions are documented on page 90.)

12.6 Integer expression loops

`\int_while_do:nn` These are quite easy given the above functions. The `while` versions test first and then execute the body. The `do_while` does it the other way round.

```

\int_until_do:nn
\int_do_while:nn
\int_do_until:nn
8944 \cs_new:Npn \int_while_do:nn #1#2
8945 {
8946     \int_compare:nT {#1}
8947     {
8948         #2
8949         \int_while_do:nn {#1} {#2}
8950     }
8951 }
8952 \cs_new:Npn \int_until_do:nn #1#2
8953 {
8954     \int_compare:nF {#1}
8955     {
8956         #2
8957         \int_until_do:nn {#1} {#2}
8958     }
8959 }
8960 \cs_new:Npn \int_do_while:nn #1#2
8961 {
8962     #2
8963     \int_compare:nT {#1}
8964     { \int_do_while:nn {#1} {#2} }
8965 }
8966 \cs_new:Npn \int_do_until:nn #1#2
8967 {
8968     #2
8969     \int_compare:nF {#1}
8970     { \int_do_until:nn {#1} {#2} }
8971 }

```

(End definition for `\int_while_do:nn` and others. These functions are documented on page 91.)

`\int_while_do:nNnn` As above but not using the more natural syntax.

```

\int_until_do:nNnn
\int_do_while:nNnn
\int_do_until:nNnn
8972 \cs_new:Npn \int_while_do:nNnn #1#2#3#4
8973 {
8974     \int_compare:nNnT {#1} #2 {#3}
8975     {
8976         #4
8977         \int_while_do:nNnn {#1} #2 {#3} {#4}
8978     }
8979 }
8980 \cs_new:Npn \int_until_do:nNnn #1#2#3#4
8981 {

```

```

8982     \int_compare:nNnF {#1} #2 {#3}
8983     {
8984         #4
8985         \int_until_do:nNnn {#1} #2 {#3} {#4}
8986     }
8987 }
8988 \cs_new:Npn \int_do_while:nNnn #1#2#3#4
8989 {
8990     #4
8991     \int_compare:nNnT {#1} #2 {#3}
8992     { \int_do_while:nNnn {#1} #2 {#3} {#4} }
8993 }
8994 \cs_new:Npn \int_do_until:nNnn #1#2#3#4
8995 {
8996     #4
8997     \int_compare:nNnF {#1} #2 {#3}
8998     { \int_do_until:nNnn {#1} #2 {#3} {#4} }
8999 }

```

(End definition for `\int_while_do:nNnn` and others. These functions are documented on page 91.)

12.7 Integer step functions

`\int_step_function:nnnN` Before all else, evaluate the initial value, step, and final value. Repeating a function by steps first needs a check on the direction of the steps. After that, do the function for the start value then step and loop around. It would be more symmetrical to test for a step size of zero before checking the sign, but we optimize for the most frequent case (positive step).

```

9000 \__kernel_patch_args:nNNpn
9001 {
9002     {
9003         \__kernel_chk_expr:nNnN {#1} \__int_eval:w { }
9004         \int_step_function:nnnN
9005     }
9006     {
9007         \__kernel_chk_expr:nNnN {#2} \__int_eval:w { }
9008         \int_step_function:nnnN
9009     }
9010     {
9011         \__kernel_chk_expr:nNnN {#3} \__int_eval:w { }
9012         \int_step_function:nnnN
9013     }
9014 }
9015 \cs_new:Npn \int_step_function:nnnN #1#2#3
9016 {
9017     \exp_after:wN \__int_step:wwwN
9018     \int_value:w \__int_eval:w #1 \exp_after:wN ;
9019     \int_value:w \__int_eval:w #2 \exp_after:wN ;
9020     \int_value:w \__int_eval:w #3 ;
9021 }
9022 \cs_new:Npn \__int_step:wwwN #1; #2; #3; #4
9023 {
9024     \int_compare:nNnTF {#2} > \c_zero_int
9025     { \__int_step:NwnnnN > }

```

```

9026     {
9027         \int_compare:nNnTF {#2} = \c_zero_int
9028         {
9029             \__kernel_msg_expandable_error:nnn
9030             { kernel } { zero-step } {#4}
9031             \prg_break:
9032         }
9033         { \__int_step:NwnnnN < }
9034     }
9035     #1 ; {#2} {#3} #4
9036     \prg_break_point:
9037 }
9038 \cs_new:Npn \__int_step:NwnnnN #1#2 ; #3#4#5
9039 {
9040     \if_int_compare:w #2 #1 #4 \exp_stop_f:
9041         \prg_break:n
9042     \fi:
9043     #5 {#2}
9044     \exp_after:wN \__int_step:NwnnnN
9045     \exp_after:wN #1
9046     \int_value:w \__int_eval:w #2 + #3 ; {#3} {#4} #5
9047 }
9048 \cs_new:Npn \int_step_function:nN
9049 { \int_step_function:nnnN { 1 } { 1 } }
9050 \cs_new:Npn \int_step_function:nnN #1
9051 { \int_step_function:nnnN {#1} { 1 } }

```

(End definition for `\int_step_function:nnnN` and others. These functions are documented on page 92.)

```

\int_step_inline:nn
\int_step_inline:nnn
\int_step_inline:nnnn
\int_step_variable:nNn
\int_step_variable:nnNn
\int_step_variable:nnnnNn
\__int_step:NNnnnn

```

The approach here is to build a function, with a global integer required to make the nesting safe (as seen in other in line functions), and map that function using `\int_step_function:nnnN`. We put a `\prg_break_point:Nn` so that `map_break` functions from other modules correctly decrement `\g__kernel_prg_map_int` before looking for their own break point. The first argument is `\scan_stop:`, so that no breaking function recognizes this break point as its own.

```

9052 \cs_new_protected:Npn \int_step_inline:nn
9053 { \int_step_inline:nnnn { 1 } { 1 } }
9054 \cs_new_protected:Npn \int_step_inline:nnn #1
9055 { \int_step_inline:nnnn {#1} { 1 } }
9056 \cs_new_protected:Npn \int_step_inline:nnnn
9057 {
9058     \int_gincr:N \g__kernel_prg_map_int
9059     \exp_args:NNc \__int_step:NNnnnn
9060     \cs_gset_protected:Npn
9061     { __int_map_ \int_use:N \g__kernel_prg_map_int :w }
9062 }
9063 \cs_new_protected:Npn \int_step_variable:nNn
9064 { \int_step_variable:nnnnN { 1 } { 1 } }
9065 \cs_new_protected:Npn \int_step_variable:nnNn #1
9066 { \int_step_variable:nnnnN {#1} { 1 } }
9067 \cs_new_protected:Npn \int_step_variable:nnnnNn #1#2#3#4#5
9068 {
9069     \int_gincr:N \g__kernel_prg_map_int
9070     \exp_args:NNc \__int_step:NNnnnn

```

```

9071 \cs_gset_protected:Npx
9072 { __int_map_ \int_use:N \g__kernel_prg_map_int :w }
9073 {#1}{#2}{#3}
9074 {
9075 \tl_set:Nn \exp_not:N #4 {##1}
9076 \exp_not:n {#5}
9077 }
9078 }
9079 \cs_new_protected:Npn \__int_step:NNnnnn #1#2#3#4#5#6
9080 {
9081 #1 #2 ##1 {#6}
9082 \int_step_function:nnnN {#3} {#4} {#5} #2
9083 \prg_break_point:Nn \scan_stop: { \int_gdecr:N \g__kernel_prg_map_int }
9084 }

```

(End definition for `\int_step_inline:nn` and others. These functions are documented on page 92.)

12.8 Formatting integers

`\int_to_arabic:n` Nothing exciting here.

```

9085 \cs_new_eq:NN \int_to_arabic:n \int_eval:n

```

(End definition for `\int_to_arabic:n`. This function is documented on page 93.)

`\int_to_symbols:nnn` For conversion of integers to arbitrary symbols the method is in general as follows. The input number (#1) is compared to the total number of symbols available at each place (#2). If the input is larger than the total number of symbols available then the modulus is needed, with one added so that the positions don't have to number from zero. Using an `f`-type expansion, this is done so that the system is recursive. The actual conversion function therefore gets a 'nice' number at each stage. Of course, if the initial input was small enough then there is no problem and everything is easy.

```

9086 \cs_new:Npn \int_to_symbols:nnn #1#2#3
9087 {
9088 \int_compare:nNnTF {#1} > {#2}
9089 {
9090 \exp_args:NNo \exp_args:No \__int_to_symbols:nnnn
9091 {
9092 \int_case:nn
9093 { 1 + \int_mod:nn { #1 - 1 } {#2} }
9094 {#3}
9095 }
9096 {#1} {#2} {#3}
9097 }
9098 { \int_case:nn {#1} {#3} }
9099 }
9100 \cs_new:Npn \__int_to_symbols:nnnn #1#2#3#4
9101 {
9102 \exp_args:Nf \int_to_symbols:nnn
9103 { \int_div_truncate:nn { #2 - 1 } {#3} } {#3} {#4}
9104 #1
9105 }

```

(End definition for `\int_to_symbols:nnn` and `__int_to_symbols:nnnn`. This function is documented on page 93.)

`\int_to_alph:n` These both use the above function with input functions that make sense for the alphabet
`\int_to_Alph:n` in English.

```

9106 \cs_new:Npn \int_to_alph:n #1
9107 {
9108   \int_to_symbols:nnn {#1} { 26 }
9109   {
9110     { 1 } { a }
9111     { 2 } { b }
9112     { 3 } { c }
9113     { 4 } { d }
9114     { 5 } { e }
9115     { 6 } { f }
9116     { 7 } { g }
9117     { 8 } { h }
9118     { 9 } { i }
9119     { 10 } { j }
9120     { 11 } { k }
9121     { 12 } { l }
9122     { 13 } { m }
9123     { 14 } { n }
9124     { 15 } { o }
9125     { 16 } { p }
9126     { 17 } { q }
9127     { 18 } { r }
9128     { 19 } { s }
9129     { 20 } { t }
9130     { 21 } { u }
9131     { 22 } { v }
9132     { 23 } { w }
9133     { 24 } { x }
9134     { 25 } { y }
9135     { 26 } { z }
9136   }
9137 }
9138 \cs_new:Npn \int_to_Alph:n #1
9139 {
9140   \int_to_symbols:nnn {#1} { 26 }
9141   {
9142     { 1 } { A }
9143     { 2 } { B }
9144     { 3 } { C }
9145     { 4 } { D }
9146     { 5 } { E }
9147     { 6 } { F }
9148     { 7 } { G }
9149     { 8 } { H }
9150     { 9 } { I }
9151     { 10 } { J }
9152     { 11 } { K }
9153     { 12 } { L }
9154     { 13 } { M }
9155     { 14 } { N }
9156     { 15 } { O }
9157     { 16 } { P }

```



```

9158     { 17 } { Q }
9159     { 18 } { R }
9160     { 19 } { S }
9161     { 20 } { T }
9162     { 21 } { U }
9163     { 22 } { V }
9164     { 23 } { W }
9165     { 24 } { X }
9166     { 25 } { Y }
9167     { 26 } { Z }
9168   }
9169 }

```

(End definition for `\int_to_alph:n` and `\int_to_Alph:n`. These functions are documented on page 93.)

`\int_to_base:nn` Converting from base ten (#1) to a second base (#2) starts with computing #1: if it is a complicated calculation, we shouldn't perform it twice. Then check the sign, store it, either - or `\c_empty_tl`, and feed the absolute value to the next auxiliary function.

```

\int_to_Base:nn
\__int_to_base:nn
\__int_to_Base:nnN
\__int_to_Base:nnN
\__int_to_base:nnnN
\__int_to_Base:nnnN
\__int_to_letter:n
\__int_to_Letter:n
9170 \cs_new:Npn \int_to_base:nn #1
9171 { \exp_args:Nf \__int_to_base:nn { \int_eval:n {#1} } }
9172 \cs_new:Npn \int_to_Base:nn #1
9173 { \exp_args:Nf \__int_to_Base:nn { \int_eval:n {#1} } }
9174 \cs_new:Npn \__int_to_base:nn #1#2
9175 {
9176   \int_compare:nNnTF {#1} < 0
9177   { \exp_args:No \__int_to_base:nnN { \use_none:n #1 } {#2} - }
9178   { \__int_to_base:nnN {#1} {#2} \c_empty_tl }
9179 }
9180 \cs_new:Npn \__int_to_Base:nn #1#2
9181 {
9182   \int_compare:nNnTF {#1} < 0
9183   { \exp_args:No \__int_to_Base:nnN { \use_none:n #1 } {#2} - }
9184   { \__int_to_Base:nnN {#1} {#2} \c_empty_tl }
9185 }

```

Here, the idea is to provide a recursive system to deal with the input. The output is built up after the end of the function. At each pass, the value in #1 is checked to see if it is less than the new base (#2). If it is, then it is converted directly, putting the sign back in front. On the other hand, if the value to convert is greater than or equal to the new base then the modulus and remainder values are found. The modulus is converted to a symbol and put on the right, and the remainder is carried forward to the next round.

```

9186 \cs_new:Npn \__int_to_base:nnN #1#2#3
9187 {
9188   \int_compare:nNnTF {#1} < {#2}
9189   { \exp_last_unbraced:Nf #3 { \__int_to_letter:n {#1} } }
9190   {
9191     \exp_args:Nf \__int_to_base:nnnN
9192     { \__int_to_letter:n { \int_mod:nn {#1} {#2} } }
9193     {#1}
9194     {#2}
9195     #3
9196   }
9197 }
9198 \cs_new:Npn \__int_to_base:nnnN #1#2#3#4

```

```

9199 {
9200   \exp_args:Nf \__int_to_base:nnN
9201   { \int_div_truncate:nn {#2} {#3} }
9202   {#3}
9203   #4
9204   #1
9205 }
9206 \cs_new:Npn \__int_to_Base:nnN #1#2#3
9207 {
9208   \int_compare:nNnTF {#1} < {#2}
9209   { \exp_last_unbraced:Nf #3 { \__int_to_Letter:n {#1} } }
9210   {
9211     \exp_args:Nf \__int_to_Base:nnnN
9212     { \__int_to_Letter:n { \int_mod:nn {#1} {#2} } }
9213     {#1}
9214     {#2}
9215     #3
9216   }
9217 }
9218 \cs_new:Npn \__int_to_Base:nnnN #1#2#3#4
9219 {
9220   \exp_args:Nf \__int_to_Base:nnN
9221   { \int_div_truncate:nn {#2} {#3} }
9222   {#3}
9223   #4
9224   #1
9225 }

```

Convert to a letter only if necessary, otherwise simply return the value unchanged. It would be cleaner to use `\int_case:nn`, but in our case, the cases are contiguous, so it is forty times faster to use the `\if_case:w` primitive. The first `\exp_after:wN` expands the conditional, jumping to the correct case, the second one expands after the resulting character to close the conditional. Since `#1` might be an expression, and not directly a single digit, we need to evaluate it properly, and expand the trailing `\fi:`.

```

9226 \cs_new:Npn \__int_to_letter:n #1
9227 {
9228   \exp_after:wN \exp_after:wN
9229   \if_case:w \__int_eval:w #1 - 10 \__int_eval_end:
9230     a
9231   \or: b
9232   \or: c
9233   \or: d
9234   \or: e
9235   \or: f
9236   \or: g
9237   \or: h
9238   \or: i
9239   \or: j
9240   \or: k
9241   \or: l
9242   \or: m
9243   \or: n
9244   \or: o
9245   \or: p

```

```

9246     \or: q
9247     \or: r
9248     \or: s
9249     \or: t
9250     \or: u
9251     \or: v
9252     \or: w
9253     \or: x
9254     \or: y
9255     \or: z
9256     \else: \int_value:w \_int_eval:w #1 \exp_after:wN \_int_eval_end:
9257     \fi:
9258   }
9259 \cs_new:Npn \_int_to_Letter:n #1
9260 {
9261   \exp_after:wN \exp_after:wN
9262   \if_case:w \_int_eval:w #1 - 10 \_int_eval_end:
9263     A
9264     \or: B
9265     \or: C
9266     \or: D
9267     \or: E
9268     \or: F
9269     \or: G
9270     \or: H
9271     \or: I
9272     \or: J
9273     \or: K
9274     \or: L
9275     \or: M
9276     \or: N
9277     \or: O
9278     \or: P
9279     \or: Q
9280     \or: R
9281     \or: S
9282     \or: T
9283     \or: U
9284     \or: V
9285     \or: W
9286     \or: X
9287     \or: Y
9288     \or: Z
9289     \else: \int_value:w \_int_eval:w #1 \exp_after:wN \_int_eval_end:
9290     \fi:
9291   }

```

(End definition for `\int_to_base:nn` and others. These functions are documented on page 94.)

```

\int_to_bin:n Wrappers around the generic function.
\int_to_hex:n 9292 \cs_new:Npn \int_to_bin:n #1
\int_to_Hex:n 9293 { \int_to_base:nn {#1} { 2 } }
\int_to_oct:n 9294 \cs_new:Npn \int_to_hex:n #1
9295 { \int_to_base:nn {#1} { 16 } }

```

```

9296 \cs_new:Npn \int_to_Hex:n #1
9297 { \int_to_Base:nn {#1} { 16 } }
9298 \cs_new:Npn \int_to_oct:n #1
9299 { \int_to_base:nn {#1} { 8 } }

```

(End definition for `\int_to_bin:n` and others. These functions are documented on page 94.)

```

\int_to_roman:n
\int_to_Roman:n
__int_to_roman:N
__int_to_roman:N
__int_to_roman_i:w
__int_to_roman_v:w
__int_to_roman_x:w
__int_to_roman_l:w
__int_to_roman_c:w
__int_to_roman_d:w
__int_to_roman_m:w
__int_to_roman_Q:w
__int_to_Roman_i:w
__int_to_Roman_v:w
__int_to_Roman_x:w
__int_to_Roman_l:w
__int_to_Roman_c:w
__int_to_Roman_d:w
__int_to_Roman_m:w
__int_to_Roman_Q:w
9300 \cs_new:Npn \int_to_roman:n #1
9301 {
9302   \exp_after:wN __int_to_roman:N
9303   \int_to_roman:w \int_eval:n {#1} Q
9304 }
9305 \cs_new:Npn __int_to_roman:N #1
9306 {
9307   \use:c { __int_to_roman_ #1 :w }
9308   __int_to_roman:N
9309 }
9310 \cs_new:Npn \int_to_Roman:n #1
9311 {
9312   \exp_after:wN __int_to_Roman_aux:N
9313   \int_to_roman:w \int_eval:n {#1} Q
9314 }
9315 \cs_new:Npn __int_to_Roman_aux:N #1
9316 {
9317   \use:c { __int_to_Roman_ #1 :w }
9318   __int_to_Roman_aux:N
9319 }
9320 \cs_new:Npn __int_to_roman_i:w { i }
9321 \cs_new:Npn __int_to_roman_v:w { v }
9322 \cs_new:Npn __int_to_roman_x:w { x }
9323 \cs_new:Npn __int_to_roman_l:w { l }
9324 \cs_new:Npn __int_to_roman_c:w { c }
9325 \cs_new:Npn __int_to_roman_d:w { d }
9326 \cs_new:Npn __int_to_roman_m:w { m }
9327 \cs_new:Npn __int_to_roman_Q:w #1 { }
9328 \cs_new:Npn __int_to_Roman_i:w { I }
9329 \cs_new:Npn __int_to_Roman_v:w { V }
9330 \cs_new:Npn __int_to_Roman_x:w { X }
9331 \cs_new:Npn __int_to_Roman_l:w { L }
9332 \cs_new:Npn __int_to_Roman_c:w { C }
9333 \cs_new:Npn __int_to_Roman_d:w { D }
9334 \cs_new:Npn __int_to_Roman_m:w { M }
9335 \cs_new:Npn __int_to_Roman_Q:w #1 { }

```

(End definition for `\int_to_roman:n` and others. These functions are documented on page 94.)

12.9 Converting from other formats to integers

`__int_pass_signs:wn` Called as `__int_pass_signs:wn <signs and digits> \q_stop {<code>}`, this function leaves in the input stream any sign it finds, then inserts the `<code>` before the first non-

sign token (and removes `\q_stop`). More precisely, it deletes any + and passes any - to the input stream, hence should be called in an integer expression.

```

9336 \cs_new:Npn \__int_pass_signs:wn #1
9337 {
9338   \if:w + \if:w - \exp_not:N #1 + \fi: \exp_not:N #1
9339   \exp_after:wN \__int_pass_signs:wn
9340   \else:
9341     \exp_after:wN \__int_pass_signs_end:wn
9342     \exp_after:wN #1
9343   \fi:
9344 }
9345 \cs_new:Npn \__int_pass_signs_end:wn #1 \q_stop #2 { #2 #1 }

```

(End definition for `__int_pass_signs:wn` and `__int_pass_signs_end:wn`.)

`\int_from_alph:n` First take care of signs then loop through the input using the recursion quarks. The `__int_from_alph:nN` auxiliary collects in its first argument the value obtained so far, and the auxiliary `__int_from_alph:N` converts one letter to an expression which evaluates to the correct number.

```

9346 \cs_new:Npn \int_from_alph:n #1
9347 {
9348   \int_eval:n
9349   {
9350     \exp_after:wN \__int_pass_signs:wn \tl_to_str:n {#1}
9351     \q_stop { \__int_from_alph:nN { 0 } }
9352     \q_recursion_tail \q_recursion_stop
9353   }
9354 }
9355 \cs_new:Npn \__int_from_alph:nN #1#2
9356 {
9357   \quark_if_recursion_tail_stop_do:Nn #2 {#1}
9358   \exp_args:Nf \__int_from_alph:nN
9359   { \int_eval:n { #1 * 26 + \__int_from_alph:N #2 } }
9360 }
9361 \cs_new:Npn \__int_from_alph:N #1
9362 { '#1 - \int_compare:nNnTF { '#1 } < { 91 } { 64 } { 96 } }

```

(End definition for `\int_from_alph:n`, `__int_from_alph:nN`, and `__int_from_alph:N`. This function is documented on page 94.)

`\int_from_base:nn` Leave the signs into the integer expression, then loop through characters, collecting the value found so far in the first argument of `__int_from_base:nnN`. To convert a single character, `__int_from_base:N` checks first for digits, then distinguishes lower from upper case letters, turning them into the appropriate number. Note that this auxiliary does not use `\int_eval:n`, hence is not safe for general use.

```

9363 \cs_new:Npn \int_from_base:nn #1#2
9364 {
9365   \int_eval:n
9366   {
9367     \exp_after:wN \__int_pass_signs:wn \tl_to_str:n {#1}
9368     \q_stop { \__int_from_base:nnN { 0 } {#2} }
9369     \q_recursion_tail \q_recursion_stop
9370   }
9371 }

```

```

9372 \cs_new:Npn \__int_from_base:nnN #1#2#3
9373 {
9374   \quark_if_recursion_tail_stop_do:Nn #3 {#1}
9375   \exp_args:Nf \__int_from_base:nnN
9376     { \int_eval:n { #1 * #2 + \__int_from_base:N #3 } }
9377     {#2}
9378 }
9379 \cs_new:Npn \__int_from_base:N #1
9380 {
9381   \int_compare:nNnTF { '#1 } < { 58 }
9382     {#1}
9383     { '#1 - \int_compare:nNnTF { '#1 } < { 91 } { 55 } { 87 } }
9384 }

```

(End definition for `\int_from_base:nn`, `__int_from_base:nnN`, and `__int_from_base:N`. This function is documented on page 95.)

`\int_from_bin:n` Wrappers around the generic function.

```

\int_from_hex:n
\int_from_oct:n
9385 \cs_new:Npn \int_from_bin:n #1
9386 { \int_from_base:nn {#1} { 2 } }
9387 \cs_new:Npn \int_from_hex:n #1
9388 { \int_from_base:nn {#1} { 16 } }
9389 \cs_new:Npn \int_from_oct:n #1
9390 { \int_from_base:nn {#1} { 8 } }

```

(End definition for `\int_from_bin:n`, `\int_from_hex:n`, and `\int_from_oct:n`. These functions are documented on page 95.)

`\c_int_from_roman_i_int` Constants used to convert from Roman numerals to integers.

```

\c_int_from_roman_v_int
\c_int_from_roman_x_int
\c_int_from_roman_l_int
\c_int_from_roman_c_int
\c_int_from_roman_d_int
\c_int_from_roman_m_int
\c_int_from_roman_I_int
\c_int_from_roman_V_int
\c_int_from_roman_X_int
\c_int_from_roman_L_int
\c_int_from_roman_C_int
\c_int_from_roman_D_int
\c_int_from_roman_M_int
9391 \int_const:cn { \c_int_from_roman_i_int } { 1 }
9392 \int_const:cn { \c_int_from_roman_v_int } { 5 }
9393 \int_const:cn { \c_int_from_roman_x_int } { 10 }
9394 \int_const:cn { \c_int_from_roman_l_int } { 50 }
9395 \int_const:cn { \c_int_from_roman_c_int } { 100 }
9396 \int_const:cn { \c_int_from_roman_d_int } { 500 }
9397 \int_const:cn { \c_int_from_roman_m_int } { 1000 }
9398 \int_const:cn { \c_int_from_roman_I_int } { 1 }
9399 \int_const:cn { \c_int_from_roman_V_int } { 5 }
9400 \int_const:cn { \c_int_from_roman_X_int } { 10 }
9401 \int_const:cn { \c_int_from_roman_L_int } { 50 }
9402 \int_const:cn { \c_int_from_roman_C_int } { 100 }
9403 \int_const:cn { \c_int_from_roman_D_int } { 500 }
9404 \int_const:cn { \c_int_from_roman_M_int } { 1000 }

```

(End definition for `\c_int_from_roman_i_int` and others.)

`\int_from_roman:n` The method here is to iterate through the input, finding the appropriate value for each letter and building up a sum. This is then evaluated by \TeX . If any unknown letter is found, skip to the closing parenthesis and insert `*0-1` afterwards, to replace the value by `-1`.

```

\__int_from_roman:NN
\__int_from_roman_error:w

```

```

9405 \cs_new:Npn \int_from_roman:n #1
9406 {
9407   \int_eval:n
9408     {
9409     (

```

```

9410         0
9411         \exp_after:wN \_int_from_roman:NN \tl_to_str:n {#1}
9412         \q_recursion_tail \q_recursion_tail \q_recursion_stop
9413     )
9414 }
9415 }
9416 \cs_new:Npn \_int_from_roman:NN #1#2
9417 {
9418     \quark_if_recursion_tail_stop:N #1
9419     \int_if_exist:cF { c__int_from_roman_ #1 _int }
9420     { \_int_from_roman_error:w }
9421     \quark_if_recursion_tail_stop_do:Nn #2
9422     { + \use:c { c__int_from_roman_ #1 _int } }
9423     \int_if_exist:cF { c__int_from_roman_ #2 _int }
9424     { \_int_from_roman_error:w }
9425     \int_compare:nNnTF
9426     { \use:c { c__int_from_roman_ #1 _int } }
9427     <
9428     { \use:c { c__int_from_roman_ #2 _int } }
9429     {
9430         + \use:c { c__int_from_roman_ #2 _int }
9431         - \use:c { c__int_from_roman_ #1 _int }
9432         \_int_from_roman:NN
9433     }
9434     {
9435         + \use:c { c__int_from_roman_ #1 _int }
9436         \_int_from_roman:NN #2
9437     }
9438 }
9439 \cs_new:Npn \_int_from_roman_error:w #1 \q_recursion_stop #2
9440 { #2 * 0 - 1 }

```

(End definition for `\int_from_roman:n`, `_int_from_roman:NN`, and `_int_from_roman_error:w`. This function is documented on page 95.)

12.10 Viewing integer

`\int_show:N` Diagnostics.
`\int_show:c` 9441 `\cs_new_eq:NN \int_show:N _kernel_register_show:N`
`_int_show:nN` 9442 `\cs_generate_variant:Nn \int_show:N { c }`

(End definition for `\int_show:N` and `_int_show:nN`. This function is documented on page 96.)

`\int_show:n` We don't use the TeX primitive `\showthe` to show integer expressions: this gives a more unified output.

```

9443 \cs_new_protected:Npn \int_show:n
9444 { \msg_show_eval:Nn \int_eval:n }

```

(End definition for `\int_show:n`. This function is documented on page 96.)

`\int_log:N` Diagnostics.
`\int_log:c` 9445 `\cs_new_eq:NN \int_log:N _kernel_register_log:N`
9446 `\cs_generate_variant:Nn \int_log:N { c }`

(End definition for `\int_log:N`. This function is documented on page 96.)

\int_log:n Similar to \int_show:n.

```
9447 \cs_new_protected:Npn \int_log:n
9448 { \msg_log_eval:Nn \int_eval:n }
```

(End definition for \int_log:n. This function is documented on page 96.)

12.11 Random integers

\int_rand:nn Defined in l3fp-random.

(End definition for \int_rand:nn. This function is documented on page 95.)

12.12 Constant integers

\c_zero_int The zero is defined in l3basics.

\c_one_int

```
9449 \int_const:Nn \c_one_int { 1 }
```

(End definition for \c_zero_int and \c_one_int. These variables are documented on page 96.)

\c_max_int The largest number allowed is $2^{31} - 1$

```
9450 \int_const:Nn \c_max_int { 2 147 483 647 }
```

(End definition for \c_max_int. This variable is documented on page 96.)

\c_max_char_int The largest character code is 1114111 (hexadecimal 10FFFF) in XeTeX and LuaTeX and 255 in other engines. In many places pTeX and upTeX support larger character codes but for instance the values of \lccode are restricted to [0, 255].

```
9451 \int_const:Nn \c_max_char_int
9452 {
9453   \if_int_odd:w 0
9454     \cs_if_exist:NT \tex luatexversion:D { 1 }
9455     \cs_if_exist:NT \tex XeTeXversion:D { 1 } ~
9456     "10FFFF
9457   \else:
9458     "FF
9459   \fi:
9460 }
```

(End definition for \c_max_char_int. This variable is documented on page 96.)

12.13 Scratch integers

\l_tmpa_int We provide two local and two global scratch counters, maybe we need more or less.

\l_tmpb_int

```
9461 \int_new:N \l_tmpa_int
```


\l_tmpb_int

```
9462 \int_new:N \l_tmpb_int
```


\g_tmpa_int

```
9463 \int_new:N \g_tmpa_int
```


\g_tmpb_int

```
9464 \int_new:N \g_tmpb_int
```

(End definition for \l_tmpa_int and others. These variables are documented on page 96.)

```
9465 </initex | package>
```


13 l3flag implementation

9466 $\langle *initex | package \rangle$

9467 $\langle @@=flag \rangle$

The following test files are used for this code: m3flag001.

13.1 Non-expandable flag commands

The height h of a flag (initially zero) is stored by setting control sequences of the form $\backslash flag \langle name \rangle \langle integer \rangle$ to $\backslash relax$ for $0 \leq \langle integer \rangle < h$. When a flag is raised, a “trap” function $\backslash flag \langle name \rangle$ is called. The existence of this function is also used to test for the existence of a flag.

$\backslash flag_new:n$ For each flag, we define a “trap” function, which by default simply increases the flag by 1 by letting the appropriate control sequence to $\backslash relax$. This can be done expandably!

```
9468 \cs_new_protected:Npn \flag_new:n #1
9469 {
9470   \cs_new:cpn { flag~#1 } ##1 ;
9471   { \exp_after:wN \use_none:n \cs:w flag~#1~##1 \cs_end: }
9472 }
```

(End definition for $\backslash flag_new:n$. This function is documented on page 99.)

$\backslash flag_clear:n$ Undefine control sequences, starting from the 0 flag, upwards, until reaching an undefined control sequence. We don’t use $\backslash cs_undefine:c$ because that would act globally. When the option `check-declarations` is used, check for the function defined by $\backslash flag_new:n$.

$\backslash _flag_clear:wn$

```
9473 \__kernel_patch:nnNNpn
9474 { \exp_args:Nc \__kernel_chk_var_exist:N { flag~#1 } } { }
9475 \cs_new_protected:Npn \flag_clear:n #1 { \_flag_clear:wn 0 ; {#1} }
9476 \cs_new_protected:Npn \_flag_clear:wn #1 ; #2
9477 {
9478   \if_cs_exist:w flag~#2~#1 \cs_end:
9479   \cs_set_eq:cN { flag~#2~#1 } \tex_undefined:D
9480   \exp_after:wN \_flag_clear:wn
9481   \int_value:w \int_eval:w 1 + #1
9482   \else:
9483     \use_i:nnn
9484   \fi:
9485   ; {#2}
9486 }
```

(End definition for $\backslash flag_clear:n$ and $\backslash _flag_clear:wn$. This function is documented on page 99.)

$\backslash flag_clear_new:n$ As for other datatypes, clear the $\langle flag \rangle$ or create a new one, as appropriate.

```
9487 \cs_new_protected:Npn \flag_clear_new:n #1
9488 { \flag_if_exist:nTF {#1} { \flag_clear:n } { \flag_new:n } {#1} }
```

(End definition for $\backslash flag_clear_new:n$. This function is documented on page 99.)

$\backslash flag_show:n$ Show the height (terminal or log file) using appropriate `l3msg` auxiliaries.

$\backslash flag_log:n$

$\backslash _flag_show:Nn$

```
9489 \cs_new_protected:Npn \flag_show:n { \_flag_show:Nn \tl_show:n }
9490 \cs_new_protected:Npn \flag_log:n { \_flag_show:Nn \tl_log:n }
9491 \cs_new_protected:Npn \_flag_show:Nn #1#2
9492 {
```

```

9493 \exp_args:Nc \__kernel_chk_defined:NT { flag~#2 }
9494 {
9495   \exp_args:Nx #1
9496   { \tl_to_str:n { flag~#2~height } = \flag_height:n {#2} }
9497 }
9498 }

```

(End definition for `\flag_show:n`, `\flag_log:n`, and `__flag_show:Nn`. These functions are documented on page 99.)

13.2 Expandable flag commands

`__flag_chk_exist:n` Analogue of `__kernel_chk_var_exist:N` for flags, and with an expandable error. We need to add checks by hand because flags are not implemented in terms of other variables. Not all functions need to be patched since some are defined in terms of others.

```

9499 \*package
9500 \__kernel_if_debug:TF
9501 {
9502   \cs_new:Npn \__flag_chk_exist:n #1
9503   {
9504     \flag_if_exist:nF {#1}
9505     {
9506       \__kernel_msg_expandable_error:nnn
9507       { kernel } { bad-variable } { flag~#1~ }
9508     }
9509   }
9510 }
9511 { }
9512 \*package

```

(End definition for `__flag_chk_exist:n`.)

`\flag_if_exist_p:n` A flag exist if the corresponding trap `\flag <flag name>:n` is defined.

```

\flag_if_exist:nTF
9513 \prg_new_conditional:Npnn \flag_if_exist:n #1 { p , T , F , TF }
9514 {
9515   \cs_if_exist:cTF { flag~#1 }
9516   { \prg_return_true: } { \prg_return_false: }
9517 }

```

(End definition for `\flag_if_exist:nTF`. This function is documented on page 100.)

`\flag_if_raised_p:n` Test if the flag has a non-zero height, by checking the 0 control sequence.

```

\flag_if_raised:nTF
9518 \__kernel_patch_conditional:nNNpnn { \__flag_chk_exist:n {#1} }
9519 \prg_new_conditional:Npnn \flag_if_raised:n #1 { p , T , F , TF }
9520 {
9521   \if_cs_exist:w flag~#1~0 \cs_end:
9522   \prg_return_true:
9523   \else:
9524   \prg_return_false:
9525   \fi:
9526 }

```

(End definition for `\flag_if_raised:nTF`. This function is documented on page 100.)

`\flag_height:n` Extract the value of the flag by going through all of the control sequences starting from 0.

```

9527 \__flag_height_loop:wn
9528 \__flag_height_end:wn
9529 \__kernel_patch:nnNNpn { \__flag_chk_exist:n {#1} } { }
9530 \cs_new:Npn \flag_height:n #1 { \__flag_height_loop:wn 0; {#1} }
9531 {
9532   \if_cs_exist:w flag~#2~#1 \cs_end:
9533   \exp_after:wN \__flag_height_loop:wn \int_value:w \int_eval:w 1 +
9534   \else:
9535   \exp_after:wN \__flag_height_end:wn
9536   \fi:
9537   #1 ; {#2}
9538 }
9539 \cs_new:Npn \__flag_height_end:wn #1 ; #2 {#1}

```

(End definition for `\flag_height:n`, `__flag_height_loop:wn`, and `__flag_height_end:wn`. This function is documented on page 100.)

`\flag_raise:n` Simply apply the trap to the height, after expanding the latter.

```

9539 \cs_new:Npn \flag_raise:n #1
9540 {
9541   \cs:w flag~#1 \exp_after:wN \cs_end:
9542   \int_value:w \flag_height:n {#1} ;
9543 }

```

(End definition for `\flag_raise:n`. This function is documented on page 100.)

```

9544 </initex | package>

```

14 l3prg implementation

The following test files are used for this code: `m3prg001.lvt`, `m3prg002.lvt`, `m3prg003.lvt`.

```

9545 <*initex | package>

```

14.1 Primitive conditionals

`\if_bool:N` Those two primitive TeX conditionals are synonyms.
`\if_predicate:w`

```

9546 \cs_new_eq:NN \if_bool:N \tex_ifodd:D
9547 \cs_new_eq:NN \if_predicate:w \tex_ifodd:D

```

(End definition for `\if_bool:N` and `\if_predicate:w`. These functions are documented on page 109.)

14.2 Defining a set of conditional functions

`\prg_set_conditional:Npnn` These are all defined in `l3basics`, as they are needed “early”. This is just a reminder!

`\prg_new_conditional:Npnn` (End definition for `\prg_set_conditional:Npnn` and others. These functions are documented on page 101.)
`\prg_set_protected_conditional:Npnn`
`\prg_new_protected_conditional:Npnn`

`\prg_set_conditional:Nnn`

`\prg_new_conditional:Nnn`

`\prg_set_protected_conditional:Nnn`

`\prg_new_protected_conditional:Nnn`

`\prg_set_eq_conditional:NNN`

`\prg_new_eq_conditional:NNN`

`\prg_return_true:`

`\prg_return_false:`

14.3 The boolean data type

9548 <@@=bool>

\bool_new:N Boolean variables have to be initiated when they are created. Other than that there is not much to say here.

\bool_new:c

9549 \cs_new_protected:Npn \bool_new:N #1 { \cs_new_eq:NN #1 \c_false_bool }
9550 \cs_generate_variant:Nn \bool_new:N { c }

(End definition for \bool_new:N. This function is documented on page 103.)

\bool_set_true:N Setting is already pretty easy. When `check-declarations` is active, the definitions are patched to make sure the boolean exists. This is needed because booleans are not based on token lists nor on T_EX registers.

\bool_set_true:c

\bool_gset_true:N

\bool_gset_true:c

\bool_set_false:N

\bool_set_false:c

\bool_gset_false:N

\bool_gset_false:c

9551 __kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }
9552 \cs_new_protected:Npn \bool_set_true:N #1
9553 { \cs_set_eq:NN #1 \c_true_bool }
9554 __kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }
9555 \cs_new_protected:Npn \bool_set_false:N #1
9556 { \cs_set_eq:NN #1 \c_false_bool }
9557 __kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }
9558 \cs_new_protected:Npn \bool_gset_true:N #1
9559 { \cs_gset_eq:NN #1 \c_true_bool }
9560 __kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }
9561 \cs_new_protected:Npn \bool_gset_false:N #1
9562 { \cs_gset_eq:NN #1 \c_false_bool }
9563 \cs_generate_variant:Nn \bool_set_true:N { c }
9564 \cs_generate_variant:Nn \bool_set_false:N { c }
9565 \cs_generate_variant:Nn \bool_gset_true:N { c }
9566 \cs_generate_variant:Nn \bool_gset_false:N { c }

(End definition for \bool_set_true:N and others. These functions are documented on page 104.)

\bool_set_eq:NN The usual copy code. While it would be cleaner semantically to copy the `\cs_set_eq:NN` family of functions, we copy `\tl_set_eq:NN` because that has the correct checking code.

\bool_set_eq:cN

\bool_set_eq:Nc

\bool_set_eq:cc

\bool_gset_eq:NN

\bool_gset_eq:cN

\bool_gset_eq:Nc

\bool_gset_eq:cc

9567 \cs_new_eq:NN \bool_set_eq:NN \tl_set_eq:NN
9568 \cs_new_eq:NN \bool_gset_eq:NN \tl_gset_eq:NN
9569 \cs_generate_variant:Nn \bool_set_eq:NN { Nc, cN, cc }
9570 \cs_generate_variant:Nn \bool_gset_eq:NN { Nc, cN, cc }

(End definition for \bool_set_eq:NN and \bool_gset_eq:NN. These functions are documented on page 104.)

\bool_set:Nn This function evaluates a boolean expression and assigns the first argument the meaning `\c_true_bool` or `\c_false_bool`. Again, we include some checking code. It is important to evaluate the expression before applying the `\chardef` primitive, because that primitive sets the left-hand side to `\scan_stop:` before looking for the right-hand side.

\bool_set:cn

\bool_gset:Nn

\bool_gset:cn

9571 __kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }
9572 \cs_new_protected:Npn \bool_set:Nn #1#2
9573 {
9574 \exp_last_unbraced:NNNf
9575 \tex_chardef:D #1 = { \bool_if_p:n {#2} }
9576 }
9577 __kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }
9578 \cs_new_protected:Npn \bool_gset:Nn #1#2

```

9579 {
9580   \exp_last_unbraced:NNNNf
9581   \tex_global:D \tex_chardef:D #1 = { \bool_if_p:n {#2} }
9582 }
9583 \cs_generate_variant:Nn \bool_set:Nn { c }
9584 \cs_generate_variant:Nn \bool_gset:Nn { c }

```

(End definition for `\bool_set:Nn` and `\bool_gset:Nn`. These functions are documented on page 104.)

`\bool_if_p:N` Straight forward here. We could optimize here if we wanted to as the boolean can just be input directly.

```

\bool_if_p:c
\bool_if:N $\overline{TF}$ 
\bool_if:c $\overline{TF}$ 
9585 \prg_new_conditional:Npnn \bool_if:N #1 { p , T , F , TF }
9586 {
9587   \if_bool:N #1
9588     \prg_return_true:
9589   \else:
9590     \prg_return_false:
9591   \fi:
9592 }
9593 \prg_generate_conditional_variant:Nnn \bool_if:N { c } { p , T , F , TF }

```

(End definition for `\bool_if:N \overline{TF}` . This function is documented on page 104.)

`\bool_show:n` Show the truth value of the boolean, as true or false.

```

\bool_log:n
\__bool_to_str:n
9594 \cs_new_protected:Npn \bool_show:n
9595 { \msg_show_eval:Nn \__bool_to_str:n }
9596 \cs_new_protected:Npn \bool_log:n
9597 { \msg_log_eval:Nn \__bool_to_str:n }
9598 \cs_new:Npn \__bool_to_str:n #1
9599 { \bool_if:nTF {#1} { true } { false } }

```

(End definition for `\bool_show:n`, `\bool_log:n`, and `__bool_to_str:n`. These functions are documented on page 104.)

`\bool_show:N` Show the truth value of the boolean, as true or false.

```

\bool_show:c
\bool_log:N
\bool_log:c
\__bool_show:NN
9600 \cs_new_protected:Npn \bool_show:N { \__bool_show:NN \tl_show:n }
9601 \cs_generate_variant:Nn \bool_show:N { c }
9602 \cs_new_protected:Npn \bool_log:N { \__bool_show:NN \tl_log:n }
9603 \cs_generate_variant:Nn \bool_log:N { c }
9604 \cs_new_protected:Npn \__bool_show:NN #1#2
9605 {
9606   \__kernel_chk_defined:NT #2
9607   { \exp_args:Nx #1 { \token_to_str:N #2 = \__bool_to_str:n {#2} } }
9608 }

```

(End definition for `\bool_show:N`, `\bool_log:N`, and `__bool_show:NN`. These functions are documented on page 104.)

`\l_tmpa_bool` A few booleans just if you need them.

```

\l_tmpb_bool
\g_tmpa_bool
\g_tmpb_bool
9609 \bool_new:N \l_tmpa_bool
9610 \bool_new:N \l_tmpb_bool
9611 \bool_new:N \g_tmpa_bool
9612 \bool_new:N \g_tmpb_bool

```

(End definition for `\l_tmpa_bool` and others. These variables are documented on page 105.)

```

\bool_if_exist_p:N Copies of the cs functions defined in l3basics.
\bool_if_exist_p:c 9613 \prg_new_eq_conditional:NNn \bool_if_exist:N \cs_if_exist:N
\bool_if_exist:NTF 9614 { TF , T , F , p }
\bool_if_exist:cTF 9615 \prg_new_eq_conditional:NNn \bool_if_exist:c \cs_if_exist:c
9616 { TF , T , F , p }

```

(End definition for \bool_if_exist:N~~TF~~. This function is documented on page 105.)

14.4 Boolean expressions

\bool_if_p:n Evaluating the truth value of a list of predicates is done using an input syntax somewhat similar to the one found in other programming languages with (and) for grouping, ! for logical “Not”, && for logical “And” and || for logical “Or”. However, they perform eager evaluation. We shall use the terms Not, And, Or, Open and Close for these operations.

Any expression is terminated by a Close operation. Evaluation happens from left to right in the following manner using a GetNext function:

- If an Open is seen, start evaluating a new expression using the Eval function and call GetNext again.
- If a Not is seen, remove the ! and call a GetNext function with the logic reversed.
- If none of the above, reinsert the token found (this is supposed to be a predicate function) in front of an Eval function, which evaluates it to the boolean value *<true>* or *<false>*.

The Eval function then contains a post-processing operation which grabs the instruction following the predicate. This is either And, Or or Close. In each case the truth value is used to determine where to go next. The following situations can arise:

*<true>***And** Current truth value is true, logical And seen, continue with GetNext to examine truth value of next boolean (sub-)expression.

*<false>***And** Current truth value is false, logical And seen, stop using the values of predicates within this sub-expression until the next Close. Then return *<false>*.

*<true>***Or** Current truth value is true, logical Or seen, stop using the values of predicates within this sub-expression until the nearest Close. Then return *<true>*.

*<false>***Or** Current truth value is false, logical Or seen, continue with GetNext to examine truth value of next boolean (sub-)expression.

*<true>***Close** Current truth value is true, Close seen, return *<true>*.

*<false>***Close** Current truth value is false, Close seen, return *<false>*.

```

9617 \prg_new_conditional:Npnn \bool_if:n #1 { T , F , TF }
9618 {
9619   \if_predicate:w \bool_if_p:n {#1}
9620   \prg_return_true:
9621   \else:
9622     \prg_return_false:
9623   \fi:
9624 }

```

(End definition for \bool_if:n~~TF~~. This function is documented on page 106.)

`\bool_if_p:n` To speed up the case of a single predicate, `f-expand` and check whether the result is one token (possibly surrounded by spaces), which must be `\c_true_bool` or `\c_false_bool`. We use a version of `\tl_if_single:nTF` optimized for speed since we know that an empty `#1` is an error. The auxiliary `__bool_if_p_aux:w` removes the trailing parenthesis and gets rid of any space. For the general case, first issue a `\group_align_safe_begin:` as we are using `&&` as syntax shorthand for the And operation and we need to hide it for `TeX`. This group is closed after `__bool_get_next:NN` returns `\c_true_bool` or `\c_false_bool`. That function requires the trailing parenthesis to know where the expression ends.

```

9625 \cs_new:Npn \bool_if_p:n { \exp_args:Nf \__bool_if_p:n }
9626 \cs_new:Npn \__bool_if_p:n #1
9627 {
9628   \tl_if_empty:oT { \use_none:nn #1 . } { \__bool_if_p_aux:w }
9629   \group_align_safe_begin:
9630   \exp_after:wN
9631   \group_align_safe_end:
9632   \exp:w \exp_end_continue_f:w % (
9633   \__bool_get_next:NN \use_i:nnnn #1 )
9634 }
9635 \cs_new:Npn \__bool_if_p_aux:w #1 \use_i:nnnn #2#3 {#2}

```

(End definition for `\bool_if_p:n`, `__bool_if_p:n`, and `__bool_if_p_aux:w`. This function is documented on page 106.)

`__bool_get_next:NN` The GetNext operation. Its first argument is `\use_i:nnnn`, `\use_ii:nnnn`, `\use_iii:nnnn`, or `\use_iv:nnnn` (we call these “states”). In the first state, this function eventually expand to the truth value `\c_true_bool` or `\c_false_bool` of the expression which follows until the next unmatched closing parenthesis. For instance “`__bool_get_next:NN \use_i:nnnn \c_true_bool && \c_true_bool)`” (including the closing parenthesis) expands to `\c_true_bool`. In the second state (after a `!`) the logic is reversed. We call these two states “normal” and the next two “skipping”. In the third state (after `\c_true_bool||`) it always returns `\c_true_bool`. In the fourth state (after `\c_false_bool&&`) it always returns `\c_false_bool` and also stops when encountering `||`, not only parentheses. This code itself is a switch: if what follows is neither `!` nor `(`, we assume it is a predicate.

```

9636 \cs_new:Npn \__bool_get_next:NN #1#2
9637 {
9638   \use:c
9639   {
9640     __bool_
9641     \if_meaning:w !#2 ! \else: \if_meaning:w (#2 ( \else: p \fi: \fi:
9642     :Nw
9643   }
9644   #1 #2
9645 }

```

(End definition for `__bool_get_next:NN`.)

`__bool_!:Nw` The Not operation reverses the logic: it discards the `!` token and calls the GetNext operation with the appropriate first argument. Namely the first and second states are interchanged, but after `\c_true_bool||` or `\c_false_bool&&` the `!` is ignored.

```

9646 \cs_new:cpn { __bool_!:Nw } #1#2
9647 {

```

```

9648     \exp_after:wN \_bool_get_next:NN
9649     #1 \use_ii:nnnn \use_i:nnnn \use_iii:nnnn \use_iv:nnnn
9650 }

```

(End definition for _bool_!:Nw.)

bool(:Nw The Open operation starts a sub-expression after discarding the open parenthesis. This is done by calling GetNext (which eventually discards the corresponding closing parenthesis), with a post-processing step which looks for And, Or or Close after the group.

```

9651 \cs_new:cpn { \_bool_(:Nw } #1#2
9652 {
9653     \exp_after:wN \_bool_choose:NNN \exp_after:wN #1
9654     \int_value:w \_bool_get_next:NN \use_i:nnnn
9655 }

```

(End definition for _bool_(:Nw.)

_bool_p:Nw If what follows GetNext is neither ! nor (, evaluate the predicate using the primitive \int_value:w. The canonical true and false values have numerical values 1 and 0 respectively. Look for And, Or or Close afterwards.

```

9656 \cs_new:cpn { \_bool_p:Nw } #1
9657 { \exp_after:wN \_bool_choose:NNN \exp_after:wN #1 \int_value:w }

```

(End definition for _bool_p:Nw.)

_bool_choose:NNN The arguments are #1: a function such as \use_i:nnnn, #2: 0 or 1 encoding the current truth value, #3: the next operation, And, Or or Close. We distinguish three cases according to a combination of #1 and #2. Case 2 is when #1 is \use_iii:nnnn (state 3), namely after \c_true_bool ||. Case 1 is when #1 is \use_i:nnnn and #2 is true or when #1 is \use_ii:nnnn and #2 is false, for instance for !\c_false_bool. Case 0 includes the same with true/false interchanged and the case where #1 is \use_iv:nnnn namely after \c_false_bool &&.

bool|_0: When seeing) the current subexpression is done, leave the appropriate boolean.
bool|_1: When seeing & in case 0 go into state 4, equivalent to having seen \c_false_bool &&.
bool|_2: In case 1, namely when the argument is true and we are in a normal state continue in the normal state 1. In case 2, namely when skipping alternatives in an Or, continue in the same state. When seeing | in case 0, continue in a normal state; in particular stop skipping for \c_false_bool && because that binds more tightly than ||. In the other two cases start skipping for \c_true_bool ||.

```

9658 \cs_new:Npn \_bool_choose:NNN #1#2#3
9659 {
9660     \use:c
9661     {
9662         \_bool_ \token_to_str:N #3 _
9663         #1 #2 { \if_meaning:w 0 #2 1 \else: 0 \fi: } 2 0 :
9664     }
9665 }
9666 \cs_new:cpn { \_bool_)_0: } { \c_false_bool }
9667 \cs_new:cpn { \_bool_)_1: } { \c_true_bool }
9668 \cs_new:cpn { \_bool_)_2: } { \c_true_bool }
9669 \cs_new:cpn { \_bool_&_0: } & { \_bool_get_next:NN \use_iv:nnnn }
9670 \cs_new:cpn { \_bool_&_1: } & { \_bool_get_next:NN \use_i:nnnn }
9671 \cs_new:cpn { \_bool_&_2: } & { \_bool_get_next:NN \use_iii:nnnn }

```



```

9672 \cs_new:cpn { __bool_|_0: } | { \__bool_get_next:NN \use_i:nnnn }
9673 \cs_new:cpn { __bool_|_1: } | { \__bool_get_next:NN \use_iii:nnnn }
9674 \cs_new:cpn { __bool_|_2: } | { \__bool_get_next:NN \use_iii:nnnn }

```

(End definition for __bool_choose:NNN and others.)

\bool_lazy_all_p:n Go through the list of expressions, stopping whenever an expression is **false**. If the end
\bool_lazy_all:nTF is reached without finding any false expression, then the result is **true**.

```

\__bool_lazy_all:n
9675 \cs_new:Npn \bool_lazy_all_p:n #1
9676 { \__bool_lazy_all:n #1 \q_recursion_tail \q_recursion_stop }
9677 \prg_new_conditional:Npnn \bool_lazy_all:n #1 { T , F , TF }
9678 {
9679   \if_predicate:w \bool_lazy_all_p:n {#1}
9680   \prg_return_true:
9681   \else:
9682     \prg_return_false:
9683   \fi:
9684 }
9685 \cs_new:Npn \__bool_lazy_all:n #1
9686 {
9687   \quark_if_recursion_tail_stop_do:nn {#1} { \c_true_bool }
9688   \bool_if:nF {#1}
9689   { \use_i_delimit_by_q_recursion_stop:nw { \c_false_bool } }
9690   \__bool_lazy_all:n
9691 }

```

(End definition for \bool_lazy_all:nTF and __bool_lazy_all:n. This function is documented on page 106.)

\bool_lazy_and_p:nn Only evaluate the second expression if the first is **true**. Note that #2 must be removed
\bool_lazy_and:nnTF as an argument, not just by skipping to the **\else:** branch of the conditional since #2 may contain unbalanced **TeX** conditionals.

```

9692 \prg_new_conditional:Npnn \bool_lazy_and:nn #1#2 { p , T , F , TF }
9693 {
9694   \if_predicate:w
9695     \bool_if:nTF {#1} { \bool_if_p:n {#2} } { \c_false_bool }
9696     \prg_return_true:
9697   \else:
9698     \prg_return_false:
9699   \fi:
9700 }

```

(End definition for \bool_lazy_and:nnTF. This function is documented on page 106.)

\bool_lazy_any_p:n Go through the list of expressions, stopping whenever an expression is **true**. If the end
\bool_lazy_any:nTF is reached without finding any true expression, then the result is **false**.

```

\__bool_lazy_any:n
9701 \cs_new:Npn \bool_lazy_any_p:n #1
9702 { \__bool_lazy_any:n #1 \q_recursion_tail \q_recursion_stop }
9703 \prg_new_conditional:Npnn \bool_lazy_any:n #1 { T , F , TF }
9704 {
9705   \if_predicate:w \bool_lazy_any_p:n {#1}
9706   \prg_return_true:
9707   \else:
9708     \prg_return_false:

```

```

9709     \fi:
9710   }
9711 \cs_new:Npn \__bool_lazy_any:n #1
9712 {
9713   \quark_if_recursion_tail_stop_do:nn {#1} { \c_false_bool }
9714   \bool_if:nT {#1}
9715     { \use_i_delimit_by_q_recursion_stop:nw { \c_true_bool } }
9716   \__bool_lazy_any:n
9717 }

```

(End definition for `\bool_lazy_any:nTF` and `__bool_lazy_any:n`. This function is documented on page 106.)

`\bool_lazy_or_p:nn` Only evaluate the second expression if the first is false.

```

\bool_lazy_or:nnTF
9718 \prg_new_conditional:Npnn \bool_lazy_or:nn #1#2 { p , T , F , TF }
9719 {
9720   \if_predicate:w
9721     \bool_if:nTF {#1} { \c_true_bool } { \bool_if_p:n {#2} }
9722   \prg_return_true:
9723   \else:
9724     \prg_return_false:
9725   \fi:
9726 }

```

(End definition for `\bool_lazy_or:nnTF`. This function is documented on page 107.)

`\bool_not_p:n` The Not variant just reverses the outcome of `\bool_if_p:n`. Can be optimized but this is nice and simple and according to the implementation plan. Not even particularly useful to have it when the infix notation is easier to use.

```

9727 \cs_new:Npn \bool_not_p:n #1 { \bool_if_p:n { ! ( #1 ) } }

```

(End definition for `\bool_not_p:n`. This function is documented on page 107.)

`\bool_xor_p:nn` Exclusive or. If the boolean expressions have same truth value, return `false`, otherwise
`\bool_xor:nnTF` return `true`.

```

9728 \prg_new_conditional:Npnn \bool_xor:nn #1#2 { p , T , F , TF }
9729 {
9730   \bool_if:nT {#1} \reverse_if:N
9731   \if_predicate:w \bool_if_p:n {#2}
9732     \prg_return_true:
9733   \else:
9734     \prg_return_false:
9735   \fi:
9736 }

```

(End definition for `\bool_xor:nnTF`. This function is documented on page 107.)

14.5 Logical loops

`\bool_while_do:Nn` A while loop where the boolean is tested before executing the statement. The “while”
`\bool_while_do:cn` version executes the code as long as the boolean is true; the “until” version executes the
`\bool_until_do:Nn` code as long as the boolean is false.

```

\bool_until_do:cn
9737 \cs_new:Npn \bool_while_do:Nn #1#2
9738 { \bool_if:NT #1 { #2 \bool_while_do:Nn #1 {#2} } }

```

```

9739 \cs_new:Npn \bool_until_do:Nn #1#2
9740 { \bool_if:NF #1 { #2 \bool_until_do:Nn #1 {#2} } }
9741 \cs_generate_variant:Nn \bool_while_do:Nn { c }
9742 \cs_generate_variant:Nn \bool_until_do:Nn { c }

```

(End definition for `\bool_while_do:Nn` and `\bool_until_do:Nn`. These functions are documented on page 107.)

`\bool_do_while:Nn` A do-while loop where the body is performed at least once and the boolean is tested after executing the body. Otherwise identical to the above functions.

```

\bool_do_while:cn
\bool_do_until:Nn
\bool_do_until:cn
9743 \cs_new:Npn \bool_do_while:Nn #1#2
9744 { #2 \bool_if:NT #1 { \bool_do_while:Nn #1 {#2} } }
9745 \cs_new:Npn \bool_do_until:Nn #1#2
9746 { #2 \bool_if:NF #1 { \bool_do_until:Nn #1 {#2} } }
9747 \cs_generate_variant:Nn \bool_do_while:Nn { c }
9748 \cs_generate_variant:Nn \bool_do_until:Nn { c }

```

(End definition for `\bool_do_while:Nn` and `\bool_do_until:Nn`. These functions are documented on page 107.)

`\bool_while_do:nn` Loop functions with the test either before or after the first body expansion.

```

\bool_while_do:nn
\bool_do_while:nn
\bool_until_do:nn
\bool_do_until:nn
9749 \cs_new:Npn \bool_while_do:nn #1#2
9750 {
9751   \bool_if:nT {#1}
9752   {
9753     #2
9754     \bool_while_do:nn {#1} {#2}
9755   }
9756 }
9757 \cs_new:Npn \bool_do_while:nn #1#2
9758 {
9759   #2
9760   \bool_if:nT {#1} { \bool_do_while:nn {#1} {#2} }
9761 }
9762 \cs_new:Npn \bool_until_do:nn #1#2
9763 {
9764   \bool_if:nF {#1}
9765   {
9766     #2
9767     \bool_until_do:nn {#1} {#2}
9768   }
9769 }
9770 \cs_new:Npn \bool_do_until:nn #1#2
9771 {
9772   #2
9773   \bool_if:nF {#1} { \bool_do_until:nn {#1} {#2} }
9774 }

```

(End definition for `\bool_while_do:nn` and others. These functions are documented on page 108.)

14.6 Producing multiple copies

```

9775 <@@=prg>

```

`\prg_replicate:nn` This function uses a cascading csname technique by David Kastrup (who else :-)

```

\__prg_replicate:N
\__prg_replicate_first:N
\__prg_replicate_
\__prg_replicate_0:n
\__prg_replicate_1:n
\__prg_replicate_2:n
\__prg_replicate_3:n
\__prg_replicate_4:n
\__prg_replicate_5:n
\__prg_replicate_6:n

```

The idea is to make the input 25 result in first adding five, and then 20 copies of the code to be replicated. The technique uses cascading csnames which means that we start building several csnames so we end up with a list of functions to be called in reverse order. This is important here (and other places) because it means that we can for instance make the function that inserts five copies of something to also hand down ten to the next function in line. This is exactly what happens here: in the example with 25 then the next function is the one that inserts two copies but it sees the ten copies handed down by the previous function. In order to avoid the last function to insert say, 100 copies of the original argument just to gobble them again we define separate functions to be inserted first. These functions also close the expansion of `\exp:w`, which ensures that `\prg_replicate:nn` only requires two steps of expansion.

This function has one flaw though: Since it constantly passes down ten copies of its previous argument it severely affects the main memory once you start demanding hundreds of thousands of copies. Now I don't think this is a real limitation for any ordinary use, and if necessary, it is possible to write `\prg_replicate:nn {1000} { \prg_replicate:nn {1000} {<code>} }`. An alternative approach is to create a string of m's with `\exp:w` which can be done with just four macros but that method has its own problems since it can exhaust the string pool. Also, it is considerably slower than what we use here so the few extra csnames are well spent I would say.

```

9776 \cs_new:Npn \prg_replicate:nn #1
9777 {
9778   \exp:w
9779   \exp_after:wN \__prg_replicate_first:N
9780   \int_value:w \int_eval:n {#1}
9781   \cs_end:
9782 }
9783 \cs_new:Npn \__prg_replicate:N #1
9784 { \cs:w \__prg_replicate_#1 :n \__prg_replicate:N }
9785 \cs_new:Npn \__prg_replicate_first:N #1
9786 { \cs:w \__prg_replicate_first_#1 :n \__prg_replicate:N }

```

Then comes all the functions that do the hard work of inserting all the copies. The first function takes `:n` as a parameter.

```

9787 \cs_new:Npn \__prg_replicate_ :n #1 { \cs_end: }
9788 \cs_new:cpn { \__prg_replicate_0:n } #1
9789 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} }
9790 \cs_new:cpn { \__prg_replicate_1:n } #1
9791 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1 }
9792 \cs_new:cpn { \__prg_replicate_2:n } #1
9793 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1 }
9794 \cs_new:cpn { \__prg_replicate_3:n } #1
9795 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1 }
9796 \cs_new:cpn { \__prg_replicate_4:n } #1
9797 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1#1 }
9798 \cs_new:cpn { \__prg_replicate_5:n } #1
9799 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1#1#1 }
9800 \cs_new:cpn { \__prg_replicate_6:n } #1
9801 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1#1#1#1 }
9802 \cs_new:cpn { \__prg_replicate_7:n } #1
9803 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1#1#1#1#1 }
9804 \cs_new:cpn { \__prg_replicate_8:n } #1
9805 { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1#1#1#1#1#1 }

```

```

9806 \cs_new:cpn { __prg_replicate_9:n } #1
9807   { \cs_end: {#1#1#1#1#1#1#1#1#1#1} #1#1#1#1#1#1#1#1#1#1 }

```

Users shouldn't ask for something to be replicated once or even not at all but...

```

9808 \cs_new:cpn { __prg_replicate_first_-:n } #1
9809   {
9810     \exp_end:
9811     \__kernel_msg_expandable_error:nn { kernel } { negative-replication }
9812   }
9813 \cs_new:cpn { __prg_replicate_first_0:n } #1 { \exp_end: }
9814 \cs_new:cpn { __prg_replicate_first_1:n } #1 { \exp_end: #1 }
9815 \cs_new:cpn { __prg_replicate_first_2:n } #1 { \exp_end: #1#1 }
9816 \cs_new:cpn { __prg_replicate_first_3:n } #1 { \exp_end: #1#1#1 }
9817 \cs_new:cpn { __prg_replicate_first_4:n } #1 { \exp_end: #1#1#1#1 }
9818 \cs_new:cpn { __prg_replicate_first_5:n } #1 { \exp_end: #1#1#1#1#1 }
9819 \cs_new:cpn { __prg_replicate_first_6:n } #1 { \exp_end: #1#1#1#1#1#1 }
9820 \cs_new:cpn { __prg_replicate_first_7:n } #1 { \exp_end: #1#1#1#1#1#1#1 }
9821 \cs_new:cpn { __prg_replicate_first_8:n } #1 { \exp_end: #1#1#1#1#1#1#1#1 }
9822 \cs_new:cpn { __prg_replicate_first_9:n } #1
9823   { \exp_end: #1#1#1#1#1#1#1#1#1#1 }

```

(End definition for \prg_replicate:nn and others. This function is documented on page 108.)

14.7 Detecting TeX's mode

\mode_if_vertical_p: For testing vertical mode. Strikes me here on the bus with David, that as long as we are just talking about returning true and false states, we can just use the primitive conditionals for this and gobbling the \exp_end: in the input stream. However this requires knowledge of the implementation so we keep things nice and clean and use the return statements.

```

9824 \prg_new_conditional:Npnn \mode_if_vertical: { p , T , F , TF }
9825   { \if_mode_vertical: \prg_return_true: \else: \prg_return_false: \fi: }

```

(End definition for \mode_if_vertical:TF. This function is documented on page 108.)

\mode_if_horizontal_p: For testing horizontal mode.

\mode_if_horizontal:TF

```

9826 \prg_new_conditional:Npnn \mode_if_horizontal: { p , T , F , TF }
9827   { \if_mode_horizontal: \prg_return_true: \else: \prg_return_false: \fi: }

```

(End definition for \mode_if_horizontal:TF. This function is documented on page 108.)

\mode_if_inner_p: For testing inner mode.

\mode_if_inner:TF

```

9828 \prg_new_conditional:Npnn \mode_if_inner: { p , T , F , TF }
9829   { \if_mode_inner: \prg_return_true: \else: \prg_return_false: \fi: }

```

(End definition for \mode_if_inner:TF. This function is documented on page 108.)

\mode_if_math_p: For testing math mode. At the beginning of an alignment cell, this should be used only inside a non-expandable function.

\mode_if_math:TF

```

9830 \prg_new_conditional:Npnn \mode_if_math: { p , T , F , TF }
9831   { \if_mode_math: \prg_return_true: \else: \prg_return_false: \fi: }

```

(End definition for \mode_if_math:TF. This function is documented on page 108.)

14.8 Internal programming functions

`\group_align_safe_begin:` `\group_align_safe_end:` T_EX’s alignment structures present many problems. As Knuth says himself in *T_EX: The Program*: “It’s sort of a miracle whenever `\halign` or `\valign` work, [...]” One problem relates to commands that internally issues a `\cr` but also peek ahead for the next character for use in, say, an optional argument. If the next token happens to be a `&` with category code 4 we get some sort of weird error message because the underlying `\futurelet` stores the token at the end of the alignment template. This could be a `&_4` giving a message like `! Misplaced \cr.` or even worse: it could be the `\endtemplate` token causing even more trouble! To solve this we have to open a special group so that T_EX still thinks it’s on safe ground but at the same time we don’t want to introduce any brace group that may find its way to the output. The following functions help with this by using code documented only in Appendix D of *The T_EXbook*... We place the `\if_false: { \fi:` part at that place so that the successive expansions of `\group_align_safe_begin/end:` are always brace balanced.

```

9832 \cs_new:Npn \group_align_safe_begin:
9833   { \if_int_compare:w \if_false: { \fi: ‘} = \c_zero_int \fi: }
9834 \cs_new:Npn \group_align_safe_end:
9835   { \if_int_compare:w ‘{ = \c_zero_int } \fi: }

```

(End definition for `\group_align_safe_begin:` and `\group_align_safe_end:`. These functions are documented on page 110.)

```

9836 <@@=prg>

```

`\g__kernel_prg_map_int` A nesting counter for mapping.

```

9837 \int_new:N \g__kernel_prg_map_int

```

(End definition for `\g__kernel_prg_map_int:`)

`\prg_break_point:Nn` `\prg_map_break:Nn` These are defined in `l3basics`, as they are needed “early”. This is just a reminder that is the case!

(End definition for `\prg_break_point:Nn` and `\prg_map_break:Nn`. These functions are documented on page 109.)

`\prg_break_point:` Also done in `l3basics` as in format mode these are needed within `l3alloc`.

`\prg_break:` `\prg_break:n` (End definition for `\prg_break_point:`, `\prg_break:`, and `\prg_break:n`. These functions are documented on page 109.)

```

9838 </initex | package>

```

15 l3sys implementation

```

9839 <*initex | package>

```

```

9840 <@@=sys>

```

15.1 The name of the job

`\c_sys_jobname_str` Inherited from the L^AT_EX3 name for the primitive: this needs to actually contain the text of the job name rather than the name of the primitive, of course.

```

9841 <*initex>
9842 \tex_everyjob:D \exp_after:wN
9843   {

```

```

9844 \tex_the:D \tex_everyjob:D
9845 \str_const:Nx \c_sys_jobname_str { \tex_jobname:D }
9846 }
9847 </initex>
9848 <*package>
9849 \str_const:Nx \c_sys_jobname_str { \tex_jobname:D }
9850 </package>

```

(End definition for `\c_sys_jobname_str`. This variable is documented on page 111.)

15.2 Detecting the engine

`__sys_const:nn` Set the T, F, TF, p forms of #1 to be constants equal to the result of evaluating the boolean expression #2.

```

9851 \cs_new_protected:Npn \__sys_const:nn #1#2
9852 {
9853   \bool_if:nTF {#2}
9854   {
9855     \cs_new_eq:cN { #1 :T } \use:n
9856     \cs_new_eq:cN { #1 :F } \use_none:n
9857     \cs_new_eq:cN { #1 :TF } \use_i:nn
9858     \cs_new_eq:cN { #1 _p: } \c_true_bool
9859   }
9860   {
9861     \cs_new_eq:cN { #1 :T } \use_none:n
9862     \cs_new_eq:cN { #1 :F } \use:n
9863     \cs_new_eq:cN { #1 :TF } \use_ii:nn
9864     \cs_new_eq:cN { #1 _p: } \c_false_bool
9865   }
9866 }

```

(End definition for `__sys_const:nn`.)

`\sys_if_engine luatex_p:` Set up the engine tests on the basis exactly one test should be true. Mainly a case of looking for the appropriate marker primitive. For up \TeX , there is a complexity in that setting `-kanji-internal=sjis` or `-kanji-internal=euc` effective makes it more like p \TeX . In those cases we therefore report p \TeX rather than up \TeX .

```

\sys_if_engine_pdftex_p:TF
\sys_if_engine_ptex_p:
\sys_if_engine_ptex:TF
\sys_if_engine_uptex_p:
\sys_if_engine_uptex:TF
\sys_if_engine_xetex_p:
\sys_if_engine_xetex:TF
\c_sys_engine_str
9867 \str_const:Nx \c_sys_engine_str
9868 {
9869   \cs_if_exist:NT \tex luatexversion:D { luatex }
9870   \cs_if_exist:NT \tex pdftexversion:D { pdftex }
9871   \cs_if_exist:NT \tex kanjiskip:D
9872   {
9873     \bool_lazy_and:nnTF
9874     { \cs_if_exist_p:N \tex disablecjktoken:D }
9875     { \int_compare_p:nNn { \tex jis:D "2121 } = { "3000 } }
9876     { uptex }
9877     { ptex }
9878   }
9879   \cs_if_exist:NT \tex XeTeXversion:D { xetex }
9880 }
9881 \tl_map_inline:nn { { luatex } { pdftex } { ptex } { uptex } { xetex } }
9882 {
9883   \__sys_const:nn { sys_if_engine_ #1 }

```

```

9884     { \str_if_eq_p:Vn \c_sys_engine_str {#1} }
9885   }

```

(End definition for `\sys_if_engine luatex:TF` and others. These functions are documented on page 111.)

15.3 Time and date

`\c_sys_minute_int` `\c_sys_hour_int` `\c_sys_day_int` `\c_sys_month_int` `\c_sys_year_int` Copies of the information provided by T_EX. There is a lot of defensive code in package mode: someone may have moved the primitives, and they can only be recovered if we have `\primitive` and it is working correctly.

```

9886 (*initex)
9887 \int_const:Nn \c_sys_minute_int
9888   { \int_mod:nn { \tex_time:D } { 60 } }
9889 \int_const:Nn \c_sys_hour_int
9890   { \int_div_truncate:nn { \tex_time:D } { 60 } }
9891 \int_const:Nn \c_sys_day_int   { \tex_day:D }
9892 \int_const:Nn \c_sys_month_int { \tex_month:D }
9893 \int_const:Nn \c_sys_year_int  { \tex_year:D }
9894 
```

(End definition for `\c_sys_minute_int` and others. These variables are documented on page 111.)

15.4 Detecting the output

`\sys_if_output_dvi_p:` This is a simple enough concept: the two views here are complementary.

```

\sys_if_output_dvi:TF
\sys_if_output_pdf_p:
\sys_if_output_pdf:TF
\c_sys_output_str
9926 \str_const:Nx \c_sys_output_str
9927 {
9928   \int_compare:nNnTF
9929     { \cs_if_exist_use:NF \tex_pdfoutput:D { 0 } } > { 0 }
9930     { pdf }
9931     { dvi }
9932 }
9933 \__sys_const:nn { sys_if_output_dvi }
9934 { \str_if_eq_p:Vn \c_sys_output_str { dvi } }
9935 \__sys_const:nn { sys_if_output_pdf }
9936 { \str_if_eq_p:Vn \c_sys_output_str { pdf } }
```

(End definition for `\sys_if_output_dvi:TF`, `\sys_if_output_pdf:TF`, and `\c_sys_output_str`. These functions are documented on page 112.)

15.5 Randomness

This candidate function is placed there because `\sys_if_rand_exist:TF` is used in `l3fp-rand`.

`\sys_if_rand_exist_p:` Currently, randomness exists under pdfTeX, LuaTeX, pTeX and upTeX.

```

\sys_if_rand_exist:TF
9937 \__sys_const:nn { sys_if_rand_exist }
9938 { \cs_if_exist_p:N \tex_uniformdeviate:D }
```

(End definition for `\sys_if_rand_exist:TF`. This function is documented on page 260.)

```
9939 </initex | package>
```

16 l3clist implementation

The following test files are used for this code: `m3clist002`.

```

9940 <*initex | package>
9941 <@@=clist>
```

`\c_empty_clist` An empty comma list is simply an empty token list.

```
9942 \cs_new_eq:NN \c_empty_clist \c_empty_tl
```

(End definition for `\c_empty_clist`. This variable is documented on page 122.)

`\l__clist_internal_clist` Scratch space for various internal uses. This comma list variable cannot be declared as such because it comes before `\clist_new:N`

```
9943 \tl_new:N \l__clist_internal_clist
```

(End definition for `\l__clist_internal_clist`.)

`__clist_tmp:w` A temporary function for various purposes.

```
9944 \cs_new_protected:Npn \__clist_tmp:w { }
```

(End definition for `__clist_tmp:w`.)

16.1 Removing spaces around items

`__clist_trim_next:w` Called as `\exp:w __clist_trim_next:w \prg_do_nothing: <comma list> ...` it expands to `{<trimmed item>}` where the `<trimmed item>` is the first non-empty result from removing spaces from both ends of comma-delimited items in the `<comma list>`. The `\prg_do_nothing:` marker avoids losing braces. The test for blank items is a somewhat optimized `\tl_if_empty:oTF` construction; if blank, another item is sought, otherwise trim spaces.

```

9945 \cs_new:Npn \__clist_trim_next:w #1 ,
9946 {
9947   \tl_if_empty:oTF { \use_none:nn #1 ? }
9948   { \__clist_trim_next:w \prg_do_nothing: }
9949   { \tl_trim_spaces_apply:oN {#1} \exp_end: }
9950 }
```

(End definition for `__clist_trim_next:w`.)

`__clist_sanitize:n` The auxiliary `__clist_sanitize:Nn` receives a delimiter (`\c_empty_tl` the first time, afterwards a comma) and that item as arguments. Unless we are done with the loop it calls `__clist_wrap_item:w` to unbrace the item (using a comma delimiter is safe since `#2` came from removing spaces from an argument delimited by a comma) and possibly re-brace it if needed.

```

9951 \cs_new:Npn \__clist_sanitize:n #1
9952 {
9953   \exp_after:wN \__clist_sanitize:Nn \exp_after:wN \c_empty_tl
9954   \exp:w \__clist_trim_next:w \prg_do_nothing:
9955   #1 , \q_recursion_tail , \q_recursion_stop
9956 }
9957 \cs_new:Npn \__clist_sanitize:Nn #1#2
9958 {
9959   \quark_if_recursion_tail_stop:n {#2}
9960   #1 \__clist_wrap_item:w #2 ,
9961   \exp_after:wN \__clist_sanitize:Nn \exp_after:wN ,
9962   \exp:w \__clist_trim_next:w \prg_do_nothing:
9963 }
```

(End definition for `__clist_sanitize:n` and `__clist_sanitize:Nn`.)

`__clist_if_wrap:nTF` True if the argument must be wrapped to avoid getting altered by some clist operations.
`__clist_if_wrap:w` That is the case whenever the argument

- starts or end with a space or contains a comma,
- is empty, or
- consists of a single braced group.

All `l3clist` functions go through the same test when they need to determine whether to brace an item, so it is not a problem that this test has false positives such as “`\q_mark ?`”. If the argument starts or end with a space or contains a comma then one of the three arguments of `__clist_if_wrap:w` will have its end delimiter (partly) in one of the three copies of `#1` in `__clist_if_wrap:nTF`; this has a knock-on effect meaning that the result of the expansion is not empty; in that case, wrap. Otherwise, the argument

is safe unless it starts with a brace group (or is empty) and it is empty or consists of a single n-type argument.

```

9964 \prg_new_conditional:Npnn \__clist_if_wrap:n #1 { TF }
9965 {
9966   \tl_if_empty:oTF
9967   {
9968     \__clist_if_wrap:w
9969     \q_mark ? #1 ~ \q_mark ? ~ #1 \q_mark , ~ \q_mark #1 ,
9970   }
9971   {
9972     \tl_if_head_is_group:nTF { #1 { } }
9973     {
9974       \tl_if_empty:nTF {#1}
9975       { \prg_return_true: }
9976       {
9977         \tl_if_empty:oTF { \use_none:n #1}
9978         { \prg_return_true: }
9979         { \prg_return_false: }
9980       }
9981     }
9982     { \prg_return_false: }
9983   }
9984   { \prg_return_true: }
9985 }
9986 \cs_new:Npn \__clist_if_wrap:w #1 \q_mark ? ~ #2 ~ \q_mark #3 , { }

```

(End definition for __clist_if_wrap:nTF and __clist_if_wrap:w.)

__clist_wrap_item:w Safe items are put in \exp_not:n, otherwise we put an extra set of braces.

```

9987 \cs_new:Npn \__clist_wrap_item:w #1 ,
9988 { \__clist_if_wrap:nTF {#1} { \exp_not:n { {#1} } } { \exp_not:n {#1} } }

```

(End definition for __clist_wrap_item:w.)

16.2 Allocation and initialisation

\clist_new:N Internally, comma lists are just token lists.

```

\clist_new:c 9989 \cs_new_eq:NN \clist_new:N \tl_new:N
9990 \cs_new_eq:NN \clist_new:c \tl_new:c

```

(End definition for \clist_new:N. This function is documented on page 113.)

\clist_const:Nn Creating and initializing a constant comma list is done by sanitizing all items (stripping spaces and braces).

```

\clist_const:cn 9991 \cs_new_protected:Npn \clist_const:Nn #1#2
\clist_const:Nx 9992 { \tl_const:Nx #1 { \__clist_sanitize:n {#2} } }
\clist_const:cx 9993 \cs_generate_variant:Nn \clist_const:Nn { c , Nx , cx }

```

(End definition for \clist_const:Nn. This function is documented on page 114.)

\clist_clear:N Clearing comma lists is just the same as clearing token lists.

```

\clist_clear:c 9994 \cs_new_eq:NN \clist_clear:N \tl_clear:N
\clist_gclear:N 9995 \cs_new_eq:NN \clist_clear:c \tl_clear:c
\clist_gclear:c 9996 \cs_new_eq:NN \clist_gclear:N \tl_gclear:N
9997 \cs_new_eq:NN \clist_gclear:c \tl_gclear:c

```

(End definition for `\clist_clear:N` and `\clist_gclear:N`. These functions are documented on page 114.)

```

\clist_clear_new:N Once again a copy from the token list functions.
\clist_clear_new:c 9998 \cs_new_eq:NN \clist_clear_new:N \tl_clear_new:N
\clist_gclear_new:N 9999 \cs_new_eq:NN \clist_clear_new:c \tl_clear_new:c
\clist_gclear_new:c 10000 \cs_new_eq:NN \clist_gclear_new:N \tl_gclear_new:N
10001 \cs_new_eq:NN \clist_gclear_new:c \tl_gclear_new:c

```

(End definition for `\clist_clear_new:N` and `\clist_gclear_new:N`. These functions are documented on page 114.)

```

\clist_set_eq:NN Once again, these are simple copies from the token list functions.
\clist_set_eq:cN 10002 \cs_new_eq:NN \clist_set_eq:NN \tl_set_eq:NN
\clist_set_eq:Nc 10003 \cs_new_eq:NN \clist_set_eq:Nc \tl_set_eq:Nc
\clist_set_eq:cc 10004 \cs_new_eq:NN \clist_set_eq:cN \tl_set_eq:cN
\clist_gset_eq:NN 10005 \cs_new_eq:NN \clist_set_eq:cc \tl_set_eq:cc
\clist_gset_eq:cN 10006 \cs_new_eq:NN \clist_gset_eq:NN \tl_gset_eq:NN
\clist_gset_eq:Nc 10007 \cs_new_eq:NN \clist_gset_eq:Nc \tl_gset_eq:Nc
\clist_gset_eq:cN 10008 \cs_new_eq:NN \clist_gset_eq:cN \tl_gset_eq:cN
10009 \cs_new_eq:NN \clist_gset_eq:cc \tl_gset_eq:cc

```

(End definition for `\clist_set_eq:NN` and `\clist_gset_eq:NN`. These functions are documented on page 114.)

```

\clist_set_from_seq:NN Setting a comma list from a comma-separated list is done using a simple mapping. Safe
\clist_set_from_seq:cN items are put in \exp_not:n, otherwise we put an extra set of braces. The first comma
\clist_set_from_seq:Nc must be removed, except in the case of an empty comma-list.
\clist_set_from_seq:cc 10010 \cs_new_protected:Npn \clist_set_from_seq:NN
\clist_gset_from_seq:NN 10011 { \__clist_set_from_seq:NNNN \clist_clear:N \tl_set:Nx }
\clist_gset_from_seq:cN 10012 \cs_new_protected:Npn \clist_gset_from_seq:NN
\clist_gset_from_seq:Nc 10013 { \__clist_set_from_seq:NNNN \clist_gclear:N \tl_gset:Nx }
\clist_gset_from_seq:cc 10014 \cs_new_protected:Npn \__clist_set_from_seq:NNNN #1#2#3#4
\__clist_set_from_seq:NNNN 10015 {
\__clist_set_from_seq:n 10016 \seq_if_empty:NTF #4
10017 { #1 #3 }
10018 {
10019 #2 #3
10020 {
10021 \exp_after:wN \use_none:n \exp:w \exp_end_continue_f:w
10022 \seq_map_function:NN #4 \__clist_set_from_seq:n
10023 }
10024 }
10025 }
10026 \cs_new:Npn \__clist_set_from_seq:n #1
10027 {
10028 ,
10029 \__clist_if_wrap:NTF {#1}
10030 { \exp_not:n { {#1} } }
10031 { \exp_not:n {#1} }
10032 }
10033 \cs_generate_variant:Nn \clist_set_from_seq:NN { Nc }
10034 \cs_generate_variant:Nn \clist_set_from_seq:NN { c , cc }
10035 \cs_generate_variant:Nn \clist_gset_from_seq:NN { Nc }
10036 \cs_generate_variant:Nn \clist_gset_from_seq:NN { c , cc }

```

(End definition for `\clist_set_from_seq:Nn` and others. These functions are documented on page 114.)

```

\clist_concat:NNN Concatenating comma lists is not quite as easy as it seems, as there needs to be the
\clist_concat:ccc correct addition of a comma to the output. So a little work to do.
\clist_gconcat:NNN
\clist_gconcat:ccc
\__clist_concat:NNNN
10037 \cs_new_protected:Npn \clist_concat:NNN
10038 { \__clist_concat:NNNN \tl_set:Nx }
10039 \cs_new_protected:Npn \clist_gconcat:NNN
10040 { \__clist_concat:NNNN \tl_gset:Nx }
10041 \cs_new_protected:Npn \__clist_concat:NNNN #1#2#3#4
10042 {
10043   #1 #2
10044   {
10045     \exp_not:o #3
10046     \clist_if_empty:NF #3 { \clist_if_empty:NF #4 { , } }
10047     \exp_not:o #4
10048   }
10049 }
10050 \cs_generate_variant:Nn \clist_concat:NNN { ccc }
10051 \cs_generate_variant:Nn \clist_gconcat:NNN { ccc }

```

(End definition for `\clist_concat:NNN`, `\clist_gconcat:NNN`, and `__clist_concat:NNNN`. These functions are documented on page 114.)

```

\clist_if_exist_p:N Copies of the cs functions defined in l3basics.
\clist_if_exist_p:c
\clist_if_exist:NTF
\clist_if_exist:cTF
10052 \prg_new_eq_conditional:NNn \clist_if_exist:N \cs_if_exist:N
10053 { TF , T , F , p }
10054 \prg_new_eq_conditional:NNn \clist_if_exist:c \cs_if_exist:c
10055 { TF , T , F , p }

```

(End definition for `\clist_if_exist:NTF`. This function is documented on page 114.)

16.3 Adding data to comma lists

```

\clist_set:Nn
\clist_set:NV
\clist_set:No
\clist_set:Nx
\clist_set:cn
\clist_set:cV
\clist_set:co
\clist_set:cx
\clist_gset:Nn
\clist_gset:NV
\clist_gset:No
\clist_gset:Nx
\clist_gset:cn
\clist_gset:cV
\clist_gset:co
\clist_gset:cx
10056 \cs_new_protected:Npn \clist_set:Nn #1#2
10057 { \tl_set:Nx #1 { \__clist_sanitiz:n {#2} } }
10058 \cs_new_protected:Npn \clist_gset:Nn #1#2
10059 { \tl_gset:Nx #1 { \__clist_sanitiz:n {#2} } }
10060 \cs_generate_variant:Nn \clist_set:Nn { NV , No , Nx , c , cV , co , cx }
10061 \cs_generate_variant:Nn \clist_gset:Nn { NV , No , Nx , c , cV , co , cx }

```

(End definition for `\clist_set:Nn` and `\clist_gset:Nn`. These functions are documented on page 115.)

```

\clist_put_left:Nn Everything is based on concatenation after storing in \l__clist_internal_clist. This
\clist_put_left:NV avoids having to worry here about space-trimming and so on.
\clist_put_left:No
\clist_put_left:Nx
\clist_put_left:cn
\clist_put_left:cV
\clist_put_left:co
\clist_put_left:cx
\clist_gput_left:Nn
\clist_gput_left:NV
\clist_gput_left:No
\clist_gput_left:Nx
\clist_gput_left:cn
\clist_gput_left:cV
\clist_gput_left:co
\clist_gput_left:cx
\__clist_put_left:NNNn
10062 \cs_new_protected:Npn \clist_put_left:Nn
10063 { \__clist_put_left:NNNn \clist_concat:NNN \clist_set:Nn }
10064 \cs_new_protected:Npn \clist_gput_left:Nn
10065 { \__clist_put_left:NNNn \clist_gconcat:NNN \clist_set:Nn }
10066 \cs_new_protected:Npn \__clist_put_left:NNNn #1#2#3#4
10067 {
10068   #2 \l__clist_internal_clist {#4}
10069   #1 #3 \l__clist_internal_clist #3
10070 }

```

```

10071 \cs_generate_variant:Nn \clist_put_left:Nn { NV , No , Nx }
10072 \cs_generate_variant:Nn \clist_put_left:Nn { c , cV , co , cx }
10073 \cs_generate_variant:Nn \clist_gput_left:Nn { NV , No , Nx }
10074 \cs_generate_variant:Nn \clist_gput_left:Nn { c , cV , co , cx }

```

(End definition for `\clist_put_left:Nn`, `\clist_gput_left:Nn`, and `__clist_put_left:NNNn`. These functions are documented on page 115.)

```

\clist_put_right:Nn
\clist_put_right:NV
\clist_put_right:No
\clist_put_right:Nx
\clist_put_right:cn
\clist_put_right:cV
\clist_put_right:co
\clist_put_right:cx
\clist_gput_right:Nn
\clist_gput_right:NV
\clist_gput_right:No
\clist_gput_right:Nx
\clist_gput_right:cn
\clist_gput_right:cV
\clist_gput_right:co
\clist_gput_right:cx
\__clist_put_right:NNNn

```

```

10075 \cs_new_protected:Npn \clist_put_right:Nn
10076 { \__clist_put_right:NNNn \clist_concat:NNN \clist_set:Nn }
10077 \cs_new_protected:Npn \clist_gput_right:Nn
10078 { \__clist_put_right:NNNn \clist_gconcat:NNN \clist_set:Nn }
10079 \cs_new_protected:Npn \__clist_put_right:NNNn #1#2#3#4
10080 {
10081   #2 \l__clist_internal_clist {#4}
10082   #1 #3 #3 \l__clist_internal_clist
10083 }
10084 \cs_generate_variant:Nn \clist_put_right:Nn { NV , No , Nx }
10085 \cs_generate_variant:Nn \clist_put_right:Nn { c , cV , co , cx }
10086 \cs_generate_variant:Nn \clist_gput_right:Nn { NV , No , Nx }
10087 \cs_generate_variant:Nn \clist_gput_right:Nn { c , cV , co , cx }

```

(End definition for `\clist_put_right:Nn`, `\clist_gput_right:Nn`, and `__clist_put_right:NNNn`. These functions are documented on page 115.)

16.4 Comma lists as stacks

`\clist_get:NN` Getting an item from the left of a comma list is pretty easy: just trim off the first item using the comma. No need to trim spaces as comma-list *variables* are assumed to have “cleaned-up” items. (Note that grabbing a comma-delimited item removes an outer pair of braces if present, exactly as needed to uncover the underlying item.)

```

10088 \cs_new_protected:Npn \clist_get:NN #1#2
10089 {
10090   \if_meaning:w #1 \c_empty_clist
10091     \tl_set:Nn #2 { \q_no_value }
10092   \else:
10093     \exp_after:wN \__clist_get:wN #1 , \q_stop #2
10094   \fi:
10095 }
10096 \cs_new_protected:Npn \__clist_get:wN #1 , #2 \q_stop #3
10097 { \tl_set:Nn #3 {#1} }
10098 \cs_generate_variant:Nn \clist_get:NN { c }

```

(End definition for `\clist_get:NN` and `__clist_get:wN`. This function is documented on page 120.)

`\clist_pop:NN` An empty clist leads to `\q_no_value`, otherwise grab until the first comma and assign to the variable. The second argument of `__clist_pop:wwNNN` is a comma list ending in a comma and `\q_mark`, unless the original clist contained exactly one item: then the argument is just `\q_mark`. The next auxiliary picks either `\exp_not:n` or `\use_none:n` as #2, ensuring that the result can safely be an empty comma list.

```

\clist_pop:cn
\clist_gpop:NN
\__clist_pop:NNN
\__clist_pop:wwNNN
\__clist_pop:wN

```

```

10099 \cs_new_protected:Npn \clist_pop:NN
10100 { \__clist_pop:NNN \tl_set:Nx }
10101 \cs_new_protected:Npn \clist_gpop:NN

```

```

10102 { \_clst_pop:NNN \tl_gset:Nx }
10103 \cs_new_protected:Npn \_clst_pop:NNN #1#2#3
10104 {
10105   \if_meaning:w #2 \c_empty_clst
10106     \tl_set:Nn #3 { \q_no_value }
10107   \else:
10108     \exp_after:wN \_clst_pop:wwNNN #2 , \q_mark \q_stop #1#2#3
10109   \fi:
10110 }
10111 \cs_new_protected:Npn \_clst_pop:wwNNN #1 , #2 \q_stop #3#4#5
10112 {
10113   \tl_set:Nn #5 {#1}
10114   #3 #4
10115   {
10116     \_clst_pop:wN \prg_do_nothing:
10117     #2 \exp_not:o
10118     , \q_mark \use_none:n
10119     \q_stop
10120   }
10121 }
10122 \cs_new:Npn \_clst_pop:wN #1 , \q_mark #2 #3 \q_stop { #2 {#1} }
10123 \cs_generate_variant:Nn \clst_pop:NN { c }
10124 \cs_generate_variant:Nn \clst_gpop:NN { c }

```

(End definition for \clst_pop:NN and others. These functions are documented on page 120.)

```

\clst_get:NNTF The same, as branching code: very similar to the above.
\clst_get:cNTF 10125 \prg_new_protected_conditional:Npnn \clst_get:NN #1#2 { T , F , TF }
\clst_pop:NNTF 10126 {
\clst_pop:cNTF 10127   \if_meaning:w #1 \c_empty_clst
\clst_gpop:NNTF 10128   \prg_return_false:
\clst_gpop:cNTF 10129   \else:
\_clst_pop_TF:NNN 10130   \exp_after:wN \_clst_get:wN #1 , \q_stop #2
10131   \prg_return_true:
10132   \fi:
10133 }
10134 \prg_generate_conditional_variant:Nnn \clst_get:NN { c } { T , F , TF }
10135 \prg_new_protected_conditional:Npnn \clst_pop:NN #1#2 { T , F , TF }
10136 { \_clst_pop_TF:NNN \tl_set:Nx #1 #2 }
10137 \prg_new_protected_conditional:Npnn \clst_gpop:NN #1#2 { T , F , TF }
10138 { \_clst_pop_TF:NNN \tl_gset:Nx #1 #2 }
10139 \cs_new_protected:Npn \_clst_pop_TF:NNN #1#2#3
10140 {
10141   \if_meaning:w #2 \c_empty_clst
10142     \prg_return_false:
10143   \else:
10144     \exp_after:wN \_clst_pop:wwNNN #2 , \q_mark \q_stop #1#2#3
10145     \prg_return_true:
10146   \fi:
10147 }
10148 \prg_generate_conditional_variant:Nnn \clst_pop:NN { c } { T , F , TF }
10149 \prg_generate_conditional_variant:Nnn \clst_gpop:NN { c } { T , F , TF }

```

(End definition for \clst_get:NNTF and others. These functions are documented on page 120.)

\clist_push:Nn Pushing to a comma list is the same as adding on the left.

\clist_push:Nv	10150	\cs_new_eq:NN \clist_push:Nn \clist_put_left:Nn
\clist_push:No	10151	\cs_new_eq:NN \clist_push:Nv \clist_put_left:Nv
\clist_push:Nx	10152	\cs_new_eq:NN \clist_push:No \clist_put_left:No
\clist_push:cn	10153	\cs_new_eq:NN \clist_push:Nx \clist_put_left:Nx
\clist_push:cV	10154	\cs_new_eq:NN \clist_push:cn \clist_put_left:cn
\clist_push:co	10155	\cs_new_eq:NN \clist_push:cV \clist_put_left:cV
\clist_push:cx	10156	\cs_new_eq:NN \clist_push:co \clist_put_left:co
\clist_gpush:Nn	10157	\cs_new_eq:NN \clist_gpush:Nn \clist_gput_left:Nn
\clist_gpush:Nv	10158	\cs_new_eq:NN \clist_gpush:Nv \clist_gput_left:Nv
\clist_gpush:No	10159	\cs_new_eq:NN \clist_gpush:No \clist_gput_left:No
\clist_gpush:Nx	10160	\cs_new_eq:NN \clist_gpush:Nx \clist_gput_left:Nx
\clist_gpush:cn	10161	\cs_new_eq:NN \clist_gpush:cn \clist_gput_left:cn
\clist_gpush:cV	10162	\cs_new_eq:NN \clist_gpush:cV \clist_gput_left:cV
\clist_gpush:co	10163	\cs_new_eq:NN \clist_gpush:co \clist_gput_left:co
\clist_gpush:cx	10164	\cs_new_eq:NN \clist_gpush:cx \clist_gput_left:cx

(End definition for \clist_push:Nn and \clist_gpush:Nn. These functions are documented on page 120.)

16.5 Modifying comma lists

\l__clist_internal_remove_clist An internal comma list and a sequence for the removal routines.

\l__clist_internal_remove_seq	10166	\clist_new:N \l__clist_internal_remove_clist
	10167	\seq_new:N \l__clist_internal_remove_seq

(End definition for \l__clist_internal_remove_clist and \l__clist_internal_remove_seq.)

\clist_remove_duplicates:N Removing duplicates means making a new list then copying it.

\clist_remove_duplicates:c	10168	\cs_new_protected:Npn \clist_remove_duplicates:N
\clist_gremove_duplicates:N	10169	{ __clist_remove_duplicates:NN \clist_set_eq:NN }
\clist_gremove_duplicates:c	10170	\cs_new_protected:Npn \clist_gremove_duplicates:N
__clist_remove_duplicates:NN	10171	{ __clist_remove_duplicates:NN \clist_gset_eq:NN }
	10172	\cs_new_protected:Npn __clist_remove_duplicates:NN #1#2
	10173	{
	10174	\clist_clear:N \l__clist_internal_remove_clist
	10175	\clist_map_inline:Nn #2
	10176	{
	10177	\clist_if_in:NnF \l__clist_internal_remove_clist {##1}
	10178	{ \clist_put_right:Nn \l__clist_internal_remove_clist {##1} }
	10179	}
	10180	#1 #2 \l__clist_internal_remove_clist
	10181	}
	10182	\cs_generate_variant:Nn \clist_remove_duplicates:N { c }
	10183	\cs_generate_variant:Nn \clist_gremove_duplicates:N { c }

(End definition for \clist_remove_duplicates:N, \clist_gremove_duplicates:N, and __clist_remove_duplicates:NN. These functions are documented on page 116.)

\clist_remove_all:Nn The method used here for safe items is very similar to \tl_replace_all:Nnn. However,

\clist_remove_all:cn if the item contains commas or leading/trailing spaces, or is empty, or consists of a

\clist_gremove_all:Nn single brace group, we know that it can only appear within braces so the code would

\clist_gremove_all:cn fail; instead just convert to a sequence and do the removal with l3seq code (it involves

__clist_remove_all:NNNn

__clist_remove_all:w

__clist_remove_all:

somewhat elaborate code to do most of the work expandably but the final token list comparisons non-expandably).

For “safe” items, build a function delimited by the $\langle item \rangle$ that should be removed, surrounded with commas, and call that function followed by the expanded comma list, and another copy of the $\langle item \rangle$. The loop is controlled by the argument grabbed by `__clist_remove_all:w`: when the item was found, the `\q_mark` delimiter used is the one inserted by `__clist_tmp:w`, and `\use_none_delimit_by_q_stop:w` is deleted. At the end, the final $\langle item \rangle$ is grabbed, and the argument of `__clist_tmp:w` contains `\q_mark`: in that case, `__clist_remove_all:w` removes the second `\q_mark` (inserted by `__clist_tmp:w`), and lets `\use_none_delimit_by_q_stop:w` act.

No brace is lost because items are always grabbed with a leading comma. The result of the first assignment has an extra leading comma, which we remove in a second assignment. Two exceptions: if the clist lost all of its elements, the result is empty, and we shouldn’t remove anything; if the clist started up empty, the first step happens to turn it into a single comma, and the second step removes it.

```

10184 \cs_new_protected:Npn \clist_remove_all:Nn
10185   { \__clist_remove_all:NNNn \clist_set_from_seq:NN \tl_set:Nx }
10186 \cs_new_protected:Npn \clist_gremove_all:Nn
10187   { \__clist_remove_all:NNNn \clist_gset_from_seq:NN \tl_gset:Nx }
10188 \cs_new_protected:Npn \__clist_remove_all:NNNn #1#2#3#4
10189   {
10190     \__clist_if_wrap:nTF {#4}
10191     {
10192       \seq_set_from_clist:NN \l__clist_internal_remove_seq #3
10193       \seq_remove_all:Nn \l__clist_internal_remove_seq {#4}
10194       #1 #3 \l__clist_internal_remove_seq
10195     }
10196     {
10197       \cs_set:Npn \__clist_tmp:w ##1 , #4 ,
10198       {
10199         ##1
10200         , \q_mark , \use_none_delimit_by_q_stop:w ,
10201         \__clist_remove_all:
10202       }
10203       #2 #3
10204       {
10205         \exp_after:wN \__clist_remove_all:
10206         #3 , \q_mark , #4 , \q_stop
10207       }
10208       \clist_if_empty:NF #3
10209       {
10210         #2 #3
10211         {
10212           \exp_args:No \exp_not:o
10213           { \exp_after:wN \use_none:n #3 }
10214         }
10215       }
10216     }
10217   }
10218 \cs_new:Npn \__clist_remove_all:
10219   { \exp_after:wN \__clist_remove_all:w \__clist_tmp:w , }
10220 \cs_new:Npn \__clist_remove_all:w #1 , \q_mark , #2 , { \exp_not:n {#1} }

```

```

10221 \cs_generate_variant:Nn \clist_remove_all:Nn { c }
10222 \cs_generate_variant:Nn \clist_gremove_all:Nn { c }

```

(End definition for `\clist_remove_all:Nn` and others. These functions are documented on page 116.)

`\clist_reverse:N` Use `\clist_reverse:n` in an x-expanding assignment. The extra work that `\clist_reverse:n` does to preserve braces and spaces would not be needed for the well-controlled case of N-type comma lists, but the slow-down is not too bad.

```

\clist_reverse:c
\clist_greverse:N
\clist_greverse:c
10223 \cs_new_protected:Npn \clist_reverse:N #1
10224 { \tl_set:Nx #1 { \exp_args:No \clist_reverse:n {#1} } }
10225 \cs_new_protected:Npn \clist_greverse:N #1
10226 { \tl_gset:Nx #1 { \exp_args:No \clist_reverse:n {#1} } }
10227 \cs_generate_variant:Nn \clist_reverse:N { c }
10228 \cs_generate_variant:Nn \clist_greverse:N { c }

```

(End definition for `\clist_reverse:N` and `\clist_greverse:N`. These functions are documented on page 116.)

`\clist_reverse:n` The reversed token list is built one item at a time, and stored between `\q_stop` and `\q_mark`, in the form of ? followed by zero or more instances of “ $\langle item \rangle$,”. We start from a comma list “ $\langle item_1 \rangle, \dots, \langle item_n \rangle$ ”. During the loop, the auxiliary `__clist_reverse:wwNww` receives “? $\langle item_i \rangle$ ” as #1, “ $\langle item_{i+1} \rangle, \dots, \langle item_n \rangle$ ” as #2, `__clist_reverse:wwNww` as #3, what remains until `\q_stop` as #4, and “ $\langle item_{i-1} \rangle, \dots, \langle item_1 \rangle$,” as #5. The auxiliary moves #1 just before #5, with a comma, and calls itself (#3). After the last item is moved, `__clist_reverse:wwNww` receives “`\q_mark __clist_reverse:wwNww !`” as its argument #1, thus `__clist_reverse_end:ww` as its argument #3. This second auxiliary cleans up until the marker !, removes the trailing comma (introduced when the first item was moved after `\q_stop`), and leaves its argument #1 within `\exp_not:n`. There is also a need to remove a leading comma, hence `\exp_not:o` and `\use_none:n`.

```

10229 \cs_new:Npn \clist_reverse:n #1
10230 {
10231   \__clist_reverse:wwNww ? #1 ,
10232   \q_mark \__clist_reverse:wwNww ! ,
10233   \q_mark \__clist_reverse_end:ww
10234   \q_stop ? \q_mark
10235 }
10236 \cs_new:Npn \__clist_reverse:wwNww
10237   #1 , #2 \q_mark #3 #4 \q_stop ? #5 \q_mark
10238   { #3 ? #2 \q_mark #3 #4 \q_stop #1 , #5 \q_mark }
10239 \cs_new:Npn \__clist_reverse_end:ww #1 ! #2 , \q_mark
10240   { \exp_not:o { \use_none:n #2 } }

```

(End definition for `\clist_reverse:n`, `__clist_reverse:wwNww`, and `__clist_reverse_end:ww`. This function is documented on page 116.)

`\clist_sort:Nn` Implemented in `l3sort`.

`\clist_sort:cn`
`\clist_gsort:Nn`
`\clist_gsort:cn` (End definition for `\clist_sort:Nn` and `\clist_gsort:Nn`. These functions are documented on page 116.)

16.6 Comma list conditionals

```

\clist_if_empty_p:N Simple copies from the token list variable material.
\clist_if_empty_p:c 10241 \prg_new_eq_conditional:NNn \clist_if_empty:N \tl_if_empty:N
\clist_if_empty:NTF 10242 { p , T , F , TF }
\clist_if_empty:cTF 10243 \prg_new_eq_conditional:NNn \clist_if_empty:c \tl_if_empty:c
10244 { p , T , F , TF }

```

(End definition for `\clist_if_empty:N`. This function is documented on page 117.)

```

\clist_if_empty_p:n As usual, we insert a token (here ?) before grabbing any argument: this avoids losing
\clist_if_empty:nTF braces. The argument of \tl_if_empty:oTF is empty if #1 is ? followed by blank spaces
  \__clist_if_empty_n:w (besides, this particular variant of the emptiness test is optimized). If the item of the
  \__clist_if_empty_n:wNw comma list is blank, grab the next one. As soon as one item is non-blank, exit: the second
                        auxiliary grabs \prg_return_false: as #2, unless every item in the comma list was blank
                        and the loop actually got broken by the trailing \q_mark \prg_return_false: item.

```

```

10245 \prg_new_conditional:Npnn \clist_if_empty:n #1 { p , T , F , TF }
10246 {
10247   \__clist_if_empty_n:w ? #1
10248   , \q_mark \prg_return_false:
10249   , \q_mark \prg_return_true:
10250   \q_stop
10251 }
10252 \cs_new:Npn \__clist_if_empty_n:w #1 ,
10253 {
10254   \tl_if_empty:oTF { \use_none:nn #1 ? }
10255   { \__clist_if_empty_n:w ? }
10256   { \__clist_if_empty_n:wNw }
10257 }
10258 \cs_new:Npn \__clist_if_empty_n:wNw #1 \q_mark #2#3 \q_stop {#2}

```

(End definition for `\clist_if_empty:nTF`, `__clist_if_empty_n:w`, and `__clist_if_empty_n:wNw`. This function is documented on page 117.)

```

\clist_if_in:NnTF For “safe” items, we simply surround the comma list, and the item, with commas, then
\clist_if_in:NVTf use the same code as for \tl_if_in:Nn. For “unsafe” items we follow the same route as
\clist_if_in:NoTF \seq_if_in:Nn, mapping through the list a comparison function. If found, return true
\clist_if_in:cnTF and remove \prg_return_false:.
\clist_if_in:cVTf 10259 \prg_new_protected_conditional:Npnn \clist_if_in:Nn #1#2 { T , F , TF }
\clist_if_in:coTF 10260 {
\clist_if_in:nnTF 10261   \exp_args:No \__clist_if_in_return:nnN #1 {#2} #1
\clist_if_in:nVTf 10262 }
\clist_if_in:noTF 10263 \prg_new_protected_conditional:Npnn \clist_if_in:nn #1#2 { T , F , TF }
  \__clist_if_in_return:nnN 10264 {
10265   \clist_set:Nn \l__clist_internal_clist {#1}
10266   \exp_args:No \__clist_if_in_return:nnN \l__clist_internal_clist {#2}
10267   \l__clist_internal_clist
10268 }
10269 \cs_new_protected:Npn \__clist_if_in_return:nnN #1#2#3
10270 {
10271   \__clist_if_wrap:nTF {#2}
10272   {
10273     \cs_set:Npx \__clist_tmp:w ##1
10274     {

```

```

10275         \exp_not:N \tl_if_eq:nnT {##1}
10276         \exp_not:n
10277         {
10278             {#2}
10279             { \clist_map_break:n { \prg_return_true: \use_none:n } }
10280         }
10281     }
10282     \clist_map_function:NN #3 \__clist_tmp:w
10283     \prg_return_false:
10284 }
10285 {
10286     \cs_set:Npn \__clist_tmp:w ##1 ,#2, { }
10287     \tl_if_empty:oTF
10288     { \__clist_tmp:w ,#1, {} {} ,#2, }
10289     { \prg_return_false: } { \prg_return_true: }
10290 }
10291 }
10292 \prg_generate_conditional_variant:Nnn \clist_if_in:Nn
10293 { NV , No , c , cV , co } { T , F , TF }
10294 \prg_generate_conditional_variant:Nnn \clist_if_in:nn
10295 { nV , no } { T , F , TF }

```

(End definition for `\clist_if_in:NnTF`, `\clist_if_in:nnTF`, and `__clist_if_in_return:nnN`. These functions are documented on page 117.)

16.7 Mapping to comma lists

`\clist_map_function:NN` If the variable is empty, the mapping is skipped (otherwise, that comma-list would be seen as consisting of one empty item). Then loop over the comma-list, grabbing one comma-delimited item at a time. The end is marked by `\q_recursion_tail`. The auxiliary function `__clist_map_function:Nw` is also used in `\clist_map_inline:Nn`.

```

10296 \cs_new:Npn \clist_map_function:NN #1#2
10297 {
10298     \clist_if_empty:NF #1
10299     {
10300         \exp_last_unbraced:NNo \__clist_map_function:Nw #2 #1
10301         , \q_recursion_tail ,
10302         \prg_break_point:Nn \clist_map_break: { }
10303     }
10304 }
10305 \cs_new:Npn \__clist_map_function:Nw #1#2 ,
10306 {
10307     \quark_if_recursion_tail_break:nN {#2} \clist_map_break:
10308     #1 {#2}
10309     \__clist_map_function:Nw #1
10310 }
10311 \cs_generate_variant:Nn \clist_map_function:NN { c }

```

(End definition for `\clist_map_function:NN` and `__clist_map_function:Nw`. This function is documented on page 117.)

`\clist_map_function:nN` The n-type mapping function is a bit more awkward, since spaces must be trimmed from each item. Space trimming is again based on `__clist_trim_next:w`. The auxiliary `__clist_map_unbrace:Nw`

`__clist_map_function_n:Nn` receives as arguments the function, and the next non-empty item (after space trimming but before brace removal). One level of braces is removed by `__clist_map_unbrace:Nw`.

```

10312 \cs_new:Npn \clist_map_function:nN #1#2
10313 {
10314   \exp_after:wN \__clist_map_function_n:Nn \exp_after:wN #2
10315   \exp:w \__clist_trim_next:w \prg_do_nothing: #1 , \q_recursion_tail ,
10316   \prg_break_point:Nn \clist_map_break: { }
10317 }
10318 \cs_new:Npn \__clist_map_function_n:Nn #1 #2
10319 {
10320   \quark_if_recursion_tail_break:nN {#2} \clist_map_break:
10321   \__clist_map_unbrace:Nw #1 #2,
10322   \exp_after:wN \__clist_map_function_n:Nn \exp_after:wN #1
10323   \exp:w \__clist_trim_next:w \prg_do_nothing:
10324 }
10325 \cs_new:Npn \__clist_map_unbrace:Nw #1 #2, { #1 {#2} }

```

(End definition for `\clist_map_function:nN`, `__clist_map_function_n:Nn`, and `__clist_map_unbrace:Nw`. This function is documented on page 117.)

`\clist_map_inline:Nn` Inline mapping is done by creating a suitable function “on the fly”: this is done globally
`\clist_map_inline:cn` to avoid any issues with \TeX ’s groups. We use a different function for each level of
`\clist_map_inline:nn` nesting.

Since the mapping is non-expandable, we can perform the space-trimming needed by the `n` version simply by storing the comma-list in a variable. We don’t need a different comma-list for each nesting level: the comma-list is expanded before the mapping starts.

```

10326 \cs_new_protected:Npn \clist_map_inline:Nn #1#2
10327 {
10328   \clist_if_empty:NF #1
10329   {
10330     \int_gincr:N \g__kernel_prg_map_int
10331     \cs_gset_protected:cpn
10332       { \__clist_map_ \int_use:N \g__kernel_prg_map_int :w } ##1 {#2}
10333     \exp_last_unbraced:Nco \__clist_map_function:Nw
10334     { \__clist_map_ \int_use:N \g__kernel_prg_map_int :w }
10335     #1 , \q_recursion_tail ,
10336     \prg_break_point:Nn \clist_map_break:
10337     { \int_gdecr:N \g__kernel_prg_map_int }
10338   }
10339 }
10340 \cs_new_protected:Npn \clist_map_inline:nn #1
10341 {
10342   \clist_set:Nn \l__clist_internal_clist {#1}
10343   \clist_map_inline:Nn \l__clist_internal_clist
10344 }
10345 \cs_generate_variant:Nn \clist_map_inline:Nn { c }

```

(End definition for `\clist_map_inline:Nn` and `\clist_map_inline:nn`. These functions are documented on page 118.)

`\clist_map_variable:NNn` As for other comma-list mappings, filter out the case of an empty list. Same approach
`\clist_map_variable:cNn` as `\clist_map_function:Nn`, additionally we store each item in the given variable. As
`\clist_map_variable:nNn` for inline mappings, space trimming for the `n` variant is done by storing the comma
`__clist_map_variable:Nnw`

list in a variable. The strange `\use:n` avoids unlikely problems when #2 would contain `\q_recursion_stop`.

```

10346 \cs_new_protected:Npn \clist_map_variable:NNn #1#2#3
10347 {
10348   \clist_if_empty:NF #1
10349   {
10350     \exp_args:Nno \use:nn
10351     { \__clist_map_variable:Nnw #2 {#3} }
10352     #1
10353     , \q_recursion_tail , \q_recursion_stop
10354     \prg_break_point:Nn \clist_map_break: { }
10355   }
10356 }
10357 \cs_new_protected:Npn \clist_map_variable:nNn #1
10358 {
10359   \clist_set:Nn \l__clist_internal_clist {#1}
10360   \clist_map_variable:NNn \l__clist_internal_clist
10361 }
10362 \cs_new_protected:Npn \__clist_map_variable:Nnw #1#2#3,
10363 {
10364   \tl_set:Nn #1 {#3}
10365   \quark_if_recursion_tail_stop:N #1
10366   \use:n {#2}
10367   \__clist_map_variable:Nnw #1 {#2}
10368 }
10369 \cs_generate_variant:Nn \clist_map_variable:NNn { c }

```

(End definition for `\clist_map_variable:NNn`, `\clist_map_variable:nNn`, and `__clist_map_variable:Nnw`. These functions are documented on page 118.)

`\clist_map_break:` The break statements use the general `\prg_map_break:Nn` mechanism.
`\clist_map_break:n`

```

10370 \cs_new:Npn \clist_map_break:
10371 { \prg_map_break:Nn \clist_map_break: { } }
10372 \cs_new:Npn \clist_map_break:n
10373 { \prg_map_break:Nn \clist_map_break: }

```

(End definition for `\clist_map_break:` and `\clist_map_break:n`. These functions are documented on page 118.)

`\clist_count:N` Counting the items in a comma list is done using the same approach as for other token
`\clist_count:c` count functions: turn each entry into a +1 then use integer evaluation to actually do the
`\clist_count:n` mathematics. In the case of an n-type comma-list, we could of course use `\clist_map_-`
`__clist_count:n` **function:nN**, but that is very slow, because it carefully removes spaces. Instead, we loop
`__clist_count:w` manually, and skip blank items (but not {}, hence the extra spaces).

```

10374 \cs_new:Npn \clist_count:N #1
10375 {
10376   \int_eval:n
10377   {
10378     0
10379     \clist_map_function:NN #1 \__clist_count:n
10380   }
10381 }
10382 \cs_generate_variant:Nn \clist_count:N { c }
10383 \cs_new:Npx \clist_count:n #1

```

```

10384 {
10385   \exp_not:N \int_eval:n
10386   {
10387     0
10388     \exp_not:N \__clist_count:w \c_space_tl
10389     #1 \exp_not:n { , \q_recursion_tail , \q_recursion_stop }
10390   }
10391 }
10392 \cs_new:Npn \__clist_count:n #1 { + 1 }
10393 \cs_new:Npx \__clist_count:w #1 ,
10394 {
10395   \exp_not:n { \exp_args:Nf \quark_if_recursion_tail_stop:n } {#1}
10396   \exp_not:N \tl_if_blank:nF {#1} { + 1 }
10397   \exp_not:N \__clist_count:w \c_space_tl
10398 }

```

(End definition for `\clist_count:N` and others. These functions are documented on page 119.)

16.8 Using comma lists

`\clist_use:Nnnn` First check that the variable exists. Then count the items in the comma list. If it has none, output nothing. If it has one item, output that item, brace stripped (note that space-trimming has already been done when the comma list was assigned). If it has two, place the *<separator between two>* in the middle.

`__clist_use:nwwwnwn` Otherwise, `__clist_use:nwwwnwn` takes the following arguments; 1: a *<separator>*, 2, 3, 4: three items from the comma list (or quarks), 5: the rest of the comma list, 6: a *<continuation>* function (`use_ii` or `use_iii` with its *<separator>* argument), 7: junk, and 8: the temporary result, which is built in a brace group following `\q_stop`. The *<separator>* and the first of the three items are placed in the result, then we use the *<continuation>*, placing the remaining two items after it. When we begin this loop, the three items really belong to the comma list, the first `\q_mark` is taken as a delimiter to the `use_ii` function, and the continuation is `use_ii` itself. When we reach the last two items of the original token list, `\q_mark` is taken as a third item, and now the second `\q_mark` serves as a delimiter to `use_ii`, switching to the other *<continuation>*, `use_iii`, which uses the *<separator between final two>*.

```

10399 \cs_new:Npn \clist_use:Nnnn #1#2#3#4
10400 {
10401   \clist_if_exist:NTF #1
10402   {
10403     \int_case:nnF { \clist_count:N #1 }
10404     {
10405       { 0 } { }
10406       { 1 } { \exp_after:wN \__clist_use:wnn #1 , , { } }
10407       { 2 } { \exp_after:wN \__clist_use:wnn #1 , {#2} }
10408     }
10409     {
10410       \exp_after:wN \__clist_use:nwwwnwn
10411       \exp_after:wN { \exp_after:wN } #1 ,
10412       \q_mark , { \__clist_use:nwwwnwn {#3} }
10413       \q_mark , { \__clist_use:nwnn {#4} }
10414       \q_stop { }
10415     }
10416   }

```

```

10417     {
10418         \__kernel_msg_expandable_error:nnn
10419         { kernel } { bad-variable } {#1}
10420     }
10421 }
10422 \cs_generate_variant:Nn \clist_use:Nnnn { c }
10423 \cs_new:Npn \__clist_use:wnn #1 , #2 , #3 { \exp_not:n { #1 #3 #2 } }
10424 \cs_new:Npn \__clist_use:nwwwnnw
10425     #1#2 , #3 , #4 , #5 \q_mark , #6#7 \q_stop #8
10426     { #6 {#3} , {#4} , #5 \q_mark , {#6} #7 \q_stop { #8 #1 #2 } }
10427 \cs_new:Npn \__clist_use:nwnn #1#2 , #3 \q_stop #4
10428     { \exp_not:n { #4 #1 #2 } }
10429 \cs_new:Npn \clist_use:Nn #1#2
10430     { \clist_use:Nnnn #1 {#2} {#2} {#2} }
10431 \cs_generate_variant:Nn \clist_use:Nn { c }

```

(End definition for `\clist_use:Nnnn` and others. These functions are documented on page 119.)

16.9 Using a single item

<pre> \clist_item:Nn \clist_item:cn __clist_item:nnnN __clist_item:ffoN __clist_item:ffnN __clist_item_N_loop:nw </pre>	<p>To avoid needing to test the end of the list at each step, we first compute the $\langle length \rangle$ of the list. If the item number is 0, less than $-\langle length \rangle$, or more than $\langle length \rangle$, the result is empty. If it is negative, but not less than $-\langle length \rangle$, add $\langle length \rangle + 1$ to the item number before performing the loop. The loop itself is very simple, return the item if the counter reached 1, otherwise, decrease the counter and repeat.</p> <pre> 10432 \cs_new:Npn \clist_item:Nn #1#2 10433 { 10434 __clist_item:ffoN 10435 { \clist_count:N #1 } 10436 { \int_eval:n {#2} } 10437 #1 10438 __clist_item_N_loop:nw 10439 } 10440 \cs_new:Npn __clist_item:nnnN #1#2#3#4 10441 { 10442 \int_compare:nNnTF {#2} < 0 10443 { 10444 \int_compare:nNnTF {#2} < { - #1 } 10445 { \use_none_delimit_by_q_stop:w } 10446 { \exp_args:Nf #4 { \int_eval:n { #2 + 1 + #1 } } } 10447 } 10448 { 10449 \int_compare:nNnTF {#2} > {#1} 10450 { \use_none_delimit_by_q_stop:w } 10451 { #4 {#2} } 10452 } 10453 { } , #3 , \q_stop 10454 } 10455 \cs_generate_variant:Nn __clist_item:nnnN { ffo, ff } 10456 \cs_new:Npn __clist_item_N_loop:nw #1 #2, 10457 { 10458 \int_compare:nNnTF {#1} = 0 10459 { \use_i_delimit_by_q_stop:nw { \exp_not:n {#2} } } 10460 { \exp_args:Nf __clist_item_N_loop:nw { \int_eval:n { #1 - 1 } } } </pre>
---	---


```

10461 }
10462 \cs_generate_variant:Nn \clist_item:Nn { c }

```

(End definition for `\clist_item:Nn`, `__clist_item:nnnN`, and `__clist_item_N_loop:nw`. This function is documented on page 121.)

```

\clist_item:nn This starts in the same way as \clist_item:Nn by counting the items of the comma list.
\__clist_item_n:nw The final item should be space-trimmed before being brace-stripped, hence we insert a
\__clist_item_n_loop:nw couple of odd-looking \prg_do_nothing: to avoid losing braces. Blank items are ignored.
\__clist_item_n_end:n
\__clist_item_n_strip:n
\__clist_item_n_strip:w
10463 \cs_new:Npn \clist_item:nn #1#2
10464 {
10465   \__clist_item:ffnN
10466   { \clist_count:n {#1} }
10467   { \int_eval:n {#2} }
10468   {#1}
10469   \__clist_item_n:nw
10470 }
10471 \cs_new:Npn \__clist_item_n:nw #1
10472 { \__clist_item_n_loop:nw {#1} \prg_do_nothing: }
10473 \cs_new:Npn \__clist_item_n_loop:nw #1 #2,
10474 {
10475   \exp_args:No \tl_if_blank:nTF {#2}
10476   { \__clist_item_n_loop:nw {#1} \prg_do_nothing: }
10477   {
10478     \int_compare:nNnTF {#1} = 0
10479     { \exp_args:No \__clist_item_n_end:n {#2} }
10480     {
10481       \exp_args:Nf \__clist_item_n_loop:nw
10482       { \int_eval:n { #1 - 1 } }
10483       \prg_do_nothing:
10484     }
10485   }
10486 }
10487 \cs_new:Npn \__clist_item_n_end:n #1 #2 \q_stop
10488 { \tl_trim_spaces_apply:nN {#1} \__clist_item_n_strip:n }
10489 \cs_new:Npn \__clist_item_n_strip:n #1 { \__clist_item_n_strip:w #1 , }
10490 \cs_new:Npn \__clist_item_n_strip:w #1 , { \exp_not:n {#1} }

```

(End definition for `\clist_item:nn` and others. This function is documented on page 121.)

```

\clist_rand_item:n The N-type function is not implemented through the n-type function for efficiency: for
\clist_rand_item:N instance comma-list variables do not require space-trimming of their items. Even testing
\clist_rand_item:c for emptiness of an n-type comma-list is slow, so we count items first and use that both
\__clist_rand_item:nn for the emptiness test and the pseudo-random integer. Importantly, \clist_item:Nn
and \clist_item:nn only evaluate their argument once.

```

```

10491 \cs_new:Npn \clist_rand_item:n #1
10492 { \exp_args:Nf \__clist_rand_item:nn { \clist_count:n {#1} } {#1} }
10493 \cs_new:Npn \__clist_rand_item:nn #1#2
10494 {
10495   \int_compare:nNnF {#1} = 0
10496   { \clist_item:nn {#2} { \int_rand:nn { 1 } {#1} } }
10497 }
10498 \cs_new:Npn \clist_rand_item:N #1
10499 {

```

```

10500 \clist_if_empty:NF #1
10501 { \clist_item:Nn #1 { \int_rand:nn { 1 } { \clist_count:N #1 } } }
10502 }
10503 \cs_generate_variant:Nn \clist_rand_item:N { c }

```

(End definition for `\clist_rand_item:n`, `\clist_rand_item:N`, and `__clist_rand_item:nn`. These functions are documented on page 121.)

16.10 Viewing comma lists

```

\clist_show:N Apply the general \__kernel_chk_defined:NT and \msg_show:nnnnnn.
\clist_show:c 10504 \cs_new_protected:Npn \clist_show:N { \__clist_show:NN \msg_show:nnxxxx }
\clist_log:N   10505 \cs_generate_variant:Nn \clist_show:N { c }
\clist_log:c   10506 \cs_new_protected:Npn \clist_log:N { \__clist_show:NN \msg_log:nnxxxx }
\__clist_show:NN 10507 \cs_generate_variant:Nn \clist_log:N { c }
                  10508 \cs_new_protected:Npn \__clist_show:NN #1#2
                  10509 {
10510     \__kernel_chk_defined:NT #2
10511     {
10512         #1 { LaTeX/kernel } { show-clist }
10513         { \token_to_str:N #2 }
10514         { \clist_map_function:NN #2 \msg_show_item:n }
10515         { } { }
10516     }
10517 }

```

(End definition for `\clist_show:N`, `\clist_log:N`, and `__clist_show:NN`. These functions are documented on page 121.)

```

\clist_show:n A variant of the above: no existence check, empty first argument for the message.
\clist_log:n   10518 \cs_new_protected:Npn \clist_show:n { \__clist_show:NN \msg_show:nnxxxx }
\__clist_show:Nn 10519 \cs_new_protected:Npn \clist_log:n { \__clist_show:NN \msg_log:nnxxxx }
                  10520 \cs_new_protected:Npn \__clist_show:Nn #1#2
                  10521 {
10522     #1 { LaTeX/kernel } { show-clist }
10523     { } { \clist_map_function:nN {#2} \msg_show_item:n } { } { }
10524 }

```

(End definition for `\clist_show:n`, `\clist_log:n`, and `__clist_show:Nn`. These functions are documented on page 121.)

16.11 Scratch comma lists

```

\l_tmpa_clist Temporary comma list variables.
\l_tmpb_clist
\g_tmpa_clist 10525 \clist_new:N \l_tmpa_clist
\g_tmpb_clist 10526 \clist_new:N \l_tmpb_clist
               10527 \clist_new:N \g_tmpa_clist
               10528 \clist_new:N \g_tmpb_clist

```

(End definition for `\l_tmpa_clist` and others. These variables are documented on page 122.)

```

10529 </initex | package>

```

17 l3token implementation

10530 $\langle *initex | package \rangle$

10531 $\langle @@=char \rangle$

17.1 Manipulating and interrogating character tokens

$\backslash char_set_catcode:nn$ Simple wrappers around the primitives.

$\backslash char_value_catcode:n$ 10532 $\backslash cs_new_protected:Npn \backslash char_set_catcode:nn \#1\#2$
 $\backslash char_show_value_catcode:n$ 10533 $\{ \backslash tex_catcode:D \backslash int_eval:n \{ \#1 \} = \backslash int_eval:n \{ \#2 \} \backslash exp_stop_f: \}$
10534 $\backslash cs_new:Npn \backslash char_value_catcode:n \#1$
10535 $\{ \backslash tex_the:D \backslash tex_catcode:D \backslash int_eval:n \{ \#1 \} \backslash exp_stop_f: \}$
10536 $\backslash cs_new_protected:Npn \backslash char_show_value_catcode:n \#1$
10537 $\{ \backslash exp_args:Nf \backslash tl_show:n \{ \backslash char_value_catcode:n \{ \#1 \} \} \}$

(End definition for $\backslash char_set_catcode:nn$, $\backslash char_value_catcode:n$, and $\backslash char_show_value_catcode:n$. These functions are documented on page 126.)

$\backslash char_set_catcode_escape:N$
 $\backslash char_set_catcode_group_begin:N$ 10538 $\backslash cs_new_protected:Npn \backslash char_set_catcode_escape:N \#1$
 $\backslash char_set_catcode_group_end:N$ 10539 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 0 \} \}$
 $\backslash char_set_catcode_math_toggle:N$ 10540 $\backslash cs_new_protected:Npn \backslash char_set_catcode_group_begin:N \#1$
 $\backslash char_set_catcode_alignment:N$ 10541 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 1 \} \}$
 $\backslash char_set_catcode_end_line:N$ 10542 $\backslash cs_new_protected:Npn \backslash char_set_catcode_group_end:N \#1$
 $\backslash char_set_catcode_parameter:N$ 10543 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 2 \} \}$
 $\backslash char_set_catcode_math_superscript:N$ 10544 $\backslash cs_new_protected:Npn \backslash char_set_catcode_math_toggle:N \#1$
 $\backslash char_set_catcode_math_subscript:N$ 10545 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 3 \} \}$
 $\backslash char_set_catcode_ignore:N$ 10546 $\backslash cs_new_protected:Npn \backslash char_set_catcode_alignment:N \#1$
 $\backslash char_set_catcode_space:N$ 10547 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 4 \} \}$
 $\backslash char_set_catcode_letter:N$ 10548 $\backslash cs_new_protected:Npn \backslash char_set_catcode_end_line:N \#1$
 $\backslash char_set_catcode_other:N$ 10549 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 5 \} \}$
 $\backslash char_set_catcode_active:N$ 10550 $\backslash cs_new_protected:Npn \backslash char_set_catcode_parameter:N \#1$
 $\backslash char_set_catcode_comment:N$ 10551 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 6 \} \}$
 $\backslash char_set_catcode_invalid:N$ 10552 $\backslash cs_new_protected:Npn \backslash char_set_catcode_math_superscript:N \#1$
10553 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 7 \} \}$
10554 $\backslash cs_new_protected:Npn \backslash char_set_catcode_math_subscript:N \#1$
10555 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 8 \} \}$
10556 $\backslash cs_new_protected:Npn \backslash char_set_catcode_ignore:N \#1$
10557 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 9 \} \}$
10558 $\backslash cs_new_protected:Npn \backslash char_set_catcode_space:N \#1$
10559 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 10 \} \}$
10560 $\backslash cs_new_protected:Npn \backslash char_set_catcode_letter:N \#1$
10561 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 11 \} \}$
10562 $\backslash cs_new_protected:Npn \backslash char_set_catcode_other:N \#1$
10563 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 12 \} \}$
10564 $\backslash cs_new_protected:Npn \backslash char_set_catcode_active:N \#1$
10565 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 13 \} \}$
10566 $\backslash cs_new_protected:Npn \backslash char_set_catcode_comment:N \#1$
10567 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 14 \} \}$
10568 $\backslash cs_new_protected:Npn \backslash char_set_catcode_invalid:N \#1$
10569 $\{ \backslash char_set_catcode:nn \{ ' \#1 \} \{ 15 \} \}$

(End definition for $\backslash char_set_catcode_escape:N$ and others. These functions are documented on page 125.)

```

\char_set_catcode_escape:n
\char_set_catcode_group_begin:n
\char_set_catcode_group_end:n
\char_set_catcode_math_toggle:n
\char_set_catcode_alignment:n
\char_set_catcode_end_line:n
\char_set_catcode_parameter:n
\char_set_catcode_math_superscript:n
\char_set_catcode_math_subscript:n
\char_set_catcode_ignore:n
\char_set_catcode_space:n
\char_set_catcode_letter:n
\char_set_catcode_other:n
\char_set_catcode_active:n
\char_set_catcode_comment:n
\char_set_catcode_invalid:n

10570 \cs_new_protected:Npn \char_set_catcode_escape:n #1
10571 { \char_set_catcode:nn {#1} { 0 } }
10572 \cs_new_protected:Npn \char_set_catcode_group_begin:n #1
10573 { \char_set_catcode:nn {#1} { 1 } }
10574 \cs_new_protected:Npn \char_set_catcode_group_end:n #1
10575 { \char_set_catcode:nn {#1} { 2 } }
10576 \cs_new_protected:Npn \char_set_catcode_math_toggle:n #1
10577 { \char_set_catcode:nn {#1} { 3 } }
10578 \cs_new_protected:Npn \char_set_catcode_alignment:n #1
10579 { \char_set_catcode:nn {#1} { 4 } }
10580 \cs_new_protected:Npn \char_set_catcode_end_line:n #1
10581 { \char_set_catcode:nn {#1} { 5 } }
10582 \cs_new_protected:Npn \char_set_catcode_parameter:n #1
10583 { \char_set_catcode:nn {#1} { 6 } }
10584 \cs_new_protected:Npn \char_set_catcode_math_superscript:n #1
10585 { \char_set_catcode:nn {#1} { 7 } }
10586 \cs_new_protected:Npn \char_set_catcode_math_subscript:n #1
10587 { \char_set_catcode:nn {#1} { 8 } }
10588 \cs_new_protected:Npn \char_set_catcode_ignore:n #1
10589 { \char_set_catcode:nn {#1} { 9 } }
10590 \cs_new_protected:Npn \char_set_catcode_space:n #1
10591 { \char_set_catcode:nn {#1} { 10 } }
10592 \cs_new_protected:Npn \char_set_catcode_letter:n #1
10593 { \char_set_catcode:nn {#1} { 11 } }
10594 \cs_new_protected:Npn \char_set_catcode_other:n #1
10595 { \char_set_catcode:nn {#1} { 12 } }
10596 \cs_new_protected:Npn \char_set_catcode_active:n #1
10597 { \char_set_catcode:nn {#1} { 13 } }
10598 \cs_new_protected:Npn \char_set_catcode_comment:n #1
10599 { \char_set_catcode:nn {#1} { 14 } }
10600 \cs_new_protected:Npn \char_set_catcode_invalid:n #1
10601 { \char_set_catcode:nn {#1} { 15 } }

```

(End definition for `\char_set_catcode_escape:n` and others. These functions are documented on page 125.)

```

\char_set_mathcode:nn
\char_value_mathcode:n
\char_show_value_mathcode:n
\char_set_lccode:nn
\char_value_lccode:n
\char_show_value_lccode:n
\char_set_uccode:nn
\char_value_uccode:n
\char_show_value_uccode:n
\char_set_sfcode:nn
\char_value_sfcode:n
\char_show_value_sfcode:n

Pretty repetitive, but necessary!

10602 \cs_new_protected:Npn \char_set_mathcode:nn #1#2
10603 { \tex_mathcode:D \int_eval:n {#1} = \int_eval:n {#2} \exp_stop_f: }
10604 \cs_new:Npn \char_value_mathcode:n #1
10605 { \tex_the:D \tex_mathcode:D \int_eval:n {#1} \exp_stop_f: }
10606 \cs_new_protected:Npn \char_show_value_mathcode:n #1
10607 { \exp_args:Nf \tl_show:n { \char_value_mathcode:n {#1} } }
10608 \cs_new_protected:Npn \char_set_lccode:nn #1#2
10609 { \tex_lccode:D \int_eval:n {#1} = \int_eval:n {#2} \exp_stop_f: }
10610 \cs_new:Npn \char_value_lccode:n #1
10611 { \tex_the:D \tex_lccode:D \int_eval:n {#1} \exp_stop_f: }
10612 \cs_new_protected:Npn \char_show_value_lccode:n #1
10613 { \exp_args:Nf \tl_show:n { \char_value_lccode:n {#1} } }
10614 \cs_new_protected:Npn \char_set_uccode:nn #1#2
10615 { \tex_uccode:D \int_eval:n {#1} = \int_eval:n {#2} \exp_stop_f: }
10616 \cs_new:Npn \char_value_uccode:n #1
10617 { \tex_the:D \tex_uccode:D \int_eval:n {#1} \exp_stop_f: }

```

```

10618 \cs_new_protected:Npn \char_show_value_uccode:n #1
10619 { \exp_args:Nf \tl_show:n { \char_value_uccode:n {#1} } }
10620 \cs_new_protected:Npn \char_set_sfcode:nn #1#2
10621 { \tex_sfcode:D \int_eval:n {#1} = \int_eval:n {#2} \exp_stop_f: }
10622 \cs_new:Npn \char_value_sfcode:n #1
10623 { \tex_the:D \tex_sfcode:D \int_eval:n {#1} \exp_stop_f: }
10624 \cs_new_protected:Npn \char_show_value_sfcode:n #1
10625 { \exp_args:Nf \tl_show:n { \char_value_sfcode:n {#1} } }

```

(End definition for `\char_set_mathcode:nn` and others. These functions are documented on page 127.)

`\l_char_active_seq`
`\l_char_special_seq`

Two sequences for dealing with special characters. The first is characters which may be active, the second longer list is for “special” characters more generally. Both lists are escaped so that for example bulk code assignments can be carried out. In both cases, the order is by ASCII character code (as is done in for example `\ExplSyntaxOn`).

```

10626 \seq_new:N \l_char_special_seq
10627 \seq_set_split:Nnn \l_char_special_seq { }
10628 { \ \ " \# \$ \% \& \ \ ^ \_ \{ \} \~ }
10629 \seq_new:N \l_char_active_seq
10630 \seq_set_split:Nnn \l_char_active_seq { }
10631 { \ " \$ \& \^ \_ \~ }

```

(End definition for `\l_char_active_seq` and `\l_char_special_seq`. These variables are documented on page 127.)

17.2 Creating character tokens

`\char_set_active_eq:NN`
`\char_set_active_eq:Nc`
`\char_gset_active_eq:NN`
`\char_gset_active_eq:Nc`
`\char_set_active_eq:nN`
`\char_set_active_eq:nc`
`\char_gset_active_eq:nN`
`\char_gset_active_eq:nc`

Four simple functions with very similar definitions, so set up using an auxiliary. These are similar to LuaTeX’s `\lsetcharcode` primitive.

```

10632 \group_begin:
10633 \char_set_catcode_active:N \^^@
10634 \cs_set_protected:Npn \__char_tmp:nN #1#2
10635 {
10636   \cs_new_protected:cpn { #1 :nN } ##1
10637   {
10638     \group_begin:
10639     \char_set_lccode:nn { \^^@ } { ##1 }
10640     \tex_lowercase:D { \group_end: #2 ^^@ }
10641   }
10642   \cs_new_protected:cpx { #1 :NN } ##1
10643   { \exp_not:c { #1 : nN } { '##1 } }
10644 }
10645 \__char_tmp:nN { char_set_active_eq } \cs_set_eq:NN
10646 \__char_tmp:nN { char_gset_active_eq } \cs_gset_eq:NN
10647 \group_end:
10648 \cs_generate_variant:Nn \char_set_active_eq:NN { Nc }
10649 \cs_generate_variant:Nn \char_gset_active_eq:NN { Nc }
10650 \cs_generate_variant:Nn \char_set_active_eq:nN { nc }
10651 \cs_generate_variant:Nn \char_gset_active_eq:nN { nc }

```

(End definition for `\char_set_active_eq:NN` and others. These functions are documented on page 123.)

`__char_int_to_roman:w`

For efficiency in 8-bit engines, we use the faster primitive approach to making roman numerals.

```

10652 \cs_new_eq:NN \__char_int_to_roman:w \tex_romannumeral:D

```

(End definition for `_char_int_to_roman:w`.)

`\char_generate:nn` The aim here is to generate characters of (broadly) arbitrary category code. Where possible, that is done using engine support (X_YTeX, LuaTeX). There are though various issues which are covered below. At the interface layer, turn the two arguments into integers up-front so this is only done once.

```

\__char_generate_aux:nn
\__char_generate_aux:nnw
\__char_generate_auxii:nnw
  \l__char_tmp_tl
\__char_generate_invalid_catcode:
10653 \cs_new:Npn \char_generate:nn #1#2
10654 {
10655   \exp:w \exp_after:wN \__char_generate_aux:w
10656   \int_value:w \int_eval:n {#1} \exp_after:wN ;
10657   \int_value:w \int_eval:n {#2} ;
10658 }

```

Before doing any actual conversion, first some special case filtering. Spaces are out here as LuaTeX emulation only makes normal (charcode 32 spaces). However, `^^@` is filtered out separately as that can't be done with macro emulation either, so is flagged up separately. That done, hand off to the engine-dependent part.

```

10659 \cs_new:Npn \__char_generate_aux:w #1 ; #2 ;
10660 {
10661   \if_int_compare:w #2 = 10 \exp_stop_f:
10662     \if_int_compare:w #1 = 0 \exp_stop_f:
10663       \__kernel_msg_expandable_error:nn { kernel } { char-null-space }
10664     \else:
10665       \__kernel_msg_expandable_error:nn { kernel } { char-space }
10666     \fi:
10667   \else:
10668     \if_int_odd:w 0
10669       \if_int_compare:w #2 < 1 \exp_stop_f: 1 \fi:
10670       \if_int_compare:w #2 = 5 \exp_stop_f: 1 \fi:
10671       \if_int_compare:w #2 = 9 \exp_stop_f: 1 \fi:
10672       \if_int_compare:w #2 > 13 \exp_stop_f: 1 \fi: \exp_stop_f:
10673       \__kernel_msg_expandable_error:nn { kernel }
10674       { char-invalid-catcode }
10675     \else:
10676       \if_int_odd:w 0
10677         \if_int_compare:w #1 < 0 \exp_stop_f: 1 \fi:
10678         \if_int_compare:w #1 > \c_max_char_int 1 \fi: \exp_stop_f:
10679         \__kernel_msg_expandable_error:nn { kernel }
10680         { char-out-of-range }
10681       \else:
10682         \__char_generate_aux:nnw {#1} {#2}
10683       \fi:
10684     \fi:
10685   \fi:
10686   \exp_end:
10687 }
10688 \tl_new:N \l__char_tmp_tl

```

Engine-dependent definitions are now needed for the implementation. For LuaTeX and X_YTeX there is engine-level support. They can do cases that macro emulation can't. All of those are filtered out here using a primitive-based boolean expression to avoid fixing the category code of the null character used in the false branch (for 8-bit engines). The final level is the basic definition at the engine level: the arguments here are integers so there is no need to worry about them too much. Older versions of X_YTeX cannot generate

active characters so we filter that: at some future stage that may change: the slightly odd ordering of auxiliaries reflects that.

```

10689 \group_begin:
10690 \*package>
10691   \char_set_catcode_active:N \^^L
10692   \cs_set:Npn \^^L { }
10693 \*package>
10694   \char_set_catcode_other:n { 0 }
10695   \if_int_odd:w 0
10696     \sys_if_engine luatex:T { 1 }
10697     \sys_if_engine xetex:T { 1 } \exp_stop_f:
10698   \sys_if_engine luatex:TF
10699   {
10700     \cs_new:Npn \__char_generate_aux:nnw #1#2#3 \exp_end:
10701     {
10702       #3
10703       \exp_after:wN \exp_after:wN \exp_after:wN \exp_end:
10704       \lua_now:e { 13kernel.charcat(#1, #2) }
10705     }
10706   }
10707   {
10708     \cs_new:Npn \__char_generate_aux:nnw #1#2#3 \exp_end:
10709     {
10710       #3
10711       \exp_after:wN \exp_end:
10712       \tex_Ucharcat:D #1 \exp_stop_f: #2 \exp_stop_f:
10713     }
10714     \cs_if_exist:NF \tex_expanded:D
10715     {
10716       \cs_new_eq:NN \__char_generate_auxii:nnw \__char_generate_aux:nnw
10717       \cs_gset:Npn \__char_generate_aux:nnw #1#2#3 \exp_end:
10718       {
10719         #3
10720         \if_int_compare:w #2 = 13 \exp_stop_f:
10721           \__kernel_msg_expandable_error:nn { kernel } { char-active }
10722         \else:
10723           \__char_generate_auxii:nnw {#1} {#2}
10724         \fi:
10725         \exp_end:
10726       }
10727     }
10728   }
10729   \else:

```

For engines where `\Ucharcat` isn't available or emulated, we have to work in macros, and cover only the 8-bit range. The first stage is to build up a `t1` containing `^^@` with each category code that can be accessed in this way, with an error set up for the other cases. This is all done such that it can be quickly accessed using a `\if_case:w` low-level conditional. There are a few things to notice here. As `^^L` is `\outer` we need to locally set it to avoid a problem. To get open/close braces into the list, they are set up using `\if_false:` pairing and are then x-type expanded together into the desired form.

```

10730   \t1_set:Nn \l__char_tmp_t1 { \exp_not:N \or: }
10731   \char_set_catcode_group_begin:n { 0 } % {
10732   \t1_put_right:Nn \l__char_tmp_t1 { ^^@ \if_false: } }

```

```

10733 \char_set_catcode_group_end:n { 0 }
10734 \tl_put_right:Nn \l__char_tmp_tl { { \fi: \exp_not:N \or: ^^@ } % }
10735 \tl_set:Nx \l__char_tmp_tl { \l__char_tmp_tl }
10736 \char_set_catcode_math_toggle:n { 0 }
10737 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10738 \char_set_catcode_alignment:n { 0 }
10739 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10740 \tl_put_right:Nn \l__char_tmp_tl { \or: }
10741 \char_set_catcode_parameter:n { 0 }
10742 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10743 \char_set_catcode_math_superscript:n { 0 }
10744 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10745 \char_set_catcode_math_subscript:n { 0 }
10746 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10747 \tl_put_right:Nn \l__char_tmp_tl { \or: }

```

For making spaces, there needs to be an o-type expansion of a `\use:n` (or some other tokenization) to avoid dropping the space. We also set up active tokens although they are (currently) filtered out by the interface layer (`\Ucharcat` cannot make active tokens).

```

10748 \char_set_catcode_space:n { 0 }
10749 \tl_put_right:No \l__char_tmp_tl { \use:n { \or: } ^^@ }
10750 \char_set_catcode_letter:n { 0 }
10751 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10752 \char_set_catcode_other:n { 0 }
10753 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }
10754 \char_set_catcode_active:n { 0 }
10755 \tl_put_right:Nn \l__char_tmp_tl { \or: ^^@ }

```

Convert the above temporary list into a series of constant token lists, one for each character code, using `\tex_lowercase:D` to convert `^^@` in each case. The x-type expansion ensures that `\tex_lowercase:D` receives the contents of the token list. In package mode, `^^L` is awkward hence this is done in three parts. Notice that at this stage `^^@` is active.

```

10756 \cs_set_protected:Npn \__char_tmp:n #1
10757 {
10758   \char_set_lccode:nn { 0 } {#1}
10759   \char_set_lccode:nn { 32 } {#1}
10760   \exp_args:Nx \tex_lowercase:D
10761   {
10762     \tl_const:Nn
10763       \exp_not:c { c__char_ \__char_int_to_roman:w #1 _tl }
10764       { \exp_not:o \l__char_tmp_tl }
10765   }
10766 }
10767 <*package>
10768 \int_step_function:nnN { 0 } { 11 } \__char_tmp:n
10769 \group_begin:
10770   \tl_replace_once:Nnn \l__char_tmp_tl { ^^@ } { \ERROR }
10771   \__char_tmp:n { 12 }
10772 \group_end:
10773 \int_step_function:nnN { 13 } { 255 } \__char_tmp:n
10774 </package>
10775 <*initex>
10776 \int_step_function:nnN { 0 } { 255 } \__char_tmp:n
10777 </initex>

```


As T_EX is very unhappy if it finds an alignment character inside a primitive `\halign` even when skipping false branches, some precautions are required. T_EX is happy if the token is hidden between braces within `\if_false: ... \fi:`.

```

10778     \cs_new:Npn \__char_generate_aux:nnw #1#2#3 \exp_end:
10779     {
10780         #3
10781         \if_false: { \fi:
10782             \exp_after:wN \exp_after:wN
10783             \exp_after:wN \exp_end:
10784             \exp_after:wN \exp_after:wN
10785             \if_case:w #2
10786                 \exp_last_unbraced:Nv \exp_stop_f:
10787                 { c__char_ \__char_int_to_roman:w #1 _tl }
10788             \or: }
10789             \fi:
10790         }
10791     \fi:
10792 \group_end:

```

(End definition for `\char_generate:nn` and others. This function is documented on page 124.)

`\c_catcode_other_space_tl` Create a space with category code 12: an “other” space.

```

10793 \tl_const:Nx \c_catcode_other_space_tl { \char_generate:nn { ‘\ ’ } { 12 } }

```

(End definition for `\c_catcode_other_space_tl`. This function is documented on page 124.)

17.3 Generic tokens

```

10794 <@@=token>

```

`\token_to_meaning:N` These are all defined in `l3basics`, as they are needed “early”. This is just a reminder!

`\token_to_meaning:c`

`\token_to_str:N`

`\token_to_str:c`

(End definition for `\token_to_meaning:N` and `\token_to_str:N`. These functions are documented on page 128.)

`\c_group_begin_token`

`\c_group_end_token`

`\c_math_toggle_token`

`\c_alignment_token`

`\c_parameter_token`

`\c_math_superscript_token`

`\c_math_subscript_token`

`\c_space_token`

`\c_catcode_letter_token`

`\c_catcode_other_token`

We define these useful tokens. For the brace and space tokens things have to be done by hand: the formal argument spec. for `\cs_new_eq:NN` does not cover them so we do things by hand. (As currently coded it would *work* with `\cs_new_eq:NN` but that’s not really a great idea to show off: we want people to stick to the defined interfaces and that includes us.) So that these few odd names go into the log when appropriate there is a need to hand-apply the `__kernel_chk_if_free_cs:N` check.

```

10795 \group_begin:
10796     \__kernel_chk_if_free_cs:N \c_group_begin_token
10797     \tex_global:D \tex_let:D \c_group_begin_token {
10798         \__kernel_chk_if_free_cs:N \c_group_end_token
10799         \tex_global:D \tex_let:D \c_group_end_token }
10800     \char_set_catcode_math_toggle:N \*
10801     \cs_new_eq:NN \c_math_toggle_token *
10802     \char_set_catcode_alignment:N \*
10803     \cs_new_eq:NN \c_alignment_token *
10804     \cs_new_eq:NN \c_parameter_token #
10805     \cs_new_eq:NN \c_math_superscript_token ^
10806     \char_set_catcode_math_subscript:N \*
10807     \cs_new_eq:NN \c_math_subscript_token *

```

```

10808 \__kernel_chk_if_free_cs:N \c_space_token
10809 \use:n { \tex_global:D \tex_let:D \c_space_token = ~ } ~
10810 \cs_new_eq:NN \c_catcode_letter_token a
10811 \cs_new_eq:NN \c_catcode_other_token 1
10812 \group_end:

```

(End definition for \c_group_begin_token and others. These functions are documented on page 128.)

\c_catcode_active_tl Not an implicit token!

```

10813 \group_begin:
10814 \char_set_catcode_active:N \*
10815 \tl_const:Nn \c_catcode_active_tl { \exp_not:N * }
10816 \group_end:

```

(End definition for \c_catcode_active_tl. This variable is documented on page 128.)

17.4 Token conditionals

\token_if_group_begin_p:N Check if token is a begin group token. We use the constant \c_group_begin_token for this.

\token_if_group_begin:NTF

```

10817 \prg_new_conditional:Npnn \token_if_group_begin:N #1 { p , T , F , TF }
10818 {
10819     \if_catcode:w \exp_not:N #1 \c_group_begin_token
10820     \prg_return_true: \else: \prg_return_false: \fi:
10821 }

```

(End definition for \token_if_group_begin:NTF. This function is documented on page 129.)

\token_if_group_end_p:N Check if token is a end group token. We use the constant \c_group_end_token for this.

\token_if_group_end:NTF

```

10822 \prg_new_conditional:Npnn \token_if_group_end:N #1 { p , T , F , TF }
10823 {
10824     \if_catcode:w \exp_not:N #1 \c_group_end_token
10825     \prg_return_true: \else: \prg_return_false: \fi:
10826 }

```

(End definition for \token_if_group_end:NTF. This function is documented on page 129.)

\token_if_math_toggle_p:N Check if token is a math shift token. We use the constant \c_math_toggle_token for this.

\token_if_math_toggle:NTF

```

10827 \prg_new_conditional:Npnn \token_if_math_toggle:N #1 { p , T , F , TF }
10828 {
10829     \if_catcode:w \exp_not:N #1 \c_math_toggle_token
10830     \prg_return_true: \else: \prg_return_false: \fi:
10831 }

```

(End definition for \token_if_math_toggle:NTF. This function is documented on page 129.)

\token_if_alignment_p:N Check if token is an alignment tab token. We use the constant \c_alignment_token for this.

\token_if_alignment:NTF

```

10832 \prg_new_conditional:Npnn \token_if_alignment:N #1 { p , T , F , TF }
10833 {
10834     \if_catcode:w \exp_not:N #1 \c_alignment_token
10835     \prg_return_true: \else: \prg_return_false: \fi:
10836 }

```

(End definition for `\token_if_alignment:NTF`. This function is documented on page 129.)

`\token_if_parameter_p:N` Check if token is a parameter token. We use the constant `\c_parameter_token` for this.
`\token_if_parameter:N \underline{TF}` We have to trick TeX a bit to avoid an error message: within a group we prevent `\c_parameter_token` from behaving like a macro parameter character. The definitions of `\prg_new_conditional:Npnn` are global, so they remain after the group.

```

10837 \group_begin:
10838 \cs_set_eq:NN \c_parameter_token \scan_stop:
10839 \prg_new_conditional:Npnn \token_if_parameter:N #1 { p , T , F , TF }
10840 {
10841     \if_catcode:w \exp_not:N #1 \c_parameter_token
10842     \prg_return_true: \else: \prg_return_false: \fi:
10843 }
10844 \group_end:

```

(End definition for `\token_if_parameter:NTF`. This function is documented on page 129.)

`\token_if_math_superscript_p:N` Check if token is a math superscript token. We use the constant `\c_math_superscript_token` for this.
`\token_if_math_superscript:N \underline{TF}`

```

10845 \prg_new_conditional:Npnn \token_if_math_superscript:N #1
10846 { p , T , F , TF }
10847 {
10848     \if_catcode:w \exp_not:N #1 \c_math_superscript_token
10849     \prg_return_true: \else: \prg_return_false: \fi:
10850 }

```

(End definition for `\token_if_math_superscript:NTF`. This function is documented on page 129.)

`\token_if_math_subscript_p:N` Check if token is a math subscript token. We use the constant `\c_math_subscript_token` for this.
`\token_if_math_subscript:N \underline{TF}`

```

10851 \prg_new_conditional:Npnn \token_if_math_subscript:N #1 { p , T , F , TF }
10852 {
10853     \if_catcode:w \exp_not:N #1 \c_math_subscript_token
10854     \prg_return_true: \else: \prg_return_false: \fi:
10855 }

```

(End definition for `\token_if_math_subscript:NTF`. This function is documented on page 129.)

`\token_if_space_p:N` Check if token is a space token. We use the constant `\c_space_token` for this.

`\token_if_space:N \underline{TF}`

```

10856 \prg_new_conditional:Npnn \token_if_space:N #1 { p , T , F , TF }
10857 {
10858     \if_catcode:w \exp_not:N #1 \c_space_token
10859     \prg_return_true: \else: \prg_return_false: \fi:
10860 }

```

(End definition for `\token_if_space:NTF`. This function is documented on page 129.)

`\token_if_letter_p:N` Check if token is a letter token. We use the constant `\c_catcode_letter_token` for this.

`\token_if_letter:N \underline{TF}`

```

10861 \prg_new_conditional:Npnn \token_if_letter:N #1 { p , T , F , TF }
10862 {
10863     \if_catcode:w \exp_not:N #1 \c_catcode_letter_token
10864     \prg_return_true: \else: \prg_return_false: \fi:
10865 }

```

(End definition for `\token_if_letter:NTF`. This function is documented on page 130.)

`\token_if_other_p:N` Check if token is an other char token. We use the constant `\c_catcode_other_token`
`\token_if_other:N \underline{TF}` for this.

```
10866 \prg_new_conditional:Npnn \token_if_other:N #1 { p , T , F , TF }
10867 {
10868     \if_catcode:w \exp_not:N #1 \c_catcode_other_token
10869     \prg_return_true: \else: \prg_return_false: \fi:
10870 }
```

(End definition for `\token_if_other:N \underline{TF}` . This function is documented on page 130.)

`\token_if_active_p:N` Check if token is an active char token. We use the constant `\c_catcode_active_tl` for
`\token_if_active:N \underline{TF}` this. A technical point is that `\c_catcode_active_tl` is in fact a macro expanding to
`\exp_not:N *`, where `*` is active.

```
10871 \prg_new_conditional:Npnn \token_if_active:N #1 { p , T , F , TF }
10872 {
10873     \if_catcode:w \exp_not:N #1 \c_catcode_active_tl
10874     \prg_return_true: \else: \prg_return_false: \fi:
10875 }
```

(End definition for `\token_if_active:N \underline{TF}` . This function is documented on page 130.)

`\token_if_eq_meaning_p:NN` Check if the tokens #1 and #2 have same meaning.

`\token_if_eq_meaning:NN \underline{TF}`

```
10876 \prg_new_conditional:Npnn \token_if_eq_meaning:NN #1#2 { p , T , F , TF }
10877 {
10878     \if_meaning:w #1 #2
10879     \prg_return_true: \else: \prg_return_false: \fi:
10880 }
```

(End definition for `\token_if_eq_meaning:NN \underline{TF}` . This function is documented on page 130.)

`\token_if_eq_catcode_p:NN` Check if the tokens #1 and #2 have same category code.

`\token_if_eq_catcode:NN \underline{TF}`

```
10881 \prg_new_conditional:Npnn \token_if_eq_catcode:NN #1#2 { p , T , F , TF }
10882 {
10883     \if_catcode:w \exp_not:N #1 \exp_not:N #2
10884     \prg_return_true: \else: \prg_return_false: \fi:
10885 }
```

(End definition for `\token_if_eq_catcode:NN \underline{TF}` . This function is documented on page 130.)

`\token_if_eq_charcode_p:NN` Check if the tokens #1 and #2 have same character code.

`\token_if_eq_charcode:NN \underline{TF}`

```
10886 \prg_new_conditional:Npnn \token_if_eq_charcode:NN #1#2 { p , T , F , TF }
10887 {
10888     \if_charcode:w \exp_not:N #1 \exp_not:N #2
10889     \prg_return_true: \else: \prg_return_false: \fi:
10890 }
```

(End definition for `\token_if_eq_charcode:NN \underline{TF}` . This function is documented on page 130.)

`\token_if_macro_p:N` When a token is a macro, `\token_to_meaning:N` always outputs something like
`\token_if_macro:N \underline{TF}` `\long macro:#1->#1` so we could naively check to see if the meaning contains `->`.
`__token_if_macro_p:w` However, this can fail the five `\...mark` primitives, whose meaning has the form
`\...mark:<user material>`. The problem is that the `<user material>` can contain `->`.

However, only characters, macros, and marks can contain the colon character. The idea is thus to grab until the first `:`, and analyse what is left. However, macros can have

any combination of `\long`, `\protected` or `\outer` (not used in L^AT_EX3) before the string `macro:`. We thus only select the part of the meaning between the first `ma` and the first following `:`. If this string is `cro`, then we have a macro. If the string is `rk`, then we have a mark. The string can also be `cro parameter character` for a colon with a weird category code (namely the usual category code of `#`). Otherwise, it is empty.

This relies on the fact that `\long`, `\protected`, `\outer` cannot contain `ma`, regardless of the escape character, even if the escape character is `m...`.

Both `ma` and `:` must be of category code 12 (other), so are detokenized.

```

10891 \use:x
10892 {
10893   \prg_new_conditional:Npnn \exp_not:N \token_if_macro:N #1
10894   { p , T , F , TF }
10895   {
10896     \exp_not:N \exp_after:wN \exp_not:N \__token_if_macro_p:w
10897     \exp_not:N \token_to_meaning:N #1 \tl_to_str:n { ma : }
10898     \exp_not:N \q_stop
10899   }
10900   \cs_new:Npn \exp_not:N \__token_if_macro_p:w
10901   ##1 \tl_to_str:n { ma } ##2 \c_colon_str ##3 \exp_not:N \q_stop
10902 }
10903 {
10904   \str_if_eq:nnTF { #2 } { cro }
10905   { \prg_return_true: }
10906   { \prg_return_false: }
10907 }

```

(End definition for `\token_if_macro:N` and `__token_if_macro_p:w`. This function is documented on page 130.)

`\token_if_cs_p:N` Check if token has same catcode as a control sequence. This follows the same pattern as `\token_if_letter:N` etc. We use `\scan_stop:` for this.

`\token_if_cs:N` *TF*

```

10908 \prg_new_conditional:Npnn \token_if_cs:N #1 { p , T , F , TF }
10909 {
10910   \if_catcode:w \exp_not:N #1 \scan_stop:
10911   \prg_return_true: \else: \prg_return_false: \fi:
10912 }

```

(End definition for `\token_if_cs:N`. This function is documented on page 130.)

`\token_if_expandable_p:N` Check if token is expandable. We use the fact that T_EX temporarily converts `\exp_not:N` $\langle token \rangle$ into `\scan_stop:` if $\langle token \rangle$ is expandable. An undefined token is not considered as expandable. No problem nesting the conditionals, since the third `#1` is only skipped if it is non-expandable (hence not part of T_EX's conditional apparatus).

`\token_if_expandable:N` *TF*

```

10913 \prg_new_conditional:Npnn \token_if_expandable:N #1 { p , T , F , TF }
10914 {
10915   \exp_after:wN \if_meaning:w \exp_not:N #1 #1
10916   \prg_return_false:
10917   \else:
10918     \if_cs_exist:N #1
10919     \prg_return_true:
10920     \else:
10921     \prg_return_false:
10922   \fi:

```

```

10923     \fi:
10924   }

```

(End definition for `\token_if_expandable:NTF`. This function is documented on page 130.)

`__token_delimit_by_char:w` These auxiliary functions are used below to define some conditionals which detect whether the `\meaning` of their argument begins with a particular string. Each auxiliary takes an argument delimited by a string, a second one delimited by `\q_stop`, and returns the first one and its delimiter. This result is eventually compared to another string.

```

\__token_delimit_by_count:w
\__token_delimit_by_dimen:w
\__token_delimit_by_macro:w
\__token_delimit_by_muskip:w
\__token_delimit_by_skip:w
\__token_delimit_by_toks:w

10925 \group_begin:
10926 \cs_set_protected:Npn \__token_tmp:w #1
10927 {
10928   \use:x
10929   {
10930     \cs_new:Npn \exp_not:c { __token_delimit_by_ #1 :w }
10931     #####1 \tl_to_str:n {#1} #####2 \exp_not:N \q_stop
10932     { #####1 \tl_to_str:n {#1} }
10933   }
10934 }
10935 \__token_tmp:w { char" }
10936 \__token_tmp:w { count }
10937 \__token_tmp:w { dimen }
10938 \__token_tmp:w { macro }
10939 \__token_tmp:w { muskip }
10940 \__token_tmp:w { skip }
10941 \__token_tmp:w { toks }
10942 \group_end:

```

(End definition for `__token_delimit_by_char:w` and others.)

`\token_if_chardef_p:N` Each of these conditionals tests whether its argument's `\meaning` starts with a given string. This is essentially done by having an auxiliary grab an argument delimited by the string and testing whether the argument was empty. Of course, a copy of this string must first be added to the end of the `\meaning` to avoid a runaway argument in case it does not contain the string. Two complications arise. First, the escape character is not fixed, and cannot be included in the delimiter of the auxiliary function (this function cannot be defined on the fly because tests must remain expandable): instead the first argument of the auxiliary (plus the delimiter to avoid complications with trailing spaces) is compared using `\str_if_eq:eeTF` to the result of applying `\token_to_str:N` to a control sequence. Second, the `\meaning` of primitives such as `\dimen` or `\dimendef` starts in the same way as registers such as `\dimen123`, so they must be tested for.

`\token_if_chardef:NTF` Characters used as delimiters must have catcode 12 and are obtained through `\tl_to_str:n`. This requires doing all definitions within `x`-expansion. The temporary function `__token_tmp:w` used to define each conditional receives three arguments: the name of the conditional, the auxiliary's delimiter (also used to name the auxiliary), and the string to which one compares the auxiliary's result. Note that the `\meaning` of a protected long macro starts with `\protected\long macro`, with no space after `\protected` but a space after `\long`, hence the mixture of `\token_to_str:N` and `\tl_to_str:n`.

`\token_if_dim_register_p:N` For the first five conditionals, `\cs_if_exist:cT` turns out to be `false`, and the code boils down to a string comparison between the result of the auxiliary on the `\meaning` of the conditional's argument `#####1`, and `#3`. Both are evaluated at run-time, as this is important to get the correct escape character.

The other five conditionals have additional code that compares the argument #####1 to two T_EX primitives which would wrongly be recognized as registers otherwise. Despite using T_EX's primitive conditional construction, this does not break when #####1 is itself a conditional, because branches of the conditionals are only skipped if #####1 is one of the two primitives that are tested for (which are not T_EX conditionals).

```

10943 \group_begin:
10944 \cs_set_protected:Npn \__token_tmp:w #1#2#3
10945 {
10946   \use:x
10947   {
10948     \prg_new_conditional:Npnn \exp_not:c { token_if_ #1 :N } #####1
10949     { p , T , F , TF }
10950     {
10951       \cs_if_exist:cT { tex_ #2 :D }
10952       {
10953         \exp_not:N \if_meaning:w #####1 \exp_not:c { tex_ #2 :D }
10954         \exp_not:N \prg_return_false:
10955         \exp_not:N \else:
10956         \exp_not:N \if_meaning:w #####1 \exp_not:c { tex_ #2 def:D }
10957         \exp_not:N \prg_return_false:
10958         \exp_not:N \else:
10959       }
10960       \exp_not:N \str_if_eq:eeTF
10961       {
10962         \exp_not:N \exp_after:wN
10963         \exp_not:c { __token_delimit_by_ #2 :w }
10964         \exp_not:N \token_to_meaning:N #####1
10965         ? \tl_to_str:n {#2} \exp_not:N \q_stop
10966       }
10967       { \exp_not:n {#3} }
10968       { \exp_not:N \prg_return_true: }
10969       { \exp_not:N \prg_return_false: }
10970       \cs_if_exist:cT { tex_ #2 :D }
10971       {
10972         \exp_not:N \fi:
10973         \exp_not:N \fi:
10974       }
10975     }
10976   }
10977 }
10978 __token_tmp:w { chardef } { char" } { \token_to_str:N \char" }
10979 __token_tmp:w { mathchardef } { char" } { \token_to_str:N \mathchar" }
10980 __token_tmp:w { long_macro } { macro } { \tl_to_str:n { \long } macro }
10981 __token_tmp:w { protected_macro } { macro }
10982   { \tl_to_str:n { \protected } macro }
10983 __token_tmp:w { protected_long_macro } { macro }
10984   { \token_to_str:N \protected \tl_to_str:n { \long } macro }
10985 __token_tmp:w { dim_register } { dimen } { \token_to_str:N \dimen }
10986 __token_tmp:w { int_register } { count } { \token_to_str:N \count }
10987 __token_tmp:w { muskip_register } { muskip } { \token_to_str:N \muskip }
10988 __token_tmp:w { skip_register } { skip } { \token_to_str:N \skip }
10989 __token_tmp:w { toks_register } { toks } { \token_to_str:N \toks }
10990 \group_end:

```

(End definition for `\token_if_chardef:NTF` and others. These functions are documented on page 131.)

```
\token_if_primitive_p:N
\token_if_primitive:NTF
\__token_if_primitive:NNw
  \__token_if_primitive_space:w
  \__token_if_primitive_nullfont:N
\__token_if_primitive_loop:N
  \__token_if_primitive:Nw
  \__token_if_primitive_undefined:N
```

We filter out macros first, because they cause endless trouble later otherwise.

Primitives are almost distinguished by the fact that the result of `\token_to_meaning:N` is formed from letters only. Every other token has either a space (e.g., the letter A), a digit (e.g., `\count123`) or a double quote (e.g., `\char"A`).

Ten exceptions: on the one hand, `\tex_undefined:D` is not a primitive, but its meaning is undefined, only letters; on the other hand, `\space`, `\italiccorr`, `\hyphen`, `\firstmark`, `\topmark`, `\botmark`, `\splitfirstmark`, `\splitbotmark`, and `\nullfont` are primitives, but have non-letters in their meaning.

We start by removing the two first (non-space) characters from the meaning. This removes the escape character (which may be nonexistent depending on `\endlinechar`), and takes care of three of the exceptions: `\space`, `\italiccorr` and `\hyphen`, whose meaning is at most two characters. This leaves a string terminated by some `:`, and `\q_stop`.

The meaning of each one of the five `\...mark` primitives has the form $\langle letters \rangle : \langle user material \rangle$. In other words, the first non-letter is a colon. We remove everything after the first colon.

We are now left with a string, which we must analyze. For primitives, it contains only letters. For non-primitives, it contains either `"`, or a space, or a digit. Two exceptions remain: `\tex_undefined:D`, which is not a primitive, and `\nullfont`, which is a primitive.

Spaces cannot be grabbed in an undelimited way, so we check them separately. If there is a space, we test for `\nullfont`. Otherwise, we go through characters one by one, and stop at the first character less than ‘A’ (this is not quite a test for “only letters”, but is close enough to work in this context). If this first character is `:` then we have a primitive, or `\tex_undefined:D`, and if it is `"` or a digit, then the token is not a primitive.

```
10991 \tex_chardef:D \c__token_A_int = 'A ~ %
10992 \use:x
10993 {
10994   \prg_new_conditional:Npnn \exp_not:N \token_if_primitive:N ##1
10995     { p , T , F , TF }
10996     {
10997       \exp_not:N \token_if_macro:NTF ##1
10998       \exp_not:N \prg_return_false:
10999       {
11000         \exp_not:N \exp_after:wN \exp_not:N \__token_if_primitive:NNw
11001         \exp_not:N \token_to_meaning:N ##1
11002         \tl_to_str:n { : : : } \exp_not:N \q_stop ##1
11003       }
11004     }
11005   \cs_new:Npn \exp_not:N \__token_if_primitive:NNw
11006     ##1##2 ##3 \c_colon_str ##4 \exp_not:N \q_stop
11007     {
11008       \exp_not:N \tl_if_empty:oTF
11009       { \exp_not:N \__token_if_primitive_space:w ##3 ~ }
11010       {
11011         \exp_not:N \__token_if_primitive_loop:N ##3
11012         \c_colon_str \exp_not:N \q_stop
11013       }
11014       { \exp_not:N \__token_if_primitive_nullfont:N }
11015     }
```



```

11016 }
11017 \cs_new:Npn \__token_if_primitive_space:w #1 ~ { }
11018 \cs_new:Npn \__token_if_primitive_nullfont:N #1
11019 {
11020   \if_meaning:w \tex_nullfont:D #1
11021     \prg_return_true:
11022   \else:
11023     \prg_return_false:
11024   \fi:
11025 }
11026 \cs_new:Npn \__token_if_primitive_loop:N #1
11027 {
11028   \if_int_compare:w '#1 < \c__token_A_int %
11029     \exp_after:wN \__token_if_primitive:Nw
11030     \exp_after:wN #1
11031   \else:
11032     \exp_after:wN \__token_if_primitive_loop:N
11033   \fi:
11034 }
11035 \cs_new:Npn \__token_if_primitive:Nw #1 #2 \q_stop
11036 {
11037   \if:w : #1
11038     \exp_after:wN \__token_if_primitive_undefined:N
11039   \else:
11040     \prg_return_false:
11041     \exp_after:wN \use_none:n
11042   \fi:
11043 }
11044 \cs_new:Npn \__token_if_primitive_undefined:N #1
11045 {
11046   \if_cs_exist:N #1
11047     \prg_return_true:
11048   \else:
11049     \prg_return_false:
11050   \fi:
11051 }

```

(End definition for `\token_if_primitive:NTF` and others. This function is documented on page [132](#).)

17.5 Peeking ahead at the next token

```
11052 <@@=peek>
```

Peeking ahead is implemented using a two part mechanism. The outer level provides a defined interface to the lower level material. This allows a large amount of code to be shared. There are four cases:

1. peek at the next token;
2. peek at the next non-space token;
3. peek at the next token and remove it;
4. peek at the next non-space token and remove it.

\l_peek_token Storage tokens which are publicly documented: the token peeked.

\g_peek_token 11053 \cs_new_eq:NN \l_peek_token ?
11054 \cs_new_eq:NN \g_peek_token ?

(End definition for \l_peek_token and \g_peek_token. These variables are documented on page 132.)

\l__peek_search_token The token to search for as an implicit token: cf. \l__peek_search_tl.

11055 \cs_new_eq:NN \l__peek_search_token ?

(End definition for \l__peek_search_token.)

\l__peek_search_tl The token to search for as an explicit token: cf. \l__peek_search_token.

11056 \tl_new:N \l__peek_search_tl

(End definition for \l__peek_search_tl.)

__peek_true:w Functions used by the branching and space-stripping code.

__peek_true_aux:w 11057 \cs_new:Npn __peek_true:w { }
__peek_false:w 11058 \cs_new:Npn __peek_true_aux:w { }
__peek_tmp:w 11059 \cs_new:Npn __peek_false:w { }
11060 \cs_new:Npn __peek_tmp:w { }

(End definition for __peek_true:w and others.)

\peek_after:Nw Simple wrappers for \futurelet: no arguments absorbed here.

\peek_gafter:Nw 11061 \cs_new_protected:Npn \peek_after:Nw
11062 { \tex_futurelet:D \l_peek_token }
11063 \cs_new_protected:Npn \peek_gafter:Nw
11064 { \tex_global:D \tex_futurelet:D \g_peek_token }

(End definition for \peek_after:Nw and \peek_gafter:Nw. These functions are documented on page 132.)

__peek_true_remove:w A function to remove the next token and then regain control.

11065 \cs_new_protected:Npn __peek_true_remove:w
11066 {
11067 \tex_afterassignment:D __peek_true_aux:w
11068 \cs_set_eq:NN __peek_tmp:w
11069 }

(End definition for __peek_true_remove:w.)

\peek_remove_spaces:n Repeatedly use __peek_true_remove:w to remove a space and call __peek_true_remove_spaces:w.

__peek_remove_spaces: 11070 \cs_new_protected:Npn \peek_remove_spaces:n #1
11071 {
11072 \cs_set:Npx __peek_false:w { \exp_not:n {#1} }
11073 \group_align_safe_begin:
11074 \cs_set:Npn __peek_true_aux:w { \peek_after:Nw __peek_remove_spaces: }
11075 __peek_true_aux:w
11076 }
11077 \cs_new_protected:Npn __peek_remove_spaces:
11078 {
11079 \if_meaning:w \l_peek_token \c_space_token
11080 \exp_after:wN __peek_true_remove:w

```

11081     \else:
11082         \group_align_safe_end:
11083         \exp_after:wN \__peek_false:w
11084     \fi:
11085 }

```

(End definition for \peek_remove_spaces:n and __peek_remove_spaces:. This function is documented on page 267.)

__peek_token_generic_aux:NNNTF

The generic functions store the test token in both implicit and explicit modes, and the true and false code as token lists, more or less. The two branches have to be absorbed here as the input stream needs to be cleared for the peek function itself. Here, #1 is __peek_true_remove:w when removing the token and __peek_true_aux:w otherwise.

```

11086 \cs_new_protected:Npn \__peek_token_generic_aux:NNNTF #1#2#3#4#5
11087 {
11088     \group_align_safe_begin:
11089     \cs_set_eq:NN \l__peek_search_token #3
11090     \tl_set:Nn \l__peek_search_tl {#3}
11091     \cs_set:Npx \__peek_true_aux:w
11092     {
11093         \exp_not:N \group_align_safe_end:
11094         \exp_not:n {#4}
11095     }
11096     \cs_set_eq:NN \__peek_true:w #1
11097     \cs_set:Npx \__peek_false:w
11098     {
11099         \exp_not:N \group_align_safe_end:
11100         \exp_not:n {#5}
11101     }
11102     \peek_after:Nw #2
11103 }

```

(End definition for __peek_token_generic_aux:NNNTF.)

__peek_token_generic:NNTF

For token removal there needs to be a call to the auxiliary function which does the work.

__peek_token_remove_generic:NNTF

```

11104 \cs_new_protected:Npn \__peek_token_generic:NNTF
11105 { \__peek_token_generic_aux:NNNTF \__peek_true_aux:w }
11106 \cs_new_protected:Npn \__peek_token_generic:NNT #1#2#3
11107 { \__peek_token_generic:NNTF #1 #2 {#3} { } }
11108 \cs_new_protected:Npn \__peek_token_generic:NNTF #1#2#3
11109 { \__peek_token_generic:NNTF #1 #2 { } {#3} }
11110 \cs_new_protected:Npn \__peek_token_remove_generic:NNTF
11111 { \__peek_token_generic_aux:NNNTF \__peek_true_remove:w }
11112 \cs_new_protected:Npn \__peek_token_remove_generic:NNT #1#2#3
11113 { \__peek_token_remove_generic:NNTF #1 #2 {#3} { } }
11114 \cs_new_protected:Npn \__peek_token_remove_generic:NNTF #1#2#3
11115 { \__peek_token_remove_generic:NNTF #1 #2 { } {#3} }

```

(End definition for __peek_token_generic:NNTF and __peek_token_remove_generic:NNTF.)

__peek_execute_branches_meaning:

The meaning test is straight forward.

```

11116 \cs_new:Npn \__peek_execute_branches_meaning:
11117 {
11118     \if_meaning:w \l_peek_token \l__peek_search_token
11119     \exp_after:wN \__peek_true:w

```

```

11120     \else:
11121         \exp_after:wN \__peek_false:w
11122     \fi:
11123 }

```

(End definition for __peek_execute_branches_meaning:.)

```

\__peek_execute_branches_catcode:
\__peek_execute_branches_charcode:
\__peek_execute_branches_catcode_aux:
\__peek_execute_branches_catcode_auxii:N
\__peek_execute_branches_catcode_auxiii:

```

The catcode and charcode tests are very similar, and in order to use the same auxiliaries we do something a little bit odd, firing \if_catcode:w and \if_charcode:w before finding the operands for those tests, which are only given in the auxii:N and auxiii: auxiliaries. For our purposes, three kinds of tokens may follow the peeking function:

- control sequences which are not equal to a non-active character token (*e.g.*, macro, primitive);
- active characters which are not equal to a non-active character token (*e.g.*, macro, primitive);
- explicit non-active character tokens, or control sequences or active characters set equal to a non-active character token.

The first two cases are not distinguishable simply using T_EX's \futurelet, because we can only access the \meaning of tokens in that way. In those cases, detected thanks to a comparison with \scan_stop:, we grab the following token, and compare it explicitly with the explicit search token stored in \l__peek_search_tl. The \exp_not:N prevents outer macros (coming from non-L^AT_EX3 code) from blowing up. In the third case, \l__peek_token is good enough for the test, and we compare it again with the explicit search token. Just like the peek token, the search token may be of any of the three types above, hence the need to use the explicit token that was given to the peek function.

```

11124 \cs_new:Npn \__peek_execute_branches_catcode:
11125 { \if_catcode:w \__peek_execute_branches_catcode_aux: }
11126 \cs_new:Npn \__peek_execute_branches_charcode:
11127 { \if_charcode:w \__peek_execute_branches_catcode_aux: }
11128 \cs_new:Npn \__peek_execute_branches_catcode_aux:
11129 {
11130     \if_catcode:w \exp_not:N \l__peek_token \scan_stop:
11131     \exp_after:wN \exp_after:wN
11132     \exp_after:wN \__peek_execute_branches_catcode_auxii:N
11133     \exp_after:wN \exp_not:N
11134     \else:
11135     \exp_after:wN \__peek_execute_branches_catcode_auxiii:
11136     \fi:
11137 }
11138 \cs_new:Npn \__peek_execute_branches_catcode_auxii:N #1
11139 {
11140     \exp_not:N #1
11141     \exp_after:wN \exp_not:N \l__peek_search_tl
11142     \exp_after:wN \__peek_true:w
11143     \else:
11144     \exp_after:wN \__peek_false:w
11145     \fi:
11146     #1
11147 }
11148 \cs_new:Npn \__peek_execute_branches_catcode_auxiii:

```

```

11149 {
11150     \exp_not:N \l_peek_token
11151     \exp_after:wN \exp_not:N \l_peek_search_tl
11152     \exp_after:wN \__peek_true:w
11153     \else:
11154     \exp_after:wN \__peek_false:w
11155     \fi:
11156 }

```

(End definition for `__peek_execute_branches_catcode:` and others.)

`\peek_catcode:N \underline{TF}` The public functions themselves cannot be defined using `\prg_new_conditional:Npnn`. Instead, the TF, T, F variants are defined in terms of corresponding variants of `__peek_token_generic:NNTF` or `__peek_token_remove_generic:NNTF`, with first argument one of `__peek_execute_branches_catcode:`, `__peek_execute_branches_charcode:`, or `__peek_execute_branches_meaning:`.

```

11157 \tl_map_inline:nn { { catcode } { charcode } { meaning } }
11158 {
11159     \tl_map_inline:nn { { } { _remove } }
11160     {
11161         \tl_map_inline:nn { { TF } { T } { F } }
11162         {
11163             \cs_new_protected:cpx { peek_ #1 ##1 :N ####1 }
11164             {
11165                 \exp_not:c { __peek_token ##1 _generic:NN ####1 }
11166                 \exp_not:c { __peek_execute_branches_ #1 : }
11167             }
11168         }
11169     }
11170 }

```

(End definition for `\peek_catcode:N \underline{TF}` and others. These functions are documented on page 132.)

`\peek_catcode_ignore_spaces:N \underline{TF}` To ignore spaces, remove them using `\peek_remove_spaces:n` before running the tests.

```

11171 \tl_map_inline:nn
11172 {
11173     { catcode } { catcode_remove }
11174     { charcode } { charcode_remove }
11175     { meaning } { meaning_remove }
11176 }
11177 {
11178     \cs_new_protected:cpx { peek_#1_ignore_spaces:N $\underline{TF}$  } ##1##2##3
11179     {
11180         \peek_remove_spaces:n
11181         { \exp_not:c { peek_#1:N $\underline{TF}$  } ##1 {##2} {##3} }
11182     }
11183     \cs_new_protected:cpx { peek_#1_ignore_spaces:NT } ##1##2
11184     {
11185         \peek_remove_spaces:n
11186         { \exp_not:c { peek_#1:NT } ##1 {##2} }
11187     }
11188     \cs_new_protected:cpx { peek_#1_ignore_spaces:N $\underline{F}$  } ##1##2
11189     {
11190         \peek_remove_spaces:n

```

```

11191         { \exp_not:c { peek_#1:NF } ##1 {##2} }
11192     }
11193 }

```

(End definition for `\peek_catcode_ignore_spaces:NTF` and others. These functions are documented on page 133.)

`\peek_N_type:TF`
`__peek_execute_branches_N_type:`
`__peek_N_type:w`
`__peek_N_type_aux:nnw`

All tokens are N-type tokens, except in four cases: begin-group tokens, end-group tokens, space tokens with character code 32, and outer tokens. Since `\l_peek_token` might be outer, we cannot use the convenient `\bool_if:nTF` function, and must resort to the old trick of using `\ifodd` to expand a set of tests. The `false` branch of this test is taken if the token is one of the first three kinds of non-N-type tokens (explicit or implicit), thus we call `__peek_false:w`. In the `true` branch, we must detect outer tokens, without impacting performance too much for non-outer tokens. The first filter is to search for `outer` in the `\meaning` of `\l_peek_token`. If that is absent, `\use_none_delimit_by_q_stop:w` cleans up, and we call `__peek_true:w`. Otherwise, the token can be a non-outer macro or a primitive mark whose parameter or replacement text contains `outer`, it can be the primitive `\outer`, or it can be an outer token. Macros and marks would have `ma` in the part before the first occurrence of `outer`; the meaning of `\outer` has nothing after `outer`, contrarily to outer macros; and that covers all cases, calling `__peek_true:w` or `__peek_false:w` as appropriate. Here, there is no *search token*, so we feed a dummy `\scan_stop:` to the `__peek_token_generic:NNTF` function.

```

11194 \group_begin:
11195   \cs_set_protected:Npn \__peek_tmp:w #1 \q_stop
11196   {
11197     \cs_new_protected:Npn \__peek_execute_branches_N_type:
11198     {
11199       \if_int_odd:w
11200         \if_catcode:w \exp_not:N \l_peek_token { 0 \exp_stop_f: \fi:
11201         \if_catcode:w \exp_not:N \l_peek_token } 0 \exp_stop_f: \fi:
11202         \if_meaning:w \l_peek_token \c_space_token 0 \exp_stop_f: \fi:
11203         1 \exp_stop_f:
11204         \exp_after:wN \__peek_N_type:w
11205         \token_to_meaning:N \l_peek_token
11206         \q_mark \__peek_N_type_aux:nnw
11207         #1 \q_mark \use_none_delimit_by_q_stop:w
11208         \q_stop
11209         \exp_after:wN \__peek_true:w
11210       \else:
11211         \exp_after:wN \__peek_false:w
11212       \fi:
11213     }
11214     \cs_new_protected:Npn \__peek_N_type:w ##1 #1 ##2 \q_mark ##3
11215     { ##3 {##1} {##2} }
11216   }
11217   \exp_after:wN \__peek_tmp:w \tl_to_str:n { outer } \q_stop
11218 \group_end:
11219 \cs_new_protected:Npn \__peek_N_type_aux:nnw #1 #2 #3 \fi:
11220 {
11221   \fi:
11222   \tl_if_in:noTF {#1} { \tl_to_str:n {ma} }
11223   { \__peek_true:w }
11224   { \tl_if_empty:nTF {#2} { \__peek_true:w } { \__peek_false:w } }

```

```

11225 }
11226 \cs_new_protected:Npn \peek_N_type:TF
11227 {
11228   \__peek_token_generic:NNTF
11229   \__peek_execute_branches_N_type: \scan_stop:
11230 }
11231 \cs_new_protected:Npn \peek_N_type:T
11232 { \__peek_token_generic:NNT \__peek_execute_branches_N_type: \scan_stop: }
11233 \cs_new_protected:Npn \peek_N_type:F
11234 { \__peek_token_generic:NNTF \__peek_execute_branches_N_type: \scan_stop: }

```

(End definition for `\peek_N_type:TF` and others. This function is documented on page 135.)

```
11235 </initex | package>
```

18 l3prop implementation

The following test files are used for this code: `m3prop001`, `m3prop002`, `m3prop003`, `m3prop004`, `m3show001`.

```
11236 <*initex | package>
```

```
11237 <@@=prop>
```

A property list is a macro whose top-level expansion is of the form

```

\__prop \__prop_pair:wn <key1> \s__prop {<value1>}
...
\__prop_pair:wn <keyn> \s__prop {<valuen>}

```

where `\s__prop` is a scan mark (equal to `\scan_stop:`), and `__prop_pair:wn` can be used to map through the property list.

`\s__prop` The internal token used at the beginning of property lists. This is also used after each `<key>` (see `__prop_pair:wn`).

(End definition for `\s__prop`.)

`__prop_pair:wn` `__prop_pair:wn <key> \s__prop {<item>}`

The internal token used to begin each key–value pair in the property list. If expanded outside of a mapping or manipulation function, an error is raised. The definition should always be set globally.

(End definition for `__prop_pair:wn`.)

`\l__prop_internal_tl` Token list used to store new key–value pairs to be inserted by functions of the `\prop_put:Nnn` family.

(End definition for `\l__prop_internal_tl`.)

`__prop_split:NnTF`

Updated: 2013-01-08

`__prop_split:NnTF` $\langle\textit{property list}\rangle$ $\langle\textit{key}\rangle$ $\langle\textit{true code}\rangle$ $\langle\textit{false code}\rangle$

Splits the $\langle\textit{property list}\rangle$ at the $\langle\textit{key}\rangle$, giving three token lists: the $\langle\textit{extract}\rangle$ of $\langle\textit{property list}\rangle$ before the $\langle\textit{key}\rangle$, the $\langle\textit{value}\rangle$ associated with the $\langle\textit{key}\rangle$ and the $\langle\textit{extract}\rangle$ of the $\langle\textit{property list}\rangle$ after the $\langle\textit{value}\rangle$. Both $\langle\textit{extracts}\rangle$ retain the internal structure of a property list, and the concatenation of the two $\langle\textit{extracts}\rangle$ is a property list. If the $\langle\textit{key}\rangle$ is present in the $\langle\textit{property list}\rangle$ then the $\langle\textit{true code}\rangle$ is left in the input stream, with #1, #2, and #3 replaced by the first $\langle\textit{extract}\rangle$, the $\langle\textit{value}\rangle$, and the second $\langle\textit{extract}\rangle$. If the $\langle\textit{key}\rangle$ is not present in the $\langle\textit{property list}\rangle$ then the $\langle\textit{false code}\rangle$ is left in the input stream, with no trailing material. Both $\langle\textit{true code}\rangle$ and $\langle\textit{false code}\rangle$ are used in the replacement text of a macro defined internally, hence macro parameter characters should be doubled, except #1, #2, and #3 which stand in the $\langle\textit{true code}\rangle$ for the three extracts from the property list. The $\langle\textit{key}\rangle$ comparison takes place as described for `\str_if_eq:nn`.

`\s__prop` A private scan mark is used as a marker after each key, and at the very beginning of the property list.

11238 `\scan_new:N \s__prop`

(End definition for `\s__prop`.)

`__prop_pair:wn` The delimiter is always defined, but when misused simply triggers an error and removes its argument.

11239 `\cs_new:Npn __prop_pair:wn #1 \s__prop #2`

11240 `{ __kernel_msg_expandable_error:nn { kernel } { misused-prop } }`

(End definition for `__prop_pair:wn`.)

`\l__prop_internal_tl` Token list used to store the new key–value pair inserted by `\prop_put:Nnn` and friends.

11241 `\tl_new:N \l__prop_internal_tl`

(End definition for `\l__prop_internal_tl`.)

`\c_empty_prop` An empty prop.

11242 `\tl_const:Nn \c_empty_prop { \s__prop }`

(End definition for `\c_empty_prop`. This variable is documented on page 143.)

18.1 Allocation and initialisation

`\prop_new:N` Property lists are initialized with the value `\c_empty_prop`.

`\prop_new:c`

11243 `\cs_new_protected:Npn \prop_new:N #1`

11244 `{`

11245 `__kernel_chk_if_free_cs:N #1`

11246 `\cs_gset_eq:NN #1 \c_empty_prop`

11247 `}`

11248 `\cs_generate_variant:Nn \prop_new:N { c }`

(End definition for `\prop_new:N`. This function is documented on page 138.)

`\prop_clear:N` The same idea for clearing.

`\prop_clear:c`

11249 `\cs_new_protected:Npn \prop_clear:N #1`

`\prop_gclear:N`

11250 `{ \prop_set_eq:NN #1 \c_empty_prop }`

`\prop_gclear:c`

11251 `\cs_generate_variant:Nn \prop_clear:N { c }`

11252 `\cs_new_protected:Npn \prop_gclear:N #1`

11253 `{ \prop_gset_eq:NN #1 \c_empty_prop }`

11254 `\cs_generate_variant:Nn \prop_gclear:N { c }`

(End definition for `\prop_clear:N` and `\prop_gclear:N`. These functions are documented on page 138.)

`\prop_clear_new:N` Once again a simple variation of the token list functions.
`\prop_clear_new:c` 11255 `\cs_new_protected:Npn \prop_clear_new:N #1`
`\prop_gclear_new:N` 11256 `{ \prop_if_exist:NTF #1 { \prop_clear:N #1 } { \prop_new:N #1 } }`
`\prop_gclear_new:c` 11257 `\cs_generate_variant:Nn \prop_clear_new:N { c }`
11258 `\cs_new_protected:Npn \prop_gclear_new:N #1`
11259 `{ \prop_if_exist:NTF #1 { \prop_gclear:N #1 } { \prop_new:N #1 } }`
11260 `\cs_generate_variant:Nn \prop_gclear_new:N { c }`

(End definition for `\prop_clear_new:N` and `\prop_gclear_new:N`. These functions are documented on page 138.)

`\prop_set_eq:NN` These are simply copies from the token list functions.
`\prop_set_eq:cN` 11261 `\cs_new_eq:NN \prop_set_eq:NN \tl_set_eq:NN`
`\prop_set_eq:Nc` 11262 `\cs_new_eq:NN \prop_set_eq:Nc \tl_set_eq:Nc`
`\prop_set_eq:cc` 11263 `\cs_new_eq:NN \prop_set_eq:cN \tl_set_eq:cN`
`\prop_gset_eq:NN` 11264 `\cs_new_eq:NN \prop_set_eq:cc \tl_set_eq:cc`
`\prop_gset_eq:cN` 11265 `\cs_new_eq:NN \prop_gset_eq:NN \tl_gset_eq:NN`
`\prop_gset_eq:Nc` 11266 `\cs_new_eq:NN \prop_gset_eq:Nc \tl_gset_eq:Nc`
`\prop_gset_eq:cN` 11267 `\cs_new_eq:NN \prop_gset_eq:cN \tl_gset_eq:cN`
11268 `\cs_new_eq:NN \prop_gset_eq:cc \tl_gset_eq:cc`

(End definition for `\prop_set_eq:NN` and `\prop_gset_eq:NN`. These functions are documented on page 138.)

`\l_tmpa_prop` We can now initialize the scratch variables.
`\l_tmpb_prop` 11269 `\prop_new:N \l_tmpa_prop`
`\g_tmpa_prop` 11270 `\prop_new:N \l_tmpb_prop`
`\g_tmpb_prop` 11271 `\prop_new:N \g_tmpa_prop`
11272 `\prop_new:N \g_tmpb_prop`

(End definition for `\l_tmpa_prop` and others. These variables are documented on page 143.)

`\prop_set_from_keyval:Nn` Loop through items separated by commas, with `\q_mark` to avoid losing braces. After
`\prop_set_from_keyval:cN` checking for termination, split the item at the first then at the second = (which ought
`\prop_gset_from_keyval:Nn` to be the first of the trailing =). At both splits, trim spaces and call `__prop_from_`
`\prop_gset_from_keyval:cN` `keyval_key:w`, then `__prop_from_keyval_value:w`, followed by the trimmed material,
`\prop_const_from_keyval:Nn` `\q_nil`, the subsequent part of the item, and the trailing =’s and `\q_stop`. After finding
`\prop_const_from_keyval:cN` the `<key>` just store it after `\q_stop`. After finding the `<value>` ignore completely empty
`__prop_from_keyval:n` items (both trailing = were used as delimiters and all parts are empty); if the remaining
`__prop_from_keyval_loop:w` part #2 consists exactly of the second trailing = (namely there was exactly one = in the
`__prop_from_keyval_split:Nw` item) then output one key–value pair for the property list; otherwise complain about a
`__prop_from_keyval_key:n` missing or extra =.
`__prop_from_keyval_key:w` 11273 `\cs_new_protected:Npn \prop_set_from_keyval:Nn #1#2`
`__prop_from_keyval_value:n` 11274 `{ \tl_set:Nx #1 { __prop_from_keyval:n {#2} } }`
`__prop_from_keyval_value:w` 11275 `\cs_generate_variant:Nn \prop_set_from_keyval:Nn { c }`
11276 `\cs_new_protected:Npn \prop_gset_from_keyval:Nn #1#2`
11277 `{ \tl_gset:Nx #1 { __prop_from_keyval:n {#2} } }`
11278 `\cs_generate_variant:Nn \prop_gset_from_keyval:Nn { c }`
11279 `\cs_new_protected:Npn \prop_const_from_keyval:Nn #1#2`
11280 `{ \tl_const:Nx #1 { __prop_from_keyval:n {#2} } }`
11281 `\cs_generate_variant:Nn \prop_const_from_keyval:Nn { c }`
11282 `\cs_new:Npn __prop_from_keyval:n #1`

```

11283 {
11284   \s__prop
11285   \__prop_from_keyval_loop:w \q_mark #1 ,
11286   \q_recursion_tail , \q_recursion_stop
11287 }
11288 \cs_new:Npn \__prop_from_keyval_loop:w #1 ,
11289 {
11290   \quark_if_recursion_tail_stop:o { \use_none:n #1 }
11291   \__prop_from_keyval_split:Nw \__prop_from_keyval_key:n
11292   #1 = = \q_stop { \use_none:n #1 }
11293   \__prop_from_keyval_loop:w \q_mark
11294 }
11295 \cs_new:Npn \__prop_from_keyval_split:Nw #1#2 =
11296 {
11297   \tl_trim_spaces_apply:oN { \use_none:n #2 } #1
11298   \q_nil
11299 }
11300 \cs_new:Npn \__prop_from_keyval_key:n #1
11301 { \__prop_from_keyval_key:w #1 }
11302 \cs_new:Npn \__prop_from_keyval_key:w #1 \q_nil #2 \q_stop
11303 {
11304   \__prop_from_keyval_split:Nw \__prop_from_keyval_value:n
11305   \q_mark #2 \q_stop {#1}
11306 }
11307 \cs_new:Npn \__prop_from_keyval_value:n #1
11308 { \__prop_from_keyval_value:w #1 }
11309 \cs_new:Npn \__prop_from_keyval_value:w #1 \q_nil #2 \q_stop #3#4
11310 {
11311   \tl_if_empty:nF { #3 #1 #2 }
11312   {
11313     \str_if_eq:nnTF {#2} { = }
11314     {
11315       \exp_not:N \__prop_pair:wn \tl_to_str:n {#3}
11316       \s__prop { \exp_not:n {#1} }
11317     }
11318     {
11319       \__kernel_msg_expandable_error:nnf
11320       { kernel } { prop-keyval }
11321       { \exp_after:wN \exp_stop_f: #4 }
11322     }
11323   }
11324 }

```

(End definition for `\prop_set_from_keyval:Nn` and others. These functions are documented on page 257.)

18.2 Accessing data in property lists

`__prop_split:NnTF`
`__prop_split_aux:NnTF`
`__prop_split_aux:w`

This function is used by most of the module, and hence must be fast. It receives a *property list*, a *key*, a *true code* and a *false code*. The aim is to split the *property list* at the given *key* into the *extract₁* before the key–value pair, the *value* associated with the *key* and the *extract₂* after the key–value pair. This is done using a delimited function, whose definition is as follows, where the *key* is turned into a string.

```

\cs_set:Npn \__prop_split_aux:w #1
\__prop_pair:wn <key> \s__prop #2
#3 \q_mark #4 #5 \q_stop
{ #4 {\true code} {\false code} }

```

If the $\langle key \rangle$ is present in the property list, $\backslash_prop_split_aux:w$'s #1 is the part before the $\langle key \rangle$, #2 is the $\langle value \rangle$, #3 is the part after the $\langle key \rangle$, #4 is $\backslash use_i:nn$, and #5 is additional tokens that we do not care about. The $\langle true\ code \rangle$ is left in the input stream, and can use the parameters #1, #2, #3 for the three parts of the property list as desired. Namely, the original property list is in this case #1 $\backslash_prop_pair:wn\ \langle key \rangle\ \backslash s_prop\ \{ \#2 \}\ \#3$.

If the $\langle key \rangle$ is not there, then the $\langle function \rangle$ is $\backslash use_ii:nn$, which keeps the $\langle false\ code \rangle$.

```

11325 \cs_new_protected:Npn \__prop_split:NnTF #1#2
11326 { \exp_args:NNo \__prop_split_aux:NnTF #1 { \tl_to_str:n {#2} } }
11327 \cs_new_protected:Npn \__prop_split_aux:NnTF #1#2#3#4
11328 {
11329   \cs_set:Npn \__prop_split_aux:w ##1
11330     \__prop_pair:wn #2 \s__prop ##2 ##3 \q_mark ##4 ##5 \q_stop
11331     { ##4 {#3} {#4} }
11332   \exp_after:wN \__prop_split_aux:w #1 \q_mark \use_i:nn
11333   \__prop_pair:wn #2 \s__prop { } \q_mark \use_ii:nn \q_stop
11334 }
11335 \cs_new:Npn \__prop_split_aux:w { }

```

(End definition for $\backslash_prop_split:NnTF$, $\backslash_prop_split_aux:NnTF$, and $\backslash_prop_split_aux:w$.)

$\backslash prop_remove:Nn$ Deleting from a property starts by splitting the list. If the key is present in the property list, the returned value is ignored. If the key is missing, nothing happens.

```

\prop_remove:NV
\prop_remove:cn
\prop_remove:cV
\prop_gremove:Nn
\prop_gremove:NV
\prop_gremove:cn
\prop_gremove:cV
11336 \cs_new_protected:Npn \prop_remove:Nn #1#2
11337 {
11338   \__prop_split:NnTF #1 {#2}
11339   { \tl_set:Nn #1 { ##1 ##3 } }
11340   { }
11341 }
11342 \cs_new_protected:Npn \prop_gremove:Nn #1#2
11343 {
11344   \__prop_split:NnTF #1 {#2}
11345   { \tl_gset:Nn #1 { ##1 ##3 } }
11346   { }
11347 }
11348 \cs_generate_variant:Nn \prop_remove:Nn { NV }
11349 \cs_generate_variant:Nn \prop_remove:Nn { c , cV }
11350 \cs_generate_variant:Nn \prop_gremove:Nn { NV }
11351 \cs_generate_variant:Nn \prop_gremove:Nn { c , cV }

```

(End definition for $\backslash prop_remove:Nn$ and $\backslash prop_gremove:Nn$. These functions are documented on page 140.)

$\backslash prop_get:NnN$ Getting an item from a list is very easy: after splitting, if the key is in the property list, just set the token list variable to the return value, otherwise to $\backslash q_no_value$.

```

\prop_get:NVN
\prop_get:NoN
\prop_get:cnN
\prop_get:cVN
\prop_get:coN
11352 \cs_new_protected:Npn \prop_get:NnN #1#2#3
11353 {

```

```

11354     \__prop_split:NnTF #1 {#2}
11355     { \tl_set:Nn #3 {##2} }
11356     { \tl_set:Nn #3 { \q_no_value } }
11357   }
11358 \cs_generate_variant:Nn \prop_get:NnN { NV , No }
11359 \cs_generate_variant:Nn \prop_get:NnN { c , cV , co }

```

(End definition for `\prop_get:NnN`. This function is documented on page 139.)

`\prop_pop:NnN` Popping a value also starts by doing the split. If the key is present, save the value in the token list and update the property list as when deleting. If the key is missing, save `\q_no_value` in the token list.

`\prop_pop:NoN`

`\prop_pop:cnN`

`\prop_pop:coN`

`\prop_gpop:NnN`

`\prop_gpop:NoN`

`\prop_gpop:cnN`

`\prop_gpop:coN`

```

11360 \cs_new_protected:Npn \prop_pop:NnN #1#2#3
11361 {
11362     \__prop_split:NnTF #1 {#2}
11363     {
11364         \tl_set:Nn #3 {##2}
11365         \tl_set:Nn #1 { ##1 ##3 }
11366     }
11367     { \tl_set:Nn #3 { \q_no_value } }
11368 }
11369 \cs_new_protected:Npn \prop_gpop:NnN #1#2#3
11370 {
11371     \__prop_split:NnTF #1 {#2}
11372     {
11373         \tl_set:Nn #3 {##2}
11374         \tl_gset:Nn #1 { ##1 ##3 }
11375     }
11376     { \tl_set:Nn #3 { \q_no_value } }
11377 }
11378 \cs_generate_variant:Nn \prop_pop:NnN { No }
11379 \cs_generate_variant:Nn \prop_pop:NnN { c , co }
11380 \cs_generate_variant:Nn \prop_gpop:NnN { No }
11381 \cs_generate_variant:Nn \prop_gpop:NnN { c , co }

```

(End definition for `\prop_pop:NnN` and `\prop_gpop:NnN`. These functions are documented on page 139.)

`\prop_item:Nn` Getting the value corresponding to a key in a property list in an expandable fashion is similar to mapping some tokens. Go through the property list one `<key>`–`<value>` pair at a time: the arguments of `__prop_item_Nn:nwn` are the `<key>` we are looking for, a `<key>` of the property list, and its associated value. The `<keys>` are compared (as strings). If they match, the `<value>` is returned, within `\exp_not:n`. The loop terminates even if the `<key>` is missing, and yields an empty value, because we have appended the appropriate `<key>`–`<empty value>` pair to the property list.

```

11382 \cs_new:Npn \prop_item:Nn #1#2
11383 {
11384     \exp_last_unbraced:Noo \__prop_item_Nn:nwn { \tl_to_str:n {#2} } #1
11385     \__prop_pair:wn \tl_to_str:n {#2} \s__prop { }
11386     \prg_break_point:
11387 }
11388 \cs_new:Npn \__prop_item_Nn:nwn #1#2 \__prop_pair:wn #3 \s__prop #4
11389 {
11390     \str_if_eq:eeTF {#1} {#3}
11391     { \prg_break:n { \exp_not:n {#4} } }

```

```

11392     { \_prop_item_Nn:nwn {#1} }
11393   }
11394   \cs_generate_variant:Nn \prop_item:Nn { c }

```

(End definition for `\prop_item:Nn` and `_prop_item_Nn:nwn`. This function is documented on page 140.)

`\prop_count:N` Counting the key–value pairs in a property list is done using the same approach as for
`\prop_count:c` other count functions: turn each entry into a +1 then use integer evaluation to actually
`_prop_count:nn` do the mathematics.

```

11395   \cs_new:Npn \prop_count:N #1
11396   {
11397     \int_eval:n
11398     {
11399       0
11400       \prop_map_function:NN #1 \_prop_count:nn
11401     }
11402   }
11403   \cs_new:Npn \_prop_count:nn #1#2 { + 1 }
11404   \cs_generate_variant:Nn \prop_count:N { c }

```

(End definition for `\prop_count:N` and `_prop_count:nn`. This function is documented on page 140.)

`\prop_pop:NnTF` Popping an item from a property list, keeping track of whether the key was present or
`\prop_pop:cnTF` not, is implemented as a conditional. If the key was missing, neither the property list, nor
`\prop_gpop:NnTF` the token list are altered. Otherwise, `\prg_return_true:` is used after the assignments.
`\prop_gpop:cnTF`

```

11405   \prg_new_protected_conditional:Npnn \prop_pop:NnN #1#2#3 { T , F , TF }
11406   {
11407     \_prop_split:NnTF #1 {#2}
11408     {
11409       \tl_set:Nn #3 {##2}
11410       \tl_set:Nn #1 { ##1 ##3 }
11411       \prg_return_true:
11412     }
11413     { \prg_return_false: }
11414   }
11415   \prg_new_protected_conditional:Npnn \prop_gpop:NnN #1#2#3 { T , F , TF }
11416   {
11417     \_prop_split:NnTF #1 {#2}
11418     {
11419       \tl_set:Nn #3 {##2}
11420       \tl_gset:Nn #1 { ##1 ##3 }
11421       \prg_return_true:
11422     }
11423     { \prg_return_false: }
11424   }
11425   \prg_generate_conditional_variant:Nnn \prop_pop:NnN { c } { T , F , TF }
11426   \prg_generate_conditional_variant:Nnn \prop_gpop:NnN { c } { T , F , TF }

```

(End definition for `\prop_pop:NnTF` and `\prop_gpop:NnTF`. These functions are documented on page 141.)

`\prop_put:Nnn` Since the branches of `_prop_split:NnTF` are used as the replacement text of an internal
`\prop_put:NnV` macro, and since the `<key>` and new `<value>` may contain arbitrary tokens, it is not safe
`\prop_put:Nno` to include them in the argument of `_prop_split:NnTF`. We thus start by storing
`\prop_put:Nnx`
`\prop_put:NVn`
`\prop_put:NVV`
`\prop_put:Non`
`\prop_put:Noo`
`\prop_put:cnn`
`\prop_put:cnV`
`\prop_put:cno`
`\prop_put:cnx`
`\prop_put:cVn`

in `\l__prop_internal_tl` tokens which (after x-expansion) encode the key–value pair. This variable can safely be used in `__prop_split:NnTF`. If the $\langle key \rangle$ was absent, append the new key–value to the list. Otherwise concatenate the extracts `##1` and `##3` with the new key–value pair `\l__prop_internal_tl`. The updated entry is placed at the same spot as the original $\langle key \rangle$ in the property list, preserving the order of entries.

```

11427 \cs_new_protected:Npn \prop_put:Nnn { \__prop_put:NNnn \tl_set:Nx }
11428 \cs_new_protected:Npn \prop_gput:Nnn { \__prop_put:NNnn \tl_gset:Nx }
11429 \cs_new_protected:Npn \__prop_put:NNnn #1#2#3#4
11430 {
11431   \tl_set:Nn \l__prop_internal_tl
11432   {
11433     \exp_not:N \__prop_pair:wn \tl_to_str:n {#3}
11434     \s__prop { \exp_not:n {#4} }
11435   }
11436   \__prop_split:NnTF #2 {#3}
11437   { #1 #2 { \exp_not:n {##1} \l__prop_internal_tl \exp_not:n {##3} } }
11438   { #1 #2 { \exp_not:o {#2} \l__prop_internal_tl } }
11439 }
11440 \cs_generate_variant:Nn \prop_put:Nnn
11441 { NnV , Nno , Nnx , NV , NVV , No , Noo }
11442 \cs_generate_variant:Nn \prop_put:Nnn
11443 { c , cnV , cno , cnx , cV , cVV , co , coo }
11444 \cs_generate_variant:Nn \prop_gput:Nnn
11445 { NnV , Nno , Nnx , NV , NVV , No , Noo }
11446 \cs_generate_variant:Nn \prop_gput:Nnn
11447 { c , cnV , cno , cnx , cV , cVV , co , coo }

```

(End definition for `\prop_put:Nnn`, `\prop_gput:Nnn`, and `__prop_put:NNnn`. These functions are documented on page 139.)

```

\prop_put_if_new:Nnn
\prop_put_if_new:cnn
\prop_gput_if_new:Nnn
\prop_gput_if_new:cnn
\__prop_put_if_new:NNnn

```

Adding conditionally also splits. If the key is already present, the three brace groups given by `__prop_split:NnTF` are removed. If the key is new, then the value is added, being careful to convert the key to a string using `\tl_to_str:n`.

```

11448 \cs_new_protected:Npn \prop_put_if_new:Nnn
11449 { \__prop_put_if_new:NNnn \tl_set:Nx }
11450 \cs_new_protected:Npn \prop_gput_if_new:Nnn
11451 { \__prop_put_if_new:NNnn \tl_gset:Nx }
11452 \cs_new_protected:Npn \__prop_put_if_new:NNnn #1#2#3#4
11453 {
11454   \tl_set:Nn \l__prop_internal_tl
11455   {
11456     \exp_not:N \__prop_pair:wn \tl_to_str:n {#3}
11457     \s__prop { \exp_not:n {#4} }
11458   }
11459   \__prop_split:NnTF #2 {#3}
11460   { }
11461   { #1 #2 { \exp_not:o {#2} \l__prop_internal_tl } }
11462 }
11463 \cs_generate_variant:Nn \prop_put_if_new:Nnn { c }
11464 \cs_generate_variant:Nn \prop_gput_if_new:Nnn { c }

```

(End definition for `\prop_put_if_new:Nnn`, `\prop_gput_if_new:Nnn`, and `__prop_put_if_new:NNnn`. These functions are documented on page 139.)

18.3 Property list conditionals

`\prop_if_exist_p:N` Copies of the `cs` functions defined in `l3basics`.
`\prop_if_exist_p:c` 11465 `\prg_new_eq_conditional:Nnn \prop_if_exist:N \cs_if_exist:N`
`\prop_if_exist:N \underline{TF}` 11466 `{ TF , T , F , p }`
`\prop_if_exist:c \underline{TF}` 11467 `\prg_new_eq_conditional:Nnn \prop_if_exist:c \cs_if_exist:c`
11468 `{ TF , T , F , p }`

(End definition for `\prop_if_exist:N \underline{TF}` . This function is documented on page 140.)

`\prop_if_empty_p:N` Same test as for token lists.
`\prop_if_empty_p:c` 11469 `\prg_new_conditional:Npnn \prop_if_empty:N #1 { p , T , F , TF }`
`\prop_if_empty:N \underline{TF}` 11470 `{`
`\prop_if_empty:c \underline{TF}` 11471 `\tl_if_eq:NNTF #1 \c_empty_prop`
11472 `\prg_return_true: \prg_return_false:`
11473 `}`
11474 `\prg_generate_conditional_variant:Nnn \prop_if_empty:N`
11475 `{ c } { p , T , F , TF }`

(End definition for `\prop_if_empty:N \underline{TF}` . This function is documented on page 140.)

`\prop_if_in_p:N` Testing expandably if a key is in a property list requires to go through the key–value
`\prop_if_in_p:NV` pairs one by one. This is rather slow, and a faster test would be
`\prop_if_in_p:No` `\prg_new_protected_conditional:Npnn \prop_if_in:Nn #1 #2`
`\prop_if_in_p:cn` `{`
`\prop_if_in_p:cV` `\@@_split:NnTF #1 {#2}`
`\prop_if_in_p:co` `{ \prg_return_true: }`
`\prop_if_in:Nn \underline{TF}` `{ \prg_return_false: }`
`\prop_if_in:NV \underline{TF}` `}`
`\prop_if_in:No \underline{TF}`
`\prop_if_in:cn \underline{TF}` but `__prop_split:NnTF` is non-expandable.
`\prop_if_in:cV \underline{TF}` Instead, the key is compared to each key in turn using `\str_if_eq:ee`, which is
`\prop_if_in:co \underline{TF}` expandable. To terminate the mapping, we append to the property list the key that is
`__prop_if_in:nwnn` searched for. This second `\tl_to_str:n` is not expanded at the start, but only when
`__prop_if_in:N` included in the `\str_if_eq:ee`. It cannot make the breaking mechanism choke, because
the arbitrary token list material is enclosed in braces. The second argument of `__prop_if_in:N`
receives `__prop_pair:wn`, and if it is found as the extra item, the function receives
`\q_recursion_tail`, easily recognizable.

Here, `\prop_map_function:NN` is not sufficient for the mapping, since it can only map a single token, and cannot carry the key that is searched for.

11476 `\prg_new_conditional:Npnn \prop_if_in:Nn #1#2 { p , T , F , TF }`
11477 `{`
11478 `\exp_last_unbraced:Noo __prop_if_in:nwnn { \tl_to_str:n {#2} } #1`
11479 `__prop_pair:wn \tl_to_str:n {#2} \s__prop { }`
11480 `\q_recursion_tail`
11481 `\prg_break_point:`
11482 `}`
11483 `\cs_new:Npn __prop_if_in:nwnn #1#2 __prop_pair:wn #3 \s__prop #4`
11484 `{`
11485 `\str_if_eq:eeTF {#1} {#3}`
11486 `{ __prop_if_in:N }`
11487 `{ __prop_if_in:nwnn {#1} }`

```

11488 }
11489 \cs_new:Npn \__prop_if_in:N #1
11490 {
11491   \if_meaning:w \q_recursion_tail #1
11492   \prg_return_false:
11493   \else:
11494     \prg_return_true:
11495   \fi:
11496   \prg_break:
11497 }
11498 \prg_generate_conditional_variant:Nnn \prop_if_in:Nn
11499 { NV , No , c , cV , co } { p , T , F , TF }

```

(End definition for `\prop_if_in:NnTF`, `__prop_if_in:nwwn`, and `__prop_if_in:N`. This function is documented on page 140.)

18.4 Recovering values from property lists with branching

`\prop_get:NnTF` Getting the value corresponding to a key, keeping track of whether the key was present or not, is implemented as a conditional (with side effects). If the key was absent, the token list is not altered.

```

\prop_get:NnTF
\prop_get:NVNTF
\prop_get:NoNTF
\prop_get:cnNTF
\prop_get:cVNTF
\prop_get:coNTF
11500 \prg_new_protected_conditional:Npnn \prop_get:NnN #1#2#3 { T , F , TF }
11501 {
11502   \__prop_split:NnTF #1 {#2}
11503   {
11504     \tl_set:Nn #3 {##2}
11505     \prg_return_true:
11506   }
11507   { \prg_return_false: }
11508 }
11509 \prg_generate_conditional_variant:Nnn \prop_get:NnN
11510 { NV , No , c , cV , co } { T , F , TF }

```

(End definition for `\prop_get:NnTF`. This function is documented on page 141.)

18.5 Mapping to property lists

The argument delimited by `__prop_pair:wn` is empty except at the end of the loop where it is `\prg_break:.` No need for any quark test.

```

\prop_map_function:NN
\prop_map_function:Nc
\prop_map_function:cN
\prop_map_function:cc
\__prop_map_function:Nwwn
11511 \cs_new:Npn \prop_map_function:NN #1#2
11512 {
11513   \exp_after:wN \use_i_ii:nnn
11514   \exp_after:wN \__prop_map_function:Nwwn
11515   \exp_after:wN #2
11516   #1
11517   \prg_break: \__prop_pair:wn \s__prop { } \prg_break_point:
11518   \prg_break_point:Nn \prop_map_break: { }
11519 }
11520 \cs_new:Npn \__prop_map_function:Nwwn #1#2 \__prop_pair:wn #3 \s__prop #4
11521 {
11522   #2
11523   #1 {#3} {#4}
11524   \__prop_map_function:Nwwn #1
11525 }

```



```
11526 \cs_generate_variant:Nn \prop_map_function:NN { Nc , c , cc }
```

(End definition for `\prop_map_function:NN` and `__prop_map_function:Nwn`. This function is documented on page 141.)

`\prop_map_inline:Nn` Mapping in line requires a nesting level counter. Store the current definition of `__prop_pair:wn`, and define it anew. At the end of the loop, revert to the earlier definition. Note that besides pairs of the form `__prop_pair:wn <key> \s__prop {<value>}`, there are a leading and a trailing tokens, but both are equal to `\scan_stop:`, hence have no effect in such inline mapping. Such `\scan_stop:` could have affected ligatures if they appeared during the mapping.

```
\prop_map_inline:cn
11527 \cs_new_protected:Npn \prop_map_inline:Nn #1#2
11528 {
11529   \cs_gset_eq:cn
11530   { __prop_map_ \int_use:N \g__kernel_prg_map_int :wn } \__prop_pair:wn
11531   \int_gincr:N \g__kernel_prg_map_int
11532   \cs_gset_protected:Npn \__prop_pair:wn ##1 \s__prop ##2 {#2}
11533   #1
11534   \prg_break_point:Nn \prop_map_break:
11535   {
11536     \int_gdecr:N \g__kernel_prg_map_int
11537     \cs_gset_eq:Nc \__prop_pair:wn
11538     { __prop_map_ \int_use:N \g__kernel_prg_map_int :wn }
11539   }
11540 }
11541 \cs_generate_variant:Nn \prop_map_inline:Nn { c }
```

(End definition for `\prop_map_inline:Nn`. This function is documented on page 141.)

`\prop_map_break:` The break statements are based on the general `\prg_map_break:Nn`.
`\prop_map_break:n`

```
11542 \cs_new:Npn \prop_map_break:
11543 { \prg_map_break:Nn \prop_map_break: { } }
11544 \cs_new:Npn \prop_map_break:n
11545 { \prg_map_break:Nn \prop_map_break: }
```

(End definition for `\prop_map_break:` and `\prop_map_break:n`. These functions are documented on page 142.)

18.6 Viewing property lists

`\prop_show:N` Apply the general `__kernel_chk_defined:NT` and `\msg_show:nnnnnn`. Contrarily to sequences and comma lists, we use `\msg_show_item:nn` to format both the key and the value for each pair.

```
\prop_log:N
\prop_log:c
11546 \cs_new_protected:Npn \prop_show:N { \__prop_show:NN \msg_show:nnxxxx }
11547 \cs_generate_variant:Nn \prop_show:N { c }
11548 \cs_new_protected:Npn \prop_log:N { \__prop_show:NN \msg_log:nnxxxx }
11549 \cs_generate_variant:Nn \prop_log:N { c }
11550 \cs_new_protected:Npn \__prop_show:NN #1#2
11551 {
11552   \__kernel_chk_defined:NT #2
11553   {
11554     #1 { LaTeX/kernel } { show-prop }
11555     { \token_to_str:N #2 }
11556     { \prop_map_function:NN #2 \msg_show_item:nn }
```

```

11557         { } { }
11558     }
11559 }

```

(End definition for `\prop_show:N` and `\prop_log:N`. These functions are documented on page 142.)

```

11560 </initex | package>

```

19 l3msg implementation

```

11561 (*initex | package)

```

```

11562 <@@=msg>

```

`\l__msg_internal_tl` A general scratch for the module.

```

11563 \tl_new:N \l__msg_internal_tl

```

(End definition for `\l__msg_internal_tl`.)

`\l__msg_name_str` Used to save module info when creating messages.

```

\l__msg_text_str 11564 \str_new:N \l__msg_name_str

```

```

11565 \str_new:N \l__msg_text_str

```

(End definition for `\l__msg_name_str` and `\l__msg_text_str`.)

19.1 Creating messages

Messages are created and used separately, so there two parts to the code here. First, a mechanism for creating message text. This is pretty simple, as there is not actually a lot to do.

`\c__msg_text_prefix_tl` Locations for the text of messages.

`\c__msg_more_text_prefix_tl`

```

11566 \tl_const:Nn \c__msg_text_prefix_tl { msg~text~>~ }

```

```

11567 \tl_const:Nn \c__msg_more_text_prefix_tl { msg~extra~text~>~ }

```

(End definition for `\c__msg_text_prefix_tl` and `\c__msg_more_text_prefix_tl`.)

`\msg_if_exist_p:nn` Test whether the control sequence containing the message text exists or not.

`\msg_if_exist:nnTF`

```

11568 \prg_new_conditional:Npnn \msg_if_exist:nn #1#2 { p , T , F , TF }

```

```

11569 {

```

```

11570     \cs_if_exist:cTF { \c__msg_text_prefix_tl #1 / #2 }

```

```

11571     { \prg_return_true: } { \prg_return_false: }

```

```

11572 }

```

(End definition for `\msg_if_exist:nnTF`. This function is documented on page 145.)

`__msg_chk_if_free:nn` This auxiliary is similar to `__kernel_chk_if_free_cs:N`, and is used when defining messages with `\msg_new:nnnn`.

```

11573 \__kernel_patch:nnNNpn { }

```

```

11574 {

```

```

11575     \__kernel_debug_log:x

```

```

11576     { Defining~message~ #1 / #2 ~\msg_line_context: }

```

```

11577 }

```

```

11578 \cs_new_protected:Npn \__msg_chk_free:nn #1#2

```

```

11579 {

```

```

11580 \msg_if_exist:nnT {#1} {#2}
11581 {
11582   \__kernel_msg_error:nxxx { kernel } { message-already-defined }
11583   {#1} {#2}
11584 }
11585 }

```

(End definition for __msg_chk_if_free:nn.)

\msg_new:nnnn Setting a message simply means saving the appropriate text into two functions. A sanity check first.

```

\msg_new:nnn
\msg_gset:nnnn 11586 \cs_new_protected:Npn \msg_new:nnnn #1#2
\msg_gset:nnn 11587 {
\msg_set:nnnn 11588   \__msg_chk_free:nn {#1} {#2}
\msg_set:nnn 11589   \msg_gset:nnnn {#1} {#2}
11590 }
11591 \cs_new_protected:Npn \msg_new:nnn #1#2#3
11592 { \msg_new:nnnn {#1} {#2} {#3} { } }
11593 \cs_new_protected:Npn \msg_set:nnnn #1#2#3#4
11594 {
11595   \cs_set:cpn { \c__msg_text_prefix_tl #1 / #2 }
11596   ##1##2##3##4 {#3}
11597   \cs_set:cpn { \c__msg_more_text_prefix_tl #1 / #2 }
11598   ##1##2##3##4 {#4}
11599 }
11600 \cs_new_protected:Npn \msg_set:nnn #1#2#3
11601 { \msg_set:nnnn {#1} {#2} {#3} { } }
11602 \cs_new_protected:Npn \msg_gset:nnnn #1#2#3#4
11603 {
11604   \cs_gset:cpn { \c__msg_text_prefix_tl #1 / #2 }
11605   ##1##2##3##4 {#3}
11606   \cs_gset:cpn { \c__msg_more_text_prefix_tl #1 / #2 }
11607   ##1##2##3##4 {#4}
11608 }
11609 \cs_new_protected:Npn \msg_gset:nnn #1#2#3
11610 { \msg_gset:nnnn {#1} {#2} {#3} { } }

```

(End definition for \msg_new:nnnn and others. These functions are documented on page 144.)

19.2 Messages: support functions and text

\c__msg_coding_error_text_tl Simple pieces of text for messages.

```

\c__msg_continue_text_tl 11611 \tl_const:Nn \c__msg_coding_error_text_tl
\c__msg_critical_text_tl 11612 {
\c__msg_fatal_text_tl 11613   This-is-a-coding-error.
\c__msg_help_text_tl 11614   \\ \\
\c__msg_no_info_text_tl 11615 }
\c__msg_on_line_text_tl 11616 \tl_const:Nn \c__msg_continue_text_tl
\c__msg_return_text_tl 11617 { Type~<return>~to~continue }
\c__msg_trouble_text_tl 11618 \tl_const:Nn \c__msg_critical_text_tl
11619 { Reading~the~current~file~'\g_file_curr_name_str'~will~stop. }
11620 \tl_const:Nn \c__msg_fatal_text_tl
11621 { This-is-a-fatal-error:~LaTeX~will~abort. }
11622 \tl_const:Nn \c__msg_help_text_tl

```

```

11623 { For~immediate~help~type~H~<return> }
11624 \tl_const:Nn \c__msg_no_info_text_tl
11625 {
11626   LaTeX~does~not~know~anything~more~about~this~error,~sorry.
11627   \c__msg_return_text_tl
11628 }
11629 \tl_const:Nn \c__msg_on_line_text_tl { on~line }
11630 \tl_const:Nn \c__msg_return_text_tl
11631 {
11632   \\\ \\\
11633   Try~typing~<return>~to~proceed.
11634   \\\
11635   If~that~doesn't~work,~type~X~<return>~to~quit.
11636 }
11637 \tl_const:Nn \c__msg_trouble_text_tl
11638 {
11639   \\\ \\\
11640   More~errors~will~almost~certainly~follow: \\\
11641   the~LaTeX~run~should~be~aborted.
11642 }

```

(End definition for `\c__msg_coding_error_text_tl` and others.)

`\msg_line_number:` For writing the line number nicely. `\msg_line_context:` was set up earlier, so this is not new.

```

11643 \cs_new:Npn \msg_line_number: { \int_use:N \tex_inputlineno:D }
11644 \cs_gset:Npn \msg_line_context:
11645 {
11646   \c__msg_on_line_text_tl
11647   \c_space_tl
11648   \msg_line_number:
11649 }

```

(End definition for `\msg_line_number:` and `\msg_line_context:`. These functions are documented on page 145.)

19.3 Showing messages: low level mechanism

`__msg_interrupt:Nnnn`
`__msg_no_more_text:nnnn`

The low-level interruption macro is rather opaque, unfortunately. Depending on the availability of more information there is a choice of how to set up the further help. We feed the extra help text and the message itself to a wrapping auxiliary, in this order because we must first setup TeX's `\errhelp` register before issuing an `\errmessage`. To deal with the various cases of critical or fatal errors with and without help text, there is a bit of argument-passing to do.

```

11650 \cs_new_protected:Npn \__msg_interrupt:NnnnN #1#2#3#4#5
11651 {
11652   \str_set:Nx \l__msg_text_str { #1 {#2} }
11653   \str_set:Nx \l__msg_name_str { \msg_module_name:n {#2} }
11654   \cs_if_eq:cNTF
11655     { \c__msg_more_text_prefix_tl #2 / #3 }
11656     \__msg_no_more_text:nnnn
11657     {
11658       \__msg_interrupt_wrap:nnn
11659       { \use:c { \c__msg_text_prefix_tl #2 / #3 } #4 }

```

```

11660         { \c__msg_continue_text_tl }
11661         {
11662             \c__msg_no_info_text_tl
11663             \tl_if_empty:NF #5
11664             { \\ \\ #5 }
11665         }
11666     }
11667     {
11668         \__msg_interrupt_wrap:nnn
11669         { \use:c { \c__msg_text_prefix_tl #2 / #3 } #4 }
11670         { \c__msg_help_text_tl }
11671         {
11672             \use:c { \c__msg_more_text_prefix_tl #2 / #3 } #4
11673             \tl_if_empty:NF #5
11674             { \\ \\ #5 }
11675         }
11676     }
11677 }
11678 \cs_new:Npn \__msg_no_more_text:nnnn #1#2#3#4 { }

```

(End definition for `__msg_interrupt:Nnnn` and `__msg_no_more_text:nnnn`.)

`__msg_interrupt_wrap:nnn` First setup TeX's `\errhelp` register with the extra help #1, then build a nice-looking error message with #2. Everything is done using x-type expansion as the new line markers are different for the two type of text and need to be correctly set up. The auxiliary `__msg_interrupt_more_text:n` receives its argument as a line-wrapped string, which is thus unaffected by expansion. We have to split the main text into two parts as only the “message” itself is wrapped with a leader: the generic help is wrapped at full width. We also have to allow for the two characters used by `\errmessage` itself.

```

11679 \cs_new_protected:Npn \__msg_interrupt_wrap:nnn #1#2#3
11680 {
11681     \iow_wrap:nnnN { \\ #3 } { } { } \__msg_interrupt_more_text:n
11682     \group_begin:
11683     \int_sub:Nn \l_iow_line_count_int { 2 }
11684     \iow_wrap:nxnN { \l__msg_text_str : ~ #1 }
11685     {
11686         ( \l__msg_name_str )
11687         \prg_replicate:nn
11688         {
11689             \str_count:N \l__msg_text_str
11690             - \str_count:N \l__msg_name_str
11691             + 2
11692         }
11693         { ~ }
11694     }
11695     { } \__msg_interrupt_text:n
11696     \iow_wrap:nnnN { \l__msg_internal_tl \\ \\ #2 } { } { }
11697     \__msg_interrupt:n
11698 }
11699 \cs_new_protected:Npn \__msg_interrupt_text:n #1
11700 {
11701     \group_end:
11702     \tl_set:Nn \l__msg_internal_tl {#1}
11703 }

```

```

11704 \cs_new_protected:Npn \_msg_interrupt_more_text:n #1
11705 { \exp_args:Nx \tex_errhelp:D { #1 \iow_newline: } }

```

(End definition for _msg_interrupt_wrap:nnn, _msg_interrupt_text:n, and _msg_interrupt_more_text:n.)

_msg_interrupt:n

The business end of the process starts by producing some visual separation of the message from the main part of the log. The error message needs to be printed with everything made “invisible”: T_EX’s own information involves the macro in which \errmessage is called, and the end of the argument of the \errmessage, including the closing brace. We use an active ! to call the \errmessage primitive, and end its argument with \use_none:n {<spaces>} which fills the output with spaces. Two trailing closing braces are turned into spaces to hide them as well. The group in which we alter the definition of the active ! is closed before producing the message: this ensures that tokens inserted by typing I in the command-line are inserted after the message is entirely cleaned up.

The _kernel_iow_with:Nnn auxiliary, defined in l3file, expects an <integer variable>, an integer <value>, and some <code>. It runs the <code> after ensuring that the <integer variable> takes the given <value>, then restores the former value of the <integer variable> if needed. We use it to ensure that the \newlinechar is 10, as needed for \iow_newline: to work, and that \errorcontextlines is -1, to avoid showing irrelevant context. Note that restoring the former value of these integers requires inserting tokens after the \errmessage, which go in the way of tokens which could be inserted by the user. This is unavoidable.

```

11706 \group_begin:
11707   \char_set_lccode:nn { 38 } { 32 } % &
11708   \char_set_lccode:nn { 46 } { 32 } % .
11709   \char_set_lccode:nn { 123 } { 32 } % {
11710   \char_set_lccode:nn { 125 } { 32 } % }
11711   \char_set_catcode_active:N \&
11712 \tex_lowercase:D
11713 {
11714   \group_end:
11715   \cs_new_protected:Npn \_msg_interrupt:n #1
11716   {
11717     \iow_term:n { }
11718     \_kernel_iow_with:Nnn \tex_newlinechar:D { ‘^^J }
11719     {
11720       \_kernel_iow_with:Nnn \tex_errorcontextlines:D { -1 }
11721       {
11722         \group_begin:
11723         \cs_set_protected:Npn &
11724         {
11725           \tex_errmessage:D
11726           {
11727             #1
11728             \use_none:n
11729             { ..... }
11730           }
11731         }
11732         \exp_after:wN
11733         \group_end:
11734         &
11735       }
11736     }
11737   }

```

```

11736         }
11737     }
11738 }

```

(End definition for `_msg_interrupt:n`.)

19.4 Displaying messages

L^AT_EX is handling error messages and so the T_EX ones are disabled. This is already done by the L^AT_EX 2_ε kernel, so to avoid messing up any deliberate change by a user this is only set in format mode.

```

11739 <*initex>
11740 \int_gset:Nn \tex_errorcontextlines:D { -1 }
11741 </initex>

```

`\msg_fatal_text:n` A function for issuing messages: both the text and order could in principle vary. The module name may be empty for kernel messages, hence the slightly contorted code path for a space.

```

\msg_fatal_text:n
\msg_critical_text:n
\msg_error_text:n
\msg_warning_text:n
\msg_info_text:n
\_msg_text:nn
\_msg_text:n
11742 \cs_new:Npn \msg_fatal_text:n #1
11743 {
11744     Fatal ~
11745     \msg_error_text:n {#1}
11746 }
11747 \cs_new:Npn \msg_critical_text:n #1
11748 {
11749     Critical ~
11750     \msg_error_text:n {#1}
11751 }
11752 \cs_new:Npn \msg_error_text:n #1
11753 { \_msg_text:nn {#1} { Error } }
11754 \cs_new:Npn \msg_warning_text:n #1
11755 { \_msg_text:nn {#1} { Warning } }
11756 \cs_new:Npn \msg_info_text:n #1
11757 { \_msg_text:nn {#1} { Info } }
11758 \cs_new:Npn \_msg_text:nn #1#2
11759 {
11760     \exp_args:Nf \_msg_text:n { \msg_module_type:n {#1} }
11761     \msg_module_name:n {#1} ~
11762     #2
11763 }
11764 \cs_new:Npn \_msg_text:n #1
11765 {
11766     \tl_if_blank:nF {#1}
11767     { #1 ~ }
11768 }

```

(End definition for `\msg_fatal_text:n` and others. These functions are documented on page 145.)

`\g_msg_module_name_prop` For storing public module information: the kernel data is set up in advance.

```

\g_msg_module_type_prop
11769 \prop_new:N \g_msg_module_name_prop
11770 \prop_gput:Nnn \g_msg_module_name_prop { LaTeX } { LaTeX3 }
11771 \prop_new:N \g_msg_module_type_prop
11772 \prop_gput:Nnn \g_msg_module_type_prop { LaTeX } { }

```

(End definition for `\g_msg_module_name_prop` and `\g_msg_module_type_prop`. These variables are documented on page 146.)

`\msg_module_type:n` Contextual footer information, with the potential to give modules an alternative name.

```

11773 \cs_new:Npn \msg_module_type:n #1
11774 {
11775     \prop_if_in:NnTF \g_msg_module_type_prop {#1}
11776     { \prop_item:Nn \g_msg_module_type_prop {#1} }
11777     <*initex>
11778     { Module }
11779     </initex>
11780     <*package>
11781     { Package }
11782     </package>
11783 }
```

(End definition for `\msg_module_type:n`. This function is documented on page 146.)

`\msg_module_name:n` Contextual footer information, with the potential to give modules an alternative name.

`\msg_see_documentation_text:n`

```

11784 \cs_new:Npn \msg_module_name:n #1
11785 {
11786     \prop_if_in:NnTF \g_msg_module_name_prop {#1}
11787     { \prop_item:Nn \g_msg_module_name_prop {#1} }
11788     {#1}
11789 }
11790 \cs_new:Npn \msg_see_documentation_text:n #1
11791 {
11792     See~the~ \msg_module_name:n {#1} ~
11793     documentation~for~further~information.
11794 }
```

(End definition for `\msg_module_name:n` and `\msg_see_documentation_text:n`. These functions are documented on page 146.)

`_msg_class_new:nn`

```

11795 \group_begin:
11796 \cs_set_protected:Npn \_msg_class_new:nn #1#2
11797 {
11798     \prop_new:c { l__msg_redirect_ #1 _prop }
11799     \cs_new_protected:cpn { __msg_ #1 _code:nnnnnn }
11800         ##1##2##3##4##5##6 {#2}
11801     \cs_new_protected:cpn { msg_ #1 :nnnnnn } ##1##2##3##4##5##6
11802     {
11803         \use:x
11804         {
11805             \exp_not:n { \_msg_use:nnnnnn {#1} {##1} {##2} }
11806             { \tl_to_str:n {##3} } { \tl_to_str:n {##4} }
11807             { \tl_to_str:n {##5} } { \tl_to_str:n {##6} }
11808         }
11809     }
11810     \cs_new_protected:cpx { msg_ #1 :nnnnn } ##1##2##3##4##5
11811     { \exp_not:c { msg_ #1 :nnnnnn } {##1} {##2} {##3} {##4} {##5} { } }
11812     \cs_new_protected:cpx { msg_ #1 :nnnn } ##1##2##3##4
11813     { \exp_not:c { msg_ #1 :nnnnnn } {##1} {##2} {##3} {##4} { } { } }
11814     \cs_new_protected:cpx { msg_ #1 :nnn } ##1##2##3
```



```

11815     { \exp_not:c { msg_ #1 :nnnnnn } {##1} {##2} {##3} { } { } { } }
11816 \cs_new_protected:cpx { msg_ #1 :nn } ##1##2
11817     { \exp_not:c { msg_ #1 :nnnnnn } {##1} {##2} { } { } { } { } }
11818 \cs_new_protected:cpx { msg_ #1 :nnxxxx } ##1##2##3##4##5##6
11819     {
11820     \use:x
11821     {
11822     \exp_not:N \exp_not:n
11823     { \exp_not:c { msg_ #1 :nnnnnn } {##1} {##2} }
11824     {##3} {##4} {##5} {##6}
11825     }
11826     }
11827 \cs_new_protected:cpx { msg_ #1 :nnxxx } ##1##2##3##4##5
11828     { \exp_not:c { msg_ #1 :nnxxxx } {##1} {##2} {##3} {##4} {##5} { } }
11829 \cs_new_protected:cpx { msg_ #1 :nnxx } ##1##2##3##4
11830     { \exp_not:c { msg_ #1 :nnxxxx } {##1} {##2} {##3} {##4} { } { } }
11831 \cs_new_protected:cpx { msg_ #1 :nnx } ##1##2##3
11832     { \exp_not:c { msg_ #1 :nnxxxx } {##1} {##2} {##3} { } { } { } }
11833 }

```

(End definition for `_msg_class_new:nn`.)

`\msg_fatal:nnnnnn` For fatal errors, after the error message `TeX` bails out. We force a bail out rather than using `\end` as this means it does not matter if we are in a context where normally the run cannot end.

```

\msg_fatal:nnxxxx
\msg_fatal:nnnnn
\msg_fatal:nnxxx
\msg_fatal:nnnn
\msg_fatal:nnxx
\msg_fatal:nnn
\msg_fatal:nnx
\msg_fatal:nn
\_msg_fatal_exit:
11834 \_msg_class_new:nn { fatal }
11835 {
11836     \_msg_interrupt:NnnnN
11837     \msg_fatal_text:n {#1} {#2}
11838     { {#3} {#4} {#5} {#6} }
11839     \c\_msg_fatal_text_tl
11840     \_msg_fatal_exit:
11841 }
11842 \cs_new_protected:Npn \_msg_fatal_exit:
11843 {
11844     \tex_batchmode:D
11845     \tex_read:D -1 to \l\_msg_internal_tl
11846 }

```

(End definition for `\msg_fatal:nnnnnn` and others. These functions are documented on page 147.)

`\msg_critical:nnnnnn` Not quite so bad: just end the current file.

```

\msg_critical:nnxxxx
\msg_critical:nnnnn
\msg_critical:nnxxx
\msg_critical:nnnn
\msg_critical:nnxx
\msg_critical:nnn
\msg_critical:nnx
\msg_critical:nn
11847 \_msg_class_new:nn { critical }
11848 {
11849     \_msg_interrupt:NnnnN
11850     \msg_critical_text:n {#1} {#2}
11851     { {#3} {#4} {#5} {#6} }
11852     \c\_msg_critical_text_tl
11853     \tex_endinput:D
11854 }

```

(End definition for `\msg_critical:nnnnnn` and others. These functions are documented on page 147.)

`\msg_error:nnnnnn` For an error, the interrupt routine is called. We check if there is a “more text” by
`\msg_error:nnxxxx` comparing that control sequence with a permanently empty text.

```

\msg_error:nnnnnn 11855 \_msg_class_new:nn { error }
\msg_error:nnxxxx 11856 {
\msg_error:nnnnn 11857 \_msg_interrupt:NnnnN
\msg_error:nnxxx 11858 \msg_error_text:n {#1} {#2}
\msg_error:nnnn 11859 { {#3} {#4} {#5} {#6} }
\msg_error:nnx 11860 \c_empty_tl
\msg_error:nn 11861 }

```

(End definition for `\msg_error:nnnnnn` and others. These functions are documented on page 147.)

`\msg_warning:nnnnnn` Warnings are printed to the terminal.

```

\msg_warning:nnxxxx 11862 \_msg_class_new:nn { warning }
\msg_warning:nnnnnn 11863 {
\msg_warning:nnxxx 11864 \str_set:Nx \l__msg_text_str { \msg_warning_text:n {#1} }
\msg_warning:nnnn 11865 \str_set:Nx \l__msg_name_str { \msg_module_name:n {#1} }
\msg_warning:nnxxx 11866 \iow_term:n { }
\msg_warning:nnnn 11867 \iow_wrap:nxnN
\msg_warning:nnx 11868 {
11869 \l__msg_text_str : ~
11870 \use:c { \c__msg_text_prefix_tl #1 / #2 } {#3} {#4} {#5} {#6}
11871 }
11872 {
11873 ( \l__msg_name_str )
11874 \prg_replicate:nn
11875 {
11876 \str_count:N \l__msg_text_str
11877 - \str_count:N \l__msg_name_str
11878 }
11879 { ~ }
11880 }
11881 { } \iow_term:n
11882 \iow_term:n { }
11883 }

```

(End definition for `\msg_warning:nnnnnn` and others. These functions are documented on page 147.)

`\msg_info:nnnnnn` Information only goes into the log.

```

\msg_info:nnxxxx 11884 \_msg_class_new:nn { info }
\msg_info:nnnnnn 11885 {
\msg_info:nnxxx 11886 \str_set:Nx \l__msg_text_str { \msg_info_text:n {#1} }
\msg_info:nnnn 11887 \str_set:Nx \l__msg_name_str { \msg_module_name:n {#1} }
\msg_info:nnxxx 11888 \iow_log:n { }
\msg_info:nnnn 11889 \iow_wrap:nxnN
\msg_info:nnx 11890 {
11891 \l__msg_text_str : ~
11892 \use:c { \c__msg_text_prefix_tl #1 / #2 } {#3} {#4} {#5} {#6}
11893 }
11894 {
11895 ( \l__msg_name_str )
11896 \prg_replicate:nn
11897 {
11898 \str_count:N \l__msg_text_str

```

```

11899         - \str_count:N \l__msg_name_str
11900     }
11901     { ~ }
11902 }
11903 { } \iow_log:n
11904 \iow_log:n { }
11905 }

```

(End definition for `\msg_info:nnnnnn` and others. These functions are documented on page 148.)

`\msg_log:nnnnnn` “Log” data is very similar to information, but with no extras added.

```

\msg_log:nnxxxx 11906 \__msg_class_new:nn { log }
\msg_log:nnnnn 11907 {
\msg_log:nnxxx 11908 \iow_wrap:nnnN
\msg_log:nnnn 11909 { \use:c { \c__msg_text_prefix_tl #1 / #2 } {#3} {#4} {#5} {#6} }
\msg_log:nnxx 11910 { } { } \iow_log:n
\msg_log:nnn 11911 }

```

`\msg_log:nnx` (End definition for `\msg_log:nnnnnn` and others. These functions are documented on page 148.)

`\msg_log:nn`

`\msg_none:nnnnnn` The none message type is needed so that input can be gobbled.

```

\msg_none:nnxxxx 11912 \__msg_class_new:nn { none } { }

```

`\msg_none:nnnnn` (End definition for `\msg_none:nnnnnn` and others. These functions are documented on page 148.)

`\msg_none:nnxxx`

`\msg_none:nnnn`

`\msg_show:nnnnnn`

`\msg_show:nnxxx`

`\msg_show:nnnn`

`\msg_show:nnnnn`

`\msg_show:nnxxx`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

`\msg_show:nnn`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

`\msg_show:nnn`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

`\msg_show:nnn`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

`\msg_show:nnn`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

`\msg_show:nnn`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

`\msg_show:nnn`

`\msg_show:nnxx`

`\msg_show:nnx`

`\msg_show:nn`

The show message type is used for `\seq_show:N` and similar complicated data structures. Wrap the given text with a trailing dot (important later) then pass it to `__msg_show:n`. If there is `\\>~` (or if the whole thing starts with `>~`) we split there, print the first part and show the second part using `\showtokens` (the `\exp_after:wN` ensure a nice display). Note that that primitive adds a leading `>~` and trailing dot. That is why we included a trailing dot before wrapping and removed it afterwards. If there is no `\\>~` do the same but with an empty second part which adds a spurious but inevitable `>~`.

```

11913 \__msg_class_new:nn { show }
11914 {
11915 \iow_wrap:nnnN
11916 { \use:c { \c__msg_text_prefix_tl #1 / #2 } {#3} {#4} {#5} {#6} }
11917 { } { } \__msg_show:n
11918 }
11919 \cs_new_protected:Npn \__msg_show:n #1
11920 {
11921 \tl_if_in:nnTF { ^^J #1 } { ^^J > ~ }
11922 {
11923 \tl_if_in:nnTF { #1 \q_mark } { . \q_mark }
11924 { \__msg_show_dot:w } { \__msg_show:w }
11925 ^^J #1 \q_stop
11926 }
11927 { \__msg_show:nn { ? #1 } { } }
11928 }
11929 \cs_new:Npn \__msg_show_dot:w #1 ^^J > ~ #2 . \q_stop
11930 { \__msg_show:nn {#1} {#2} }
11931 \cs_new:Npn \__msg_show:w #1 ^^J > ~ #2 \q_stop
11932 { \__msg_show:nn {#1} {#2} }
11933 \cs_new_protected:Npn \__msg_show:nn #1#2
11934 {

```

```

11935 \tl_if_empty:nF {#1}
11936 { \exp_args:No \iow_term:n { \use_none:n #1 } }
11937 \tl_set:Nn \l__msg_internal_tl {#2}
11938 \__kernel_iow_with:Nnn \tex_newlinechar:D { 10 }
11939 {
11940 \__kernel_iow_with:Nnn \tex_errorcontextlines:D { -1 }
11941 {
11942 \tex_showtokens:D \exp_after:wN \exp_after:wN \exp_after:wN
11943 { \exp_after:wN \l__msg_internal_tl }
11944 }
11945 }
11946 }

```

(End definition for `\msg_show:nnnnnn` and others. These functions are documented on page 256.)

End the group to eliminate `__msg_class_new:nn`.

```

11947 \group_end:

```

`__msg_class_chk_exist:nT` Checking that a message class exists. We build this from `\cs_if_free:cTF` rather than `\cs_if_exist:cTF` because that avoids reading the second argument earlier than necessary.

```

11948 \cs_new:Npn \__msg_class_chk_exist:nT #1
11949 {
11950 \cs_if_free:cTF { __msg_ #1 _code:nnnnnn }
11951 { \__kernel_msg_error:nx { kernel } { message-class-unknown } {#1} }
11952 }

```

(End definition for `__msg_class_chk_exist:nT`.)

`\l__msg_class_tl` Support variables needed for the redirection system.
`\l__msg_current_class_tl`

```

11953 \tl_new:N \l__msg_class_tl
11954 \tl_new:N \l__msg_current_class_tl

```

(End definition for `\l__msg_class_tl` and `\l__msg_current_class_tl`.)

`\l__msg_redirect_prop` For redirection of individually-named messages

```

11955 \prop_new:N \l__msg_redirect_prop

```

(End definition for `\l__msg_redirect_prop`.)

`\l__msg_hierarchy_seq` During redirection, split the message name into a sequence: `{/module/submodule}`, `{/module}`, and `{}`.

```

11956 \seq_new:N \l__msg_hierarchy_seq

```

(End definition for `\l__msg_hierarchy_seq`.)

`\l__msg_class_loop_seq` Classes encountered when following redirections to check for loops.

```

11957 \seq_new:N \l__msg_class_loop_seq

```

(End definition for `\l__msg_class_loop_seq`.)

```

    \_msg\_use:nnnnnnn
    \_msg\_use\_redirect\_name:n
    \_msg\_use\_hierarchy:nwN
    \_msg\_use\_redirect\_module:n
    \_msg\_use\_code:

```

Actually using a message is a multi-step process. First, some safety checks on the message and class requested. The code and arguments are then stored to avoid passing them around. The assignment to `_msg_use_code:` is similar to `\tl_set:Nn`. The message is eventually produced with whatever `\l_msg_class_tl` is when `_msg_use_code:` is called. Here is also a good place to suppress tracing output if the trace package is loaded since all (non-expandable) messages go through this auxiliary.

```

11958 \cs\_new\_protected:Npn \_msg\_use:nnnnnnn #1#2#3#4#5#6#7
11959 {
11960   <package> \use:c { conditionally@traceoff }
11961   \msg\_if\_exist:nnTF {#2} {#3}
11962   {
11963     \_msg\_class\_chk\_exist:nT {#1}
11964     {
11965       \tl\_set:Nn \l\_msg\_current\_class\_tl {#1}
11966       \cs\_set\_protected:Npx \_msg\_use\_code:
11967       {
11968         \exp\_not:n
11969         {
11970           \use:c { \_msg\_ \l\_msg\_class\_tl \_code:nnnnnnn }
11971           {#2} {#3} {#4} {#5} {#6} {#7}
11972         }
11973       }
11974       \_msg\_use\_redirect\_name:n { #2 / #3 }
11975     }
11976   }
11977   { \_kernel\_msg\_error:nnxx { kernel } { message-unknown } {#2} {#3} }
11978   <package> \use:c { conditionally@traceon }
11979 }
11980 \cs\_new\_protected:Npn \_msg\_use\_code: { }

```

The first check is for a individual message redirection. If this applies then no further redirection is attempted. Otherwise, split the message name into `<module>`, `<submodule>` and `<message>` (with an arbitrary number of slashes), and store `{/module/submodule}`, `{/module}` and `{}` into `\l_msg_hierarchy_seq`. We then map through this sequence, applying the most specific redirection.

```

11981 \cs\_new\_protected:Npn \_msg\_use\_redirect\_name:n #1
11982 {
11983   \prop\_get:NnNTF \l\_msg\_redirect\_prop { / #1 } \l\_msg\_class\_tl
11984   { \_msg\_use\_code: }
11985   {
11986     \seq\_clear:N \l\_msg\_hierarchy\_seq
11987     \_msg\_use\_hierarchy:nwN { }
11988     #1 \q\_mark \_msg\_use\_hierarchy:nwN
11989     / \q\_mark \use\_none\_delimit\_by\_q\_stop:w
11990     \q\_stop
11991     \_msg\_use\_redirect\_module:n { }
11992   }
11993 }
11994 \cs\_new\_protected:Npn \_msg\_use\_hierarchy:nwN #1#2 / #3 \q\_mark #4
11995 {
11996   \seq\_put\_left:Nn \l\_msg\_hierarchy\_seq {#1}
11997   #4 { #1 / #2 } #3 \q\_mark #4
11998 }

```

At this point, the items of `\l__msg_hierarchy_seq` are the various levels at which we should look for a redirection. Redirections which are less specific than the argument of `__msg_use_redirect_module:n` are not attempted. This argument is empty for a class redirection, `/module` for a module redirection, *etc.* Loop through the sequence to find the most specific redirection, with module `##1`. The loop is interrupted after testing for a redirection for `##1` equal to the argument `#1` (least specific redirection allowed). When a redirection is found, break the mapping, then if the redirection targets the same class, output the code with that class, and otherwise set the target as the new current class, and search for further redirections. Those redirections should be at least as specific as `##1`.

```

11999 \cs_new_protected:Npn \__msg_use_redirect_module:n #1
12000 {
12001   \seq_map_inline:Nn \l__msg_hierarchy_seq
12002   {
12003     \prop_get:cnNTF { l__msg_redirect_ \l__msg_current_class_tl _prop }
12004     {##1} \l__msg_class_tl
12005     {
12006       \seq_map_break:n
12007       {
12008         \tl_if_eq:NNTF \l__msg_current_class_tl \l__msg_class_tl
12009         { \__msg_use_code: }
12010         {
12011           \tl_set_eq:NN \l__msg_current_class_tl \l__msg_class_tl
12012           \__msg_use_redirect_module:n {##1}
12013         }
12014       }
12015     }
12016     {
12017       \str_if_eq:nnT {##1} {#1}
12018       {
12019         \tl_set_eq:NN \l__msg_class_tl \l__msg_current_class_tl
12020         \seq_map_break:n { \__msg_use_code: }
12021       }
12022     }
12023   }
12024 }

```

(End definition for `__msg_use:nnnnnnn` and others.)

`\msg_redirect_name:nnn` Named message always use the given class even if that class is redirected further. An empty target class cancels any existing redirection for that message.

```

12025 \cs_new_protected:Npn \msg_redirect_name:nnn #1#2#3
12026 {
12027   \tl_if_empty:nTF {#3}
12028   { \prop_remove:Nn \l__msg_redirect_prop { / #1 / #2 } }
12029   {
12030     \__msg_class_chk_exist:nT {#3}
12031     { \prop_put:Nnn \l__msg_redirect_prop { / #1 / #2 } {#3} }
12032   }
12033 }

```

(End definition for `\msg_redirect_name:nnn`. This function is documented on page [149](#).)

```

\msg_redirect_class:nn
\msg_redirect_module:nnn
  \__msg_redirect:nnn
\__msg_redirect_loop_chk:nnn
\__msg_redirect_loop_list:n

```

If the target class is empty, eliminate the corresponding redirection. Otherwise, add the redirection. We must then check for a loop: as an initialization, we start by storing the initial class in \l__msg_current_class_tl.

```

12034 \cs_new_protected:Npn \msg_redirect_class:nn
12035   { \__msg_redirect:nnn { } }
12036 \cs_new_protected:Npn \msg_redirect_module:nnn #1
12037   { \__msg_redirect:nnn { / #1 } }
12038 \cs_new_protected:Npn \__msg_redirect:nnn #1#2#3
12039   {
12040     \__msg_class_chk_exist:nT {#2}
12041     {
12042       \tl_if_empty:nTF {#3}
12043       { \prop_remove:cn { l__msg_redirect_ #2 _prop } {#1} }
12044       {
12045         \__msg_class_chk_exist:nT {#3}
12046         {
12047           \prop_put:cnn { l__msg_redirect_ #2 _prop } {#1} {#3}
12048           \tl_set:Nn \l__msg_current_class_tl {#2}
12049           \seq_clear:N \l__msg_class_loop_seq
12050           \__msg_redirect_loop_chk:nnn {#2} {#3} {#1}
12051         }
12052       }
12053     }
12054   }

```

Since multiple redirections can only happen with increasing specificity, a loop requires that all steps are of the same specificity. The new redirection can thus only create a loop with other redirections for the exact same module, #1, and not submodules. After some initialization above, follow redirections with \l__msg_class_tl, and keep track in \l__msg_class_loop_seq of the various classes encountered. A redirection from a class to itself, or the absence of redirection both mean that there is no loop. A redirection to the initial class marks a loop. To break it, we must decide which redirection to cancel. The user most likely wants the newly added redirection to hold with no further redirection. We thus remove the redirection starting from #2, target of the new redirection. Note that no message is emitted by any of the underlying functions: otherwise we may get an infinite loop because of a message from the message system itself.

```

12055 \cs_new_protected:Npn \__msg_redirect_loop_chk:nnn #1#2#3
12056   {
12057     \seq_put_right:Nn \l__msg_class_loop_seq {#1}
12058     \prop_get:cnNT { l__msg_redirect_ #1 _prop } {#3} \l__msg_class_tl
12059     {
12060       \str_if_eq:VnF \l__msg_class_tl {#1}
12061       {
12062         \tl_if_eq:NNTF \l__msg_class_tl \l__msg_current_class_tl
12063         {
12064           \prop_put:cnn { l__msg_redirect_ #2 _prop } {#3} {#2}
12065           \__kernel_msg_warning:nnxxxx
12066           { kernel } { message-redirect-loop }
12067           { \seq_item:Nn \l__msg_class_loop_seq { 1 } }
12068           { \seq_item:Nn \l__msg_class_loop_seq { 2 } }
12069           {#3}
12070           {
12071             \seq_map_function:NN \l__msg_class_loop_seq

```

```

12072         \_msg_redirect_loop_list:n
12073         { \seq_item:Nn \l__msg_class_loop_seq { 1 } }
12074     }
12075 }
12076 { \_msg_redirect_loop_chk:onn \l__msg_class_tl {#2} {#3} }
12077 }
12078 }
12079 }
12080 \cs_generate_variant:Nn \_msg_redirect_loop_chk:nnn { o }
12081 \cs_new:Npn \_msg_redirect_loop_list:n #1 { {#1} ~ => ~ }

```

(End definition for `\msg_redirect_class:nn` and others. These functions are documented on page 149.)

19.5 Kernel-specific functions

`_kernel_msg_new:nnnn` The kernel needs some messages of its own. These are created using pre-built functions. Two functions are provided: one more general and one which only has the short text part.

```

\_kernel_msg_new:nnn
\_kernel_msg_set:nnnn
\_kernel_msg_set:nnn
12082 \cs_new_protected:Npn \_kernel_msg_new:nnnn #1#2
12083 { \msg_new:nnnn { LaTeX } { #1 / #2 } }
12084 \cs_new_protected:Npn \_kernel_msg_new:nnn #1#2
12085 { \msg_new:nnn { LaTeX } { #1 / #2 } }
12086 \cs_new_protected:Npn \_kernel_msg_set:nnnn #1#2
12087 { \msg_set:nnnn { LaTeX } { #1 / #2 } }
12088 \cs_new_protected:Npn \_kernel_msg_set:nnn #1#2
12089 { \msg_set:nnn { LaTeX } { #1 / #2 } }

```

(End definition for `_kernel_msg_new:nnnn` and others.)

`_msg_kernel_class_new:nN` All the functions for kernel messages come in variants ranging from 0 to 4 arguments. Those with less than 4 arguments are defined in terms of the 4-argument variant, in a way very similar to `_msg_class_new:nn`. This auxiliary is destroyed at the end of the group.

```

12090 \group_begin:
12091   \cs_set_protected:Npn \_msg_kernel_class_new:nN #1
12092   { \_msg_kernel_class_new_aux:nN { __kernel_msg_ #1 } }
12093   \cs_set_protected:Npn \_msg_kernel_class_new_aux:nN #1#2
12094   {
12095     \cs_new_protected:cpn { #1 :nnnnnn } ##1##2##3##4##5##6
12096     {
12097       \use:x
12098       {
12099         \exp_not:n { #2 { LaTeX } { ##1 / ##2 } }
12100         { \tl_to_str:n {##3} } { \tl_to_str:n {##4} }
12101         { \tl_to_str:n {##5} } { \tl_to_str:n {##6} }
12102       }
12103     }
12104     \cs_new_protected:cpx { #1 :nnnnn } ##1##2##3##4##5
12105     { \exp_not:c { #1 :nnnnnn } {##1} {##2} {##3} {##4} {##5} { } }
12106     \cs_new_protected:cpx { #1 :nnnn } ##1##2##3##4
12107     { \exp_not:c { #1 :nnnnnn } {##1} {##2} {##3} {##4} { } { } }
12108     \cs_new_protected:cpx { #1 :nnn } ##1##2##3
12109     { \exp_not:c { #1 :nnnnnn } {##1} {##2} {##3} { } { } { } }
12110     \cs_new_protected:cpx { #1 :nn } ##1##2

```



```

12111 { \exp_not:c { #1 :nnnnnn } {##1} {##2} { } { } { } }
12112 \cs_new_protected:cpx { #1 :nnxxxx } ##1##2##3##4##5##6
12113 {
12114   \use:x
12115   {
12116     \exp_not:N \exp_not:n
12117     { \exp_not:c { #1 :nnnnnn } {##1} {##2} }
12118     {##3} {##4} {##5} {##6}
12119   }
12120 }
12121 \cs_new_protected:cpx { #1 :nnxxx } ##1##2##3##4##5
12122 { \exp_not:c { #1 :nnxxxx } {##1} {##2} {##3} {##4} {##5} { } }
12123 \cs_new_protected:cpx { #1 :nnxx } ##1##2##3##4
12124 { \exp_not:c { #1 :nnxxxx } {##1} {##2} {##3} {##4} { } { } }
12125 \cs_new_protected:cpx { #1 :nnx } ##1##2##3
12126 { \exp_not:c { #1 :nnxxxx } {##1} {##2} {##3} { } { } { } }
12127 }

```

```

\_kernel_msg_fatal:nnnnnn
\_kernel_msg_fatal:nnxxxx
\_kernel_msg_fatal:nnnnn
\_kernel_msg_fatal:nnxxx
\_kernel_msg_fatal:nnnn
\_kernel_msg_fatal:nnxx
\_kernel_msg_fatal:nnn
\_kernel_msg_fatal:nnx
\_kernel_msg_fatal:nn
\_kernel_msg_error:nnnnnn

```

(End definition for `__kernel_msg_fatal:nnnnnn` and others.)

[illegible]

(End definition for `__kernel_msg_warning:nnnnnn` and others.)

End the group to eliminate _msg kernel class new:nN.

```
12135 \group_end:
```

Error messages needed to actually implement the message system itself.

```

12136 \__kernel_msg_new:nnnn { kernel } { message-already-defined }
12137 { Message~'#2'~for-module~'#1'~already-defined. }
12138 {
12139   \c_msg_coding_error_text_tl
12140   LaTeX-was-asked-to-define-a-new-message-called~'#2'\
12141   by-the-module~'#1':~this-message-already-exists.
12142   \c_msg_return_text_tl
12143 }
12144 \__kernel_msg_new:nnnn { kernel } { message-unknown }
12145 { Unknown~message~'#2'~for-module~'#1'. }
12146 {
12147   \c_msg_coding_error_text_tl
12148   LaTeX-was-asked-to-display-a-message-called~'#2'\
12149   by-the-module~'#1':~this-message-does-not-exist.

```

```

12150 \c__msg_return_text_tl
12151 }
12152 \__kernel_msg_new:nnnn { kernel } { message-class-unknown }
12153 { Unknown~message~class~'~#1'~. }
12154 {
12155 LaTeX~has~been~asked~to~redirect~messages~to~a~class~'~#1':~\\
12156 this~was~never~defined.
12157 \c__msg_return_text_tl
12158 }
12159 \__kernel_msg_new:nnnn { kernel } { message-redirect-loop }
12160 {
12161 Message~redirection~loop~caused~by~ {~#1~} ~>~ {~#2~}
12162 \tl_if_empty:nF {~#3~} { ~for~module~'~ \use_none:n #3 ' } .
12163 }
12164 {
12165 Adding~the~message~redirection~ {~#1~} ~>~ {~#2~}
12166 \tl_if_empty:nF {~#3~} { ~for~the~module~'~ \use_none:n #3 ' } ~
12167 created~an~infinite~loop~\\\
12168 \iow_indent:n { #4 \\\ }
12169 }

```

Messages for earlier kernel modules plus a few for l3keys which cover coding errors.

```

12170 \__kernel_msg_new:nnnn { kernel } { bad-number-of-arguments }
12171 { Function~'~#1'~cannot~be~defined~with~#2~arguments. }
12172 {
12173 \c__msg_coding_error_text_tl
12174 LaTeX~has~been~asked~to~define~a~function~'~#1'~with~
12175 #2~arguments~.~
12176 TeX~allows~between~0~and~9~arguments~for~a~single~function.
12177 }
12178 \__kernel_msg_new:nnn { kernel } { char-active }
12179 { Cannot~generate~active~chars. }
12180 \__kernel_msg_new:nnn { kernel } { char-invalid-catcode }
12181 { Invalid~catcode~for~char~generation. }
12182 \__kernel_msg_new:nnn { kernel } { char-null-space }
12183 { Cannot~generate~null~char~as~a~space. }
12184 \__kernel_msg_new:nnn { kernel } { char-out-of-range }
12185 { Charcode~requested~out~of~engine~range. }
12186 \__kernel_msg_new:nnn { kernel } { char-space }
12187 { Cannot~generate~space~chars. }
12188 \__kernel_msg_new:nnnn { kernel } { command-already-defined }
12189 { Control~sequence~#1~already~defined. }
12190 {
12191 \c__msg_coding_error_text_tl
12192 LaTeX~has~been~asked~to~create~a~new~control~sequence~'~#1'~
12193 but~this~name~has~already~been~used~elsewhere. \\ \\
12194 The~current~meaning~is:\\
12195 \\ #2
12196 }
12197 \__kernel_msg_new:nnnn { kernel } { command-not-defined }
12198 { Control~sequence~#1~undefined. }
12199 {
12200 \c__msg_coding_error_text_tl
12201 LaTeX~has~been~asked~to~use~a~control~sequence~'~#1'~:\\
12202 this~has~not~been~defined~yet.

```

```

12203 }
12204 \__kernel_msg_new:nnnn { kernel } { empty-search-pattern }
12205 { Empty~search~pattern. }
12206 {
12207   \c__msg_coding_error_text_tl
12208   LaTeX~has~been~asked~to~replace~an~empty~pattern~by~'#1':~that~
12209   would~lead~to~an~infinite~loop!
12210 }
12211 \__kernel_msg_new:nnnn { kernel } { out-of-registers }
12212 { No~room~for~a~new~#1. }
12213 {
12214   TeX~only~supports~\int_use:N \c_max_register_int \ %
12215   of~each~type.~All~the~#1~registers~have~been~used.~
12216   This~run~will~be~aborted~now.
12217 }
12218 \__kernel_msg_new:nnnn { kernel } { non-base-function }
12219 { Function~'#1'~is~not~a~base~function }
12220 {
12221   \c__msg_coding_error_text_tl
12222   Functions~defined~through~\iow_char:N\cs_new:Nn~must~have~
12223   a~signature~consisting~of~only~normal~arguments~'N'~and~'n'.~
12224   To~define~variants~use~\iow_char:N\cs_generate_variant:Nn~
12225   and~to~define~other~functions~use~\iow_char:N\cs_new:Npn.
12226 }
12227 \__kernel_msg_new:nnnn { kernel } { missing-colon }
12228 { Function~'#1'~contains~no~':'~. }
12229 {
12230   \c__msg_coding_error_text_tl
12231   Code~level~functions~must~contain~':'~to~separate~the~
12232   argument~specification~from~the~function~name.~This~is~
12233   needed~when~defining~conditionals~or~variants,~or~when~building~a~
12234   parameter~text~from~the~number~of~arguments~of~the~function.
12235 }
12236 \__kernel_msg_new:nnnn { kernel } { overflow }
12237 { Integers~larger~than~230-1~cannot~be~stored~in~arrays. }
12238 {
12239   An~attempt~was~made~to~store~#3~
12240   \tl_if_empty:nF {#2} { at~position~#2~ } in~the~array~'#1'.~
12241   The~largest~allowed~value~#4~will~be~used~instead.
12242 }
12243 \__kernel_msg_new:nnnn { kernel } { out-of-bounds }
12244 { Access~to~an~entry~beyond~an~array's~bounds. }
12245 {
12246   An~attempt~was~made~to~access~or~store~data~at~position~#2~of~the~
12247   array~'#1',~but~this~array~has~entries~at~positions~from~1~to~#3.
12248 }
12249 \__kernel_msg_new:nnnn { kernel } { protected-predicate }
12250 { Predicate~'#1'~must~be~expandable. }
12251 {
12252   \c__msg_coding_error_text_tl
12253   LaTeX~has~been~asked~to~define~'#1'~as~a~protected~predicate.~
12254   Only~expandable~tests~can~have~a~predicate~version.
12255 }
12256 \__kernel_msg_new:nnn { kernel } { randint-backward-range }

```

```

12257 { Bounds~ordered~backwards~in~\iow_char:N\int_rand:nn~{#1}~{#2}. }
12258 \__kernel_msg_new:nnnn { kernel } { conditional-form-unknown }
12259 { Conditional~form~'#1'~for~function~'#2'~unknown. }
12260 {
12261   \c__msg_coding_error_text_tl
12262   LaTeX~has~been~asked~to~define~the~conditional~form~'#1'~of~
12263   the~function~'#2',~but~only~'TF',~'T',~'F',~and~'p'~forms~exist.
12264 }
12265 \__kernel_msg_new:nnnn { kernel } { key-no-property }
12266 { No~property~given~in~definition~of~key~'#1'. }
12267 {
12268   \c__msg_coding_error_text_tl
12269   Inside~\keys_define:nn each~key~name~
12270   needs~a~property:  \ \ \
12271   \iow_indent:n { #1 .<property> } \ \ \
12272   LaTeX~did~not~find~a~'.'~to~indicate~the~start~of~a~property.
12273 }
12274 \__kernel_msg_new:nnnn { kernel } { key-property-boolean-values-only }
12275 { The~property~'#1'~accepts~boolean~values~only. }
12276 {
12277   \c__msg_coding_error_text_tl
12278   The~property~'#1'~only~accepts~the~values~'true'~and~'false'.
12279 }
12280 \__kernel_msg_new:nnnn { kernel } { key-property-requires-value }
12281 { The~property~'#1'~requires~a~value. }
12282 {
12283   \c__msg_coding_error_text_tl
12284   LaTeX~was~asked~to~set~property~'#1'~for~key~'#2'. \ \
12285   No~value~was~given~for~the~property,~and~one~is~required.
12286 }
12287 \__kernel_msg_new:nnnn { kernel } { key-property-unknown }
12288 { The~key~property~'#1'~is~unknown. }
12289 {
12290   \c__msg_coding_error_text_tl
12291   LaTeX~has~been~asked~to~set~the~property~'#1'~for~key~'#2':~
12292   this~property~is~not~defined.
12293 }
12294 \__kernel_msg_new:nnnn { kernel } { scanmark-already-defined }
12295 { Scan~mark~#1~already~defined. }
12296 {
12297   \c__msg_coding_error_text_tl
12298   LaTeX~has~been~asked~to~create~a~new~scan~mark~'#1'~
12299   but~this~name~has~already~been~used~for~a~scan~mark.
12300 }
12301 \__kernel_msg_new:nnnn { kernel } { variable-not-defined }
12302 { Variable~#1~undefined. }
12303 {
12304   \c__msg_coding_error_text_tl
12305   LaTeX~has~been~asked~to~show~a~variable~#1,~but~this~has~not~
12306   been~defined~yet.
12307 }
12308 \__kernel_msg_new:nnnn { kernel } { variant-too-long }
12309 { Variant~form~'#1'~longer~than~base~signature~of~'#2'. }
12310 {

```

```

12311 \c__msg_coding_error_text_tl
12312 LaTeX~has~been~asked~to~create~a~variant~of~the~function~'#2'~
12313 with~a~signature~starting~with~'#1',~but~that~is~longer~than~
12314 the~signature~(part~after~the~colon)~of~'#2'.
12315 }
12316 \__kernel_msg_new:nnnn { kernel } { invalid-variant }
12317 { Variant~form~'#1'~invalid~for~base~form~'#2'. }
12318 {
12319 \c__msg_coding_error_text_tl
12320 LaTeX~has~been~asked~to~create~a~variant~of~the~function~'#2'~
12321 with~a~signature~starting~with~'#1',~but~cannot~change~an~argument~
12322 from~type~'#3'~to~type~'#4'.
12323 }
12324 \__kernel_msg_new:nnnn { kernel } { invalid-exp-args }
12325 { Invalid~variant~specifier~'#1'~in~'#2'. }
12326 {
12327 \c__msg_coding_error_text_tl
12328 LaTeX~has~been~asked~to~create~an~\iow_char:N\exp_args:N...~
12329 function~with~signature~'N#2'~but~'#1'~is~not~a~valid~argument~
12330 specifier.
12331 }
12332 \__kernel_msg_new:nnn { kernel } { deprecated-variant }
12333 {
12334 Variant~form~'#1'~deprecated~for~base~form~'#2'.~
12335 One~should~not~change~an~argument~from~type~'#3'~to~type~'#4'
12336 \str_case:nnF {#3}
12337 {
12338 { n } { :~use~a~'\token_if_eq_charcode:NNTF #4 c v V'~variant? }
12339 { N } { :~base~form~only~accepts~a~single~token~argument. }
12340 {#4} { :~base~form~is~already~a~variant. }
12341 } { . }
12342 }

```

Some errors are only needed in package mode if debugging is enabled by one of the options `enable-debug`, `check-declarations`, `log-functions`, or on the contrary if debugging is turned off. In format mode the error is somewhat different.

```

12343 (*package)
12344 \__kernel_if_debug:TF
12345 {
12346 \__kernel_msg_new:nnnn { kernel } { debug }
12347 { The~debugging~option~'#1'~does~not~exist~\msg_line_context:. }
12348 {
12349 The~functions~'\iow_char:N\debug_on:n'~and~
12350 '\iow_char:N\debug_off:n'~only~accept~the~arguments~
12351 'check-declarations',~'deprecation',~'log-functions',~not~'#1'.
12352 }
12353 \__kernel_msg_new:nnn { kernel } { expr } { '#2'~in~#1 }
12354 \__kernel_msg_new:nnnn { kernel } { local-global }
12355 { Inconsistent~local/global~assignment }
12356 {
12357 \c__msg_coding_error_text_tl
12358 \if:w l #2 Local
12359 \else:
12360 \if:w g #2 Global \else: Constant \fi:

```

```

12361 \fi:
12362 \ %
12363 assignment~to~a~
12364 \if:w l #1 local
12365 \else:
12366 \if:w g #1 global \else: constant \fi:
12367 \fi:
12368 \ %
12369 variable~'#3'.
12370 }
12371 \__kernel_msg_new:nnnn { kernel } { non-declared-variable }
12372 { The~variable~#1~has~not~been~declared~\msg_line_context:. }
12373 {
12374 \c__msg_coding_error_text_tl
12375 Checking~is~active,~and~you~have~tried~do~so~something~like: \\
12376 \\ \tl_set:Nn ~ #1 ~ \{ ~ ... ~ \} \\
12377 without~first~having: \\
12378 \\ \tl_new:N ~ #1 \\
12379 \\
12380 LaTeX~will~create~the~variable~and~continue.
12381 }
12382 }
12383 {
12384 \__kernel_msg_new:nnnn { kernel } { enable-debug }
12385 { To~use~'#1'~load~expl3~with~the~'enable-debug'~option. }
12386 {
12387 The~function~'#1'~will~be~ignored~because~it~can~only~work~if~
12388 some~internal~functions~in~expl3~have~been~appropriately~
12389 defined.~This~only~happens~if~one~of~the~options~
12390 'enable-debug',~'check-declarations'~or~'log-functions'~was~
12391 given~when~loading~expl3.
12392 }
12393 }
12394 \</package>
12395 \<*/initex>
12396 \__kernel_msg_new:nnnn { kernel } { enable-debug }
12397 { '#1'~cannot~be~used~in~format~mode. }
12398 {
12399 The~function~'#1'~will~be~ignored~because~it~can~only~work~if~
12400 some~internal~functions~in~expl3~have~been~appropriately~
12401 defined.~This~only~happens~in~package~mode~(and~only~if~one~of~
12402 the~options~'enable-debug',~'check-declarations'~or~'log-functions'~
12403 was~given~when~loading~expl3.
12404 }
12405 \</initex>

```

Some errors only appear in expandable settings, hence don't need a "more-text" argument.

```

12406 \__kernel_msg_new:nnn { kernel } { bad-exp-end-f }
12407 { Misused~\exp_end_continue_f:w or~:nw }
12408 \__kernel_msg_new:nnn { kernel } { bad-variable }
12409 { Erroneous~variable~#1 used! }
12410 \__kernel_msg_new:nnn { kernel } { misused-sequence }
12411 { A~sequence~was~misused. }

```

```

12412 \__kernel_msg_new:nnn { kernel } { misused-prop }
12413 { A~property~list~was~misused. }
12414 \__kernel_msg_new:nnn { kernel } { negative-replication }
12415 { Negative~argument~for~\iow_char:N\prg_replicate:nn. }
12416 \__kernel_msg_new:nnn { kernel } { prop-keyval }
12417 { Missing/extra~'='~in~'#1'~(in~'..._keyval:Nn') }
12418 \__kernel_msg_new:nnn { kernel } { unknown-comparison }
12419 { Relation~'#1'~unknown:~use~<,>,<=,>=,~<,>=,~<=>. }
12420 \__kernel_msg_new:nnn { kernel } { zero-step }
12421 { Zero~step~size~for~step~function~#1. }
12422 \cs_if_exist:NF \tex_expanded:D
12423 {
12424   \__kernel_msg_new:nnn { kernel } { e-type }
12425   { #1 ~ in~e-type~argument }
12426 }

```

Messages used by the “show” functions.

```

12427 \__kernel_msg_new:nnn { kernel } { show-clist }
12428 {
12429   The~comma~list~ \tl_if_empty:NF {#1} { #1 ~ }
12430   \tl_if_empty:NTF {#2}
12431   { is~empty \>~ . }
12432   { contains~the~items~(without~outer~braces): #2 . }
12433 }
12434 \__kernel_msg_new:nnn { kernel } { show-intarray }
12435 { The~integer~array~#1~contains~#2~items: \> #3 . }
12436 \__kernel_msg_new:nnn { kernel } { show-prop }
12437 {
12438   The~property~list~#1~
12439   \tl_if_empty:NTF {#2}
12440   { is~empty \>~ . }
12441   { contains~the~pairs~(without~outer~braces): #2 . }
12442 }
12443 \__kernel_msg_new:nnn { kernel } { show-seq }
12444 {
12445   The~sequence~#1~
12446   \tl_if_empty:NTF {#2}
12447   { is~empty \>~ . }
12448   { contains~the~items~(without~outer~braces): #2 . }
12449 }
12450 \__kernel_msg_new:nnn { kernel } { show-streams }
12451 {
12452   \tl_if_empty:NTF {#2} { No~ } { The~following~ }
12453   \str_case:nn {#1}
12454   {
12455     { ior } { input ~ }
12456     { iow } { output ~ }
12457   }
12458   streams~are~
12459   \tl_if_empty:NTF {#2} { open } { in~use: #2 . }
12460 }

```

19.6 Expandable errors

`_msg_expandable_error:n` In expansion only context, we cannot use the normal means of reporting errors. Instead, we feed \TeX an undefined control sequence, `\LaTeX3 error:`. It is thus interrupted, and shows the context, which thanks to the odd-looking `\use:n` is

```
<argument> \LaTeX3 error:
                The error message.
```

In other words, \TeX is processing the argument of `\use:n`, which is `\LaTeX3 error: <error message>`. Then `_msg_expandable_error:w` cleans up. In fact, there is an extra subtlety: if the user inserts tokens for error recovery, they should be kept. Thus we also use an odd space character (with category code 7) and keep tokens until that space character, dropping everything else until `\q_stop`. The `\exp_end:` prevents losing braces around the user-inserted text if any, and stops the expansion of `\exp:w`. The group is used to prevent `\LaTeX3~error:` from being globally equal to `\scan_stop:`.

```
12461 \group_begin:
12462 \cs_set_protected:Npn \_msg_tmp:w #1#2
12463 {
12464   \cs_new:Npn \_msg_expandable_error:n ##1
12465   {
12466     \exp:w
12467     \exp_after:wN \exp_after:wN
12468     \exp_after:wN \_msg_expandable_error:w
12469     \exp_after:wN \exp_after:wN
12470     \exp_after:wN \exp_end:
12471     \use:n { #1 #2 ##1 } #2
12472   }
12473   \cs_new:Npn \_msg_expandable_error:w ##1 #2 ##2 #2 {##1}
12474 }
12475 \exp_args:Ncx \_msg_tmp:w { LaTeX3~error: }
12476 { \char_generate:nn { ‘\ ’ } { 7 } }
12477 \group_end:
```

(End definition for `_msg_expandable_error:n` and `_msg_expandable_error:w`.)

`_kernel_msg_expandable_error:nnnnnn` The command built from the csname `\c__msg_text_prefix_tl LaTeX / #1 / #2` takes four arguments and builds the error text, which is fed to `_msg_expandable_error:n` with appropriate expansion: just as for usual messages the arguments are first turned to strings, then the message is fully expanded.

```
12478 \exp_args_generate:n { oooo }
12479 \cs_new:Npn \_kernel_msg_expandable_error:nnnnnn #1#2#3#4#5#6
12480 {
12481   \exp_args:Ne \_msg_expandable_error:n
12482   {
12483     \exp_args:Nc \exp_args:Noooo
12484     { \c__msg_text_prefix_tl LaTeX / #1 / #2 }
12485     { \tl_to_str:n {#3} }
12486     { \tl_to_str:n {#4} }
12487     { \tl_to_str:n {#5} }
12488     { \tl_to_str:n {#6} }
12489   }
12490 }
12491 \cs_new:Npn \_kernel_msg_expandable_error:nnnnn #1#2#3#4#5
```



```

12492 {
12493   \__kernel_msg_expandable_error:nnnnnn
12494   {#1} {#2} {#3} {#4} {#5} { }
12495 }
12496 \cs_new:Npn \__kernel_msg_expandable_error:nnnn #1#2#3#4
12497 {
12498   \__kernel_msg_expandable_error:nnnnnn
12499   {#1} {#2} {#3} {#4} { } { }
12500 }
12501 \cs_new:Npn \__kernel_msg_expandable_error:nnn #1#2#3
12502 {
12503   \__kernel_msg_expandable_error:nnnnnn
12504   {#1} {#2} {#3} { } { } { }
12505 }
12506 \cs_new:Npn \__kernel_msg_expandable_error:nn #1#2
12507 {
12508   \__kernel_msg_expandable_error:nnnnnn
12509   {#1} {#2} { } { } { } { }
12510 }
12511 \cs_generate_variant:Nn \__kernel_msg_expandable_error:nnnnnn { nnffff }
12512 \cs_generate_variant:Nn \__kernel_msg_expandable_error:nnnnn { nnfff }
12513 \cs_generate_variant:Nn \__kernel_msg_expandable_error:nnnn { nnff }
12514 \cs_generate_variant:Nn \__kernel_msg_expandable_error:nnn { nnf }

(End definition for \__kernel_msg_expandable_error:nnnnnn and others.)

12515 </initex | package>

```

20 l3file implementation

The following test files are used for this code: *m3file001*.

```

12516 <*initex | package>

```

20.1 Input operations

```

12517 <@@=ior>

```

20.1.1 Variables and constants

`\l__ior_internal_tl` Used as a short-term scratch variable.

```

12518 \tl_new:N \l__ior_internal_tl

```

(End definition for `\l__ior_internal_tl`.)

`\c_term_ior` Reading from the terminal (with a prompt) is done using a positive but non-existent stream number. Unlike writing, there is no concept of reading from the log.

```

12519 \int_const:Nn \c_term_ior { 16 }

```

(End definition for `\c_term_ior`. This variable is documented on page [157](#).)

`\g__ior_streams_seq` A list of the currently-available input streams to be used as a stack. In format mode, all streams (from 0 to 15) are available, while the package requests streams to L^AT_EX 2_ε as they are needed (initially none are needed), so the starting point varies!

```

12520 \seq_new:N \g__ior_streams_seq

```

```

12521 \<initex>
12522 \seq_gset_split:Nnn \g__ior_streams_seq { , }
12523 { 0 , 1 , 2 , 3 , 4 , 5 , 6 , 7 , 8 , 9 , 10 , 11 , 12 , 13 , 14 , 15 }
12524 \</initex>

```

(End definition for \g__ior_streams_seq.)

\l__ior_stream_tl Used to recover the raw stream number from the stack.

```

12525 \tl_new:N \l__ior_stream_tl

```

(End definition for \l__ior_stream_tl.)

\g__ior_streams_prop The name of the file attached to each stream is tracked in a property list. To get the correct number of reserved streams in package mode the underlying mechanism needs to be queried. For L^AT_EX 2_ε and plain T_EX this data is stored in \count16: with the etex package loaded we need to subtract 1 as the register holds the number of the next stream to use. In ConT_EXt, we need to look at \count38 but there is no subtraction: like the original plain T_EX/L^AT_EX 2_ε mechanism it holds the value of the *last* stream allocated.

```

12526 \prop_new:N \g__ior_streams_prop
12527 \<*package>
12528 \int_step_inline:nnn
12529 { 0 }
12530 {
12531   \cs_if_exist:NTF \normalend
12532   { \tex_count:D 38 ~ }
12533   {
12534     \tex_count:D 16 ~ %
12535     \cs_if_exist:NT \loccount { - 1 }
12536   }
12537 }
12538 {
12539   \prop_gput:Nnn \g__ior_streams_prop {#1} { Reserved-by~format }
12540 }
12541 \</package>

```

(End definition for \g__ior_streams_prop.)

20.1.2 Stream management

\ior_new:N Reserving a new stream is done by defining the name as equal to using the terminal.

```

\ior_new:c 12542 \cs_new_protected:Npn \ior_new:N #1 { \cs_new_eq:NN #1 \c_term_ior }
12543 \cs_generate_variant:Nn \ior_new:N { c }

```

(End definition for \ior_new:N. This function is documented on page 150.)

\g_tmpa_ior The usual scratch space.

```

\g_tmpb_ior 12544 \ior_new:N \g_tmpa_ior
12545 \ior_new:N \g_tmpb_ior

```

(End definition for \g_tmpa_ior and \g_tmpb_ior. These variables are documented on page 157.)

\ior_open:Nn Use the conditional version, with an error if the file is not found.

```

\ior_open:cn 12546 \cs_new_protected:Npn \ior_open:Nn #1#2
12547 { \ior_open:NnF #1 {#2} { \__kernel_file_missing:n {#2} } }
12548 \cs_generate_variant:Nn \ior_open:Nn { c }

```

(End definition for `\ior_open:Nn`. This function is documented on page 150.)

`\l__ior_file_name_tl` Data storage.

```
12549 \tl_new:N \l__ior_file_name_tl
```

(End definition for `\l__ior_file_name_tl`.)

`\ior_open:NnTF` An auxiliary searches for the file in the T_EX, L^AT_EX 2_ε and L^AT_EX 3 paths. Then pass the file found to the lower-level function which deals with streams. The `full_name` is empty when the file is not found.

```
12550 \prg_new_protected_conditional:Npnn \ior_open:Nn #1#2 { T , F , TF }
12551 {
12552   \file_get_full_name:nNTF {#2} \l__ior_file_name_tl
12553   {
12554     \__kernel_ior_open:No #1 \l__ior_file_name_tl
12555     \prg_return_true:
12556   }
12557   { \prg_return_false: }
12558 }
12559 \prg_generate_conditional_variant:Nnn \ior_open:Nn { c } { T , F , TF }
```

(End definition for `\ior_open:NnTF`. This function is documented on page 151.)

`__ior_new:N` In package mode, streams are reserved using `\newread` before they can be managed by `ior`. To prevent `ior` from being affected by redefinitions of `\newread` (such as done by the third-party package `morewrites`), this macro is saved here under a private name. The complicated code ensures that `__ior_new:N` is not `\outer` despite plain T_EX's `\newread` being `\outer`. For ConT_EXt, we have to deal with the fact that `\newread` works like our own: it actually checks before altering definition.

```
12560 \*package
12561 \exp_args:NNf \cs_new_protected:Npn \__ior_new:N
12562 { \exp_args:NNc \exp_after:wN \exp_stop_f: { newread } }
12563 \cs_if_exist:NT \normalend
12564 {
12565   \cs_new_eq:NN \__ior_new_aux:N \__ior_new:N
12566   \cs_set_protected:Npn \__ior_new:N #1
12567   {
12568     \cs_undefine:N #1
12569     \__ior_new_aux:N #1
12570   }
12571 }
12572 \*package
```

(End definition for `__ior_new:N`.)

`__kernel_ior_open:Nn` The stream allocation itself uses the fact that there is a list of all of those available, so allocation is simply a question of using the number at the top of the list. In package mode, life gets more complex as it's important to keep things in sync. That is done using a two-part approach: any streams that have already been taken up by `ior` but are now free are tracked, so we first try those. If that fails, ask plain T_EX or L^AT_EX 2_ε for a new stream and use that number (after a bit of conversion).

```
12573 \cs_new_protected:Npn \__kernel_ior_open:Nn #1#2
12574 {
```

```

12575 \ior_close:N #1
12576 \seq_gpop:NNTF \g__ior_streams_seq \l__ior_stream_tl
12577 { \__ior_open_stream:Nn #1 {#2} }
12578 <*initex>
12579 { \__kernel_msg_fatal:nn { kernel } { input-streams-exhausted } }
12580 </initex>
12581 <*package>
12582 {
12583 \__ior_new:N #1
12584 \tl_set:Nx \l__ior_stream_tl { \int_eval:n {#1} }
12585 \__ior_open_stream:Nn #1 {#2}
12586 }
12587 </package>
12588 }
12589 \cs_generate_variant:Nn \__kernel_ior_open:Nn { No }
12590 \cs_new_protected:Npn \__ior_open_stream:Nn #1#2
12591 {
12592 \tex_global:D \tex_chardef:D #1 = \l__ior_stream_tl \scan_stop:
12593 \prop_gput:Nvn \g__ior_streams_prop #1 {#2}
12594 \tex_openin:D #1 #2 \scan_stop:
12595 }

```

(End definition for `__kernel_ior_open:Nn` and `__ior_open_stream:Nn`.)

`\ior_close:N` Closing a stream means getting rid of it at the T_EX level and removing from the various data structures. Unless the name passed is an invalid stream number (outside the range [0, 15]), it can be closed. On the other hand, it only gets added to the stack if it was not already there, to avoid duplicates building up.

`\ior_close:c`

```

12596 \cs_new_protected:Npn \ior_close:N #1
12597 {
12598 \int_compare:nT { -1 < #1 < \c_term_ior }
12599 {
12600 \tex_closein:D #1
12601 \prop_gremove:Nv \g__ior_streams_prop #1
12602 \seq_if_in:NvF \g__ior_streams_seq #1
12603 { \seq_gpush:Nv \g__ior_streams_seq #1 }
12604 \cs_gset_eq:NN #1 \c_term_ior
12605 }
12606 }
12607 \cs_generate_variant:Nn \ior_close:N { c }

```

(End definition for `\ior_close:N`. This function is documented on page 151.)

`\ior_show_list:` Show the property lists, but with some “pretty printing”. See the l3msg module. The first argument of the message is `ior` (as opposed to `iow`) and the second is empty if no read stream is open and non-empty (the list of streams formatted using `\msg_show_item_unbraced:nn`) otherwise. The code of the message `show-streams` takes care of translating `ior/iow` to English.

`\ior_log_list:`
`__ior_list:N`

```

12608 \cs_new_protected:Npn \ior_show_list: { \__ior_list:N \msg_show:nnxxxx }
12609 \cs_new_protected:Npn \ior_log_list: { \__ior_list:N \msg_log:nnxxxx }
12610 \cs_new_protected:Npn \__ior_list:N #1
12611 {
12612 #1 { LaTeX / kernel } { show-streams }
12613 { ior }

```

```

12614     {
12615         \prop_map_function:NN \g__ior_streams_prop
12616         \msg_show_item_unbraced:nn
12617     }
12618     { } { }
12619 }

```

(End definition for `\ior_show_list:`, `\ior_log_list:`, and `__ior_list:N`. These functions are documented on page 151.)

20.1.3 Reading input

`\if_eof:w` The primitive conditional

```

12620 \cs_new_eq:NN \if_eof:w \tex_ifeof:D

```

(End definition for `\if_eof:w`. This function is documented on page 157.)

`\ior_if_eof_p:N` To test if some particular input stream is exhausted the following conditional is provided.
`\ior_if_eof:N \underline{TF}` The primitive test can only deal with numbers in the range $[0,15]$ so we catch outliers (they are exhausted).

```

12621 \prg_new_conditional:Npnn \ior_if_eof:N #1 { p , T , F , TF }
12622 {
12623     \cs_if_exist:NTF #1
12624     {
12625         \int_compare:nTF { -1 < #1 < \c_term_ior }
12626         {
12627             \if_eof:w #1
12628             \prg_return_true:
12629             \else:
12630             \prg_return_false:
12631             \fi:
12632         }
12633         { \prg_return_true: }
12634     }
12635     { \prg_return_true: }
12636 }

```

(End definition for `\ior_if_eof:N \underline{TF}` . This function is documented on page 154.)

`\ior_get:NN` And here we read from files.

```

\__ior_get:NN 12637 \cs_new_protected:Npn \ior_get:NN #1#2
\ior_get:NN $\underline{TF}$  12638 { \ior_get:NNF #1 #2 { \tl_set:Nn #2 { \q_no_value } } }
12639 \cs_new_protected:Npn \__ior_get:NN #1#2
12640 { \tex_read:D #1 to #2 }
12641 \prg_new_protected_conditional:Npnn \ior_get:NN #1#2 { T , F , TF }
12642 {
12643     \ior_if_eof:N $\underline{TF}$  #1
12644     { \prg_return_false: }
12645     {
12646         \__ior_get:NN #1 #2
12647         \prg_return_true:
12648     }
12649 }

```

(End definition for `\ior_get:NN`, `_ior_get:NN`, and `\ior_get:NNTF`. These functions are documented on page 152.)

`\ior_str_get:NN` Reading as strings is a more complicated wrapper, as we wish to remove the endline character and restore it afterwards.

```
\_ior_str_get:NN
\ior_str_get:NNTF
12650 \cs_new_protected:Npn \ior_str_get:NN #1#2
12651 { \ior_str_get:NNTF #1 #2 { \tl_set:Nn #2 { \q_no_value } } }
12652 \cs_new_protected:Npn \_ior_str_get:NN #1#2
12653 {
12654   \exp_args:Nno \use:n
12655   {
12656     \int_set:Nn \tex_endlinechar:D { -1 }
12657     \tex_readline:D #1 to #2
12658     \int_set:Nn \tex_endlinechar:D
12659     } { \int_use:N \tex_endlinechar:D }
12660   }
12661 \prg_new_protected_conditional:Npnn \ior_str_get:NN #1#2 { T , F , TF }
12662 {
12663   \ior_if_eof:NTF #1
12664   { \prg_return_false: }
12665   {
12666     \_ior_str_get:NN #1 #2
12667     \prg_return_true:
12668   }
12669 }
```

(End definition for `\ior_str_get:NN`, `_ior_str_get:NN`, and `\ior_str_get:NNTF`. These functions are documented on page 152.)

`\c_ior_term_ior` For reading without a prompt.

```
12670 \int_const:Nn \c_ior_term_ior { -1 }
```

(End definition for `\c_ior_term_ior`.)

`\ior_get_term:nN` Getting from the terminal is better with pretty-printing.

```
\ior_str_get_term:nN
\_ior_get_term:NnN
12671 \cs_new_protected:Npn \ior_get_term:nN #1#2
12672 { \_ior_get_term:NnN \_ior_get:NN {#1} #2 }
12673 \cs_new_protected:Npn \ior_str_get_term:nN #1#2
12674 { \_ior_get_term:NnN \_ior_str_get:NN {#1} #2 }
12675 \cs_new_protected:Npn \_ior_get_term:NnN #1#2#3
12676 {
12677   \group_begin:
12678   \tex_escapechar:D = -1 \scan_stop:
12679   \tl_if_blank:nTF {#2}
12680   { \exp_args:NNc #1 \c_ior_term_ior }
12681   { \exp_args:NNc #1 \c_term_ior }
12682   {#2}
12683   \exp_args:NNNv \group_end:
12684   \tl_set:Nn #3 {#2}
12685 }
```

(End definition for `\ior_get_term:nN`, `\ior_str_get_term:nN`, and `_ior_get_term:NnN`. These functions are documented on page 253.)

`\ior_map_break:` Usual map breaking functions.

```
\ior_map_break:n
12686 \cs_new:Npn \ior_map_break:
12687 { \prg_map_break:Nn \ior_map_break: { } }
12688 \cs_new:Npn \ior_map_break:n
12689 { \prg_map_break:Nn \ior_map_break: }
```

(End definition for `\ior_map_break:` and `\ior_map_break:n`. These functions are documented on page 153.)

`\ior_map_inline:Nn` Mapping to an input stream can be done on either a token or a string basis, hence the set up. Within that, there is a check to avoid reading past the end of a file, hence the two applications of `\ior_if_eof:N` and its lower-level analogue `\if_eof:w`. This mapping cannot be nested with twice the same stream, as the stream has only one “current line”.

```
\ior_str_map_inline:Nn
\__ior_map_inline:NNn
\__ior_map_inline:NNNn
\__ior_map_inline_loop:NNN
12690 \cs_new_protected:Npn \ior_map_inline:Nn
12691 { \__ior_map_inline:NNn \__ior_get:NN }
12692 \cs_new_protected:Npn \ior_str_map_inline:Nn
12693 { \__ior_map_inline:NNn \__ior_str_get:NN }
12694 \cs_new_protected:Npn \__ior_map_inline:NNn
12695 {
12696   \int_gincr:N \g__kernel_prg_map_int
12697   \exp_args:Nc \__ior_map_inline:NNNn
12698     { \__ior_map_ \int_use:N \g__kernel_prg_map_int :n }
12699 }
12700 \cs_new_protected:Npn \__ior_map_inline:NNNn #1#2#3#4
12701 {
12702   \cs_gset_protected:Npn #1 ##1 {#4}
12703   \ior_if_eof:NF #3 { \__ior_map_inline_loop:NNN #1#2#3 }
12704   \prg_break_point:Nn \ior_map_break:
12705     { \int_gdecr:N \g__kernel_prg_map_int }
12706 }
12707 \cs_new_protected:Npn \__ior_map_inline_loop:NNN #1#2#3
12708 {
12709   #2 #3 \l__ior_internal_tl
12710   \if_eof:w #3
12711     \exp_after:wN \ior_map_break:
12712     \fi:
12713     \exp_args:No #1 \l__ior_internal_tl
12714     \__ior_map_inline_loop:NNN #1#2#3
12715 }
```

(End definition for `\ior_map_inline:Nn` and others. These functions are documented on page 153.)

`\ior_map_variable:NNn` Since the $\text{T}_{\text{E}}\text{X}$ primitive (`\read` or `\readline`) assigns the tokens read in the same way as a token list assignment, we simply call the appropriate primitive. The end-of-loop is checked using the primitive conditional for speed.

```
\ior_str_map_variable:NNn
\__ior_map_variable:NNNn
\__ior_map_variable_loop:NNNn
12716 \cs_new_protected:Npn \ior_map_variable:NNn
12717 { \__ior_map_variable:NNNn \ior_get:NN }
12718 \cs_new_protected:Npn \ior_str_map_variable:NNn
12719 { \__ior_map_variable:NNNn \ior_str_get:NN }
12720 \cs_new_protected:Npn \__ior_map_variable:NNNn #1#2#3#4
12721 {
12722   \ior_if_eof:NF #2 { \__ior_map_variable_loop:NNNn #1#2#3 {#4} }
12723   \prg_break_point:Nn \ior_map_break: { }
12724 }
```

```

12725 \cs_new_protected:Npn \__ior_map_variable_loop:NNNn #1#2#3#4
12726 {
12727     #1 #2 #3
12728     \if_eof:w #2
12729         \exp_after:wN \ior_map_break:
12730     \fi:
12731     #4
12732     \__ior_map_variable_loop:NNNn #1#2#3 {#4}
12733 }

```

(End definition for `\ior_map_variable:NNn` and others. These functions are documented on page 253.)

20.2 Output operations

```

12734 (@@=iow)

```

There is a lot of similarity here to the input operations, at least for many of the basics. Thus quite a bit is copied from the earlier material with minor alterations.

20.2.1 Variables and constants

`\c_log_iow` Here we allocate two output streams for writing to the transcript file only (`\c_log_iow`) and to both the terminal and transcript file (`\c_term_iow`). Recent LuaTeX provide 128 write streams; we also use `\c_term_iow` as the first non-allowed write stream so its value depends on the engine.

```

12735 \int_const:Nn \c_log_iow { -1 }
12736 \int_const:Nn \c_term_iow
12737 {
12738     \bool_lazy_and:nnTF
12739     { \sys_if_engine luatex_p: }
12740     { \int_compare_p:nNn \tex_luatexversion:D > { 80 } }
12741     { 128 }
12742     { 16 }
12743 }

```

(End definition for `\c_log_iow` and `\c_term_iow`. These variables are documented on page 157.)

`\g__iow_streams_seq` A list of the currently-available output streams to be used as a stack. The stream 18 is special, as `\write18` is used to denote commands to be sent to the OS.

```

12744 \seq_new:N \g__iow_streams_seq
12745 \*initex
12746 \exp_args:Nnx \use:n
12747 { \seq_gset_split:Nnn \g__iow_streams_seq { } }
12748 {
12749     \int_step_function:nnN { 0 } { \c_term_iow }
12750     \prg_do_nothing:
12751 }
12752 \int_compare:nNnF \c_term_iow < { 18 }
12753 { \seq_gremove_all:Nn \g__iow_streams_seq { 18 } }
12754 \</initex>

```

(End definition for `\g__iow_streams_seq`.)

`\l__iow_stream_tl` Used to recover the raw stream number from the stack.

```

12755 \tl_new:N \l__iow_stream_tl

```


(End definition for \l__iow_stream_tl.)

\g__iow_streams_prop As for reads with the appropriate adjustment of the register numbers to check on.

```

12756 \prop_new:N \g__iow_streams_prop
12757 \<*package>
12758 \int_step_inline:nnn
12759 { 0 }
12760 {
12761   \cs_if_exist:NTF \normalend
12762   { \tex_count:D 39 ~ }
12763   {
12764     \tex_count:D 17 ~
12765     \cs_if_exist:NT \loccount { - 1 }
12766   }
12767 }
12768 {
12769   \prop_gput:Nnn \g__iow_streams_prop {#1} { Reserved-by~format }
12770 }
12771 \</package>

```

(End definition for \g__iow_streams_prop.)

20.3 Stream management

\iow_new:N Reserving a new stream is done by defining the name as equal to writing to the terminal:
\iow_new:c odd but at least consistent.

```

12772 \cs_new_protected:Npn \iow_new:N #1 { \cs_new_eq:NN #1 \c_term_iow }
12773 \cs_generate_variant:Nn \iow_new:N { c }

```

(End definition for \iow_new:N. This function is documented on page 150.)

\g_tmpa_iow The usual scratch space.

\g_tmpb_iow

```

12774 \iow_new:N \g_tmpa_iow
12775 \iow_new:N \g_tmpb_iow

```

(End definition for \g_tmpa_iow and \g_tmpb_iow. These variables are documented on page 157.)

__iow_new:N As for read streams, copy \newwrite in package mode, making sure that it is not \outer.

```

12776 \<*package>
12777 \exp_args:NNf \cs_new_protected:Npn \__iow_new:N
12778 { \exp_args:NNc \exp_after:wN \exp_stop_f: { newwrite } }
12779 \</package>

```

(End definition for __iow_new:N.)

\l__iow_file_name_tl Data storage.

```

12780 \tl_new:N \l__iow_file_name_tl

```

(End definition for \l__iow_file_name_tl.)

\iow_open:Nn The same idea as for reading, but without the path and without the need to allow for a conditional version.

\iow_open:cn

__iow_open_stream:Nn

__iow_open_stream:NV

```

12781 \cs_new_protected:Npn \iow_open:Nn #1#2
12782 {
12783   \__kernel_file_name_sanitiz:n {#2} \l__iow_file_name_tl
12784   \iow_close:N #1
12785   \seq_gpop:NNTF \g__iow_streams_seq \l__iow_stream_tl
12786   { \__iow_open_stream:NV #1 \l__iow_file_name_tl }
12787   (*initex)
12788   { \__kernel_msg_fatal:nn { kernel } { output-streams-exhausted } }
12789   (/initex)
12790   (*package)
12791   {
12792     \__iow_new:N #1
12793     \tl_set:Nx \l__iow_stream_tl { \int_eval:n {#1} }
12794     \__iow_open_stream:NV #1 \l__iow_file_name_tl
12795   }
12796   (/package)
12797 }
12798 \cs_generate_variant:Nn \iow_open:Nn { c }
12799 \cs_new_protected:Npn \__iow_open_stream:Nn #1#2
12800 {
12801   \tex_global:D \tex_chardef:D #1 = \l__iow_stream_tl \scan_stop:
12802   \prop_gput:Nvn \g__iow_streams_prop #1 {#2}
12803   \tex_immediate:D \tex_openout:D #1 #2 \scan_stop:
12804 }
12805 \cs_generate_variant:Nn \__iow_open_stream:Nn { NV }

```

(End definition for \iow_open:Nn and __iow_open_stream:Nn. This function is documented on page 151.)

\iow_close:N Closing a stream is not quite the reverse of opening one. First, the close operation is easier than the open one, and second as the stream is actually a number we can use it directly to show that the slot has been freed up.

\iow_close:c

```

12806 \cs_new_protected:Npn \iow_close:N #1
12807 {
12808   \int_compare:nT { - \c_log_iow < #1 < \c_term_iow }
12809   {
12810     \tex_immediate:D \tex_closeout:D #1
12811     \prop_gremove:Nv \g__iow_streams_prop #1
12812     \seq_if_in:NVF \g__iow_streams_seq #1
12813     { \seq_gpush:Nv \g__iow_streams_seq #1 }
12814     \cs_gset_eq:NN #1 \c_term_iow
12815   }
12816 }
12817 \cs_generate_variant:Nn \iow_close:N { c }

```

(End definition for \iow_close:N. This function is documented on page 151.)

\iow_show_list: Done as for input, but with a copy of the auxiliary so the name is correct.

\iow_log_list:

__iow_list:N

```

12818 \cs_new_protected:Npn \iow_show_list: { \__iow_list:N \msg_show:nnxxxx }
12819 \cs_new_protected:Npn \iow_log_list: { \__iow_list:N \msg_log:nnxxxx }
12820 \cs_new_protected:Npn \__iow_list:N #1
12821 {

```

```

12822     #1 { LaTeX / kernel } { show-streams }
12823     { iow }
12824     {
12825         \prop_map_function:NN \g__iow_streams_prop
12826         \msg_show_item_unbraced:nn
12827     }
12828     { } { }
12829 }

```

(End definition for `\iow_show_list:`, `\iow_log_list:`, and `__iow_list:N`. These functions are documented on page 151.)

20.3.1 Deferred writing

`\iow_shipout_x:Nn` First the easy part, this is the primitive, which expects its argument to be braced.

```

\iow_shipout_x:Nx 12830 \cs_new_protected:Npn \iow_shipout_x:Nn #1#2
\iow_shipout_x:cn 12831 { \tex_write:D #1 {#2} }
\iow_shipout_x:cx 12832 \cs_generate_variant:Nn \iow_shipout_x:Nn { c, Nx, cx }

```

(End definition for `\iow_shipout_x:Nn`. This function is documented on page 155.)

`\iow_shipout:Nn` With ε -TeX available deferred writing without expansion is easy.

```

\iow_shipout:Nx 12833 \cs_new_protected:Npn \iow_shipout:Nn #1#2
\iow_shipout:cn 12834 { \tex_write:D #1 { \exp_not:n {#2} } }
\iow_shipout:cx 12835 \cs_generate_variant:Nn \iow_shipout:Nn { c, Nx, cx }

```

(End definition for `\iow_shipout:Nn`. This function is documented on page 155.)

20.3.2 Immediate writing

`__kernel_iow_with:Nnn` If the integer #1 is equal to #2, just leave #3 in the input stream. Otherwise, pass the old value to an auxiliary, which sets the integer to the new value, runs the code, and restores the integer.

```

12836 \cs_new_protected:Npn \__kernel_iow_with:Nnn #1#2
12837 {
12838     \int_compare:nNnTF {#1} = {#2}
12839     { \use:n }
12840     { \exp_args:No \__iow_with:nNnn { \int_use:N #1 } #1 {#2} }
12841 }
12842 \cs_new_protected:Npn \__iow_with:nNnn #1#2#3#4
12843 {
12844     \int_set:Nn #2 {#3}
12845     #4
12846     \int_set:Nn #2 {#1}
12847 }

```

(End definition for `__kernel_iow_with:Nnn` and `__iow_with:nNnn`.)

`\iow_now:Nn` This routine writes the second argument onto the output stream without expansion. If this stream isn't open, the output goes to the terminal instead. If the first argument is no output stream at all, we get an internal error. We don't use the expansion done by `\write` to get the Nx variant, because it differs in subtle ways from x-expansion, namely, macro parameter characters would not need to be doubled. We set the `\newlinechar` to 10 using `__kernel_iow_with:Nnn` to support formats such as plain TeX: otherwise,

`\iow_newline:` would not work. We do not do this for `\iow_shipout:Nn` or `\iow_shipout_x:Nn`, as T_EX looks at the value of the `\newlinechar` at shipout time in those cases.

```

12848 \cs_new_protected:Npn \iow_now:Nn #1#2
12849 {
12850   \__kernel_iow_with:Nnn \tex_newlinechar:D { '\^^J }
12851   { \tex_immediate:D \tex_write:D #1 { \exp_not:n {#2} } }
12852 }
12853 \cs_generate_variant:Nn \iow_now:Nn { c, Nx, cx }

```

(End definition for `\iow_now:Nn`. This function is documented on page 154.)

`\iow_log:n` Writing to the log and the terminal directly are relatively easy.

`\iow_log:x` `\cs_set_protected:Npn \iow_log:x { \iow_now:Nx \c_log_iow }`

`\iow_term:n` `\cs_new_protected:Npn \iow_log:n { \iow_now:Nn \c_log_iow }`

`\iow_term:x` `\cs_set_protected:Npn \iow_term:x { \iow_now:Nx \c_term_iow }`

`\cs_new_protected:Npn \iow_term:n { \iow_now:Nn \c_term_iow }`

(End definition for `\iow_log:n` and `\iow_term:n`. These functions are documented on page 154.)

20.3.3 Special characters for writing

`\iow_newline:` Global variable holding the character that forces a new line when something is written to an output stream.

```

12858 \cs_new:Npn \iow_newline: { ^^J }

```

(End definition for `\iow_newline:`. This function is documented on page 155.)

`\iow_char:N` Function to write any escaped char to an output stream.

```

12859 \cs_new_eq:NN \iow_char:N \cs_to_str:N

```

(End definition for `\iow_char:N`. This function is documented on page 155.)

20.3.4 Hard-wrapping lines to a character count

The code here implements a generic hard-wrapping function. This is used by the messaging system, but is designed such that it is available for other uses.

`\l_iow_line_count_int` This is the “raw” number of characters in a line which can be written to the terminal. The standard value is the line length typically used by T_EXLive and MiK_TE_X.

```

12860 \int_new:N \l_iow_line_count_int
12861 \int_set:Nn \l_iow_line_count_int { 78 }

```

(End definition for `\l_iow_line_count_int`. This variable is documented on page 156.)

`\l__iow_newline_tl` The token list inserted to produce a new line, with the *⟨run-on text⟩*.

```

12862 \tl_new:N \l__iow_newline_tl

```

(End definition for `\l__iow_newline_tl`.)

`\l_iow_line_target_int` This stores the target line count: the full number of characters in a line, minus any part for a leader at the start of each line.

```

12863 \int_new:N \l_iow_line_target_int

```

(End definition for `\l_iow_line_target_int`.)

`__iow_set_indent:n` The `one_indent` variables hold one indentation marker and its length. The `__iow_unindent:w` auxiliary removes one indentation. The function `__iow_set_indent:n` (that could possibly be public) sets the indentation in a consistent way. We set it to four spaces by default.

```

12864 \tl_new:N \l__iow_one_indent_tl
12865 \int_new:N \l__iow_one_indent_int
12866 \cs_new:Npn \__iow_unindent:w { }
12867 \cs_new_protected:Npn \__iow_set_indent:n #1
12868 {
12869   \tl_set:Nx \l__iow_one_indent_tl
12870     { \exp_args:No \__kernel_str_to_other_fast:n { \tl_to_str:n {#1} } }
12871   \int_set:Nn \l__iow_one_indent_int
12872     { \str_count:N \l__iow_one_indent_tl }
12873   \exp_last_unbraced:NNo
12874     \cs_set:Npn \__iow_unindent:w \l__iow_one_indent_tl { }
12875 }
12876 \exp_args:Nx \__iow_set_indent:n { \prg_replicate:nn { 4 } { ~ } }

```

(End definition for `__iow_set_indent:n` and others.)

`\l__iow_indent_tl` The current indentation (some copies of `\l__iow_one_indent_tl`) and its number of
`\l__iow_indent_int` characters.

```

12877 \tl_new:N \l__iow_indent_tl
12878 \int_new:N \l__iow_indent_int

```

(End definition for `\l__iow_indent_tl` and `\l__iow_indent_int`.)

`\l__iow_line_tl` These hold the current line of text and a partial line to be added to it, respectively.
`\l__iow_line_part_tl`

```

12879 \tl_new:N \l__iow_line_tl
12880 \tl_new:N \l__iow_line_part_tl

```

(End definition for `\l__iow_line_tl` and `\l__iow_line_part_tl`.)

`\l__iow_line_break_bool` Indicates whether the line was broken precisely at a chunk boundary.

```

12881 \bool_new:N \l__iow_line_break_bool

```

(End definition for `\l__iow_line_break_bool`.)

`\l__iow_wrap_tl` Used for the expansion step before detokenizing, and for the output from wrapping text: fully expanded and with lines which are not overly long.

```

12882 \tl_new:N \l__iow_wrap_tl

```

(End definition for `\l__iow_wrap_tl`.)

`\c__iow_wrap_marker_tl` Every special action of the wrapping code is starts with the same recognizable string,
`\c__iow_wrap_end_marker_tl` `\c__iow_wrap_marker_tl`. Upon seeing that “word”, the wrapping code reads one space-
`\c__iow_wrap_newline_marker_tl` delimited argument to know what operation to perform. The setting of `\escapechar` here
`\c__iow_wrap_allow_break_marker_tl` is not very important, but makes `\c__iow_wrap_marker_tl` look marginally nicer.

```

12883 \group_begin:
12884   \int_set:Nn \tex_escapechar:D { -1 }
12885   \tl_const:Nx \c__iow_wrap_marker_tl
12886     { \tl_to_str:n { \^^I \^^O \^^W \^^_ \^^W \^^R \^^A \^^P } }
12887 \group_end:
12888 \tl_map_inline:nn

```

```

12889 { { end } { newline } { allow_break } { indent } { unindent } }
12890 {
12891   \tl_const:cx { c__iow_wrap_ #1 _marker_tl }
12892   {
12893     \c__iow_wrap_marker_tl
12894     #1
12895     \c_catcode_other_space_tl
12896   }
12897 }

```

(End definition for `\c__iow_wrap_marker_tl` and others.)

`\iow_allow_break:` We set `\iow_allow_break:n` to produce an error when outside messages. Within wrapped message, it is set to `__iow_allow_break:` when valid and otherwise to `__iow_allow_break_error:`. The second produces an error expandably.

```

12898 \cs_new_protected:Npn \iow_allow_break:
12899 {
12900   \__kernel_msg_error:nnnn { kernel } { iow-indent }
12901   { \iow_wrap:nnnN } { \iow_allow_break: }
12902 }
12903 \cs_new:Npx \__iow_allow_break: { \c__iow_wrap_allow_break_marker_tl }
12904 \cs_new:Npn \__iow_allow_break_error:
12905 {
12906   \__kernel_msg_expandable_error:nnnn { kernel } { iow-indent }
12907   { \iow_wrap:nnnN } { \iow_allow_break: }
12908 }

```

(End definition for `\iow_allow_break:`, `__iow_allow_break:`, and `__iow_allow_break_error:`. This function is documented on page 253.)

`\iow_indent:n` We set `\iow_indent:n` to produce an error when outside messages. Within wrapped message, it is set to `__iow_indent:n` when valid and otherwise to `__iow_indent_error:n`. The first places the instruction for increasing the indentation before its argument, and the instruction for unindenting afterwards. The second produces an error expandably. Note that there are no forced line-break, so the indentation only changes when the next line is started.

```

12909 \cs_new_protected:Npn \iow_indent:n #1
12910 {
12911   \__kernel_msg_error:nnnnn { kernel } { iow-indent }
12912   { \iow_wrap:nnnN } { \iow_indent:n } {#1}
12913   #1
12914 }
12915 \cs_new:Npx \__iow_indent:n #1
12916 {
12917   \c__iow_wrap_indent_marker_tl
12918   #1
12919   \c__iow_wrap_unindent_marker_tl
12920 }
12921 \cs_new:Npn \__iow_indent_error:n #1
12922 {
12923   \__kernel_msg_expandable_error:nnnnn { kernel } { iow-indent }
12924   { \iow_wrap:nnnN } { \iow_indent:n } {#1}
12925   #1
12926 }

```

(End definition for `\iow_indent:n`, `__iow_indent:n`, and `__iow_indent_error:n`. This function is documented on page 156.)

`\iow_wrap:nnnN` The main wrapping function works as follows. First give `\`, `_` and other formatting commands the correct definition for messages and perform the given setup #3. `\iow_wrap:nxnN` The definition of `_` uses an “other” space rather than a normal space, because the latter might be absorbed by \TeX to end a number or other f-type expansions. Use `\conditionally@traceoff` if defined; it is introduced by the `trace` package and suppresses uninteresting tracing of the wrapping code.

```

12927 \cs_new_protected:Npn \iow_wrap:nnnN #1#2#3#4
12928 {
12929   \group_begin:
12930   <package> \use:c { conditionally@traceoff }
12931   \int_set:Nn \tex_escapechar:D { -1 }
12932   \cs_set:Npx \{ { \token_to_str:N \{ }
12933   \cs_set:Npx \# { \token_to_str:N \# }
12934   \cs_set:Npx \} { \token_to_str:N \} }
12935   \cs_set:Npx \% { \token_to_str:N \% }
12936   \cs_set:Npx \~ { \token_to_str:N \~ }
12937   \int_set:Nn \tex_escapechar:D { 92 }
12938   \cs_set_eq:NN \_ \iow_newline:
12939   \cs_set_eq:NN \_c_catcode_other_space_tl
12940   \cs_set_eq:NN \iow_allow_break: \__iow_allow_break:
12941   \cs_set_eq:NN \iow_indent:n \__iow_indent:n
12942   #3

```

Then fully-expand the input: in package mode, the expansion uses $\text{\LaTeX} 2_{\epsilon}$ ’s `\protect` mechanism in the same way as `\typeout`. In generic mode this setting is useless but harmless. As soon as the expansion is done, reset `\iow_indent:n` to its error definition: it only works in the first argument of `\iow_wrap:nnnN`.

```

12943 <package> \cs_set_eq:NN \protect \token_to_str:N
12944 \tl_set:Nx \l__iow_wrap_tl {#1}
12945 \cs_set_eq:NN \iow_allow_break: \__iow_allow_break_error:
12946 \cs_set_eq:NN \iow_indent:n \__iow_indent_error:n

```

Afterwards, set the newline marker (two assignments to fully expand, then convert to a string) and initialize the target count for lines (the first line has target count `\l_iow_line_count_int` instead).

```

12947 \tl_set:Nx \l__iow_newline_tl { \iow_newline: #2 }
12948 \tl_set:Nx \l__iow_newline_tl { \tl_to_str:N \l__iow_newline_tl }
12949 \int_set:Nn \l__iow_line_target_int
12950 { \l_iow_line_count_int - \str_count:N \l__iow_newline_tl + 1 }

```

Sanity check.

```

12951 \int_compare:nNnT { \l__iow_line_target_int } < 0
12952 {
12953   \tl_set:Nn \l__iow_newline_tl { \iow_newline: }
12954   \int_set:Nn \l__iow_line_target_int
12955   { \l_iow_line_count_int + 1 }
12956 }

```

There is then a loop over the input, which stores the wrapped result in `\l__iow_wrap_tl`. After the loop, the resulting text is passed on to the function which has been given as a post-processor. The `\tl_to_str:N` step converts the “other” spaces back to normal spaces. The f-expansion removes a leading space from `\l__iow_wrap_tl`.

```

12957     \__iow_wrap_do:
12958     \exp_args:NNf \group_end:
12959     #4 { \tl_to_str:N \l__iow_wrap_tl }
12960   }
12961 \cs_generate_variant:Nn \iow_wrap:nnnN { nx }

```

(End definition for `\iow_wrap:nnnN`. This function is documented on page 156.)

`__iow_wrap_do:` Escape spaces and change newlines to `\c__iow_wrap_newline_marker_tl`. Set up a few variables, in particular the initial value of `\l__iow_wrap_tl`: the space stops the `f`-expansion of the main wrapping function and `\use_none:n` removes a newline marker inserted by later code. The main loop consists of repeatedly calling the `chunk` auxiliary to wrap chunks delimited by (newline or indentation) markers.

```

12962 \cs_new_protected:Npn \__iow_wrap_do:
12963 {
12964   \tl_set:Nx \l__iow_wrap_tl
12965   {
12966     \exp_args:No \__kernel_str_to_other_fast:n \l__iow_wrap_tl
12967     \c__iow_wrap_end_marker_tl
12968   }
12969   \tl_set:Nx \l__iow_wrap_tl
12970   {
12971     \exp_after:wN \__iow_wrap_fix_newline:w \l__iow_wrap_tl
12972     ^^J \q_nil ^^J \q_stop
12973   }
12974   \exp_after:wN \__iow_wrap_start:w \l__iow_wrap_tl
12975 }
12976 \cs_new:Npn \__iow_wrap_fix_newline:w #1 ^^J #2 ^^J
12977 {
12978   #1
12979   \if_meaning:w \q_nil #2
12980     \use_i_delimit_by_q_stop:nw
12981   \fi:
12982   \c__iow_wrap_newline_marker_tl
12983   \__iow_wrap_fix_newline:w #2 ^^J
12984 }
12985 \cs_new_protected:Npn \__iow_wrap_start:w
12986 {
12987   \bool_set_false:N \l__iow_line_break_bool
12988   \tl_clear:N \l__iow_line_tl
12989   \tl_clear:N \l__iow_line_part_tl
12990   \tl_set:Nn \l__iow_wrap_tl { ~ \use_none:n }
12991   \int_zero:N \l__iow_indent_int
12992   \tl_clear:N \l__iow_indent_tl
12993   \__iow_wrap_chunk:nw { \l__iow_line_count_int }
12994 }

```

(End definition for `__iow_wrap_do:`, `__iow_wrap_fix_newline:w`, and `__iow_wrap_start:w`.)

`__iow_wrap_chunk:nw` The `chunk` and `next` auxiliaries are defined indirectly to obtain the expansions of `\c_catcode_other_space_tl` and `\c__iow_wrap_marker_tl` in their definition. The `next` auxiliary calls a function corresponding to the type of marker (its `##2`), which can be `newline` or `indent` or `unindent` or `end`. The first argument of the `chunk` auxiliary is a target number of characters and the second is some string to wrap. If the chunk is

empty simply call `next`. Otherwise, set up a call to `__iow_wrap_line:nw`, including the indentation if the current line is empty, and including a trailing space (`#1`) before the `__iow_wrap_end_chunk:w` auxiliary.

```

12995 \cs_set_protected:Npn \__iow_tmp:w #1#2
12996 {
12997   \cs_new_protected:Npn \__iow_wrap_chunk:nw ##1##2 #2
12998   {
12999     \tl_if_empty:NTF {##2}
13000     {
13001       \tl_clear:N \l__iow_line_part_tl
13002       \__iow_wrap_next:nw {##1}
13003     }
13004     {
13005       \tl_if_empty:NTF \l__iow_line_tl
13006       {
13007         \__iow_wrap_line:nw
13008         { \l__iow_indent_tl }
13009         ##1 - \l__iow_indent_int ;
13010       }
13011       { \__iow_wrap_line:nw { } ##1 ; }
13012       ##2 #1
13013       \__iow_wrap_end_chunk:w 7 6 5 4 3 2 1 0 \q_stop
13014     }
13015   }
13016   \cs_new_protected:Npn \__iow_wrap_next:nw ##1##2 #1
13017   { \use:c { __iow_wrap_##2:n } {##1} }
13018 }
13019 \exp_args:NVV \__iow_tmp:w \c_catcode_other_space_tl \c__iow_wrap_marker_tl

```

(End definition for `__iow_wrap_chunk:nw` and `__iow_wrap_next:nw`.)

<pre> __iow_wrap_line:nw __iow_wrap_line_loop:w __iow_wrap_line_aux:Nw __iow_wrap_line_seven:nnnnnn __iow_wrap_line_end:NnnnnnnN __iow_wrap_line_end:nw __iow_wrap_end_chunk:w </pre>	<p>This is followed by <code>{\langle string \rangle} \langle intexpr \rangle ;</code>. It stores the <code>\langle string \rangle</code> and up to <code>\langle intexpr \rangle</code> characters from the current chunk into <code>\l__iow_line_part_tl</code>. Characters are grabbed 8 at a time and left in <code>\l__iow_line_part_tl</code> by the <code>line_loop</code> auxiliary. When $k < 8$ remain to be found, the <code>line_aux</code> auxiliary calls the <code>line_end</code> auxiliary followed by (the single digit) k, then $7 - k$ empty brace groups, then the chunk's remaining characters. The <code>line_end</code> auxiliary leaves k characters from the chunk in the line part, then ends the assignment. Ignore the <code>\use_none:nnnnn</code> line for now. If the next character is a space the line can be broken there: store what we found into the result and get the next line. Otherwise some work is needed to find a break-point. So far we have ignored what happens if the chunk is shorter than the requested number of characters: this is dealt with by the <code>end_chunk</code> auxiliary, which gets treated like a character by the rest of the code. It ends up being called either as one of the arguments <code>#2-#9</code> of the <code>line_loop</code> auxiliary or as one of the arguments <code>#2-#8</code> of the <code>line_end</code> auxiliary. In both cases stop the assignment and work out how many characters are still needed. Notice that when we have exactly seven arguments to clean up, a <code>\exp_stop_f:</code> has to be inserted to stop the <code>\exp:w</code>. The weird <code>\use_none:nnnnn</code> ensures that the required data is in the right place.</p>
--	--

```

13020 \cs_new_protected:Npn \__iow_wrap_line:nw #1
13021 {
13022   \tex_edef:D \l__iow_line_part_tl { \if_false: } \fi:
13023   #1

```

```

13024     \exp_after:wN \__iow_wrap_line_loop:w
13025     \int_value:w \int_eval:w
13026   }
13027 \cs_new:Npn \__iow_wrap_line_loop:w #1 ; #2#3#4#5#6#7#8#9
13028 {
13029     \if_int_compare:w #1 < 8 \exp_stop_f:
13030     \__iow_wrap_line_aux:Nw #1
13031     \fi:
13032     #2 #3 #4 #5 #6 #7 #8 #9
13033     \exp_after:wN \__iow_wrap_line_loop:w
13034     \int_value:w \int_eval:w #1 - 8 ;
13035 }
13036 \cs_new:Npn \__iow_wrap_line_aux:Nw #1#2#3 \exp_after:wN #4 ;
13037 {
13038     #2
13039     \exp_after:wN \__iow_wrap_line_end:NnnnnnnnN
13040     \exp_after:wN #1
13041     \exp:w \exp_end_continue_f:w
13042     \exp_after:wN \exp_after:wN
13043     \if_case:w #1 \exp_stop_f:
13044         \prg_do_nothing:
13045     \or: \use_none:n
13046     \or: \use_none:nn
13047     \or: \use_none:nnn
13048     \or: \use_none:nnnn
13049     \or: \use_none:nnnnn
13050     \or: \use_none:nnnnnn
13051     \or: \__iow_wrap_line_seven:nnnnnnn
13052     \fi:
13053     { } { } { } { } { } { } { } { } { } #3
13054 }
13055 \cs_new:Npn \__iow_wrap_line_seven:nnnnnnn #1#2#3#4#5#6#7 { \exp_stop_f: }
13056 \cs_new:Npn \__iow_wrap_line_end:NnnnnnnnN #1#2#3#4#5#6#7#8#9
13057 {
13058     #2 #3 #4 #5 #6 #7 #8
13059     \use_none:nnnnn \int_eval:w 8 - ; #9
13060     \token_if_eq_charcode:NNTF \c_space_token #9
13061     { \__iow_wrap_line_end:nw { } }
13062     { \if_false: { \fi: } \__iow_wrap_break:w #9 }
13063 }
13064 \cs_new:Npn \__iow_wrap_line_end:nw #1
13065 {
13066     \if_false: { \fi: }
13067     \__iow_wrap_store_do:n {#1}
13068     \__iow_wrap_next_line:w
13069 }
13070 \cs_new:Npn \__iow_wrap_end_chunk:w
13071 #1 \int_eval:w #2 - #3 ; #4#5 \q_stop
13072 {
13073     \if_false: { \fi: }
13074     \exp_args:Nf \__iow_wrap_next:nw { \int_eval:n { #2 - #4 } }
13075 }

```

(End definition for __iow_wrap_line:nw and others.)

`__iow_wrap_break:w` Functions here are defined indirectly: `__iow_tmp:w` is eventually called with an “other”
`__iow_wrap_break_first:w` space as its argument. The goal is to remove from `\l__iow_line_part_tl` the part
`__iow_wrap_break_none:w` after the last space. In most cases this is done by repeatedly calling the `break_loop`
`__iow_wrap_break_loop:w` auxiliary, which leaves “words” (delimited by spaces) until it hits the trailing space: then
`__iow_wrap_break_end:w` its argument `##3` is ? `__iow_wrap_break_end:w` instead of a single token, and that
`break_end` auxiliary leaves in the assignment the line until the last space, then calls
`__iow_wrap_line_end:nw` to finish up the line and move on to the next. If there is
no space in `\l__iow_line_part_tl` then the `break_first` auxiliary calls the `break_`
`none` auxiliary. In that case, if the current line is empty, the complete word (including
`##4`, characters beyond what we had grabbed) is added to the line, making it over-long.
Otherwise, the word is used for the following line (and the last space of the line so far is
removed because it was inserted due to the presence of a marker).

```

13076 \cs_set_protected:Npn \__iow_tmp:w #1
13077 {
13078   \cs_new:Npn \__iow_wrap_break:w
13079   {
13080     \tex_edef:D \l__iow_line_part_tl
13081     { \if_false: } \fi:
13082     \exp_after:wN \__iow_wrap_break_first:w
13083     \l__iow_line_part_tl
13084     #1
13085     { ? \__iow_wrap_break_end:w }
13086     \q_mark
13087   }
13088   \cs_new:Npn \__iow_wrap_break_first:w ##1 #1 ##2
13089   {
13090     \use_none:nn ##2 \__iow_wrap_break_none:w
13091     \__iow_wrap_break_loop:w ##1 #1 ##2
13092   }
13093   \cs_new:Npn \__iow_wrap_break_none:w ##1##2 #1 ##3 \q_mark ##4 #1
13094   {
13095     \tl_if_empty:NTF \l__iow_line_tl
13096     { ##2 ##4 \__iow_wrap_line_end:nw { } }
13097     { \__iow_wrap_line_end:nw { \__iow_wrap_trim:N } ##2 ##4 #1 }
13098   }
13099   \cs_new:Npn \__iow_wrap_break_loop:w ##1 #1 ##2 #1 ##3
13100   {
13101     \use_none:n ##3
13102     ##1 #1
13103     \__iow_wrap_break_loop:w ##2 #1 ##3
13104   }
13105   \cs_new:Npn \__iow_wrap_break_end:w ##1 #1 ##2 ##3 #1 ##4 \q_mark
13106   { ##1 \__iow_wrap_line_end:nw { } ##3 }
13107 }
13108 \exp_args:NV \__iow_tmp:w \c_catcode_other_space_tl

```

(End definition for `__iow_wrap_break:w` and others.)

`__iow_wrap_next_line:w` The special case where the end of a line coincides with the end of a chunk is detected here,
to avoid a spurious empty line. Otherwise, call `__iow_wrap_line:nw` to find characters
for the next line (remembering to account for the indentation).

```

13109 \cs_new_protected:Npn \__iow_wrap_next_line:w #1#2 \q_stop
13110 {

```

```

13111 \tl_clear:N \l__iow_line_tl
13112 \token_if_eq_meaning:NNTF #1 \__iow_wrap_end_chunk:w
13113 {
13114   \tl_clear:N \l__iow_line_part_tl
13115   \bool_set_true:N \l__iow_line_break_bool
13116   \__iow_wrap_next:nw { \l__iow_line_target_int }
13117 }
13118 {
13119   \__iow_wrap_line:nw
13120   { \l__iow_indent_tl }
13121   \l__iow_line_target_int - \l__iow_indent_int ;
13122   #1 #2 \q_stop
13123 }
13124 }

```

(End definition for __iow_wrap_next_line:w.)

__iow_wrap_allow_break:n This is called after a chunk has been wrapped. The \l__iow_line_part_tl typically ends with a space (except at the beginning of a line?), which we remove since the **allow-break** marker should not insert a space. Then move on with the next chunk, making sure to adjust the target number of characters for the line in case we did remove a space.

```

13125 \cs_new_protected:Npn \__iow_wrap_allow_break:n #1
13126 {
13127   \tl_set:Nx \l__iow_line_tl
13128   { \l__iow_line_tl \__iow_wrap_trim:N \l__iow_line_part_tl }
13129   \bool_set_false:N \l__iow_line_break_bool
13130   \tl_if_empty:NNTF \l__iow_line_part_tl
13131   { \__iow_wrap_chunk:nw {#1} }
13132   { \exp_args:Nf \__iow_wrap_chunk:nw { \int_eval:n { #1 + 1 } } }
13133 }

```

(End definition for __iow_wrap_allow_break:n.)

__iow_wrap_indent:n These functions are called after a chunk has been wrapped, when encountering **indent/unindent** markers. Add the line part (last line part of the previous chunk) to the line so far and reset a boolean denoting the presence of a line-break. Most importantly, add or remove one indent from the current indent (both the integer and the token list). Finally, continue wrapping.

__iow_wrap_unindent:n

```

13134 \cs_new_protected:Npn \__iow_wrap_indent:n #1
13135 {
13136   \tl_put_right:Nx \l__iow_line_tl { \l__iow_line_part_tl }
13137   \bool_set_false:N \l__iow_line_break_bool
13138   \int_add:Nn \l__iow_indent_int { \l__iow_one_indent_int }
13139   \tl_put_right:No \l__iow_indent_tl { \l__iow_one_indent_tl }
13140   \__iow_wrap_chunk:nw {#1}
13141 }
13142 \cs_new_protected:Npn \__iow_wrap_unindent:n #1
13143 {
13144   \tl_put_right:Nx \l__iow_line_tl { \l__iow_line_part_tl }
13145   \bool_set_false:N \l__iow_line_break_bool
13146   \int_sub:Nn \l__iow_indent_int { \l__iow_one_indent_int }
13147   \tl_set:Nx \l__iow_indent_tl
13148   { \exp_after:wN \__iow_unindent:w \l__iow_indent_tl }
13149   \__iow_wrap_chunk:nw {#1}
13150 }

```

(End definition for _iow_wrap_indent:n and _iow_wrap_unindent:n.)

_iow_wrap_newline:n These functions are called after a chunk has been line-wrapped, when encountering a
 _iow_wrap_end:n newline/end marker. Unless we just took a line-break, store the line part and the line
 so far into the whole \l__iow_wrap_tl, trimming a trailing space. In the newline case
 look for a new line (of length \l__iow_line_target_int) in a new chunk.

```

13151 \cs_new_protected:Npn \_iow_wrap_newline:n #1
13152   {
13153     \bool_if:NF \l__iow_line_break_bool
13154     { \_iow_wrap_store_do:n { \_iow_wrap_trim:N } }
13155     \bool_set_false:N \l__iow_line_break_bool
13156     \_iow_wrap_chunk:nw { \l__iow_line_target_int }
13157   }
13158 \cs_new_protected:Npn \_iow_wrap_end:n #1
13159   {
13160     \bool_if:NF \l__iow_line_break_bool
13161     { \_iow_wrap_store_do:n { \_iow_wrap_trim:N } }
13162     \bool_set_false:N \l__iow_line_break_bool
13163   }

```

(End definition for _iow_wrap_newline:n and _iow_wrap_end:n.)

_iow_wrap_store_do:n First add the last line part to the line, then append it to \l__iow_wrap_tl with the
 appropriate new line (with “run-on” text), possibly with its last space removed (#1 is
 empty or _iow_wrap_trim:N).

```

13164 \cs_new_protected:Npn \_iow_wrap_store_do:n #1
13165   {
13166     \tl_set:Nx \l__iow_line_tl
13167     { \l__iow_line_tl \l__iow_line_part_tl }
13168     \tl_set:Nx \l__iow_wrap_tl
13169     {
13170       \l__iow_wrap_tl
13171       \l__iow_newline_tl
13172       #1 \l__iow_line_tl
13173     }
13174     \tl_clear:N \l__iow_line_tl
13175   }

```

(End definition for _iow_wrap_store_do:n.)

_iow_wrap_trim:N Remove one trailing “other” space from the argument if present.

```

13176 \cs_set_protected:Npn \_iow_tmp:w #1
13177   {
13178     \cs_new:Npn \_iow_wrap_trim:N ##1
13179     { \exp_after:wN \_iow_wrap_trim:w ##1 \q_mark #1 \q_mark \q_stop }
13180     \cs_new:Npn \_iow_wrap_trim:w ##1 #1 \q_mark
13181     { \_iow_wrap_trim_aux:w ##1 \q_mark }
13182     \cs_new:Npn \_iow_wrap_trim_aux:w ##1 \q_mark ##2 \q_stop {##1}
13183   }
13184 \exp_args:NV \_iow_tmp:w \c_catcode_other_space_tl

```

(End definition for _iow_wrap_trim:N, _iow_wrap_trim:w, and _iow_wrap_trim_aux:w.)

```

13185 <@@=file>

```

20.4 File operations

`\l__file_internal_tl` Used as a short-term scratch variable.

```
13186 \tl_new:N \l__file_internal_tl
```

(End definition for `\l__file_internal_tl`.)

`\g__file_internal_ior` A reserved stream to test for file existence.

```
13187 \ior_new:N \g__file_internal_ior
```

(End definition for `\g__file_internal_ior`.)

`\g_file_curr_dir_str` The name of the current file should be available at all times. For the format the file name
`\g_file_curr_ext_str` needs to be picked up at the start of the run. In L^AT_EX 2_ε package mode the current file
`\g_file_curr_name_str` name is collected from `\@currname`.

```
13188 \str_new:N \g_file_curr_dir_str
13189 \str_new:N \g_file_curr_ext_str
13190 \str_new:N \g_file_curr_name_str
13191 \*initex
13192 \tex_everyjob:D \exp_after:wN
13193 {
13194   \tex_the:D \tex_everyjob:D
13195   \str_gset:Nx \g_file_curr_name_str { \tex_jobname:D }
13196 }
13197 \</initex>
13198 \*package
13199 \cs_if_exist:NT \@currname
13200 { \str_gset_eq:NN \g_file_curr_name_str \@currname }
13201 \</package>
```

(End definition for `\g_file_curr_dir_str`, `\g_file_curr_ext_str`, and `\g_file_curr_name_str`. These variables are documented on page 157.)

`\g__file_stack_seq` The input list of files is stored as a sequence stack. In package mode we can recover the information from the details held by L^AT_EX 2_ε (we must be in the preamble and loaded using `\usepackage` or `\RequirePackage`). As L^AT_EX 2_ε doesn't store directory and name separately, we stick to the same convention here.

```
13202 \seq_new:N \g__file_stack_seq
13203 \*package
13204 \group_begin:
13205   \cs_set_protected:Npn \__file_tmp:w #1#2#3
13206   {
13207     \tl_if_blank:nTF {#1}
13208     {
13209       \cs_set:Npn \__file_tmp:w ##1 " ##2 " ##3 \q_stop
13210       { { } {##2} { } }
13211       \seq_gput_right:Nx \g__file_stack_seq
13212       {
13213         \exp_after:wN \__file_tmp:w \tex_jobname:D
13214         " \tex_jobname:D " \q_stop
13215       }
13216     }
13217   {
13218     \seq_gput_right:Nn \g__file_stack_seq { { } {#1} {#2} }
```

```

13219         \_file_tmp:w
13220     }
13221 }
13222 \cs_if_exist:NT \@currnamestack
13223 { \exp_after:wN \_file_tmp:w \@currnamestack }
13224 \group_end:
13225 \</package>

```

(End definition for \g_file_stack_seq.)

\g_file_record_seq The total list of files used is recorded separately from the current file stack, as nothing is ever popped from this list. The current file name should be included in the file list! In format mode, this is done at the very start of the T_EX run. In package mode we will eventually copy the contents of \@filelist.

```

13226 \seq_new:N \g_file_record_seq
13227 \<{*initex>
13228 \tex_everyjob:D \exp_after:wN
13229 {
13230     \tex_the:D \tex_everyjob:D
13231     \seq_gput_right:NV \g_file_record_seq \g_file_curr_name_str
13232 }
13233 \</initex>

```

(End definition for \g_file_record_seq.)

\l_file_base_name_tl For storing the basename and full path whilst passing data internally.

```

\l_file_full_name_tl
13234 \tl_new:N \l_file_base_name_tl
13235 \tl_new:N \l_file_full_name_tl

```

(End definition for \l_file_base_name_tl and \l_file_full_name_tl.)

\l_file_dir_str Used in parsing a path into parts: in contrast to the above, these are never used outside of the current module.

```

\l_file_ext_str
\l_file_name_str
13236 \str_new:N \l_file_dir_str
13237 \str_new:N \l_file_ext_str
13238 \str_new:N \l_file_name_str

```

(End definition for \l_file_dir_str, \l_file_ext_str, and \l_file_name_str.)

\l_file_search_path_seq The current search path.

```

13239 \seq_new:N \l_file_search_path_seq

```

(End definition for \l_file_search_path_seq. This variable is documented on page 158.)

\l_file_tmp_seq Scratch space for comma list conversion in package mode.

```

13240 \<{*package>
13241 \seq_new:N \l_file_tmp_seq
13242 \</package>

```

(End definition for \l_file_tmp_seq.)

`_kernel_file_name_sanitize:nN` For converting a token list to a string where active characters are treated as strings from the start. The logic to the quoting normalisation is the same as used by `\lualatexquotejobname`: check for balanced `"`, and assuming they balance strip all of them out before quoting the entire name if it contains spaces.

```

13243 \cs_new_protected:Npn \_kernel\_file\_name\_sanitize:nN #1#2
13244 {
13245   \group_begin:
13246   \seq_map_inline:Nn \l_char_active_seq
13247   {
13248     \tl_set:Nx \l__file\_internal\_tl { \iow\_char:N ##1 }
13249     \char\_set\_active\_eq:NN ##1 \l__file\_internal\_tl
13250   }
13251   \tl\_set:Nx \l__file\_internal\_tl {#1}
13252   \exp\_args:NNNV \group\_end:
13253   \str\_set:Nn #2 \l__file\_internal\_tl
13254 }
13255 \cs_new_protected:Npn \_file\_name\_quote:nN #1#2
13256 {
13257   \str\_set:Nx #2 {#1}
13258   \int\_if\_even:nF
13259   { 0 \tl\_map\_function:NN #2 \_file\_name\_quote\_aux:n }
13260   {
13261     \_kernel\_msg\_error:nnx
13262     { kernel } { unbalanced-quote-in-filename } {#2}
13263   }
13264   \tl\_remove\_all:Nn #2 { " }
13265   \tl\_if\_in:NnT #2 { ~ }
13266   { \str\_set:Nx #2 { " \exp\_not:V #2 " } }
13267 }
13268 \cs\_new:Npn \_file\_name\_quote\_aux:n #1
13269 { \token\_if\_eq\_charcode:NNT #1 " { + 1 } }

```

(End definition for `_kernel_file_name_sanitize:nN`, `_file_name_quote:nN`, and `_file_name_sanitize_aux:n`.)

`\c_file_marker_tl` The same idea as the marker for rescanning token lists: this pair of tokens cannot appear in a file that is being input.

```

13270 \tl\_const:Nx \c\_file\_marker\_tl { : \token\_to\_str:N : }

```

(End definition for `\c_file_marker_tl`.)

`\file_get:nnNTF` The approach here is similar to that for `\tl_set_rescan:Nnn`. The file contents are grabbed as an argument delimited by `\c_file_marker_tl`. A few subtleties: braces in `\file_get:nnN` `\if_false: ... \fi:` to deal with possible alignment tabs, `\tracingnesting` to avoid a warning about a group being closed inside the `\scantokens`, and `\prg_return_true:` is placed after the end-of-file marker.

```

13271 \cs\_new\_protected:Npn \file\_get:nnN #1#2#3
13272 {
13273   \file\_get:nnNF {#1} {#2} #3
13274   { \tl\_set:Nn #3 { \q\_no\_value } }
13275 }
13276 \prg\_new\_protected\_conditional:Npnn \file\_get:nnN #1#2#3 { T , F , TF }
13277 {
13278   \file\_get\_full\_name:nNTF {#1} \l__file\_full\_name\_tl

```



```

13279     {
13280       \exp_args:NV \__file_get_aux:nnN
13281         \l__file_full_name_tl
13282         {#2} #3
13283       \prg_return_true:
13284     }
13285     { \prg_return_false: }
13286   }
13287 \cs_new_protected:Npn \__file_get_aux:nnN #1#2#3
13288 {
13289   \if_false: { \fi:
13290     \group_begin:
13291       \int_set_eq:NN \tex_tracingnesting:D \c_zero_int
13292       \exp_args:No \tex_everyeof:D { \c__file_marker_tl }
13293       #2 \scan_stop:
13294       \exp_after:wN \__file_get_do:Nw
13295       \exp_after:wN #3
13296       \exp_after:wN \prg_do_nothing:
13297       \tex_input:D #1 \scan_stop:
13298     \if_false: } \fi:
13299   }
13300 \exp_args:Nno \use:nn
13301 { \cs_new_protected:Npn \__file_get_do:Nw #1#2 }
13302 { \c__file_marker_tl }
13303 {
13304   \group_end:
13305   \tl_set:No #1 {#2}
13306 }

```

(End definition for `\file_get:nnNTF` and others. These functions are documented on page 158.)

`\file_get_full_name:nN`
`\file_get_full_name:VN`
`\file_get_full_name:nNTF`
`\file_get_full_name:VNNTF`
`__file_get_full_name_search:nN`

The way to test if a file exists is to try to open it: if it does not exist then T_EX reports end-of-file. A search is made looking at each potential path in turn (starting from the current directory). The first location is of course treated as the correct one: this is done by jumping to `\prg_break_point:.` If nothing is found, #2 is returned empty. A special case when there is no extension is that once the first location is found we test the existence of the file with `.tex` extension in that directory, and if it exists we include the `.tex` extension in the result.

```

13307 \cs_new_protected:Npn \file_get_full_name:nN #1#2
13308 {
13309   \file_get_full_name:nNF {#1} #2
13310   { \tl_set:Nn #2 { \q_no_value } }
13311 }
13312 \cs_generate_variant:Nn \file_get_full_name:nN { V }
13313 \prg_new_protected_conditional:Npnn \file_get_full_name:nN #1#2 { T , F , TF }
13314 {
13315   \__kernel_file_name_sanitise:nN {#1} \l__file_base_name_tl
13316   \__file_get_full_name_search:nN { } \use:n
13317   \seq_map_inline:Nn \l_file_search_path_seq
13318     { \__file_get_full_name_search:nN { ##1 / } \seq_map_break:n }
13319 }
13320 \cs_if_exist:NT \input@path
13321 {
13322   \tl_map_inline:Nn \input@path

```

```

13323         { \_file_get_full_name_search:nN { ##1 } \tl_map_break:n }
13324     }
13325 \end{package}
13326 \tl_set:Nn \l__file_full_name_tl { \q_no_value }
13327 \prg_break_point:
13328 \quark_if_no_value:NTF \l__file_full_name_tl
13329 {
13330     \ior_close:N \g__file_internal_ior
13331     \prg_return_false:
13332 }
13333 {
13334     \file_parse_full_name:VNNN \l__file_full_name_tl
13335     \l__file_dir_str \l__file_name_str \l__file_ext_str
13336     \str_if_empty:NT \l__file_ext_str
13337     {
13338         \_kernel_ior_open:No \g__file_internal_ior
13339         { \l__file_full_name_tl .tex }
13340         \ior_if_eof:NF \g__file_internal_ior
13341         { \tl_put_right:Nn \l__file_full_name_tl { .tex } }
13342     }
13343     \ior_close:N \g__file_internal_ior
13344     \tl_set_eq:NN #2 \l__file_full_name_tl
13345     \prg_return_true:
13346 }
13347 }
13348 \cs_generate_variant:Nn \file_get_full_name:nNT { V }
13349 \cs_generate_variant:Nn \file_get_full_name:nNF { V }
13350 \cs_generate_variant:Nn \file_get_full_name:nNTF { V }
13351 \cs_new_protected:Npn \_file_get_full_name_search:nN #1#2
13352 {
13353     \_file_name_quote:nN
13354     { \tl_to_str:n {#1} \l__file_base_name_tl }
13355     \l__file_full_name_tl
13356     \_kernel_ior_open:No \g__file_internal_ior \l__file_full_name_tl
13357     \ior_if_eof:NF \g__file_internal_ior { #2 { \prg_break: } }
13358 }

```

(End definition for `\file_get_full_name:nN`, `\file_get_full_name:nNTF`, and `_file_get_full_name_search:nN`. These functions are documented on page 158.)

`\file_get_md5hash:nN`
`\file_get_size:nN`
`\file_get_timestamp:nN`
`_file_get_details:nnN`

These are all wrappers around the pdfTeX primitives doing the same jobs: as we want consistent file paths to be found, they are all set up using `\file_get_full_name:nN` and so are non-expandable `get` functions. Much of the code is repetitive but we need to branch for LuaTeX (emulation in Lua), for the slightly different syntax needed for `\tex_md5sum:D` and for the fact that primitive coverage varies in other engines.

```

13359 \cs_new_protected:Npn \file_get_md5hash:nN #1#2
13360 { \file_get_md5hash:nNF {#1} #2 { \tl_set:Nn #2 { \q_no_value } } }
13361 \cs_new_protected:Npn \file_get_size:nN #1#2
13362 { \file_get_size:nNF {#1} #2 { \tl_set:Nn #2 { \q_no_value } } }
13363 \cs_new_protected:Npn \file_get_timestamp:nN #1#2
13364 { \file_get_timestamp:nNF {#1} #2 { \tl_set:Nn #2 { \q_no_value } } }
13365 \prg_new_protected_conditional:Npnn \file_get_md5hash:nN #1#2 { T , F , TF }
13366 { \_file_get_details:nnN {#1} { md5sum } {#2} }
13367 \prg_new_protected_conditional:Npnn \file_get_size:nN #1#2 { T , F , TF }

```

```

13368 { \_file_get_details:nnN {#1} { size } {#2} }
13369 \prg_new_protected_conditional:Npnn \file_get_timestamp:nN #1#2 { T , F , TF }
13370 { \_file_get_details:nnN {#1} { moddate } {#2} }
13371 \cs_new_protected:Npn \_file_get_details:nnN #1#2#3
13372 {
13373   \file_get_full_name:nNTF {#1} \l__file_full_name_tl
13374   {
13375     \tl_set:Nx #3
13376     {
13377       \use:c { tex_file #2 :D } \exp_after:wN
13378       { \l__file_full_name_tl }
13379     }
13380     \prg_return_true:
13381   }
13382   { \prg_return_false: }
13383 }
13384 \sys_if_engine luatex:TF
13385 {
13386   \cs_set_protected:Npn \_file_get_details:nnN #1#2#3
13387   {
13388     \file_get_full_name:nNTF {#1} \l__file_full_name_tl
13389     {
13390       \tl_set:Nx #3
13391       {
13392         \lua_now:e
13393         {
13394           l3kernel.file#2
13395           ( " \lua_escape:e { \l__file_full_name_tl } " )
13396         }
13397       }
13398       \prg_return_true:
13399     }
13400     { \prg_return_false: }
13401   }
13402 }
13403 {
13404   \prg_set_protected_conditional:Npnn \file_get_md5sum:nN #1#2
13405   { T , F , TF }
13406   {
13407     \file_get_full_name:nNTF {#1} \l__file_full_name_tl
13408     {
13409       \tl_set:Nx #2
13410       {
13411         \tex_md5sum:D file \exp_after:wN
13412         { \l__file_full_name_tl }
13413       }
13414       \prg_return_true:
13415     }
13416     { \prg_return_false: }
13417   }
13418   \cs_if_exist:NF \tex_filesize:D
13419   {
13420     \cs_set_protected:Npn \_file_get_details:nnN #1#2#3
13421     {

```

```

13422         \tl_clear:N #3
13423         \__kernel_msg_error:nxx
13424         { kernel } { primitive-not-available }
13425         { \exp_not:c { (pdf)file #2 } }
13426         \prg_return_false:
13427     }
13428 }
13429 }
13430 \__kernel_msg_new:nnnn { kernel } { primitive-not-available }
13431 { Primitive~\token_to_str:N #1 not-available }
13432 {
13433     The~version~of~XeTeX~in~use~does~not~provide~functionality~equivalent~to~
13434     the~\token_to_str:N #1 primitive.
13435 }

```

(End definition for `\file_get_md5five_hash:nN` and others. These functions are documented on page 159.)

`\file_if_exist:nTF` The test for the existence of a file is a wrapper around the function to add a path to a file. If the file was found, the path contains something, whereas if the file was not located then the return value is empty.

```

13436 \prg_new_protected_conditional:Npnn \file_if_exist:n #1 { T , F , TF }
13437 {
13438     \file_get_full_name:nNTF {#1} \l__file_full_name_tl
13439     { \prg_return_true: }
13440     { \prg_return_false: }
13441 }

```

(End definition for `\file_if_exist:nTF`. This function is documented on page 158.)

`\file_if_exist_input:n` Input of a file with a test for existence. We do not define the T or TF variants because the most useful place to place the *⟨true code⟩* would be inconsistent with other conditionals.

`\file_if_exist_input:nF`

```

13442 \cs_new_protected:Npn \file_if_exist_input:n #1
13443 {
13444     \file_get_full_name:nNT {#1} \l__file_full_name_tl
13445     { \__file_input:V \l__file_full_name_tl }
13446 }
13447 \cs_new_protected:Npn \file_if_exist_input:nF #1#2
13448 {
13449     \file_get_full_name:nNTF {#1} \l__file_full_name_tl
13450     { \__file_input:V \l__file_full_name_tl }
13451     {#2}
13452 }

```

(End definition for `\file_if_exist_input:n` and `\file_if_exist_input:nF`. These functions are documented on page 159.)

`\file_input_stop:` A simple rename.

```

13453 \cs_new_protected:Npn \file_input_stop: { \tex_endinput:D }

```

(End definition for `\file_input_stop:.` This function is documented on page 159.)

_kernel_file_missing:n An error message for a missing file, also used in \ior_open:Nn.

```

13454 \cs_new_protected:Npn \_kernel\_file\_missing:n #1
13455 {
13456   \_kernel\_file\_name\_sanitize:nN {#1} \l\_file\_base\_name\_tl
13457   \_kernel\_msg\_error:nnx { kernel } { file-not-found }
13458   { \l\_file\_base\_name\_tl }
13459 }

```

(End definition for _kernel_file_missing:n.)

\file_input:n Loading a file is done in a safe way, checking first that the file exists and loading only if it does. Push the file name on the \g_file_stack_seq, and add it to the file list, either \g_file_record_seq, or \@filelist in package mode.

_file_input:n
_file_input:V

```

\_file\_input\_push:n 13460 \cs_new_protected:Npn \file\_input:n #1
\_kernel\_file\_input\_push:n 13461 {
  \_file\_input\_pop: 13462   \file\_get\_full\_name:nNTF {#1} \l\_file\_full\_name\_tl
  \_kernel\_file\_input\_pop: 13463   { \_file\_input:V \l\_file\_full\_name\_tl }
  \_file\_input\_pop:nnn 13464   { \_kernel\_file\_missing:n {#1} }
13465 }
13466 \cs_new_protected:Npn \_file\_input:n #1
13467 {
13468   \*initex
13469   \seq\_gput\_right:Nn \g\_file\_record\_seq {#1}
13470   \*initex
13471   \*package
13472   \clist\_if\_exist:NTF \@filelist
13473   { \@addtofilelist {#1} }
13474   { \seq\_gput\_right:Nn \g\_file\_record\_seq {#1} }
13475   \*package
13476   \_file\_input\_push:n {#1}
13477   \tex\_input:D #1 \c\_space\_tl
13478   \_file\_input\_pop:
13479 }
13480 \cs\_generate\_variant:Nn \_file\_input:n { V }

```

Keeping a track of the file data is easy enough: we store the separated parts so we do not need to parse them twice.

```

13481 \cs_new_protected:Npn \_file\_input\_push:n #1
13482 {
13483   \seq\_gpush:Nx \g\_file\_stack\_seq
13484   {
13485     { \g\_file\_curr\_dir\_str }
13486     { \g\_file\_curr\_name\_str }
13487     { \g\_file\_curr\_ext\_str }
13488   }
13489   \file\_parse\_full\_name:nNNN {#1}
13490   \l\_file\_dir\_str \l\_file\_name\_str \l\_file\_ext\_str
13491   \str\_gset\_eq:NN \g\_file\_curr\_dir\_str \l\_file\_dir\_str
13492   \str\_gset\_eq:NN \g\_file\_curr\_name\_str \l\_file\_name\_str
13493   \str\_gset\_eq:NN \g\_file\_curr\_ext\_str \l\_file\_ext\_str
13494 }
13495 \*package
13496 \cs\_new\_eq:NN \_kernel\_file\_input\_push:n \_file\_input\_push:n
13497 \*package

```

```

13498 \cs_new_protected:Npn \__file_input_pop:
13499 {
13500   \seq_gpop:NN \g__file_stack_seq \l__file_internal_tl
13501   \exp_after:wN \__file_input_pop:nnn \l__file_internal_tl
13502 }
13503 <*package>
13504 \cs_new_eq:NN \__kernel_file_input_pop: \__file_input_pop:
13505 </package>
13506 \cs_new_protected:Npn \__file_input_pop:nnn #1#2#3
13507 {
13508   \str_gset:Nn \g_file_curr_dir_str {#1}
13509   \str_gset:Nn \g_file_curr_name_str {#2}
13510   \str_gset:Nn \g_file_curr_ext_str {#3}
13511 }

```

(End definition for \file_input:n and others. This function is documented on page 159.)

```

\file_parse_full_name:nNNN
\file_parse_full_name:VNNN
  \__file_parse_full_name_auxi:w
  \__file_parse_full_name_split:nNNNTF

```

Parsing starts by stripping off any surrounding quotes. Then find the directory #4 by splitting at the last /. (The auxiliary returns true/false depending on whether it found the delimiter.) We correct for the case of a file in the root /, as in that case we wish to keep the trailing (and only) slash. Then split the base name #5 at the last dot. If there was indeed a dot, #5 contains the name and #6 the extension without the dot, which we add back for convenience. In the special case of no extension given, the auxiliary stored the name into #6, we just have to move it to #5.

```

13512 \cs_new_protected:Npn \file_parse_full_name:nNNN #1#2#3#4
13513 {
13514   \exp_after:wN \__file_parse_full_name_auxi:w
13515   \tl_to_str:n { #1 " #1 " } \q_stop #2#3#4
13516 }
13517 \cs_generate_variant:Nn \file_parse_full_name:nNNN { V }
13518 \cs_new_protected:Npn \__file_parse_full_name_auxi:w
13519   #1 " #2 " #3 \q_stop #4#5#6
13520 {
13521   \__file_parse_full_name_split:nNNNTF {#2} / #4 #5
13522   { \str_if_empty:NT #4 { \str_set:Nn #4 { / } } }
13523   { }
13524   \exp_args:No \__file_parse_full_name_split:nNNNTF {#5} . #5 #6
13525   { \str_put_left:Nn #6 { . } }
13526   {
13527     \str_set_eq:NN #5 #6
13528     \str_clear:N #6
13529   }
13530 }
13531 \cs_new_protected:Npn \__file_parse_full_name_split:nNNNTF #1#2#3#4
13532 {
13533   \cs_set_protected:Npn \__file_tmp:w ##1 ##2 #2 ##3 \q_stop
13534   {
13535     \tl_if_empty:nTF {##3}
13536     {
13537       \str_set:Nn #4 {##2}
13538       \tl_if_empty:nTF {##1}
13539       {
13540         \str_clear:N #3
13541         \use_ii:nn

```

```

13542         }
13543         {
13544             \str_set:Nx #3 { \str_tail:n {##1} }
13545             \use_i:nn
13546         }
13547     }
13548     { \__file_tmp:w { ##1 ##2 ##3 } ##3 \q_stop }
13549 }
13550 \__file_tmp:w { } #1 #2 \q_stop
13551 }

```

(End definition for `\file_parse_full_name:nNNN`, `__file_parse_full_name_auxi:w`, and `__file_parse_full_name_split:nNNNTF`. This function is documented on page 158.)

`\file_show_list:` A function to list all files used to the log, without duplicates. In package mode, if `\file_log_list:` `\@filelist` is still defined, we need to take this list of file names into account (we capture it `\AtBeginDocument` into `\g__file_record_seq`), turning it to a string (this does not affect the commas of this comma list).

```

13552 \cs_new_protected:Npn \file_show_list: { \__file_list:N \msg_show:nnxxxx }
13553 \cs_new_protected:Npn \file_log_list: { \__file_list:N \msg_log:nnxxxx }
13554 \cs_new_protected:Npn \__file_list:N #1
13555 {
13556     \seq_clear:N \l__file_tmp_seq
13557 }*package)
13558     \clist_if_exist:NT \@filelist
13559     {
13560         \exp_args:NNx \seq_set_from_clist:Nn \l__file_tmp_seq
13561         { \tl_to_str:N \@filelist }
13562     }
13563 }/package)
13564 \seq_concat:NNN \l__file_tmp_seq \l__file_tmp_seq \g__file_record_seq
13565 \seq_remove_duplicates:N \l__file_tmp_seq
13566 #1 { LaTeX/kernel } { file-list }
13567 { \seq_map_function:NN \l__file_tmp_seq \__file_list_aux:n }
13568 { } { } { }
13569 }
13570 \cs_new:Npn \__file_list_aux:n #1 { \iow_newline: #1 }

```

(End definition for `\file_show_list:` and others. These functions are documented on page 160.)

When used as a package, there is a need to hold onto the standard file list as well as the new one here. File names recorded in `\@filelist` must be turned to strings before being added to `\g__file_record_seq`.

```

13571 }*package)
13572 \AtBeginDocument
13573 {
13574     \exp_args:NNx \seq_set_from_clist:Nn \l__file_tmp_seq
13575     { \tl_to_str:N \@filelist }
13576     \seq_gconcat:NNN
13577     \g__file_record_seq
13578     \g__file_record_seq
13579     \l__file_tmp_seq
13580 }
13581 }/package)

```

20.5 GetIdInfo

\GetIdInfo As documented in expl3.dtx this function extracts file name etc from an SVN Id line. This used to be how we got version number and so on in all modules, so it had to be defined in l3bootstrap. Now it's more convenient to define it after we have set up quite a lot of tools, and l3file seems the least unreasonable place for it.

The idea here is to extract out the information needed from a standard SVN Id line, but to avoid a line that would get changed when the file is checked in. Hence the fact that none of the lines here include both a dollar sign and the Id keyword!

```

13582 \cs_new_protected:Npn \GetIdInfo
13583 {
13584   \group_begin:
13585   \char_set_catcode_space:n { 32 }
13586   \exp_after:wN
13587   \group_end:
13588   \__file_id_info_auxi:w
13589 }
```

A first check for a completely empty SVN field. If that is not the case, there is a second case when a file created using `svn cp` but has not been checked in. That leaves a special marker `-1` version, which has no further data. Dealing correctly with that is the reason for the space in the line to use `__file_id_info_auxii:w`.

```

13590 \cs_new_protected:Npn \__file_id_info_auxi:w $ #1 $ #2
13591 {
13592   \tl_set:Nn \ExplFileDescription {#2}
13593   \str_if_eq:nnTF {#1} { Id }
13594   {
13595     \tl_set:Nn \ExplFileDate { 0000/00/00 }
13596     \tl_set:Nn \ExplFileName { [unknown] }
13597     \tl_set:Nn \ExplFileExtension { [unknown~extension] }
13598     \tl_set:Nn \ExplFileVersion {-1}
13599   }
13600   { \__file_id_info_auxii:w #1 ~ \q_stop }
13601 }
```

Here, `#1` is Id, `#2` is the file name, `#3` is the extension, `#4` is the version, `#5` is the check in date and `#6` is the check in time and user, plus some trailing spaces. If `#4` is the marker `-1` value then `#5` and `#6` are empty.

```

13602 \cs_new_protected:Npn \__file_id_info_auxii:w
13603   #1 ~ #2.#3 ~ #4 ~ #5 ~ #6 \q_stop
13604 {
13605   \tl_set:Nn \ExplFileName {#2}
13606   \tl_set:Nn \ExplFileExtension {#3}
13607   \tl_set:Nn \ExplFileVersion {#4}
13608   \str_if_eq:nnTF {#4} {-1}
13609   { \tl_set:Nn \ExplFileDate { 0000/00/00 } }
13610   { \__file_id_info_auxiii:w #5 - 0 - 0 - \q_stop }
13611 }
```

Convert an SVN-style date into a L^AT_EX-style one.

```

13612 \cs_new_protected:Npn \__file_id_info_auxiii:w #1 - #2 - #3 - #4 \q_stop
13613 { \tl_set:Nn \ExplFileDate { #1/#2/#3 } }
```

(End definition for `\GetIdInfo` and others. This function is documented on page 7.)

20.6 Messages

```

13614 \__kernel_msg_new:nnnn { kernel } { file-not-found }
13615 { File~'#1'~not-found. }
13616 {
13617     The-requested-file-could-not-be-found-in-the-current-directory,~
13618     in-the-TeX-search-path-or-in-the-LaTeX-search-path.
13619 }
13620 \__kernel_msg_new:nnn { kernel } { file-list }
13621 {
13622     >~File~List~<
13623     #1 \\
13624     .....
13625 }
13626 \__kernel_msg_new:nnnn { kernel } { input-streams-exhausted }
13627 { Input-streams-exhausted }
13628 {
13629     TeX-can-only-open-up-to-16-input-streams-at-one-time.\\
13630     All-16-are-currently-in-use,~and-something-wanted-to-open-
13631     another-one.
13632 }
13633 \__kernel_msg_new:nnnn { kernel } { output-streams-exhausted }
13634 { Output-streams-exhausted }
13635 {
13636     TeX-can-only-open-up-to-16-output-streams-at-one-time.\\
13637     All-16-are-currently-in-use,~and-something-wanted-to-open-
13638     another-one.
13639 }
13640 \__kernel_msg_new:nnnn { kernel } { unbalanced-quote-in-filename }
13641 { Unbalanced-quotes-in-file-name~'#1'. }
13642 {
13643     File-names-must-contain-balanced-numbers-of-quotes~("(").
13644 }
13645 \__kernel_msg_new:nnnn { kernel } { iow-indent }
13646 { Only~#1 (arg-1)~allows~#2 }
13647 {
13648     The-command~#2 can-only-be-used-in-messages~
13649     which-will-be-wrapped-using~#1.
13650     \tl_if_empty:nF {#3} { ~ It-was-called-with-argument~'#3'. }
13651 }
13652 </initex | package>

```

21 l3skip implementation

```

13653 <*initex | package>
13654 <@@=dim>

```

21.1 Length primitives renamed

```

\if_dim:w Primitives renamed.
\__dim_eval:w 13655 \cs_new_eq:NN \if_dim:w \tex_ifdim:D
\__dim_eval_end: 13656 \cs_new_eq:NN \__dim_eval:w \tex_dimexpr:D
13657 \cs_new_eq:NN \__dim_eval_end: \tex_relax:D

```

(End definition for `\if_dim:w`, `__dim_eval:w`, and `__dim_eval_end:`. This function is documented on page 175.)

21.2 Creating and initialising dim variables

`\dim_new:N` Allocating $\langle dim \rangle$ registers ...

```
\dim_new:c 13658 \*package>
13659 \cs_new_protected:Npn \dim_new:N #1
13660 {
13661     \__kernel_chk_if_free_cs:N #1
13662     \cs:w newdimen \cs_end: #1
13663 }
13664 \</package>
13665 \cs_generate_variant:Nn \dim_new:N { c }
```

(End definition for `\dim_new:N`. This function is documented on page 161.)

`\dim_const:Nn` Contrarily to integer constants, we cannot avoid using a register, even for constants. We cannot use `\dim_gset:Nn` because debugging code would complain that the constant is not a global variable. Since `\dim_const:Nn` does not need to be fast, use `\dim_eval:n` to avoid needing a debugging patch that wraps the expression in checking code.

```
\dim_const:cn 13666 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
13667 \cs_new_protected:Npn \dim_const:Nn #1#2
13668 {
13669     \dim_new:N #1
13670     \tex_global:D #1 ~ \dim_eval:n {#2} \scan_stop:
13671 }
13672 \cs_generate_variant:Nn \dim_const:Nn { c }
```

(End definition for `\dim_const:Nn`. This function is documented on page 161.)

`\dim_zero:N` Reset the register to zero. Using `\c_zero_skip` deals with the case where the variable passed is incorrectly a skip (for example a $\text{L}^{\text{A}}\text{T}_{\text{E}}\text{X} 2_{\epsilon}$ length).

```
\dim_zero:c 13673 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\dim_gzero:N 13674 \cs_new_protected:Npn \dim_zero:N #1 { #1 \c_zero_skip }
\dim_gzero:c 13675 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
13676 \cs_new_protected:Npn \dim_gzero:N #1
13677 { \tex_global:D #1 \c_zero_skip }
13678 \cs_generate_variant:Nn \dim_zero:N { c }
13679 \cs_generate_variant:Nn \dim_gzero:N { c }
```

(End definition for `\dim_zero:N` and `\dim_gzero:N`. These functions are documented on page 161.)

`\dim_zero_new:N` Create a register if needed, otherwise clear it.

```
\dim_zero_new:c 13680 \cs_new_protected:Npn \dim_zero_new:N #1
\dim_gzero_new:N 13681 { \dim_if_exist:NTF #1 { \dim_zero:N #1 } { \dim_new:N #1 } }
\dim_gzero_new:c 13682 \cs_new_protected:Npn \dim_gzero_new:N #1
13683 { \dim_if_exist:NTF #1 { \dim_gzero:N #1 } { \dim_new:N #1 } }
13684 \cs_generate_variant:Nn \dim_zero_new:N { c }
13685 \cs_generate_variant:Nn \dim_gzero_new:N { c }
```

(End definition for `\dim_zero_new:N` and `\dim_gzero_new:N`. These functions are documented on page 161.)

```

\dim_if_exist_p:N Copies of the cs functions defined in l3basics.
\dim_if_exist_p:c 13686 \prg_new_eq_conditional:NNn \dim_if_exist:N \cs_if_exist:N
\dim_if_exist:N $\overline{TF}$  13687 { TF , T , F , p }
\dim_if_exist:c $\overline{TF}$  13688 \prg_new_eq_conditional:NNn \dim_if_exist:c \cs_if_exist:c
13689 { TF , T , F , p }

```

(End definition for `\dim_if_exist:N \overline{TF}` . This function is documented on page 161.)

21.3 Setting dim variables

Several functions here have a signature `:Nn` and are such that when debugging, the first argument should be checked to be a local/global variable and the second should be wrapped in code for an expression. The temporary function `__dim_tmp:w` finds the name `#3` of the function being redefined and writes the appropriate patch.

```

13690 \cs_set_protected:Npn \__dim_tmp:w #1#2#3
13691 {
13692   \__kernel_patch_args:nnnNNpn
13693   { #1 ##1 }
13694   { }
13695   { {##1} { \__kernel_chk_expr:nNnN {##2} \__dim_eval:w { } #3 } }
13696   #2 #3
13697 }

```

`\dim_set:Nn` Setting dimensions is easy enough but when debugging we want both to check that the variable is correctly local/global and to wrap the expression in some code. The `\scan_stop:` deals with the case where the variable passed is a skip (for example a $\text{\LaTeX} 2_{\epsilon}$ length).

```

\dim_set:cN
\dim_set:cN
\dim_gset:Nn
\dim_gset:cN
13698 \__dim_tmp:w \__kernel_chk_var_local:N
13699 \cs_new_protected:Npn \dim_set:Nn #1#2
13700 { #1 ~ \__dim_eval:w #2 \__dim_eval_end: \scan_stop: }
13701 \__dim_tmp:w \__kernel_chk_var_global:N
13702 \cs_new_protected:Npn \dim_gset:Nn #1#2
13703 { \tex_global:D #1 ~ \__dim_eval:w #2 \__dim_eval_end: \scan_stop: }
13704 \cs_generate_variant:Nn \dim_set:Nn { c }
13705 \cs_generate_variant:Nn \dim_gset:Nn { c }

```

(End definition for `\dim_set:Nn` and `\dim_gset:Nn`. These functions are documented on page 162.)

`\dim_set_eq:NN` All straightforward, with a `\scan_stop:` to deal with the case where `#1` is (incorrectly) a skip.

```

\dim_set_eq:cN
\dim_set_eq:Nc
\dim_set_eq:cc
13706 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
13707 \cs_new_protected:Npn \dim_set_eq:NN #1#2
13708 { #1 = #2 \scan_stop: }
13709 \cs_generate_variant:Nn \dim_set_eq:NN { c , Nc , cc }
\dim_gset_eq:cN
\dim_gset_eq:Nc
\dim_gset_eq:cc
13710 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
13711 \cs_new_protected:Npn \dim_gset_eq:NN #1#2
13712 { \tex_global:D #1 = #2 \scan_stop: }
13713 \cs_generate_variant:Nn \dim_gset_eq:NN { c , Nc , cc }

```

(End definition for `\dim_set_eq:NN` and `\dim_gset_eq:NN`. These functions are documented on page 162.)

`\dim_add:Nn` Using by here deals with the (incorrect) case `\dimen123`. Using `\scan_stop:` deals with skip variables. Since debugging checks that the variable is correctly local/global, the global versions cannot be defined as `\tex_global:D` followed by the local versions. The debugging code is inserted by `__dim_tmp:w`.

```

\dim_sub:Nn 13714 \__dim_tmp:w \__kernel_chk_var_local:N
\dim_sub:cn 13715 \cs_new_protected:Npn \dim_add:Nn #1#2
\dim_gadd:Nn 13716 { \tex_advance:D #1 by \__dim_eval:w #2 \__dim_eval_end: \scan_stop: }
\dim_gadd:cn 13717 \__dim_tmp:w \__kernel_chk_var_global:N
\dim_gsub:Nn 13718 \cs_new_protected:Npn \dim_gadd:Nn #1#2
\dim_gsub:cn 13719 {
13720 \tex_global:D \tex_advance:D #1 by
13721 \__dim_eval:w #2 \__dim_eval_end: \scan_stop:
13722 }
13723 \cs_generate_variant:Nn \dim_add:Nn { c }
13724 \cs_generate_variant:Nn \dim_gadd:Nn { c }
13725 \__dim_tmp:w \__kernel_chk_var_local:N
13726 \cs_new_protected:Npn \dim_sub:Nn #1#2
13727 { \tex_advance:D #1 by - \__dim_eval:w #2 \__dim_eval_end: \scan_stop: }
13728 \__dim_tmp:w \__kernel_chk_var_global:N
13729 \cs_new_protected:Npn \dim_gsub:Nn #1#2
13730 {
13731 \tex_global:D \tex_advance:D #1 by
13732 -\__dim_eval:w #2 \__dim_eval_end: \scan_stop:
13733 }
13734 \cs_generate_variant:Nn \dim_sub:Nn { c }
13735 \cs_generate_variant:Nn \dim_gsub:Nn { c }

```

(End definition for `\dim_add:Nn` and others. These functions are documented on page 162.)

21.4 Utilities for dimension calculations

`\dim_abs:n` Functions for min, max, and absolute value with only one evaluation. The absolute value is evaluated by removing a leading - if present.

`__dim_abs:N`

`\dim_max:nn`

`\dim_min:nn`

`__dim_maxmin:wwN`

```

13736 \__kernel_patch_args:nNNpn
13737 { { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_abs:n } }
13738 \cs_new:Npn \dim_abs:n #1
13739 {
13740 \exp_after:wN \__dim_abs:N
13741 \dim_use:N \__dim_eval:w #1 \__dim_eval_end:
13742 }
13743 \cs_new:Npn \__dim_abs:N #1
13744 { \if_meaning:w - #1 \else: \exp_after:wN #1 \fi: }
13745 \__kernel_patch_args:nNNpn
13746 {
13747 { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_max:nn }
13748 { \__kernel_chk_expr:nNnN {#2} \__dim_eval:w { } \dim_max:nn }
13749 }
13750 \cs_new:Npn \dim_max:nn #1#2
13751 {
13752 \dim_use:N \__dim_eval:w \exp_after:wN \__dim_maxmin:wwN
13753 \dim_use:N \__dim_eval:w #1 \exp_after:wN ;
13754 \dim_use:N \__dim_eval:w #2 ;
13755 >

```

```

13756     \__dim_eval_end:
13757 }
13758 \__kernel_patch_args:nNnpn
13759 {
13760   { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_min:nn }
13761   { \__kernel_chk_expr:nNnN {#2} \__dim_eval:w { } \dim_min:nn }
13762 }
13763 \cs_new:Npn \dim_min:nn #1#2
13764 {
13765   \dim_use:N \__dim_eval:w \exp_after:wN \__dim_maxmin:wwN
13766   \dim_use:N \__dim_eval:w #1 \exp_after:wN ;
13767   \dim_use:N \__dim_eval:w #2 ;
13768   <
13769   \__dim_eval_end:
13770 }
13771 \cs_new:Npn \__dim_maxmin:wwN #1 ; #2 ; #3
13772 {
13773   \if_dim:w #1 #3 #2 ~
13774     #1
13775   \else:
13776     #2
13777   \fi:
13778 }

```

(End definition for `\dim_abs:n` and others. These functions are documented on page 162.)

`\dim_ratio:nn` With dimension expressions, something like `10 pt * (5 pt / 10 pt)` does not work. `__dim_ratio:n` Instead, the ratio part needs to be converted to an integer expression. Using `\int_value:w` forces everything into `sp`, avoiding any decimal parts.

```

13779 \cs_new:Npn \dim_ratio:nn #1#2
13780 { \__dim_ratio:n {#1} / \__dim_ratio:n {#2} }
13781 \cs_new:Npn \__dim_ratio:n #1
13782 { \int_value:w \__dim_eval:w (#1) \__dim_eval_end: }

```

(End definition for `\dim_ratio:nn` and `__dim_ratio:n`. This function is documented on page 163.)

21.5 Dimension expression conditionals

`\dim_compare_p:nNn` Simple comparison.

`\dim_compare:nNnTF`

```

13783 \__kernel_patch_conditional_args:nNnpnn
13784 {
13785   { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_compare:nNn }
13786   { \__dim_eval_end: #2 }
13787   { \__kernel_chk_expr:nNnN {#3} \__dim_eval:w { } \dim_compare:nNn }
13788 }
13789 \prg_new_conditional:Npnn \dim_compare:nNn #1#2#3 { p , T , F , TF }
13790 {
13791   \if_dim:w \__dim_eval:w #1 #2 \__dim_eval:w #3 \__dim_eval_end:
13792   \prg_return_true: \else: \prg_return_false: \fi:
13793 }

```

(End definition for `\dim_compare:nNnTF`. This function is documented on page 163.)

```

\dim_compare_p:n This code is adapted from the \int_compare:nTF function. First make sure that there is
\dim_compare:nTF at least one relation operator, by evaluating a dimension expression with a trailing \_
\_dim_compare:w \dim_compare_error:. Just like for integers, the looping auxiliary \_dim_compare:wNN
\_dim_compare:wNN closes a primitive conditional and opens a new one. It is actually easier to grab a di-
\_dim_compare_=:w mension operand than an integer one, because once evaluated, dimensions all end with
\_dim_compare_!:w pt (with category other). Thus we do not need specific auxiliaries for the three “simple”
\_dim_compare_<:w relations <, =, and >.
\_dim_compare_>:w
\_dim_compare_error:
13794 \prg_new_conditional:Npnn \dim_compare:n #1 { p , T , F , TF }
13795 {
13796   \exp_after:wN \_dim_compare:w
13797   \dim_use:N \_dim_eval:w #1 \_dim_compare_error:
13798 }
13799 \cs_new:Npn \_dim_compare:w #1 \_dim_compare_error:
13800 {
13801   \exp_after:wN \if_false: \exp:w \exp_end_continue_f:w
13802   \_dim_compare:wNN #1 ? { = \_dim_compare_end:w \else: } \q_stop
13803 }
13804 \exp_args:Nno \use:nn
13805 { \cs_new:Npn \_dim_compare:wNN #1 } { \tl_to_str:n {pt} #2#3 }
13806 {
13807   \if_meaning:w = #3
13808   \use:c { \_dim_compare_#2:w }
13809   \fi:
13810   #1 pt \exp_stop_f:
13811   \prg_return_false:
13812   \exp_after:wN \use_none_delimit_by_q_stop:w
13813   \fi:
13814   \reverse_if:N \if_dim:w #1 pt #2
13815   \exp_after:wN \_dim_compare:wNN
13816   \dim_use:N \_dim_eval:w #3
13817 }
13818 \cs_new:cpn { \_dim_compare_ ! :w }
13819 #1 \reverse_if:N #2 ! #3 = { #1 #2 = #3 }
13820 \cs_new:cpn { \_dim_compare_ = :w }
13821 #1 \_dim_eval:w = { #1 \_dim_eval:w }
13822 \cs_new:cpn { \_dim_compare_ < :w }
13823 #1 \reverse_if:N #2 < #3 = { #1 #2 > #3 }
13824 \cs_new:cpn { \_dim_compare_ > :w }
13825 #1 \reverse_if:N #2 > #3 = { #1 #2 < #3 }
13826 \cs_new:Npn \_dim_compare_end:w #1 \prg_return_false: #2 \q_stop
13827 { #1 \prg_return_false: \else: \prg_return_true: \fi: }
13828 \cs_new_protected:Npn \_dim_compare_error:
13829 {
13830   \if_int_compare:w \c_zero_int \c_zero_int \fi:
13831   =
13832   \_dim_compare_error:
13833 }

```

(End definition for \dim_compare:nTF and others. This function is documented on page 164.)

```

\dim_case:nn For dimension cases, the first task to fully expand the check condition. The over all idea
\dim_case:nnTF is then much the same as for \str_case:nn(TF) as described in l3basics.
\_dim_case:nnTF
\_dim_case:nw
\_dim_case_end:nw
13834 \cs_new:Npn \dim_case:nnTF #1

```

```

13835 {
13836   \exp:w
13837   \exp_args:Nf \_dim_case:nnTF { \dim_eval:n {#1} }
13838 }
13839 \cs_new:Npn \dim_case:nnT #1#2#3
13840 {
13841   \exp:w
13842   \exp_args:Nf \_dim_case:nnTF { \dim_eval:n {#1} } {#2} {#3} { }
13843 }
13844 \cs_new:Npn \dim_case:nnF #1#2
13845 {
13846   \exp:w
13847   \exp_args:Nf \_dim_case:nnTF { \dim_eval:n {#1} } {#2} { }
13848 }
13849 \cs_new:Npn \dim_case:nn #1#2
13850 {
13851   \exp:w
13852   \exp_args:Nf \_dim_case:nnTF { \dim_eval:n {#1} } {#2} { } { }
13853 }
13854 \cs_new:Npn \_dim_case:nnTF #1#2#3#4
13855 { \_dim_case:nw {#1} #2 {#1} { } \q_mark {#3} \q_mark {#4} \q_stop }
13856 \cs_new:Npn \_dim_case:nw #1#2#3
13857 {
13858   \dim_compare:nNnTF {#1} = {#2}
13859   { \_dim_case_end:nw {#3} }
13860   { \_dim_case:nw {#1} }
13861 }
13862 \cs_new:Npn \_dim_case_end:nw #1#2#3 \q_mark #4#5 \q_stop
13863 { \exp_end: #1 #4 }

```

(End definition for `\dim_case:nnTF` and others. This function is documented on page 165.)

21.6 Dimension expression loops

`\dim_while_do:nn` `while_do` and `do_while` functions for dimensions. Same as for the `int` type only the names have changed.

```

\dim_until_do:nn
\dim_do_while:nn
\dim_do_until:nn
13864 \cs_new:Npn \dim_while_do:nn #1#2
13865 {
13866   \dim_compare:nT {#1}
13867   {
13868     #2
13869     \dim_while_do:nn {#1} {#2}
13870   }
13871 }
13872 \cs_new:Npn \dim_until_do:nn #1#2
13873 {
13874   \dim_compare:nF {#1}
13875   {
13876     #2
13877     \dim_until_do:nn {#1} {#2}
13878   }
13879 }
13880 \cs_new:Npn \dim_do_while:nn #1#2
13881 {

```

```

13882     #2
13883     \dim_compare:nT {#1}
13884     { \dim_do_while:nn {#1} {#2} }
13885   }
13886 \cs_new:Npn \dim_do_until:nn #1#2
13887 {
13888   #2
13889   \dim_compare:nF {#1}
13890   { \dim_do_until:nn {#1} {#2} }
13891 }

```

(End definition for `\dim_while_do:nn` and others. These functions are documented on page 166.)

`\dim_while_do:nNnn` while_do and do_while functions for dimensions. Same as for the int type only the names have changed.

```

\dim_until_do:nNnn
\dim_do_while:nNnn
\dim_do_until:nNnn
13892 \cs_new:Npn \dim_while_do:nNnn #1#2#3#4
13893 {
13894   \dim_compare:nNnT {#1} #2 {#3}
13895   {
13896     #4
13897     \dim_while_do:nNnn {#1} #2 {#3} {#4}
13898   }
13899 }
13900 \cs_new:Npn \dim_until_do:nNnn #1#2#3#4
13901 {
13902   \dim_compare:nNnF {#1} #2 {#3}
13903   {
13904     #4
13905     \dim_until_do:nNnn {#1} #2 {#3} {#4}
13906   }
13907 }
13908 \cs_new:Npn \dim_do_while:nNnn #1#2#3#4
13909 {
13910   #4
13911   \dim_compare:nNnT {#1} #2 {#3}
13912   { \dim_do_while:nNnn {#1} #2 {#3} {#4} }
13913 }
13914 \cs_new:Npn \dim_do_until:nNnn #1#2#3#4
13915 {
13916   #4
13917   \dim_compare:nNnF {#1} #2 {#3}
13918   { \dim_do_until:nNnn {#1} #2 {#3} {#4} }
13919 }

```

(End definition for `\dim_while_do:nNnn` and others. These functions are documented on page 166.)

21.7 Dimension step functions

`\dim_step_function:nnnN` Before all else, evaluate the initial value, step, and final value. Repeating a function by steps first needs a check on the direction of the steps. After that, do the function for the start value then step and loop around. It would be more symmetrical to test for a step size of zero before checking the sign, but we optimize for the most frequent case (positive step).

```

13920 \__kernel_patch_args:nNnNpn

```



```

13921 {
13922 {
13923   \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { }
13924   \dim_step_function:nnnN
13925 }
13926 {
13927   \__kernel_chk_expr:nNnN {#2} \__dim_eval:w { }
13928   \dim_step_function:nnnN
13929 }
13930 {
13931   \__kernel_chk_expr:nNnN {#3} \__dim_eval:w { }
13932   \dim_step_function:nnnN
13933 }
13934 }
13935 \cs_new:Npn \dim_step_function:nnnN #1#2#3
13936 {
13937   \exp_after:wN \__dim_step:wwwN
13938   \tex_the:D \__dim_eval:w #1 \exp_after:wN ;
13939   \tex_the:D \__dim_eval:w #2 \exp_after:wN ;
13940   \tex_the:D \__dim_eval:w #3 ;
13941 }
13942 \cs_new:Npn \__dim_step:wwwN #1; #2; #3; #4
13943 {
13944   \dim_compare:nNnTF {#2} > \c_zero_dim
13945   { \__dim_step:NnnnN > }
13946   {
13947     \dim_compare:nNnTF {#2} = \c_zero_dim
13948     {
13949       \__kernel_msg_expandable_error:nnn { kernel } { zero-step } {#4}
13950       \use_none:nnnn
13951     }
13952     { \__dim_step:NnnnN < }
13953   }
13954   {#1} {#2} {#3} #4
13955 }
13956 \cs_new:Npn \__dim_step:NnnnN #1#2#3#4#5
13957 {
13958   \dim_compare:nNnF {#2} #1 {#4}
13959   {
13960     #5 {#2}
13961     \exp_args:NNf \__dim_step:NnnnN
13962     #1 { \dim_eval:n { #2 + #3 } } {#3} {#4} #5
13963   }
13964 }

```

(End definition for `\dim_step_function:nnnN`, `__dim_step:wwwN`, and `__dim_step:NnnnN`. This function is documented on page 166.)

`\dim_step_inline:nnnn`
`\dim_step_variable:nnnNn`
`__dim_step:NNnnnn`

The approach here is to build a function, with a global integer required to make the nesting safe (as seen in other in line functions), and map that function using `\dim_step_function:nnnN`. We put a `\prg_break_point:Nn` so that `map_break` functions from other modules correctly decrement `\g__kernel_prg_map_int` before looking for their own break point. The first argument is `\scan_stop:`, so that no breaking function recognizes this break point as its own.

```

13965 \cs_new_protected:Npn \dim_step_inline:nnnn
13966 {
13967   \int_gincr:N \g__kernel_prg_map_int
13968   \exp_args:NNc \__dim_step:NNnnnn
13969   \cs_gset_protected:Npn
13970     { __dim_map_ \int_use:N \g__kernel_prg_map_int :w }
13971 }
13972 \cs_new_protected:Npn \dim_step_variable:nnnNn #1#2#3#4#5
13973 {
13974   \int_gincr:N \g__kernel_prg_map_int
13975   \exp_args:NNc \__dim_step:NNnnnn
13976   \cs_gset_protected:Npx
13977     { __dim_map_ \int_use:N \g__kernel_prg_map_int :w }
13978     {#1}{#2}{#3}
13979     {
13980       \tl_set:Nn \exp_not:N #4 {##1}
13981       \exp_not:n {#5}
13982     }
13983 }
13984 \cs_new_protected:Npn \__dim_step:NNnnnn #1#2#3#4#5#6
13985 {
13986   #1 #2 ##1 {#6}
13987   \dim_step_function:nnnN {#3} {#4} {#5} #2
13988   \prg_break_point:Nn \scan_stop: { \int_gdecr:N \g__kernel_prg_map_int }
13989 }

```

(End definition for `\dim_step_inline:nnnn`, `\dim_step_variable:nnnNn`, and `__dim_step:NNnnnn`. These functions are documented on page 166.)

21.8 Using dim expressions and variables

`\dim_eval:n` Evaluating a dimension expression expandably.

```

13990 \__kernel_patch_args:nNNpn
13991 { { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_eval:n } }
13992 \cs_new:Npn \dim_eval:n #1
13993 { \dim_use:N \__dim_eval:w #1 \__dim_eval_end: }

```

(End definition for `\dim_eval:n`. This function is documented on page 167.)

`\dim_use:N` Accessing a $\langle dim \rangle$.

`\dim_use:c` `\cs_new_eq:NN \dim_use:N \tex_the:D`

We hand-code this for some speed gain:

```

13995 %\cs_generate_variant:Nn \dim_use:N { c }
13996 \cs_new:Npn \dim_use:c #1 { \tex_the:D \cs:w #1 \cs_end: }

```

(End definition for `\dim_use:N`. This function is documented on page 167.)

`\dim_to_decimal:n` A function which comes up often enough to deserve a place in the kernel. Evaluate the dimension expression `#1` then remove the trailing pt. When debugging is enabled, the argument is put in parentheses as this prevents the dimension expression from terminating early and leaving extra tokens lying around. This is used a lot by low-level manipulations.

```

13997 \__kernel_patch_args:nNNpn
13998 { { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_to_decimal:n } }
13999 \cs_new:Npn \dim_to_decimal:n #1

```

```

14000 {
14001   \exp_after:wN
14002   \__dim_to_decimal:w \dim_use:N \__dim_eval:w #1 \__dim_eval_end:
14003 }
14004 \use:x
14005 {
14006   \cs_new:Npn \exp_not:N \__dim_to_decimal:w
14007     ##1 . ##2 \tl_to_str:n { pt }
14008 }
14009 {
14010   \int_compare:nNnTF {#2} > { 0 }
14011     { #1 . #2 }
14012     { #1 }
14013 }

```

(End definition for `\dim_to_decimal:n` and `__dim_to_decimal:w`. This function is documented on page 167.)

`\dim_to_decimal_in_bp:n` Conversion to big points is done using a scaling inside `__dim_eval:w` as ε -TeX does that using 64-bit precision. Here, 800/803 is the integer fraction for 72/72.27. This is a common case so is hand-coded for accuracy (and speed).

```

14014 \cs_new:Npn \dim_to_decimal_in_bp:n #1
14015 { \dim_to_decimal:n { ( #1 ) * 800 / 803 } }

```

(End definition for `\dim_to_decimal_in_bp:n`. This function is documented on page 168.)

`\dim_to_decimal_in_sp:n` Another hard-coded conversion: this one is necessary to avoid things going off-scale.

```

14016 \__kernel_patch_args:nNnNpn
14017 {
14018   {
14019     \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { }
14020     \dim_to_decimal_in_sp:n
14021   }
14022 }
14023 \cs_new:Npn \dim_to_decimal_in_sp:n #1
14024 { \int_value:w \__dim_eval:w #1 \__dim_eval_end: }

```

(End definition for `\dim_to_decimal_in_sp:n`. This function is documented on page 168.)

`\dim_to_decimal_in_unit:nn` An analogue of `\dim_ratio:nn` that produces a decimal number as its result, rather than a rational fraction for use within dimension expressions.

```

14025 \cs_new:Npn \dim_to_decimal_in_unit:nn #1#2
14026 {
14027   \dim_to_decimal:n
14028   {
14029     1pt *
14030     \dim_ratio:nn {#1} {#2}
14031   }
14032 }

```

(End definition for `\dim_to_decimal_in_unit:nn`. This function is documented on page 168.)

`\dim_to_fp:n` Defined in `l3fp-convert`, documented here.

(End definition for `\dim_to_fp:n`. This function is documented on page 168.)

21.9 Viewing dim variables

\dim_show:N Diagnostics.

\dim_show:c 14033 \cs_new_eq:NN \dim_show:N __kernel_register_show:N
14034 \cs_generate_variant:Nn \dim_show:N { c }

(End definition for \dim_show:N. This function is documented on page 168.)

\dim_show:n Diagnostics. We don't use the TeX primitive \showthe to show dimension expressions: this gives a more unified output.

14035 \cs_new_protected:Npn \dim_show:n
14036 { \msg_show_eval:Nn \dim_eval:n }

(End definition for \dim_show:n. This function is documented on page 169.)

\dim_log:N Diagnostics. Redirect output of \dim_show:n to the log.

\dim_log:c 14037 \cs_new_eq:NN \dim_log:N __kernel_register_log:N
\dim_log:n 14038 \cs_new_eq:NN \dim_log:c __kernel_register_log:c
14039 \cs_new_protected:Npn \dim_log:n
14040 { \msg_log_eval:Nn \dim_eval:n }

(End definition for \dim_log:N and \dim_log:n. These functions are documented on page 169.)

21.10 Constant dimensions

\c_zero_dim Constant dimensions.

\c_max_dim 14041 \dim_const:Nn \c_zero_dim { 0 pt }
14042 \dim_const:Nn \c_max_dim { 16383.99999 pt }

(End definition for \c_zero_dim and \c_max_dim. These variables are documented on page 169.)

21.11 Scratch dimensions

\l_tmpa_dim We provide two local and two global scratch registers, maybe we need more or less.

\l_tmpb_dim 14043 \dim_new:N \l_tmpa_dim
\g_tmpa_dim 14044 \dim_new:N \l_tmpb_dim
\g_tmpb_dim 14045 \dim_new:N \g_tmpa_dim
14046 \dim_new:N \g_tmpb_dim

(End definition for \l_tmpa_dim and others. These variables are documented on page 169.)

21.12 Creating and initialising skip variables

14047 <@@=skip>

\skip_new:N Allocation of a new internal registers.

\skip_new:c 14048 <*package>
14049 \cs_new_protected:Npn \skip_new:N #1
14050 {
14051 __kernel_chk_if_free_cs:N #1
14052 \cs:w newskip \cs_end: #1
14053 }
14054 </package>
14055 \cs_generate_variant:Nn \skip_new:N { c }

(End definition for `\skip_new:N`. This function is documented on page 169.)

`\skip_const:Nn` Contrarily to integer constants, we cannot avoid using a register, even for constants. See
`\skip_const:cn` `\dim_const:Nn` for why we cannot use `\skip_gset:Nn`.

```
14056 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
14057 \cs_new_protected:Npn \skip_const:Nn #1#2
14058 {
14059   \skip_new:N #1
14060   \tex_global:D #1 ~ \skip_eval:n {#2} \scan_stop:
14061 }
14062 \cs_generate_variant:Nn \skip_const:Nn { c }
```

(End definition for `\skip_const:Nn`. This function is documented on page 170.)

`\skip_zero:N` Reset the register to zero.
`\skip_zero:c`
`\skip_gzero:N`
`\skip_gzero:c`

```
14063 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
14064 \cs_new_protected:Npn \skip_zero:N #1 { #1 \c_zero_skip }
14065 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
14066 \cs_new_protected:Npn \skip_gzero:N #1 { \tex_global:D #1 \c_zero_skip }
14067 \cs_generate_variant:Nn \skip_zero:N { c }
14068 \cs_generate_variant:Nn \skip_gzero:N { c }
```

(End definition for `\skip_zero:N` and `\skip_gzero:N`. These functions are documented on page 170.)

`\skip_zero_new:N` Create a register if needed, otherwise clear it.
`\skip_zero_new:c`
`\skip_gzero_new:N`
`\skip_gzero_new:c`

```
14069 \cs_new_protected:Npn \skip_zero_new:N #1
14070 { \skip_if_exist:NTF #1 { \skip_zero:N #1 } { \skip_new:N #1 } }
14071 \cs_new_protected:Npn \skip_gzero_new:N #1
14072 { \skip_if_exist:NTF #1 { \skip_gzero:N #1 } { \skip_new:N #1 } }
14073 \cs_generate_variant:Nn \skip_zero_new:N { c }
14074 \cs_generate_variant:Nn \skip_gzero_new:N { c }
```

(End definition for `\skip_zero_new:N` and `\skip_gzero_new:N`. These functions are documented on page 170.)

`\skip_if_exist:pN` Copies of the `cs` functions defined in `l3basics`.
`\skip_if_exist:p:c`
`\skip_if_exist:NTF`
`\skip_if_exist:cTF`

```
14075 \prg_new_eq_conditional:NNn \skip_if_exist:N \cs_if_exist:N
14076 { TF , T , F , p }
14077 \prg_new_eq_conditional:NNn \skip_if_exist:c \cs_if_exist:c
14078 { TF , T , F , p }
```

(End definition for `\skip_if_exist:NTF`. This function is documented on page 170.)

21.13 Setting skip variables

Much as for `dim` variables, `__skip_tmp:w` prepares a patch for `:Nn` function definitions in which the first argument should be checked to be a local/global variable and the second should be wrapped in code for an expression.

```
14079 \cs_set_protected:Npn \__skip_tmp:w #1#2#3
14080 {
14081   \__kernel_patch_args:nnnNNpn
14082   { #1 ##1 }
14083   { }
14084   { {##1} { \__kernel_chk_expr:nNn {##2} \tex_glueexpr:D { } #3 } }
14085   #2 #3
14086 }
```

```

\skip_set:Nn Much the same as for dimensions.
\skip_set:cn 14087 \__skip_tmp:w \__kernel_chk_var_local:N
\skip_gset:Nn 14088 \cs_new_protected:Npn \skip_set:Nn #1#2
\skip_gset:cn 14089 { #1 ~ \tex_glueexpr:D #2 \scan_stop: }
14090 \__skip_tmp:w \__kernel_chk_var_global:N
14091 \cs_new_protected:Npn \skip_gset:Nn #1#2
14092 { \tex_global:D #1 ~ \tex_glueexpr:D #2 \scan_stop: }
14093 \cs_generate_variant:Nn \skip_set:Nn { c }
14094 \cs_generate_variant:Nn \skip_gset:Nn { c }

```

(End definition for `\skip_set:Nn` and `\skip_gset:Nn`. These functions are documented on page 170.)

```

\skip_set_eq:NN All straightforward.
\skip_set_eq:cn 14095 \cs_new_protected:Npn \skip_set_eq:NN #1#2 { #1 = #2 }
\skip_set_eq:Nc 14096 \cs_generate_variant:Nn \skip_set_eq:NN { c , Nc , cc }
\skip_set_eq:cc 14097 \cs_new_protected:Npn \skip_gset_eq:NN #1#2 { \tex_global:D #1 = #2 }
\skip_gset_eq:NN 14098 \cs_generate_variant:Nn \skip_gset_eq:NN { c , Nc , cc }
\skip_gset_eq:cn
\skip_gset_eq:Nc
\skip_gset_eq:cc

```

(End definition for `\skip_set_eq:NN` and `\skip_gset_eq:NN`. These functions are documented on page 170.)

```

\skip_add:Nn Using by here deals with the (incorrect) case \skip123.
\skip_add:cn 14099 \__skip_tmp:w \__kernel_chk_var_local:N
\skip_gadd:Nn 14100 \cs_new_protected:Npn \skip_add:Nn #1#2
\skip_gadd:cn 14101 { \tex_advance:D #1 by \tex_glueexpr:D #2 \scan_stop: }
\skip_sub:Nn 14102 \__skip_tmp:w \__kernel_chk_var_global:N
\skip_sub:cn 14103 \cs_new_protected:Npn \skip_gadd:Nn #1#2
\skip_gsub:Nn 14104 { \tex_global:D \tex_advance:D #1 by \tex_glueexpr:D #2 \scan_stop: }
\skip_gsub:cn 14105 \cs_generate_variant:Nn \skip_add:Nn { c }
14106 \cs_generate_variant:Nn \skip_gadd:Nn { c }
14107 \__skip_tmp:w \__kernel_chk_var_local:N
14108 \cs_new_protected:Npn \skip_sub:Nn #1#2
14109 { \tex_advance:D #1 by - \tex_glueexpr:D #2 \scan_stop: }
14110 \__skip_tmp:w \__kernel_chk_var_global:N
14111 \cs_new_protected:Npn \skip_gsub:Nn #1#2
14112 { \tex_global:D \tex_advance:D #1 by - \tex_glueexpr:D #2 \scan_stop: }
14113 \cs_generate_variant:Nn \skip_sub:Nn { c }
14114 \cs_generate_variant:Nn \skip_gsub:Nn { c }

```

(End definition for `\skip_add:Nn` and others. These functions are documented on page 170.)

21.14 Skip expression conditionals

`\skip_if_eq_p:nn` Comparing skips means doing two expansions to make strings, and then testing them.
`\skip_if_eq:nnTF` As a result, only equality is tested.

```

14115 \prg_new_conditional:Npnn \skip_if_eq:nn #1#2 { p , T , F , TF }
14116 {
14117   \str_if_eq:eeTF { \skip_eval:n { #1 } } { \skip_eval:n { #2 } }
14118   { \prg_return_true: }
14119   { \prg_return_false: }
14120 }

```

(End definition for `\skip_if_eq:nnTF`. This function is documented on page 171.)

`\skip_if_finite:p:n` With ε -TeX, we have an easy access to the order of infinities of the stretch and shrink components of a skip. However, to access both, we either need to evaluate the expression twice, or evaluate it, then call an auxiliary to extract both pieces of information from the result. Since we are going to need an auxiliary anyways, it is quicker to make it search for the string `fil` which characterizes infinite glue.

```

14121 \cs_set_protected:Npn \__skip_tmp:w #1
14122 {
14123   \__kernel_patch_conditional_args:nNNpnn
14124   {
14125     {
14126       \__kernel_chk_expr:nNnN
14127       {##1} \tex_glueexpr:D { } \skip_if_finite:n
14128     }
14129   }
14130   \prg_new_conditional:Npnn \skip_if_finite:n ##1 { p , T , F , TF }
14131   {
14132     \exp_after:wN \__skip_if_finite:wwNw
14133     \skip_use:N \tex_glueexpr:D ##1 ; \prg_return_false:
14134     #1 ; \prg_return_true: \q_stop
14135   }
14136   \cs_new:Npn \__skip_if_finite:wwNw ##1 #1 ##2 ; ##3 ##4 \q_stop {##3}
14137 }
14138 \exp_args:No \__skip_tmp:w { \tl_to_str:n { fil } }

```

(End definition for `\skip_if_finite:nTF` and `__skip_if_finite:wwNw`. This function is documented on page 171.)

21.15 Using skip expressions and variables

`\skip_eval:n` Evaluating a skip expression expandably.

```

14139 \__kernel_patch_args:nNNpnn
14140 { { \__kernel_chk_expr:nNnN {##1} \tex_glueexpr:D { } \skip_eval:n } }
14141 \cs_new:Npn \skip_eval:n #1
14142 { \skip_use:N \tex_glueexpr:D #1 \scan_stop: }

```

(End definition for `\skip_eval:n`. This function is documented on page 171.)

`\skip_use:N` Accessing a $\langle skip \rangle$.

```

\skip_use:c
14143 \cs_new_eq:NN \skip_use:N \tex_the:D
14144 %\cs_generate_variant:Nn \skip_use:N { c }
14145 \cs_new:Npn \skip_use:c #1 { \tex_the:D \cs:w #1 \cs_end: }

```

(End definition for `\skip_use:N`. This function is documented on page 171.)

21.16 Inserting skips into the output

`\skip_horizontal:N` Inserting skips.

```

\skip_horizontal:c
\skip_horizontal:n
\skip_vertical:N
\skip_vertical:c
\skip_vertical:n
14146 \cs_new_eq:NN \skip_horizontal:N \tex_hskip:D
14147 \__kernel_patch_args:nNNpnn
14148 {
14149   {
14150     \__kernel_chk_expr:nNnN {##1} \tex_glueexpr:D { }
14151     \skip_horizontal:n
14152   }

```

```

14153 }
14154 \cs_new:Npn \skip_horizontal:n #1
14155 { \skip_horizontal:N \tex_glueexpr:D #1 \scan_stop: }
14156 \cs_new_eq:NN \skip_vertical:N \tex_vskip:D
14157 \__kernel_patch_args:nNNpn
14158 {
14159 {
14160 \__kernel_chk_expr:nNnN {#1} \tex_glueexpr:D { }
14161 \skip_vertical:n
14162 }
14163 }
14164 \cs_new:Npn \skip_vertical:n #1
14165 { \skip_vertical:N \tex_glueexpr:D #1 \scan_stop: }
14166 \cs_generate_variant:Nn \skip_horizontal:N { c }
14167 \cs_generate_variant:Nn \skip_vertical:N { c }

```

(End definition for `\skip_horizontal:N` and others. These functions are documented on page 172.)

21.17 Viewing skip variables

`\skip_show:N` Diagnostics.

```

\skip_show:c 14168 \cs_new_eq:NN \skip_show:N \__kernel_register_show:N
14169 \cs_generate_variant:Nn \skip_show:N { c }

```

(End definition for `\skip_show:N`. This function is documented on page 171.)

`\skip_show:n` Diagnostics. We don't use the TeX primitive `\showthe` to show skip expressions: this gives a more unified output.

```

14170 \cs_new_protected:Npn \skip_show:n
14171 { \msg_show_eval:Nn \skip_eval:n }

```

(End definition for `\skip_show:n`. This function is documented on page 171.)

`\skip_log:N` Diagnostics. Redirect output of `\skip_show:n` to the log.

```

\skip_log:c 14172 \cs_new_eq:NN \skip_log:N \__kernel_register_log:N
\skip_log:n 14173 \cs_new_eq:NN \skip_log:c \__kernel_register_log:c
14174 \cs_new_protected:Npn \skip_log:n
14175 { \msg_log_eval:Nn \skip_eval:n }

```

(End definition for `\skip_log:N` and `\skip_log:n`. These functions are documented on page 172.)

21.18 Constant skips

`\c_zero_skip` Skips with no rubber component are just dimensions but need to terminate correctly.

```

\c_max_skip 14176 \skip_const:Nn \c_zero_skip { \c_zero_dim }
14177 \skip_const:Nn \c_max_skip { \c_max_dim }

```

(End definition for `\c_zero_skip` and `\c_max_skip`. These functions are documented on page 172.)

21.19 Scratch skips

`\l_tmpa_skip` We provide two local and two global scratch registers, maybe we need more or less.

```
\l_tmpb_skip 14178 \skip_new:N \l_tmpa_skip
\g_tmpa_skip 14179 \skip_new:N \l_tmpb_skip
\g_tmpb_skip 14180 \skip_new:N \g_tmpa_skip
14181 \skip_new:N \g_tmpb_skip
```

(End definition for `\l_tmpa_skip` and others. These variables are documented on page 172.)

21.20 Creating and initialising muskip variables

`\muskip_new:N` And then we add muskips.

```
\muskip_new:c 14182 (*package)
14183 \cs_new_protected:Npn \muskip_new:N #1
14184 {
14185     \__kernel_chk_if_free_cs:N #1
14186     \cs:w newmuskip \cs_end: #1
14187 }
14188 \package
14189 \cs_generate_variant:Nn \muskip_new:N { c }
```

(End definition for `\muskip_new:N`. This function is documented on page 173.)

`\muskip_const:Nn` See `\skip_const:Nn`.

```
\muskip_const:cn 14190 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
14191 \cs_new_protected:Npn \muskip_const:Nn #1#2
14192 {
14193     \muskip_new:N #1
14194     \tex_global:D #1 ~ \muskip_eval:n {#2} \scan_stop:
14195 }
14196 \cs_generate_variant:Nn \muskip_const:Nn { c }
```

(End definition for `\muskip_const:Nn`. This function is documented on page 173.)

`\muskip_zero:N` Reset the register to zero.

```
\muskip_zero:c 14197 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\muskip_gzero:N 14198 \cs_new_protected:Npn \muskip_zero:N #1
\muskip_gzero:c 14199 { #1 \c_zero_muskip }
14200 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
14201 \cs_new_protected:Npn \muskip_gzero:N #1
14202 { \tex_global:D #1 \c_zero_muskip }
14203 \cs_generate_variant:Nn \muskip_zero:N { c }
14204 \cs_generate_variant:Nn \muskip_gzero:N { c }
```

(End definition for `\muskip_zero:N` and `\muskip_gzero:N`. These functions are documented on page 173.)

`\muskip_zero_new:N` Create a register if needed, otherwise clear it.

```
\muskip_zero_new:c 14205 \cs_new_protected:Npn \muskip_zero_new:N #1
\muskip_gzero_new:N 14206 { \muskip_if_exist:NTF #1 { \muskip_zero:N #1 } { \muskip_new:N #1 } }
\muskip_gzero_new:c 14207 \cs_new_protected:Npn \muskip_gzero_new:N #1
14208 { \muskip_if_exist:NTF #1 { \muskip_gzero:N #1 } { \muskip_new:N #1 } }
14209 \cs_generate_variant:Nn \muskip_zero_new:N { c }
14210 \cs_generate_variant:Nn \muskip_gzero_new:N { c }
```

(End definition for `\muskip_zero_new:N` and `\muskip_gzero_new:N`. These functions are documented on page 173.)

`\muskip_if_exist_p:N` Copies of the `cs` functions defined in `l3basics`.
`\muskip_if_exist_p:c` 14211 `\prg_new_eq_conditional:NNn \muskip_if_exist:N \cs_if_exist:N`
`\muskip_if_exist:N \underline{TF}` 14212 `{ TF , T , F , p }`
`\muskip_if_exist:c \underline{TF}` 14213 `\prg_new_eq_conditional:NNn \muskip_if_exist:c \cs_if_exist:c`
14214 `{ TF , T , F , p }`

(End definition for `\muskip_if_exist:N \underline{TF}` . This function is documented on page 173.)

21.21 Setting muskip variables

See `skip` case.

```
14215 \cs_set_protected:Npn \__skip_tmp:w #1#2#3
14216 {
14217   \__kernel_patch_args:nnnNNpn
14218   { #1 ##1 }
14219   { }
14220   {
14221     {##1}
14222     {
14223       \__kernel_chk_expr:nNn {##2}
14224       \tex_muexpr:D { \tex_mutogluue:D } #3
14225     }
14226   }
14227   #2 #3
14228 }
```

`\muskip_set:Nn` This should be pretty familiar.
`\muskip_set:cn` 14229 `__skip_tmp:w __kernel_chk_var_local:N`
`\muskip_gset:Nn` 14230 `\cs_new_protected:Npn \muskip_set:Nn #1#2`
`\muskip_gset:cn` 14231 `{ #1 ~ \tex_muexpr:D #2 \scan_stop: }`
14232 `__skip_tmp:w __kernel_chk_var_global:N`
14233 `\cs_new_protected:Npn \muskip_gset:Nn #1#2`
14234 `{ \tex_global:D #1 ~ \tex_muexpr:D #2 \scan_stop: }`
14235 `\cs_generate_variant:Nn \muskip_set:Nn { c }`
14236 `\cs_generate_variant:Nn \muskip_gset:Nn { c }`

(End definition for `\muskip_set:Nn` and `\muskip_gset:Nn`. These functions are documented on page 174.)

`\muskip_set_eq:NN` All straightforward.
`\muskip_set_eq:cN` 14237 `__kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }`
`\muskip_set_eq:Nc` 14238 `\cs_new_protected:Npn \muskip_set_eq:NN #1#2 { #1 = #2 }`
`\muskip_set_eq:cc` 14239 `\cs_generate_variant:Nn \muskip_set_eq:NN { c , Nc , cc }`
`\muskip_gset_eq:NN` 14240 `__kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }`
`\muskip_gset_eq:cN` 14241 `\cs_new_protected:Npn \muskip_gset_eq:NN #1#2 { \tex_global:D #1 = #2 }`
`\muskip_gset_eq:Nc` 14242 `\cs_generate_variant:Nn \muskip_gset_eq:NN { c , Nc , cc }`
`\muskip_gset_eq:cc` (End definition for `\muskip_set_eq:NN` and `\muskip_gset_eq:NN`. These functions are documented on page 174.)

\muskip_add:Nn Using by here deals with the (incorrect) case \muskip123.

```

\muskip_add:cn 14243 \__skip_tmp:w \__kernel_chk_var_local:N
\muskip_gadd:Nn 14244 \cs_new_protected:Npn \muskip_add:Nn #1#2
\muskip_gadd:cn 14245 { \tex_advance:D #1 by \tex_muexpr:D #2 \scan_stop: }
\muskip_sub:Nn 14246 \__skip_tmp:w \__kernel_chk_var_global:N
\muskip_sub:cn 14247 \cs_new_protected:Npn \muskip_gadd:Nn #1#2
\muskip_gsub:Nn 14248 { \tex_global:D \tex_advance:D #1 by \tex_muexpr:D #2 \scan_stop: }
\muskip_gsub:cn 14249 \cs_generate_variant:Nn \muskip_add:Nn { c }
14250 \cs_generate_variant:Nn \muskip_gadd:Nn { c }
14251 \__skip_tmp:w \__kernel_chk_var_local:N
14252 \cs_new_protected:Npn \muskip_sub:Nn #1#2
14253 { \tex_advance:D #1 by - \tex_muexpr:D #2 \scan_stop: }
14254 \__skip_tmp:w \__kernel_chk_var_global:N
14255 \cs_new_protected:Npn \muskip_gsub:Nn #1#2
14256 { \tex_global:D \tex_advance:D #1 by - \tex_muexpr:D #2 \scan_stop: }
14257 \cs_generate_variant:Nn \muskip_sub:Nn { c }
14258 \cs_generate_variant:Nn \muskip_gsub:Nn { c }

```

(End definition for \muskip_add:Nn and others. These functions are documented on page 173.)

21.22 Using muskip expressions and variables

\muskip_eval:n Evaluating a muskip expression expandably.

```

14259 \__kernel_patch_args:nNNpn
14260 {
14261   {
14262     \__kernel_chk_expr:nNN {#1} \tex_muexpr:D
14263     { \tex_mutogluue:D } \muskip_eval:n
14264   }
14265 }
14266 \cs_new:Npn \muskip_eval:n #1
14267 { \muskip_use:N \tex_muexpr:D #1 \scan_stop: }

```

(End definition for \muskip_eval:n. This function is documented on page 174.)

\muskip_use:N Accessing a $\langle muskip \rangle$.

```

\muskip_use:c 14268 \cs_new_eq:NN \muskip_use:N \tex_the:D
14269 \cs_generate_variant:Nn \muskip_use:N { c }

```

(End definition for \muskip_use:N. This function is documented on page 174.)

21.23 Viewing muskip variables

\muskip_show:N Diagnostics.

```

\muskip_show:c 14270 \cs_new_eq:NN \muskip_show:N \__kernel_register_show:N
14271 \cs_generate_variant:Nn \muskip_show:N { c }

```

(End definition for \muskip_show:N. This function is documented on page 174.)

\muskip_show:n Diagnostics. We don't use the TeX primitive \showthe to show muskip expressions: this gives a more unified output.

```

14272 \cs_new_protected:Npn \muskip_show:n
14273 { \msg_show_eval:Nn \muskip_eval:n }

```

(End definition for `\muskip_show:n`. This function is documented on page 175.)

```
\muskip_log:N Diagnostics. Redirect output of \muskip_show:n to the log.
\muskip_log:c 14274 \cs_new_eq:NN \muskip_log:N \__kernel_register_log:N
\muskip_log:n 14275 \cs_new_eq:NN \muskip_log:c \__kernel_register_log:c
14276 \cs_new_protected:Npn \muskip_log:n
14277 { \msg_log_eval:Nn \muskip_eval:n }
```

(End definition for `\muskip_log:N` and `\muskip_log:n`. These functions are documented on page 175.)

21.24 Constant muskips

```
\c_zero_muskip Constant muskips given by their value.
\c_max_muskip 14278 \muskip_const:Nn \c_zero_muskip { 0 mu }
14279 \muskip_const:Nn \c_max_muskip { 16383.99999 mu }
```

(End definition for `\c_zero_muskip` and `\c_max_muskip`. These functions are documented on page 175.)

21.25 Scratch muskips

```
\l_tmpa_muskip We provide two local and two global scratch registers, maybe we need more or less.
\l_tmpb_muskip 14280 \muskip_new:N \l_tmpa_muskip
\g_tmpa_muskip 14281 \muskip_new:N \l_tmpb_muskip
\g_tmpb_muskip 14282 \muskip_new:N \g_tmpa_muskip
14283 \muskip_new:N \g_tmpb_muskip
```

(End definition for `\l_tmpa_muskip` and others. These variables are documented on page 175.)

```
14284 </initex | package>
```

22 l3keys Implementation

```
14285 <*initex | package>
```

22.1 Low-level interface

The low-level key parser is based heavily on `keyval`, but with a number of additional “safety” requirements and with the idea that the parsed list of key–value pairs can be processed in a variety of ways. The net result is that this code needs around twice the amount of time as `keyval` to parse the same list of keys. To optimise speed as far as reasonably practical, a number of lower-level approaches are taken rather than using the higher-level `expl3` interfaces.

```
14286 <@@=keyval>
```

```
\l__keyval_key_tl The current key name and value.
\l__keyval_value_tl 14287 \tl_new:N \l__keyval_key_tl
14288 \tl_new:N \l__keyval_value_tl
```

(End definition for `\l__keyval_key_tl` and `\l__keyval_value_tl`.)

```
\l__keyval_sanitise_tl A token list variable for dealing with awkward category codes in the input.
14289 \tl_new:N \l__keyval_sanitise_tl
```

(End definition for `\l__keyval_sanitise_tl`.)

`\keyval_parse:NNn` The main function starts off by normalising category codes in package mode. That’s relatively “expensive” so is skipped (hopefully) in format mode. We then hand off to the parser. The use of `\q_mark` here prevents loss of braces from the key argument. Notice that by passing the two processor commands along the input stack we avoid the need to track these at all.

```

14290 \cs_new_protected:Npn \keyval_parse:NNn #1#2#3
14291 {
14292   \*initex
14293   \__keyval_loop:NNw #1#2 \q_mark #3 , \q_recursion_tail ,
14294   \*initex
14295   \*package
14296   \tl_set:Nn \l__keyval_sanitise_tl {#3}
14297   \__keyval_sanitise_equals:
14298   \__keyval_sanitise_comma:
14299   \exp_after:wN \__keyval_loop:NNw \exp_after:wN #1 \exp_after:wN #2
14300   \exp_after:wN \q_mark \l__keyval_sanitise_tl , \q_recursion_tail ,
14301   \*package
14302 }

```

(End definition for `\keyval_parse:NNn`. This function is documented on page 188.)

`__keyval_sanitise_equals:` A reasonably fast search and replace set up specifically for the active tokens. The nature of the input is known so everything is hard-coded. With only two tokens to cover, the speed gain from using dedicated functions is worth it.

```

\__keyval_sanitise_comma:
  \__keyval_sanitise_equals_auxi:w
  \__keyval_sanitise_equals_auxii:w
  \__keyval_sanitise_comma_auxi:w
  \__keyval_sanitise_comma_auxii:w
  \__keyval_sanitise_aux:w
14303 \*package
14304 \group_begin:
14305   \char_set_catcode_active:n { \ = }
14306   \char_set_catcode_active:n { \ , }
14307   \cs_new_protected:Npn \__keyval_sanitise_equals:
14308   {
14309     \exp_after:wN \__keyval_sanitise_equals_auxi:w \l__keyval_sanitise_tl
14310     \q_mark = \q_nil =
14311     \exp_after:wN \__keyval_sanitise_aux:w \l__keyval_sanitise_tl
14312   }
14313   \cs_new_protected:Npn \__keyval_sanitise_equals_auxi:w #1 =
14314   {
14315     \tl_set:Nn \l__keyval_sanitise_tl {#1}
14316     \__keyval_sanitise_equals_auxii:w
14317   }
14318   \cs_new_protected:Npn \__keyval_sanitise_equals_auxii:w #1 =
14319   {
14320     \if_meaning:w \q_nil #1 \scan_stop:
14321     \else:
14322       \tl_set:Nx \l__keyval_sanitise_tl
14323       {
14324         \exp_not:o \l__keyval_sanitise_tl
14325         \token_to_str:N =
14326         \exp_not:n {#1}
14327       }
14328       \exp_after:wN \__keyval_sanitise_equals_auxii:w
14329       \fi:
14330   }
14331   \cs_new_protected:Npn \__keyval_sanitise_comma:
14332   {

```

```

14333 \exp_after:wN \__keyval_sanitise_comma_auxi:w \l__keyval_sanitise_tl
14334 \q_mark , \q_nil ,
14335 \exp_after:wN \__keyval_sanitise_aux:w \l__keyval_sanitise_tl
14336 }
14337 \cs_new_protected:Npn \__keyval_sanitise_comma_auxi:w #1 ,
14338 {
14339 \tl_set:Nn \l__keyval_sanitise_tl {#1}
14340 \__keyval_sanitise_comma_auxii:w
14341 }
14342 \cs_new_protected:Npn \__keyval_sanitise_comma_auxii:w #1 ,
14343 {
14344 \if_meaning:w \q_nil #1 \scan_stop:
14345 \else:
14346 \tl_set:Nx \l__keyval_sanitise_tl
14347 {
14348 \exp_not:o \l__keyval_sanitise_tl
14349 \token_to_str:N ,
14350 \exp_not:n {#1}
14351 }
14352 \exp_after:wN \__keyval_sanitise_comma_auxii:w
14353 \fi:
14354 }
14355 \group_end:
14356 \cs_new_protected:Npn \__keyval_sanitise_aux:w #1 \q_mark
14357 { \tl_set:Nn \l__keyval_sanitise_tl {#1} }
14358 </package>

```

(End definition for __keyval_sanitise_equals: and others.)

__keyval_loop:NNw A fast test for the end of the loop, remembering to remove the leading quark first. Assuming that is not the case, look for a key and value then loop around, re-inserting a leading quark in front of the next position.

```

14359 \cs_new_protected:Npn \__keyval_loop:NNw #1#2#3 ,
14360 {
14361 \exp_after:wN \if_meaning:w \exp_after:wN \q_recursion_tail
14362 \use_none:n #3 \prg_do_nothing:
14363 \else:
14364 \__keyval_split:NNw #1#2#3 == \q_stop
14365 \exp_after:wN \__keyval_loop:NNw \exp_after:wN #1 \exp_after:wN #2
14366 \exp_after:wN \q_mark
14367 \fi:
14368 }

```

(End definition for __keyval_loop:NNw.)

__keyval_split:NNw The value is picked up separately from the key so there can be another quark inserted
__keyval_split_value:NNw at the front, keeping braces and allowing both parts to share the same code paths. The
__keyval_split_tidy:w key is found first then there's a check that there is something there: this is biased to the
__keyval_action: common case of there actually being a key. For the value, we first need to see if there is
anything to do: if there is, extract it. The appropriate action is then inserted in front
of the key and value. Doing this using an assignment is marginally faster than an an
expansion chain.

```

14369 \cs_new_protected:Npn \__keyval_split:NNw #1#2#3 =
14370 {

```

```

14371 \__keyval_def:Nn \l__keyval_key_tl {#3}
14372 \if_meaning:w \l__keyval_key_tl \c_empty_tl
14373 \exp_after:wN \__keyval_split_tidy:w
14374 \else:
14375 \exp_after:wN \__keyval_split_value:NNw
14376 \exp_after:wN #1
14377 \exp_after:wN #2
14378 \exp_after:wN \q_mark
14379 \fi:
14380 }
14381 \cs_new_protected:Npn \__keyval_split_value:NNw #1#2#3 = #4 \q_stop
14382 {
14383 \if:w \scan_stop: \tl_to_str:n {#4} \scan_stop:
14384 \cs_set:Npx \__keyval_action:
14385 { \exp_not:N #1 { \exp_not:o \l__keyval_key_tl } }
14386 \else:
14387 \if:w
14388 \scan_stop:
14389 \__kernel_tl_to_str:w \exp_after:wN { \use_none:n #4 }
14390 \scan_stop:
14391 \__keyval_def:Nn \l__keyval_value_tl {#3}
14392 \cs_set:Npx \__keyval_action:
14393 {
14394 \exp_not:N #2
14395 { \exp_not:o \l__keyval_key_tl }
14396 { \exp_not:o \l__keyval_value_tl }
14397 }
14398 \else:
14399 \cs_set:Npn \__keyval_action:
14400 {
14401 \__kernel_msg_error:nn { kernel }
14402 { misplaced-equals-sign }
14403 }
14404 \fi:
14405 \fi:
14406 \__keyval_action:
14407 }
14408 \cs_new_protected:Npn \__keyval_split_tidy:w #1 \q_stop
14409 {
14410 \if:w
14411 \scan_stop:
14412 \__kernel_tl_to_str:w \exp_after:wN { \use_none:n #1 }
14413 \scan_stop:
14414 \else:
14415 \exp_after:wN \__keyval_empty_key:
14416 \fi:
14417 }
14418 \cs_new:Npn \__keyval_action: { }
14419 \cs_new_protected:Npn \__keyval_empty_key:
14420 { \__kernel_msg_error:nn { kernel } { misplaced-equals-sign } }

```

(End definition for __keyval_split:NNw and others.)

__keyval_def:Nn First remove the leading quark, then trim spaces off, and finally remove a set of braces.
__keyval_def_aux:n
__keyval_def_aux:w

```

14421 \cs_new_protected:Npn \__keyval_def:Nn #1#2
14422 {
14423   \tl_set:Nx #1
14424   { \tl_trim_spaces_apply:oN { \use_none:n #2 } \__keyval_def_aux:n }
14425 }
14426 \cs_new:Npn \__keyval_def_aux:n #1
14427 { \__keyval_def_aux:w #1 \q_stop }
14428 \cs_new:Npn \__keyval_def_aux:w #1 \q_stop { \exp_not:n {#1} }

(End definition for \__keyval_def:Nn, \__keyval_def_aux:n, and \__keyval_def_aux:w.)
One message for the low level parsing system.

14429 \__kernel_msg_new:nnnn { kernel } { misplaced-equals-sign }
14430 { Misplaced-equals-sign-in-key-value-input~\msg_line_number: }
14431 {
14432   LaTeX-is-attempting-to-parse-some-key-value-input-but-found-
14433   two-equals-signs-not-separated-by-a-comma.
14434 }

```

22.2 Constants and variables

14435 `<@@=keys>`

Various storage areas for the different data which make up keys.

```

\c__keys_code_root_tl
\c__keys_default_root_tl
\c__keys_groups_root_tl
\c__keys_inherit_root_tl
\c__keys_type_root_tl
\c__keys_validate_root_tl
14436 \tl_const:Nn \c__keys_code_root_tl { key-code->~ }
14437 \tl_const:Nn \c__keys_default_root_tl { key-default->~ }
14438 \tl_const:Nn \c__keys_groups_root_tl { key-groups->~ }
14439 \tl_const:Nn \c__keys_inherit_root_tl { key-inherit->~ }
14440 \tl_const:Nn \c__keys_type_root_tl { key-type->~ }
14441 \tl_const:Nn \c__keys_validate_root_tl { key-validate->~ }

```

(End definition for `\c__keys_code_root_tl` and others.)

`\c__keys_props_root_tl` The prefix for storing properties.

```

14442 \tl_const:Nn \c__keys_props_root_tl { key-prop->~ }

```

(End definition for `\c__keys_props_root_tl`.)

`\l_keys_choice_int` Publicly accessible data on which choice is being used when several are generated as a set.

```

14443 \int_new:N \l_keys_choice_int
14444 \tl_new:N \l_keys_choice_tl

```

(End definition for `\l_keys_choice_int` and `\l_keys_choice_tl`. These variables are documented on page 182.)

`\l__keys_groups_clist` Used for storing and recovering the list of groups which apply to a key: set as a comma list but at one point we have to use this for a token list recovery.

```

14445 \clist_new:N \l__keys_groups_clist

```

(End definition for `\l__keys_groups_clist`.)

`\l_keys_key_tl` The name of a key itself: needed when setting keys.

```

14446 \tl_new:N \l_keys_key_tl

```

(End definition for `\l_keys_key_tl`. This variable is documented on page 184.)

`\l__keys_module_tl` The module for an entire set of keys.
14447 \tl_new:N \l__keys_module_tl
(End definition for \l__keys_module_tl.)

`\l__keys_no_value_bool` A marker is needed internally to show if only a key or a key plus a value was seen: this is recorded here.
14448 \bool_new:N \l__keys_no_value_bool
(End definition for \l__keys_no_value_bool.)

`\l__keys_only_known_bool` Used to track if only “known” keys are being set.
14449 \bool_new:N \l__keys_only_known_bool
(End definition for \l__keys_only_known_bool.)

`\l_keys_path_tl` The “path” of the current key is stored here: this is available to the programmer and so is public.
14450 \tl_new:N \l_keys_path_tl
(End definition for \l_keys_path_tl. This variable is documented on page 184.)

`\l__keys_inherit_tl`
14451 \tl_new:N \l__keys_inherit_tl
(End definition for \l__keys_inherit_tl.)

`\l__keys_relative_tl` The relative path for passing keys back to the user.
14452 \tl_new:N \l__keys_relative_tl
14453 \tl_set:Nn \l__keys_relative_tl { \q_no_value }
(End definition for \l__keys_relative_tl.)

`\l__keys_property_tl` The “property” begin set for a key at definition time is stored here.
14454 \tl_new:N \l__keys_property_tl
(End definition for \l__keys_property_tl.)

`\l__keys_selective_bool` Two flags for using key groups: one to indicate that “selective” setting is active, a second
`\l__keys_filtered_bool` to specify which type (“opt-in” or “opt-out”).
14455 \bool_new:N \l__keys_selective_bool
14456 \bool_new:N \l__keys_filtered_bool
(End definition for \l__keys_selective_bool and \l__keys_filtered_bool.)

`\l__keys_selective_seq` The list of key groups being filtered in or out during selective setting.
14457 \seq_new:N \l__keys_selective_seq
(End definition for \l__keys_selective_seq.)

`\l__keys_unused_clist` Used when setting only some keys to store those left over.
14458 \tl_new:N \l__keys_unused_clist
(End definition for \l__keys_unused_clist.)

`\l_keys_value_tl` The value given for a key: may be empty if no value was given.

```
14459 \tl_new:N \l_keys_value_tl
```

(End definition for `\l_keys_value_tl`. This variable is documented on page 184.)

`\l__keys_tmp_bool` Scratch space.

```
\l__keys_tmpa_tl 14460 \bool_new:N \l__keys_tmp_bool
```

```
\l__keys_tmpb_tl 14461 \tl_new:N \l__keys_tmpa_tl
```

```
14462 \tl_new:N \l__keys_tmpb_tl
```

(End definition for `\l__keys_tmp_bool`, `\l__keys_tmpa_tl`, and `\l__keys_tmpb_tl`.)

22.3 The key defining mechanism

`\keys_define:nn` The public function for definitions is just a wrapper for the lower level mechanism, more or less. The outer function is designed to keep a track of the current module, to allow safe nesting. The module is set removing any leading / (which is not needed here).

```
\__keys_define:nnn
```

```
14463 \cs_new_protected:Npn \keys_define:nn
14464 { \__keys_define:nnn \l__keys_module_tl }
14465 \cs_new_protected:Npn \__keys_define:nnn #1#2#3
14466 {
14467   \tl_set:Nx \l__keys_module_tl { \__keys_trim_spaces:n {#2} }
14468   \keyval_parse:NNn \__keys_define:n \__keys_define:nn {#3}
14469   \tl_set:Nn \l__keys_module_tl {#1}
14470 }
14471 \cs_generate_variant:Nn \__keys_define:nnn { o }
```

(End definition for `\keys_define:nn` and `__keys_define:nnn`. This function is documented on page 177.)

`__keys_define:n` The outer functions here record whether a value was given and then converge on a common internal mechanism. There is first a search for a property in the current key name, then a check to make sure it is known before the code hands off to the next step.

```
\__keys_define:nn
\__keys_define_aux:nn
```

```
14472 \cs_new_protected:Npn \__keys_define:n #1
14473 {
14474   \bool_set_true:N \l__keys_no_value_bool
14475   \__keys_define_aux:nn {#1} { }
14476 }
14477 \cs_new_protected:Npn \__keys_define:nn #1#2
14478 {
14479   \bool_set_false:N \l__keys_no_value_bool
14480   \__keys_define_aux:nn {#1} {#2}
14481 }
14482 \cs_new_protected:Npn \__keys_define_aux:nn #1#2
14483 {
14484   \__keys_property_find:n {#1}
14485   \cs_if_exist:cTF { \c__keys_props_root_tl \l__keys_property_tl }
14486   { \__keys_define_code:n {#2}
14487     }
14488   {
14489     \tl_if_empty:NF \l__keys_property_tl
14490     {
14491       \__kernel_msg_error:nxxx { kernel } { key-property-unknown }
14492       { \l__keys_property_tl } { \l__keys_path_tl }

```

```

14493     }
14494   }
14495 }

```

(End definition for `_keys_define:n`, `_keys_define:nn`, and `_keys_define_aux:nn`.)

`_keys_property_find:n` Searching for a property means finding the last `.` in the input, and storing the text before and after it. Everything is turned into strings, so there is no problem using an `x`-type expansion.

```

14496 \cs_new_protected:Npn \_keys_property_find:n #1
14497 {
14498   \tl_set:Nx \l__keys_property_tl { \_keys_trim_spaces:n {#1} }
14499   \exp_after:wN \_keys_property_find:w \l__keys_property_tl . .
14500   \q_stop {#1}
14501 }
14502 \cs_new_protected:Npn \_keys_property_find:w #1 . #2 . #3 \q_stop #4
14503 {
14504   \tl_if_blank:nTF {#3}
14505   {
14506     \tl_clear:N \l__keys_property_tl
14507     \__kernel_msg_error:nnn { kernel } { key-no-property } {#4}
14508   }
14509   {
14510     \str_if_eq:nnTF {#3} { . }
14511     {
14512       \tl_set:Nx \l_keys_path_tl
14513       {
14514         \tl_if_empty:NF \l__keys_module_tl
14515         { \l__keys_module_tl / }
14516         \tl_trim_spaces:n {#1}
14517       }
14518       \tl_set:Nn \l__keys_property_tl { . #2 }
14519     }
14520     {
14521       \tl_set:Nx \l_keys_path_tl { \l__keys_module_tl / #1 . #2 }
14522       \_keys_property_search:w #3 \q_stop
14523     }
14524   }
14525 }
14526 \cs_new_protected:Npn \_keys_property_search:w #1 . #2 \q_stop
14527 {
14528   \str_if_eq:nnTF {#2} { . }
14529   {
14530     \tl_set:Nx \l_keys_path_tl { \l_keys_path_tl }
14531     \tl_set:Nn \l__keys_property_tl { . #1 }
14532   }
14533   {
14534     \tl_set:Nx \l_keys_path_tl { \l_keys_path_tl . #1 }
14535     \_keys_property_search:w #2 \q_stop
14536   }
14537 }

```

(End definition for `_keys_property_find:n` and `_keys_property_find:w`.)

`__keys_define_code:n` Two possible cases. If there is a value for the key, then just use the function. If not, then
`__keys_define_code:w` a check to make sure there is no need for a value with the property. If there should be
one then complain, otherwise execute it. There is no need to check for a `:` as if it was
missing the earlier tests would have failed.

```

14538 \cs_new_protected:Npn \__keys_define_code:n #1
14539 {
14540   \bool_if:NTF \l__keys_no_value_bool
14541   {
14542     \exp_after:wN \__keys_define_code:w
14543     \l__keys_property_tl \q_stop
14544     { \use:c { \c__keys_props_root_tl \l__keys_property_tl } }
14545     {
14546       \__kernel_msg_error:nxxx { kernel }
14547       { key-property-requires-value } { \l__keys_property_tl }
14548       { \l_keys_path_tl }
14549     }
14550   }
14551   { \use:c { \c__keys_props_root_tl \l__keys_property_tl } {#1} }
14552 }
14553 \exp_last_unbraced:NNNNo
14554 \cs_new:Npn \__keys_define_code:w #1 \c_colon_str #2 \q_stop
14555 { \tl_if_empty:NTF {#2} }

```

(End definition for `__keys_define_code:n` and `__keys_define_code:w`.)

22.4 Turning properties into actions

`__keys_bool_set:Nn` Boolean keys are really just choices, but all done by hand. The second argument here is
`__keys_bool_set:cn` the scope: either empty or `g` for global.

```

14556 \cs_new_protected:Npn \__keys_bool_set:Nn #1#2
14557 {
14558   \bool_if_exist:NF #1 { \bool_new:N #1 }
14559   \__keys_choice_make:
14560   \__keys_cmd_set:nx { \l_keys_path_tl / true }
14561   { \exp_not:c { bool_ #2 set_true:N } \exp_not:N #1 }
14562   \__keys_cmd_set:nx { \l_keys_path_tl / false }
14563   { \exp_not:c { bool_ #2 set_false:N } \exp_not:N #1 }
14564   \__keys_cmd_set:nn { \l_keys_path_tl / unknown }
14565   {
14566     \__kernel_msg_error:nxx { kernel } { boolean-values-only }
14567     { \l_keys_key_tl }
14568   }
14569   \__keys_default_set:n { true }
14570 }
14571 \cs_generate_variant:Nn \__keys_bool_set:Nn { c }

```

(End definition for `__keys_bool_set:Nn`.)

`__keys_bool_set_inverse:Nn` Inverse boolean setting is much the same.

```

14572 \cs_new_protected:Npn \__keys_bool_set_inverse:Nn #1#2
14573 {
14574   \bool_if_exist:NF #1 { \bool_new:N #1 }
14575   \__keys_choice_make:
14576   \__keys_cmd_set:nx { \l_keys_path_tl / true }

```

```

14577     { \exp_not:c { bool_ #2 set_false:N } \exp_not:N #1 }
14578 \__keys_cmd_set:nx { \l_keys_path_tl / false }
14579     { \exp_not:c { bool_ #2 set_true:N } \exp_not:N #1 }
14580 \__keys_cmd_set:nn { \l_keys_path_tl / unknown }
14581     {
14582         \__kernel_msg_error:nxx { kernel } { boolean-values-only }
14583         { \l_keys_key_tl }
14584     }
14585 \__keys_default_set:n { true }
14586 }
14587 \cs_generate_variant:Nn \__keys_bool_set_inverse:Nn { c }

```

(End definition for __keys_bool_set_inverse:Nn.)

__keys_choice_make: To make a choice from a key, two steps: set the code, and set the unknown key. As
 __keys_multichoice_make: multichoice and choices are essentially the same bar one function, the code is given
 __keys_choice_make:N together.
 __keys_choice_make_aux:N

```

14588 \cs_new_protected:Npn \__keys_choice_make:
14589     { \__keys_choice_make:N \__keys_choice_find:n }
14590 \cs_new_protected:Npn \__keys_multichoice_make:
14591     { \__keys_choice_make:N \__keys_multichoice_find:n }
14592 \cs_new_protected:Npn \__keys_choice_make:N #1
14593     {
14594         \cs_if_exist:cTF
14595         { \c__keys_type_root_tl \__keys_parent:o \l_keys_path_tl }
14596         {
14597             \str_if_eq:vnTF
14598             { \c__keys_type_root_tl \__keys_parent:o \l_keys_path_tl }
14599             { choice }
14600             {
14601                 \__kernel_msg_error:nxxx { kernel } { nested-choice-key }
14602                 { \l_keys_path_tl } { \__keys_parent:o \l_keys_path_tl }
14603             }
14604             { \__keys_choice_make_aux:N #1 }
14605         }
14606         { \__keys_choice_make_aux:N #1 }
14607     }
14608 \cs_new_protected:Npn \__keys_choice_make_aux:N #1
14609     {
14610         \cs_set_nopar:cpn { \c__keys_type_root_tl \l_keys_path_tl }
14611         { choice }
14612         \__keys_cmd_set:nn { \l_keys_path_tl } { #1 {##1} }
14613         \__keys_cmd_set:nn { \l_keys_path_tl / unknown }
14614         {
14615             \__kernel_msg_error:nxxx { kernel } { key-choice-unknown }
14616             { \l_keys_path_tl } {##1}
14617         }
14618     }

```

(End definition for __keys_choice_make: and others.)

__keys_choices_make:nn Auto-generating choices means setting up the root key as a choice, then defining each
 __keys_multichoice_make:nn choice in turn.
 __keys_choices_make:Nnn

```

14619 \cs_new_protected:Npn \__keys_choices_make:nn

```

```

14620 { \__keys_choices_make:Nnn \__keys_choice_make: }
14621 \cs_new_protected:Npn \__keys_multichoices_make:nn
14622 { \__keys_choices_make:Nnn \__keys_multichoice_make: }
14623 \cs_new_protected:Npn \__keys_choices_make:Nnn #1#2#3
14624 {
14625     #1
14626     \int_zero:N \l_keys_choice_int
14627     \clist_map_inline:nn {#2}
14628     {
14629         \int_incr:N \l_keys_choice_int
14630         \__keys_cmd_set:nx
14631         { \l_keys_path_tl / \__keys_trim_spaces:n {##1} }
14632         {
14633             \tl_set:Nn \exp_not:N \l_keys_choice_tl {##1}
14634             \int_set:Nn \exp_not:N \l_keys_choice_int
14635             { \int_use:N \l_keys_choice_int }
14636             \exp_not:n {#3}
14637         }
14638     }
14639 }

```

(End definition for __keys_choices_make:nn, __keys_multichoices_make:nn, and __keys_choices_make:Nnn.)

__keys_cmd_set:nn Setting the code for a key first logs if appropriate that we are defining a new key, then
 __keys_cmd_set:nx saves the code.

```

\__keys_cmd_set:Vn 14640 \__kernel_patch:nnNNpn
\__keys_cmd_set:Vo 14641 {
14642     \cs_if_exist:cF { \c__keys_code_root_tl #1 }
14643     { \__kernel_debug_log:x { Defining-key~#1~\msg_line_context: } }
14644 }
14645 { }
14646 \cs_new_protected:Npn \__keys_cmd_set:nn #1#2
14647 { \cs_set_protected:cpn { \c__keys_code_root_tl #1 } ##1 {#2} }
14648 \cs_generate_variant:Nn \__keys_cmd_set:nn { nx , Vn , Vo }

```

(End definition for __keys_cmd_set:nn.)

__keys_default_set:n Setting a default value is easy. These are stored using \cs_set:cpx as this avoids any
 worries about whether a token list exists.

```

14649 \cs_new_protected:Npn \__keys_default_set:n #1
14650 {
14651     \tl_if_empty:nTF {#1}
14652     {
14653         \cs_set_eq:cN
14654         { \c__keys_default_root_tl \l_keys_path_tl }
14655         \tex_undefined:D
14656     }
14657     {
14658         \cs_set_nopar:cpx
14659         { \c__keys_default_root_tl \l_keys_path_tl }
14660         { \exp_not:n {#1} }
14661     }
14662 }

```

(End definition for _keys_default_set:n.)

_keys_groups_set:n Assigning a key to one or more groups uses comma lists. As the list of groups only exists if there is anything to do, the setting is done using a scratch list. For the usual grouping reasons we use the low-level approach to undefining a list. We also use the low-level approach for the other case to avoid tripping up the check-declarations code.

```
14663 \cs_new_protected:Npn \_keys_groups_set:n #1
14664 {
14665   \clist_set:Nn \l_keys_groups_clist {#1}
14666   \clist_if_empty:NTF \l_keys_groups_clist
14667   {
14668     \cs_set_eq:cN { \c_keys_groups_root_tl \l_keys_path_tl }
14669     \tex_undefined:D
14670   }
14671   {
14672     \cs_set_eq:cN { \c_keys_groups_root_tl \l_keys_path_tl }
14673     \l_keys_groups_clist
14674   }
14675 }
```

(End definition for _keys_groups_set:n.)

_keys_inherit:n Inheritance means ignoring anything already said about the key: zap the lot and set up.

```
14676 \cs_new_protected:Npn \_keys_inherit:n #1
14677 {
14678   \_keys_undefine:
14679   \cs_set_nopar:cpn { \c_keys_inherit_root_tl \l_keys_path_tl } {#1}
14680 }
```

(End definition for _keys_inherit:n.)

_keys_initialise:n A set up for initialisation: just run the code if it exists.

```
14681 \cs_new_protected:Npn \_keys_initialise:n #1
14682 {
14683   \cs_if_exist_use:cT { \c_keys_code_root_tl \l_keys_path_tl } { {#1} }
14684 }
```

(End definition for _keys_initialise:n.)

_keys_meta_make:n To create a meta-key, simply set up to pass data through.

```
\_keys_meta_make:nn
14685 \cs_new_protected:Npn \_keys_meta_make:n #1
14686 {
14687   \_keys_cmd_set:Vo \l_keys_path_tl
14688   {
14689     \exp_after:wN \keys_set:nn
14690     \exp_after:wN { \l_keys_module_tl } {#1}
14691   }
14692 }
14693 \cs_new_protected:Npn \_keys_meta_make:nn #1#2
14694 { \_keys_cmd_set:Vn \l_keys_path_tl { \keys_set:nn {#1} {#2} } }
```

(End definition for _keys_meta_make:n and _keys_meta_make:nn.)

`__keys_prop_put:Nn` Much the same as other variables, but needs a dedicated auxiliary.

```

\__keys_prop_put:cn
14695 \cs_new_protected:Npn \__keys_prop_put:Nn #1#2
14696 {
14697   \prop_if_exist:NF #1 { \prop_new:N #1 }
14698   \exp_after:wN \__keys_find_key_module:NNw
14699     \exp_after:wN \l__keys_tmpa_tl
14700     \exp_after:wN \l__keys_tmpb_tl
14701     \l_keys_path_tl / \q_stop
14702   \__keys_cmd_set:nx { \l_keys_path_tl }
14703   {
14704     \exp_not:c { prop_ #2 put:Nnn }
14705     \exp_not:N #1
14706     { \l__keys_tmpb_tl }
14707     \exp_not:n { {##1} }
14708   }
14709 }
14710 \cs_generate_variant:Nn \__keys_prop_put:Nn { c }

```

(End definition for __keys_prop_put:Nn.)

`__keys_undefine:` Undefined a key has to be done without `\cs_undefine:c` as that function acts globally.

```

14711 \cs_new_protected:Npn \__keys_undefine:
14712 {
14713   \clist_map_inline:nn
14714     { code , default , groups , inherit , type , validate }
14715     {
14716       \cs_set_eq:cN
14717         { \tl_use:c { c__keys_ ##1 _root_tl } \l_keys_path_tl }
14718       \tex_undefined:D
14719     }
14720 }

```

(End definition for __keys_undefine:.)

`__keys_value_requirement:nn` Validating key input is done using a second function which runs before the main key code. Setting that up means setting it equal to a generic stub which does the check. This approach makes the lookup very fast at the cost of one additional csname per key that needs it. The cleanup here has to know the structure of the following code.

`__keys_validate_forbidden:`
`__keys_validate_required:`
`__keys_validate_cleanup:w`

```

14721 \cs_new_protected:Npn \__keys_value_requirement:nn #1#2
14722 {
14723   \str_case:nnF {#2}
14724   {
14725     { true }
14726     {
14727       \cs_set_eq:cc
14728         { \c__keys_validate_root_tl \l_keys_path_tl }
14729         { __keys_validate_ #1 : }
14730     }
14731   { false }
14732   {
14733     \cs_if_eq:ccT
14734       { \c__keys_validate_root_tl \l_keys_path_tl }
14735       { __keys_validate_ #1 : }
14736   }

```



```

14737         \cs_set_eq:cN
14738         { \c__keys_validate_root_tl \l_keys_path_tl }
14739         \tex_undefined:D
14740     }
14741 }
14742 }
14743 {
14744     \__kernel_msg_error:nxx { kernel }
14745     { key-property-boolean-values-only }
14746     { .value_ #1 :n }
14747 }
14748 }
14749 \cs_new_protected:Npn \__keys_validate_forbidden:
14750 {
14751     \bool_if:NF \l__keys_no_value_bool
14752     {
14753         \__kernel_msg_error:nxxx { kernel } { value-forbidden }
14754         { \l_keys_path_tl } { \l_keys_value_tl }
14755         \__keys_validate_cleanup:w
14756     }
14757 }
14758 \cs_new_protected:Npn \__keys_validate_required:
14759 {
14760     \bool_if:NT \l__keys_no_value_bool
14761     {
14762         \__kernel_msg_error:nxx { kernel } { value-required }
14763         { \l_keys_path_tl }
14764         \__keys_validate_cleanup:w
14765     }
14766 }
14767 \cs_new_protected:Npn \__keys_validate_cleanup:w #1 \cs_end: #2#3 { }

```

(End definition for `__keys_value_requirement:nn` and others.)

`__keys_variable_set:NnnN` Setting a variable takes the type and scope separately so that it is easy to make a new variable if needed.

```

14768 \cs_new_protected:Npn \__keys_variable_set:NnnN #1#2#3#4
14769 {
14770     \use:c { #2_if_exist:NF } #1 { \use:c { #2_new:N } #1 }
14771     \__keys_cmd_set:nx { \l_keys_path_tl }
14772     {
14773         \exp_not:c { #2 _ #3 set:N #4 }
14774         \exp_not:N #1
14775         \exp_not:n { {##1} }
14776     }
14777 }
14778 \cs_generate_variant:Nn \__keys_variable_set:NnnN { c }

```

(End definition for `__keys_variable_set:NnnN`.)

22.5 Creating key properties

The key property functions are all wrappers for internal functions, meaning that things stay readable and can also be altered later on.

Importantly, while key properties have “normal” argument specs, the underlying code always supplies one braced argument to these. As such, argument expansion is handled by hand rather than using the standard tools. This shows up particularly for the two-argument properties, where things would otherwise go badly wrong.

```
.bool_set:N One function for this.
.bool_set:c 14779 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_set:N } #1
.bool_gset:N 14780 { \__keys_bool_set:Nn #1 { } }
.bool_gset:c 14781 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_set:c } #1
14782 { \__keys_bool_set:cn {#1} { } }
14783 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_gset:N } #1
14784 { \__keys_bool_set:Nn #1 { g } }
14785 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_gset:c } #1
14786 { \__keys_bool_set:cn {#1} { g } }
```

(End definition for `.bool_set:N` and `.bool_gset:N`. These functions are documented on page 178.)

```
.bool_set_inverse:N One function for this.
.bool_set_inverse:c 14787 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_set_inverse:N } #1
.bool_gset_inverse:N 14788 { \__keys_bool_set_inverse:Nn #1 { } }
.bool_gset_inverse:c 14789 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_set_inverse:c } #1
14790 { \__keys_bool_set_inverse:cn {#1} { } }
14791 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_gset_inverse:N } #1
14792 { \__keys_bool_set_inverse:Nn #1 { g } }
14793 \cs_new_protected:cpn { \c__keys_props_root_tl .bool_gset_inverse:c } #1
14794 { \__keys_bool_set_inverse:cn {#1} { g } }
```

(End definition for `.bool_set_inverse:N` and `.bool_gset_inverse:N`. These functions are documented on page 178.)

```
.choice: Making a choice is handled internally, as it is also needed by .generate_choices:n.
14795 \cs_new_protected:cpn { \c__keys_props_root_tl .choice: }
14796 { \__keys_choice_make: }
```

(End definition for `.choice:`. This function is documented on page 178.)

```
.choices:nn For auto-generation of a series of mutually-exclusive choices. Here, #1 consists of two
.choices:Vn separate arguments, hence the slightly odd-looking implementation.
.choices:on 14797 \cs_new_protected:cpn { \c__keys_props_root_tl .choices:nn } #1
.choices:xn 14798 { \__keys_choices_make:nn #1 }
14799 \cs_new_protected:cpn { \c__keys_props_root_tl .choices:Vn } #1
14800 { \exp_args:NV \__keys_choices_make:nn #1 }
14801 \cs_new_protected:cpn { \c__keys_props_root_tl .choices:on } #1
14802 { \exp_args:No \__keys_choices_make:nn #1 }
14803 \cs_new_protected:cpn { \c__keys_props_root_tl .choices:xn } #1
14804 { \exp_args:Nx \__keys_choices_make:nn #1 }
```

(End definition for `.choices:nn`. This function is documented on page 178.)

```
.code:n Creating code is simply a case of passing through to the underlying set function.
14805 \cs_new_protected:cpn { \c__keys_props_root_tl .code:n } #1
14806 { \__keys_cmd_set:nn { \l_keys_path_tl } {#1} }
```

(End definition for `.code:n`. This function is documented on page 178.)

```

.clist_set:N
.clist_set:c 14807 \cs_new_protected:cpn { \c__keys_props_root_tl .clist_set:N } #1
.clist_gset:N 14808 { \__keys_variable_set:NnnN #1 { clist } { } n }
.clist_gset:c 14809 \cs_new_protected:cpn { \c__keys_props_root_tl .clist_set:c } #1
14810 { \__keys_variable_set:cnnN {#1} { clist } { } n }
14811 \cs_new_protected:cpn { \c__keys_props_root_tl .clist_gset:N } #1
14812 { \__keys_variable_set:NnnN #1 { clist } { g } n }
14813 \cs_new_protected:cpn { \c__keys_props_root_tl .clist_gset:c } #1
14814 { \__keys_variable_set:cnnN {#1} { clist } { g } n }

```

(End definition for .clist_set:N and .clist_gset:N. These functions are documented on page 178.)

.default:n Expansion is left to the internal functions.

```

.default:V 14815 \cs_new_protected:cpn { \c__keys_props_root_tl .default:n } #1
.default:o 14816 { \__keys_default_set:n {#1} }
.default:x 14817 \cs_new_protected:cpn { \c__keys_props_root_tl .default:V } #1
14818 { \exp_args:NV \__keys_default_set:n #1 }
14819 \cs_new_protected:cpn { \c__keys_props_root_tl .default:o } #1
14820 { \exp_args:No \__keys_default_set:n {#1} }
14821 \cs_new_protected:cpn { \c__keys_props_root_tl .default:x } #1
14822 { \exp_args:Nx \__keys_default_set:n {#1} }

```

(End definition for .default:n. This function is documented on page 179.)

.dim_set:N Setting a variable is very easy: just pass the data along.

```

.dim_set:c 14823 \cs_new_protected:cpn { \c__keys_props_root_tl .dim_set:N } #1
.dim_gset:N 14824 { \__keys_variable_set:NnnN #1 { dim } { } n }
.dim_gset:c 14825 \cs_new_protected:cpn { \c__keys_props_root_tl .dim_set:c } #1
14826 { \__keys_variable_set:cnnN {#1} { dim } { } n }
14827 \cs_new_protected:cpn { \c__keys_props_root_tl .dim_gset:N } #1
14828 { \__keys_variable_set:NnnN #1 { dim } { g } n }
14829 \cs_new_protected:cpn { \c__keys_props_root_tl .dim_gset:c } #1
14830 { \__keys_variable_set:cnnN {#1} { dim } { g } n }

```

(End definition for .dim_set:N and .dim_gset:N. These functions are documented on page 179.)

.fp_set:N Setting a variable is very easy: just pass the data along.

```

.fp_set:c 14831 \cs_new_protected:cpn { \c__keys_props_root_tl .fp_set:N } #1
.fp_gset:N 14832 { \__keys_variable_set:NnnN #1 { fp } { } n }
.fp_gset:c 14833 \cs_new_protected:cpn { \c__keys_props_root_tl .fp_set:c } #1
14834 { \__keys_variable_set:cnnN {#1} { fp } { } n }
14835 \cs_new_protected:cpn { \c__keys_props_root_tl .fp_gset:N } #1
14836 { \__keys_variable_set:NnnN #1 { fp } { g } n }
14837 \cs_new_protected:cpn { \c__keys_props_root_tl .fp_gset:c } #1
14838 { \__keys_variable_set:cnnN {#1} { fp } { g } n }

```

(End definition for .fp_set:N and .fp_gset:N. These functions are documented on page 179.)

.groups:n A single property to create groups of keys.

```

14839 \cs_new_protected:cpn { \c__keys_props_root_tl .groups:n } #1
14840 { \__keys_groups_set:n {#1} }

```

(End definition for .groups:n. This function is documented on page 179.)

.inherit:n Nothing complex: only one variant at the moment!

```
14841 \cs_new_protected:cpn { \c__keys_props_root_tl .inherit:n } #1
14842 { \__keys_inherit:n {#1} }
```

(End definition for .inherit:n. This function is documented on page 179.)

.initial:n The standard hand-off approach.

```
.initial:V 14843 \cs_new_protected:cpn { \c__keys_props_root_tl .initial:n } #1
.initial:o 14844 { \__keys_initialise:n {#1} }
.initial:x 14845 \cs_new_protected:cpn { \c__keys_props_root_tl .initial:V } #1
14846 { \exp_args:NV \__keys_initialise:n #1 }
14847 \cs_new_protected:cpn { \c__keys_props_root_tl .initial:o } #1
14848 { \exp_args:No \__keys_initialise:n {#1} }
14849 \cs_new_protected:cpn { \c__keys_props_root_tl .initial:x } #1
14850 { \exp_args:Nx \__keys_initialise:n {#1} }
```

(End definition for .initial:n. This function is documented on page 180.)

.int_set:N Setting a variable is very easy: just pass the data along.

```
.int_set:c 14851 \cs_new_protected:cpn { \c__keys_props_root_tl .int_set:N } #1
.int_gset:N 14852 { \__keys_variable_set:NnnN #1 { int } { } n }
.int_gset:c 14853 \cs_new_protected:cpn { \c__keys_props_root_tl .int_set:c } #1
14854 { \__keys_variable_set:cnnN {#1} { int } { } n }
14855 \cs_new_protected:cpn { \c__keys_props_root_tl .int_gset:N } #1
14856 { \__keys_variable_set:NnnN #1 { int } { g } n }
14857 \cs_new_protected:cpn { \c__keys_props_root_tl .int_gset:c } #1
14858 { \__keys_variable_set:cnnN {#1} { int } { g } n }
```

(End definition for .int_set:N and .int_gset:N. These functions are documented on page 180.)

.meta:n Making a meta is handled internally.

```
14859 \cs_new_protected:cpn { \c__keys_props_root_tl .meta:n } #1
14860 { \__keys_meta_make:n {#1} }
```

(End definition for .meta:n. This function is documented on page 180.)

.meta:nn Meta with path: potentially lots of variants, but for the moment no so many defined.

```
14861 \cs_new_protected:cpn { \c__keys_props_root_tl .meta:nn } #1
14862 { \__keys_meta_make:nn #1 }
```

(End definition for .meta:nn. This function is documented on page 180.)

.multichoice: The same idea as .choice: and .choices:nn, but where more than one choice is allowed.

```
.multichoices:nn 14863 \cs_new_protected:cpn { \c__keys_props_root_tl .multichoice: }
14864 { \__keys_multichoice_make: }
.multichoices:Vn 14865 \cs_new_protected:cpn { \c__keys_props_root_tl .multichoices:nn } #1
14866 { \__keys_multichoices_make:nn #1 }
.multichoices:on 14867 \cs_new_protected:cpn { \c__keys_props_root_tl .multichoices:Vn } #1
14868 { \exp_args:NV \__keys_multichoices_make:nn #1 }
.multichoices:xn 14869 \cs_new_protected:cpn { \c__keys_props_root_tl .multichoices:on } #1
14870 { \exp_args:No \__keys_multichoices_make:nn #1 }
14871 \cs_new_protected:cpn { \c__keys_props_root_tl .multichoices:xn } #1
14872 { \exp_args:Nx \__keys_multichoices_make:nn #1 }
```

(End definition for .multichoice: and .multichoices:nn. These functions are documented on page 180.)

```

.muskip_set:N Setting a variable is very easy: just pass the data along.
.muskip_set:c 14873 \cs_new_protected:cpn { \c__keys_props_root_tl .muskip_set:N } #1
.muskip_gset:N 14874 { \__keys_variable_set:NnnN #1 { muskip } { } n }
.muskip_gset:c 14875 \cs_new_protected:cpn { \c__keys_props_root_tl .muskip_set:c } #1
14876 { \__keys_variable_set:cnnN {#1} { muskip } { } n }
14877 \cs_new_protected:cpn { \c__keys_props_root_tl .muskip_gset:N } #1
14878 { \__keys_variable_set:NnnN #1 { muskip } { g } n }
14879 \cs_new_protected:cpn { \c__keys_props_root_tl .muskip_gset:c } #1
14880 { \__keys_variable_set:cnnN {#1} { muskip } { g } n }

```

(End definition for .muskip_set:N and .muskip_gset:N. These functions are documented on page 180.)

```

.prop_put:N Setting a variable is very easy: just pass the data along.
.prop_put:c 14881 \cs_new_protected:cpn { \c__keys_props_root_tl .prop_put:N } #1
.prop_gput:N 14882 { \__keys_prop_put:Nn #1 { } }
.prop_gput:c 14883 \cs_new_protected:cpn { \c__keys_props_root_tl .prop_put:c } #1
14884 { \__keys_prop_put:cn {#1} { } }
14885 \cs_new_protected:cpn { \c__keys_props_root_tl .prop_gput:N } #1
14886 { \__keys_prop_put:Nn #1 { g } }
14887 \cs_new_protected:cpn { \c__keys_props_root_tl .prop_gput:c } #1
14888 { \__keys_prop_put:cn {#1} { g } }

```

(End definition for .prop_put:N and .prop_gput:N. These functions are documented on page 180.)

```

.skip_set:N Setting a variable is very easy: just pass the data along.
.skip_set:c 14889 \cs_new_protected:cpn { \c__keys_props_root_tl .skip_set:N } #1
.skip_gset:N 14890 { \__keys_variable_set:NnnN #1 { skip } { } n }
.skip_gset:c 14891 \cs_new_protected:cpn { \c__keys_props_root_tl .skip_set:c } #1
14892 { \__keys_variable_set:cnnN {#1} { skip } { } n }
14893 \cs_new_protected:cpn { \c__keys_props_root_tl .skip_gset:N } #1
14894 { \__keys_variable_set:NnnN #1 { skip } { g } n }
14895 \cs_new_protected:cpn { \c__keys_props_root_tl .skip_gset:c } #1
14896 { \__keys_variable_set:cnnN {#1} { skip } { g } n }

```

(End definition for .skip_set:N and .skip_gset:N. These functions are documented on page 180.)

```

.tl_set:N Setting a variable is very easy: just pass the data along.
.tl_set:c 14897 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_set:N } #1
.tl_gset:N 14898 { \__keys_variable_set:NnnN #1 { tl } { } n }
.tl_gset:c 14899 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_set:c } #1
.tl_set_x:N 14900 { \__keys_variable_set:cnnN {#1} { tl } { } n }
.tl_set_x:c 14901 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_set_x:N } #1
.tl_gset_x:N 14902 { \__keys_variable_set:NnnN #1 { tl } { } x }
.tl_gset_x:c 14903 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_set_x:c } #1
14904 { \__keys_variable_set:cnnN {#1} { tl } { } x }
14905 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_gset:N } #1
14906 { \__keys_variable_set:NnnN #1 { tl } { g } n }
14907 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_gset:c } #1
14908 { \__keys_variable_set:cnnN {#1} { tl } { g } n }
14909 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_gset_x:N } #1
14910 { \__keys_variable_set:NnnN #1 { tl } { g } x }
14911 \cs_new_protected:cpn { \c__keys_props_root_tl .tl_gset_x:c } #1
14912 { \__keys_variable_set:cnnN {#1} { tl } { g } x }

```

(End definition for .tl_set:N and others. These functions are documented on page 181.)

.undefine: Another simple wrapper.

```
14913 \cs_new_protected:cpn { \c__keys_props_root_tl .undefine: }
14914 { \__keys_undefine: }
```

(End definition for .undefine:. This function is documented on page 181.)

.value_forbidden:n These are very similar, so both call the same function.

```
.value_required:n 14915 \cs_new_protected:cpn { \c__keys_props_root_tl .value_forbidden:n } #1
14916 { \__keys_value_requirement:nn { forbidden } {#1} }
14917 \cs_new_protected:cpn { \c__keys_props_root_tl .value_required:n } #1
14918 { \__keys_value_requirement:nn { required } {#1} }
```

(End definition for .value_forbidden:n and .value_required:n. These functions are documented on page 181.)

22.6 Setting keys

\keys_set:nn A simple wrapper allowing for nesting.

```
\keys_set:nV 14919 \cs_new_protected:Npn \keys_set:nn #1#2
\keys_set:nv 14920 {
\keys_set:no 14921   \use:x
\__keys_set:nn 14922   {
\__keys_set:nnn 14923     \bool_set_false:N \exp_not:N \l__keys_only_known_bool
14924     \bool_set_false:N \exp_not:N \l__keys_filtered_bool
14925     \bool_set_false:N \exp_not:N \l__keys_selective_bool
14926     \tl_set:Nn \exp_not:N \l__keys_relative_tl
14927     { \exp_not:N \q_no_value }
14928     \__keys_set:nn \exp_not:n { {#1} {#2} }
14929     \bool_if:NT \l__keys_only_known_bool
14930     { \bool_set_true:N \exp_not:N \l__keys_only_known_bool }
14931     \bool_if:NT \l__keys_filtered_bool
14932     { \bool_set_true:N \exp_not:N \l__keys_filtered_bool }
14933     \bool_if:NT \l__keys_selective_bool
14934     { \bool_set_true:N \exp_not:N \l__keys_selective_bool }
14935     \tl_set:Nn \exp_not:N \l__keys_relative_tl
14936     { \exp_not:o \l__keys_relative_tl }
14937   }
14938 }
14939 \cs_generate_variant:Nn \keys_set:nn { nV , nv , no }
14940 \cs_new_protected:Npn \__keys_set:nn #1#2
14941 { \exp_args:No \__keys_set:nnn \l__keys_module_tl {#1} {#2} }
14942 \cs_new_protected:Npn \__keys_set:nnn #1#2#3
14943 {
14944   \tl_set:Nx \l__keys_module_tl { \__keys_trim_spaces:n {#2} }
14945   \keyval_parse:NNn \__keys_set_keyval:n \__keys_set_keyval:nn {#3}
14946   \tl_set:Nn \l__keys_module_tl {#1}
14947 }
```

(End definition for \keys_set:nn, __keys_set:nn, and __keys_set:nnn. This function is documented on page 184.)

\keys_set_known:nnN Setting known keys simply means setting the appropriate flag, then running the standard code. To allow for nested setting, any existing value of \l__keys_unused_clist is saved

```
\keys_set_known:nVN
\keys_set_known:nvN
\keys_set_known:noN
```

\keys_set_known:nnnN

```
\keys_set_known:nVnN
\keys_set_known:nvnN
\keys_set_known:nonN
```

```
\__keys_set_known:nnnnN
```

\keys_set_known:nn

```
\keys_set_known:nV
```

```
\keys_set_known:nv
```

```
\keys_set_known:no
```

on the stack and reset afterwards. Note that for speed/simplicity reasons we use a `tl` operation to set the `clist` here!

```

14948 \cs_new_protected:Npn \keys_set_known:nnN #1#2#3
14949 {
14950     \exp_args:No \__keys_set_known:nnnnN
14951     \l__keys_unused_clist { \q_no_value } {#1} {#2} #3
14952 }
14953 \cs_generate_variant:Nn \keys_set_known:nnN { nV , nv , no }
14954 \cs_new_protected:Npn \keys_set_known:nnnN #1#2#3#4
14955 {
14956     \exp_args:No \__keys_set_known:nnnnN
14957     \l__keys_unused_clist {#3} {#1} {#2} #4
14958 }
14959 \cs_generate_variant:Nn \keys_set_known:nnnN { nV , nv , no }
14960 \cs_new_protected:Npn \__keys_set_known:nnnnN #1#2#3#4#5
14961 {
14962     \clist_clear:N \l__keys_unused_clist
14963     \__keys_set_known:nnn {#2} {#3} {#4}
14964     \tl_set:Nx #5 { \exp_not:o { \l__keys_unused_clist } }
14965     \tl_set:Nn \l__keys_unused_clist {#1}
14966 }
14967 \cs_new_protected:Npn \keys_set_known:nn #1#2
14968 { \__keys_set_known:nnn { \q_no_value } {#1} {#2} }
14969 \cs_generate_variant:Nn \keys_set_known:nn { nV , nv , no }
14970 \cs_new_protected:Npn \__keys_set_known:nnn #1#2#3
14971 {
14972     \use:x
14973     {
14974         \bool_set_true:N \exp_not:N \l__keys_only_known_bool
14975         \bool_set_false:N \exp_not:N \l__keys_filtered_bool
14976         \bool_set_false:N \exp_not:N \l__keys_selective_bool
14977         \tl_set:Nn \exp_not:N \l__keys_relative_tl { \exp_not:n {#1} }
14978         \__keys_set:nn \exp_not:n { {#2} {#3} }
14979         \bool_if:NF \l__keys_only_known_bool
14980         { \bool_set_false:N \exp_not:N \l__keys_only_known_bool }
14981         \bool_if:NT \l__keys_filtered_bool
14982         { \bool_set_true:N \exp_not:N \l__keys_filtered_bool }
14983         \bool_if:NT \l__keys_selective_bool
14984         { \bool_set_true:N \exp_not:N \l__keys_selective_bool }
14985         \tl_set:Nn \exp_not:N \l__keys_relative_tl
14986         { \exp_not:o \l__keys_relative_tl }
14987     }
14988 }

```

(End definition for `\keys_set_known:nnN` and others. These functions are documented on page 185.)

The idea of setting keys in a selective manner again uses flags wrapped around the basic code. The comments on `\keys_set_known:nnN` also apply here. We have a bit more shuffling to do to keep everything nestable.

```

\keys_set_filter:nnnN The idea of setting keys in a selective manner again uses flags wrapped around the basic
\keys_set_filter:nnVN code. The comments on \keys_set_known:nnN also apply here. We have a bit more
\keys_set_filter:nnvN shuffling to do to keep everything nestable.
\keys_set_filter:nnoN
\keys_set_filter:nnnnN
\keys_set_filter:nnVnN
\keys_set_filter:nnvnN
\keys_set_filter:nnonN
\__keys_set_filter:nnnnN
\keys_set_filter:nnn
\keys_set_filter:nnV
\keys_set_filter:nnv
\keys_set_filter:nno
\__keys_set_filter:nnnn
\keys_set_groups:nnn
\keys_set_groups:nnV
\keys_set_groups:nnv
\keys_set_groups:nno

```

```

14994     }
14995     \cs_generate_variant:Nn \keys_set_filter:nnnN { nnV , nnv , nno }
14996     \cs_new_protected:Npn \keys_set_filter:nnnnN #1#2#3#4#5
14997     {
14998         \exp_args:No \__keys_set_filter:nnnnnN
14999         \l__keys_unused_clist {#4} {#1} {#2} {#3} #5
15000     }
15001     \cs_generate_variant:Nn \keys_set_filter:nnnnN { nnV , nnv , nno }
15002     \cs_new_protected:Npn \__keys_set_filter:nnnnnN #1#2#3#4#5#6
15003     {
15004         \clist_clear:N \l__keys_unused_clist
15005         \__keys_set_filter:nnnn {#2} {#3} {#4} {#5}
15006         \tl_set:Nx #6 { \exp_not:o { \l__keys_unused_clist } }
15007         \tl_set:Nn \l__keys_unused_clist {#1}
15008     }
15009     \cs_new_protected:Npn \keys_set_filter:nnn #1#2#3
15010     { \__keys_set_filter:nnnn { \q_no_value } {#1} {#2} {#3} }
15011     \cs_generate_variant:Nn \keys_set_filter:nnn { nnV , nnv , nno }
15012     \cs_new_protected:Npn \__keys_set_filter:nnnn #1#2#3#4
15013     {
15014         \use:x
15015         {
15016             \bool_set_false:N \exp_not:N \l__keys_only_known_bool
15017             \bool_set_true:N \exp_not:N \l__keys_filtered_bool
15018             \bool_set_true:N \exp_not:N \l__keys_selective_bool
15019             \tl_set:Nn \exp_not:N \l__keys_relative_tl { \exp_not:n {#1} }
15020             \__keys_set_selective:nnn \exp_not:n { {#2} {#3} {#4} }
15021             \bool_if:NT \l__keys_only_known_bool
15022             { \bool_set_true:N \exp_not:N \l__keys_only_known_bool }
15023             \bool_if:NF \l__keys_filtered_bool
15024             { \bool_set_false:N \exp_not:N \l__keys_filtered_bool }
15025             \bool_if:NF \l__keys_selective_bool
15026             { \bool_set_false:N \exp_not:N \l__keys_selective_bool }
15027             \tl_set:Nn \exp_not:N \l__keys_relative_tl
15028             { \exp_not:o \l__keys_relative_tl }
15029         }
15030     }
15031     \cs_new_protected:Npn \keys_set_groups:nnn #1#2#3
15032     {
15033         \use:x
15034         {
15035             \bool_set_false:N \exp_not:N \l__keys_only_known_bool
15036             \bool_set_false:N \exp_not:N \l__keys_filtered_bool
15037             \bool_set_true:N \exp_not:N \l__keys_selective_bool
15038             \tl_set:Nn \exp_not:N \l__keys_relative_tl
15039             { \exp_not:N \q_no_value }
15040             \__keys_set_selective:nnn \exp_not:n { {#1} {#2} {#3} }
15041             \bool_if:NT \l__keys_only_known_bool
15042             { \bool_set_true:N \exp_not:N \l__keys_only_known_bool }
15043             \bool_if:NF \l__keys_filtered_bool
15044             { \bool_set_true:N \exp_not:N \l__keys_filtered_bool }
15045             \bool_if:NF \l__keys_selective_bool
15046             { \bool_set_false:N \exp_not:N \l__keys_selective_bool }
15047             \tl_set:Nn \exp_not:N \l__keys_relative_tl

```



```

15048         { \exp_not:o \l__keys_relative_tl }
15049     }
15050 }
15051 \cs_generate_variant:Nn \keys_set_groups:nnn { nnV , nnv , nno }
15052 \cs_new_protected:Npn \__keys_set_selective:nnn
15053 { \exp_args:No \__keys_set_selective:nnnn \l__keys_selective_seq }
15054 \cs_new_protected:Npn \__keys_set_selective:nnnn #1#2#3#4
15055 {
15056     \seq_set_from_clist:Nn \l__keys_selective_seq {#3}
15057     \__keys_set:nn {#2} {#4}
15058     \tl_set:Nn \l__keys_selective_seq {#1}
15059 }

```

(End definition for `\keys_set_filter:nnnN` and others. These functions are documented on page 186.)

```

\__keys_set_keyval:n A shared system once again. First, set the current path and add a default if needed.
\__keys_set_keyval:nn There are then checks to see if the a value is required or forbidden. If everything passes,
\__keys_set_keyval:nnn move on to execute the code.
\__keys_set_keyval:onn
\__keys_find_key_module:NNw
\__keys_set_selective:
15060 \cs_new_protected:Npn \__keys_set_keyval:n #1
15061 {
15062     \bool_set_true:N \l__keys_no_value_bool
15063     \__keys_set_keyval:onn \l__keys_module_tl {#1} { }
15064 }
15065 \cs_new_protected:Npn \__keys_set_keyval:nn #1#2
15066 {
15067     \bool_set_false:N \l__keys_no_value_bool
15068     \__keys_set_keyval:onn \l__keys_module_tl {#1} {#2}
15069 }

```

The key path here can be fully defined, after which there is a search for the key and module names: the user may have passed them with part of what is actually the module (for our purposes) in the key name. As that happens on a per-key basis, we use the stack approach to restore the module name without a group.

```

15070 \cs_new_protected:Npn \__keys_set_keyval:nnn #1#2#3
15071 {
15072     \tl_set:Nx \l__keys_path_tl
15073     {
15074         \tl_if_blank:nF {#1}
15075         { #1 / }
15076         \__keys_trim_spaces:n {#2}
15077     }
15078     \tl_clear:N \l__keys_module_tl
15079     \tl_clear:N \l__keys_inherit_tl
15080     \exp_after:wN \__keys_find_key_module:NNw
15081     \exp_after:wN \l__keys_module_tl
15082     \exp_after:wN \l__keys_key_tl
15083     \l__keys_path_tl / \q_stop
15084     \__keys_value_or_default:n {#3}
15085     \bool_if:NTF \l__keys_selective_bool
15086     { \__keys_set_selective: }
15087     { \__keys_execute: }
15088     \tl_set:Nn \l__keys_module_tl {#1}
15089 }
15090 \cs_generate_variant:Nn \__keys_set_keyval:nnn { o }

```

```

15091 \cs_new_protected:Npn \__keys_find_key_module:NNw #1#2#3 / #4 \q_stop
15092 {
15093   \tl_if_blank:nTF {#4}
15094   { \tl_set:Nn #2 {#3} }
15095   {
15096     \tl_put_right:Nx #1
15097     {
15098       \tl_if_empty:NF #1 { / }
15099       #3
15100     }
15101     \__keys_find_key_module:NNw #1#2 #4 \q_stop
15102   }
15103 }

```

If selective setting is active, there are a number of possible sub-cases to consider. The key name may not be known at all or if it is, it may not have any groups assigned. There is then the question of whether the selection is opt-in or opt-out.

```

15104 \cs_new_protected:Npn \__keys_set_selective:
15105 {
15106   \cs_if_exist:cTF { \c__keys_groups_root_tl \l_keys_path_tl }
15107   {
15108     \clist_set_eq:Nc \l__keys_groups_clist
15109     { \c__keys_groups_root_tl \l_keys_path_tl }
15110     \__keys_check_groups:
15111   }
15112   {
15113     \bool_if:NTF \l__keys_filtered_bool
15114     { \__keys_execute: }
15115     { \__keys_store_unused: }
15116   }
15117 }

```

In the case where selective setting requires a comparison of the list of groups which apply to a key with the list of those which have been set active. That requires two mappings, and again a different outcome depending on whether opt-in or opt-out is set.

```

15118 \cs_new_protected:Npn \__keys_check_groups:
15119 {
15120   \bool_set_false:N \l__keys_tmp_bool
15121   \seq_map_inline:Nn \l__keys_selective_seq
15122   {
15123     \clist_map_inline:Nn \l__keys_groups_clist
15124     {
15125       \str_if_eq:nnT {##1} {####1}
15126       {
15127         \bool_set_true:N \l__keys_tmp_bool
15128         \clist_map_break:n { \seq_map_break: }
15129       }
15130     }
15131   }
15132   \bool_if:NTF \l__keys_tmp_bool
15133   {
15134     \bool_if:NTF \l__keys_filtered_bool
15135     { \__keys_store_unused: }
15136     { \__keys_execute: }
15137   }

```

```

15138     {
15139         \bool_if:NTF \l__keys_filtered_bool
15140         { \__keys_execute: }
15141         { \__keys_store_unused: }
15142     }
15143 }

```

(End definition for __keys_set_keyval:n and others.)

__keys_value_or_default:n If a value is given, return it as #1, otherwise send a default if available.

```

\__keys_default_inherit:
15144 \cs_new_protected:Npn \__keys_value_or_default:n #1
15145 {
15146     \bool_if:NTF \l__keys_no_value_bool
15147     {
15148         \cs_if_exist:cTF { \c__keys_default_root_tl \l_keys_path_tl }
15149         {
15150             \tl_set_eq:Nc
15151             \l_keys_value_tl
15152             { \c__keys_default_root_tl \l_keys_path_tl }
15153         }
15154         {
15155             \tl_clear:N \l_keys_value_tl
15156             \cs_if_exist:cT
15157             { \c__keys_inherit_root_tl \__keys_parent:o \l_keys_path_tl }
15158             { \__keys_default_inherit: }
15159         }
15160     }
15161     { \tl_set:Nn \l_keys_value_tl {#1} }
15162 }
15163 \cs_new_protected:Npn \__keys_default_inherit:
15164 {
15165     \clist_map_inline:cn
15166     { \c__keys_inherit_root_tl \__keys_parent:o \l_keys_path_tl }
15167     {
15168         \cs_if_exist:cT
15169         { \c__keys_default_root_tl ##1 / \l_keys_key_tl }
15170         {
15171             \tl_set_eq:Nc
15172             \l_keys_value_tl
15173             { \c__keys_default_root_tl ##1 / \l_keys_key_tl }
15174             \clist_map_break:
15175         }
15176     }
15177 }

```

(End definition for __keys_value_or_default:n and __keys_default_inherit:.)

__keys_execute: Actually executing a key is done in two parts. First, look for the key itself, then look
 __keys_execute_inherit: for the **unknown** key with the same path. If both of these fail, complain. What exactly
 __keys_execute_unknown: happens if a key is unknown depends on whether unknown keys are being skipped or if
 __keys_execute:nn an error should be raised.

```

\__keys_store_unused:
15178 \cs_new_protected:Npn \__keys_execute:
\__keys_store_unused_aux:
15179 {
15180     \cs_if_exist:cTF { \c__keys_code_root_tl \l_keys_path_tl }

```

```

15181     {
15182         \cs_if_exist_use:c { \c__keys_validate_root_tl \l_keys_path_tl }
15183         \cs:w \c__keys_code_root_tl \l_keys_path_tl \exp_after:wN \cs_end:
15184         \exp_after:wN { \l_keys_value_tl }
15185     }
15186     {
15187         \cs_if_exist:cTF
15188         { \c__keys_inherit_root_tl \__keys_parent:o \l_keys_path_tl }
15189         { \__keys_execute_inherit: }
15190         { \__keys_execute_unknown: }
15191     }
15192 }

```

To deal with the case where there is no hit, we leave `__keys_execute_unknown:` in the input stream and clean it up using the break function: that avoids needing a boolean.

```

15193 \cs_new_protected:Npn \__keys_execute_inherit:
15194 {
15195     \clist_map_inline:cn
15196     { \c__keys_inherit_root_tl \__keys_parent:o \l_keys_path_tl }
15197     {
15198         \cs_if_exist:cT
15199         { \c__keys_code_root_tl ##1 / \l_keys_key_tl }
15200         {
15201             \tl_set:Nn \l__keys_inherit_tl {##1}
15202             \cs:w \c__keys_code_root_tl ##1 / \l_keys_key_tl
15203             \exp_after:wN \cs_end: \exp_after:wN
15204             { \l_keys_value_tl }
15205             \clist_map_break:n { \use_none:n }
15206         }
15207     }
15208     \__keys_execute_unknown:
15209 }
15210 \cs_new_protected:Npn \__keys_execute_unknown:
15211 {
15212     \bool_if:NTF \l__keys_only_known_bool
15213     { \__keys_store_unused: }
15214     {
15215         \cs_if_exist:cTF
15216         { \c__keys_code_root_tl \l__keys_module_tl / unknown }
15217         {
15218             \cs:w \c__keys_code_root_tl \l__keys_module_tl / unknown
15219             \exp_after:wN \cs_end: \exp_after:wN { \l_keys_value_tl }
15220         }
15221         {
15222             \__kernel_msg_error:nxxx { kernel } { key-unknown }
15223             { \l_keys_path_tl } { \l__keys_module_tl }
15224         }
15225     }
15226 }
15227 \cs_new:Npn \__keys_execute:nn #1#2
15228 {
15229     \cs_if_exist:cTF { \c__keys_code_root_tl #1 }
15230     {
15231         \cs:w \c__keys_code_root_tl #1 \exp_after:wN \cs_end:

```

```

15232         \exp_after:wN { \l_keys_value_tl }
15233     }
15234     {#2}
15235 }

```

When there is no relative path, things here are easy: just save the key name and value. When we are working with a relative path, first we need to turn it into a string: that can't happen earlier as we need to store `\q_no_value`. Then, use a standard delimited approach to fish out the partial path.

```

15236 \cs_new_protected:Npn \__keys_store_unused:
15237 {
15238     \quark_if_no_value:NTF \l__keys_relative_tl
15239     {
15240         \clist_put_right:Nx \l__keys_unused_clist
15241         {
15242             \exp_not:o \l_keys_key_tl
15243             \bool_if:NF \l__keys_no_value_bool
15244             { = { \exp_not:o \l_keys_value_tl } }
15245         }
15246     }
15247     {
15248         \tl_if_empty:NTF \l__keys_relative_tl
15249         {
15250             \clist_put_right:Nx \l__keys_unused_clist
15251             {
15252                 \exp_not:o \l_keys_path_tl
15253                 \bool_if:NF \l__keys_no_value_bool
15254                 { = { \exp_not:o \l_keys_value_tl } }
15255             }
15256         }
15257         { \__keys_store_unused_aux: }
15258     }
15259 }
15260 \cs_new_protected:Npn \__keys_store_unused_aux:
15261 {
15262     \tl_set:Nx \l__keys_relative_tl
15263     { \exp_args:No \__keys_trim_spaces:n \l__keys_relative_tl }
15264     \use:x
15265     {
15266         \cs_set_protected:Npn \__keys_store_unused:w
15267         #####1 \l__keys_relative_tl /
15268         #####2 \l__keys_relative_tl /
15269         #####3 \exp_not:N \q_stop
15270     }
15271     {
15272         \tl_if_blank:nF {##1}
15273         {
15274             \__kernel_msg_error:nxxx { kernel } { bad-relative-key-path }
15275             \l_keys_path_tl
15276             \l__keys_relative_tl
15277         }
15278         \clist_put_right:Nx \l__keys_unused_clist
15279         {
15280             \exp_not:n {##2}

```

```

15281         \bool_if:NF \l__keys_no_value_bool
15282         { = { \exp_not:o \l_keys_value_tl } }
15283     }
15284 }
15285 \use:x
15286 {
15287     \__keys_store_unused:w \l_keys_path_tl
15288     \l__keys_relative_tl / \l__keys_relative_tl /
15289     \exp_not:N \q_stop
15290 }
15291 }
15292 \cs_new_protected:Npn \__keys_store_unused:w { }

```

(End definition for __keys_execute: and others.)

__keys_choice_find:n Executing a choice has two parts. First, try the choice given, then if that fails call the unknown key. That always exists, as it is created when a choice is first made. So there is no need for any escape code. For multiple choices, the same code ends up used in a mapping.

```

15293 \cs_new:Npn \__keys_choice_find:n #1
15294 {
15295     \tl_if_empty:NTF \l__keys_inherit_tl
15296     { \__keys_choice_find:nn { \l_keys_path_tl } {#1} }
15297     {
15298         \__keys_choice_find:nn
15299         { \l__keys_inherit_tl / \l_keys_key_tl } {#1}
15300     }
15301 }
15302 \cs_new:Npn \__keys_choice_find:nn #1#2
15303 {
15304     \cs_if_exist:cTF { \c__keys_code_root_tl #1 / \__keys_trim_spaces:n {#2} }
15305     { \use:c { \c__keys_code_root_tl #1 / \__keys_trim_spaces:n {#2} } {#2} }
15306     { \use:c { \c__keys_code_root_tl #1 / unknown } {#2} }
15307 }
15308 \cs_new:Npn \__keys_multichoice_find:n #1
15309 { \clist_map_function:nN {#1} \__keys_choice_find:n }

```

(End definition for __keys_choice_find:n, __keys_choice_find:nn, and __keys_multichoice_find:n.)

22.7 Utilities

__keys_parent:n Used to strip off the ending part of the key path after the last /.

```

\__keys_parent:o
\__keys_parent:w
15310 \cs_new:Npn \__keys_parent:n #1
15311 { \__keys_parent:w #1 / / \q_stop { } }
15312 \cs_generate_variant:Nn \__keys_parent:n { o }
15313 \cs_new:Npn \__keys_parent:w #1 / #2 / #3 \q_stop #4
15314 {
15315     \tl_if_blank:nTF {#2}
15316     {
15317         \tl_if_blank:nF {#4}
15318         { \use_none:n #4 }
15319     }
15320     {

```

```

15321         \_keys_parent:w #2 / #3 \q_stop { #4 / #1 }
15322     }
15323 }

```

(End definition for _keys_parent:n and _keys_parent:w.)

_keys_trim_spaces:n Space stripping has to allow for the fact that the key here might have several parts, and spaces need to be stripped from each part.

```

15324 \cs_new:Npn \_keys_trim_spaces:n #1
15325 {
15326     \exp_after:wN \_keys_trim_spaces_auxi:w \tl_to_str:n {#1}
15327     / \q_nil \q_stop
15328 }
15329 }
15330 \cs_new:Npn \_keys_trim_spaces_auxi:w #1 / #2 \q_stop
15331 {
15332     \quark_if_nil:nTF {#2}
15333     { \tl_trim_spaces:n {#1} }
15334     { \_keys_trim_spaces_auxii:w #1 / #2 }
15335 }
15336 \cs_new:Npn \_keys_trim_spaces_auxii:w #1 / #2 / \q_nil
15337 {
15338     \tl_trim_spaces:n {#1}
15339     \_keys_trim_spaces_auxiii:w #2 / \q_recursion_tail / \q_recursion_stop
15340 }
15341 \cs_set:Npn \_keys_trim_spaces_auxiii:w #1 /
15342 {
15343     \quark_if_recursion_tail_stop:n {#1}
15344     \tl_trim_spaces:n { / #1 }
15345     \_keys_trim_spaces_auxiii:w
15346 }

```

(End definition for _keys_trim_spaces:n and others.)

\keys_if_exist:p:nnn A utility for others to see if a key exists.

```

\keys_if_exist:nnTF
15347 \prg_new_conditional:Npnn \keys_if_exist:nn #1#2 { p , T , F , TF }
15348 {
15349     \cs_if_exist:cTF
15350     { \c__keys_code_root_tl \_keys_trim_spaces:n { #1 / #2 } }
15351     { \prg_return_true: }
15352     { \prg_return_false: }
15353 }

```

(End definition for \keys_if_exist:nnTF. This function is documented on page 186.)

\keys_if_choice_exist:p:nnn Just an alternative view on \keys_if_exist:nnTF.

```

\keys_if_choice_exist:nnnTF
15354 \prg_new_conditional:Npnn \keys_if_choice_exist:nnn #1#2#3
15355 { p , T , F , TF }
15356 {
15357     \cs_if_exist:cTF
15358     { \c__keys_code_root_tl \_keys_trim_spaces:n { #1 / #2 / #3 } }
15359     { \prg_return_true: }
15360     { \prg_return_false: }
15361 }

```

(End definition for `\keys_if_choice_exist:nnnTF`. This function is documented on page 186.)

```

\keys_show:nn To show a key, show its code using a message.
\keys_log:nn
\__keys_show:Nnn
15362 \cs_new_protected:Npn \keys_show:nn
15363 { \__keys_show:Nnn \msg_show:nnxxxx }
15364 \cs_new_protected:Npn \keys_log:nn
15365 { \__keys_show:Nnn \msg_log:nnxxxx }
15366 \cs_new_protected:Npn \__keys_show:Nnn #1#2#3
15367 {
15368   #1 { LaTeX / kernel } { show-key }
15369   { \__keys_trim_spaces:n { #2 / #3 } }
15370   {
15371     \keys_if_exist:nnT {#2} {#3}
15372     {
15373       \exp_args:Nnf \msg_show_item_unbraced:nn { code }
15374       {
15375         \exp_args:Nc \cs_replacement_spec:N
15376         {
15377           \c__keys_code_root_tl
15378           \__keys_trim_spaces:n { #2 / #3 }
15379         }
15380       }
15381     }
15382   }
15383   { } { }
15384 }

```

(End definition for `\keys_show:nn`, `\keys_log:nn`, and `__keys_show:Nnn`. These functions are documented on page 186.)

22.8 Messages

For when there is a need to complain.

```

15385 \__kernel_msg_new:nnnn { kernel } { bad-relative-key-path }
15386 { The-key~'#1'~is-not~inside~the~'#2'~path. }
15387 { The-key~'#1'~cannot~be~expressed~relative~to~path~'#2'. }
15388 \__kernel_msg_new:nnnn { kernel } { boolean-values-only }
15389 { Key~'#1'~accepts~boolean~values~only. }
15390 { The-key~'#1'~only~accepts~the~values~'true'~and~'false'. }
15391 \__kernel_msg_new:nnnn { kernel } { key-choice-unknown }
15392 { Key~'#1'~accepts~only~a~fixed~set~of~choices. }
15393 {
15394   The-key~'#1'~only~accepts~predefined~values,~
15395   and~'#2'~is~not~one~of~these.
15396 }
15397 \__kernel_msg_new:nnnn { kernel } { key-unknown }
15398 { The-key~'#1'~is~unknown~and~is~being~ignored. }
15399 {
15400   The-module~'#2'~does~not~have~a~key~called~'#1'.\\
15401   Check~that~you~have~spelled~the~key~name~correctly.
15402 }
15403 \__kernel_msg_new:nnnn { kernel } { nested-choice-key }
15404 { Attempt~to~define~'#1'~as~a~nested~choice~key. }
15405 {

```



```

15406     The~key~'#1'~cannot~be~defined~as~a~choice~as~the~parent~key~'#2'~is~
15407     itself~a~choice.
15408   }
15409   \__kernel_msg_new:nnnn { kernel } { value-forbidden }
15410   { The~key~'#1'~does~not~take~a~value. }
15411   {
15412     The~key~'#1'~should~be~given~without~a~value.\\
15413     The~value~'#2'~was~present:~the~key~will~be~ignored.
15414   }
15415   \__kernel_msg_new:nnnn { kernel } { value-required }
15416   { The~key~'#1'~requires~a~value. }
15417   {
15418     The~key~'#1'~must~have~a~value.\\
15419     No~value~was~present:~the~key~will~be~ignored.
15420   }
15421   \__kernel_msg_new:nnn { kernel } { show-key }
15422   {
15423     The~key~#1~
15424     \tl_if_empty:nTF {#2}
15425     { is~undefined. }
15426     { has~the~properties: #2 . }
15427   }
15428 </initex | package>

```

23 l3intarray implementation

```

15429 <*initex | package>
15430 <@@=intarray>

```

23.1 Allocating arrays

`__intarray_entry:w` We use these primitives quite a lot in this module.

`__intarray_count:w` 15431 \cs_new_eq:NN __intarray_entry:w \tex_fontdimen:D
15432 \cs_new_eq:NN __intarray_count:w \tex_hyphenchar:D

(End definition for __intarray_entry:w and __intarray_count:w.)

`\l__intarray_loop_int` A loop index.

15433 \int_new:N \l__intarray_loop_int

(End definition for \l__intarray_loop_int.)

`\c__intarray_sp_dim` Used to convert integers to dimensions fast.

15434 \dim_const:Nn \c__intarray_sp_dim { 1 sp }

(End definition for \c__intarray_sp_dim.)

`\g__intarray_font_int` Used to assign one font per array.

15435 \int_new:N \g__intarray_font_int

(End definition for \g__intarray_font_int.)

15436 __kernel_msg_new:nnn { kernel } { negative-array-size }
15437 { Size~of~array~may~not~be~negative:~#1 }

\intarray_new:Nn Declare #1 to be a font (arbitrarily cmr10 at a never-used size). Store the array's size as the \hyphenchar of that font and make sure enough \fontdimen are allocated, by setting the last one. Then clear any \fontdimen that cmr10 starts with. It seems LuaTeX's cmr10 has an extra \fontdimen parameter number 8 compared to other engines (for a math font we would replace 8 by 22 or some such). Every intarray must be global; it's enough to run this check in \intarray_new:Nn.

```

15438 \cs_new_protected:Npn \__intarray_new:N #1
15439 {
15440   \__kernel_chk_if_free_cs:N #1
15441   \int_gincr:N \g__intarray_font_int
15442   \tex_global:D \tex_font:D #1
15443   = cmr10~at~ \g__intarray_font_int \c__intarray_sp_dim \scan_stop:
15444   \int_step_inline:nn { 8 }
15445   { \__kernel_intarray_gset:Nnn #1 {##1} \c_zero_int }
15446 }
15447 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN g #1 } { }
15448 \cs_new_protected:Npn \intarray_new:Nn #1#2
15449 {
15450   \__intarray_new:N #1
15451   \__intarray_count:w #1 = \int_eval:n {#2} \scan_stop:
15452   \int_compare:nNnT { \intarray_count:N #1 } < 0
15453   {
15454     \__kernel_msg_error:nxx { kernel } { negative-array-size }
15455     { \intarray_count:N #1 }
15456   }
15457   \int_compare:nNnT { \intarray_count:N #1 } > 0
15458   { \__kernel_intarray_gset:Nnn #1 { \intarray_count:N #1 } { 0 } }
15459 }

```

(End definition for \intarray_new:Nn and __intarray_new:N. This function is documented on page 189.)

\intarray_count:N Size of an array.

```

15460 \cs_new:Npn \intarray_count:N #1 { \int_value:w \__intarray_count:w #1 }

```

(End definition for \intarray_count:N. This function is documented on page 189.)

23.2 Array items

__intarray_signed_max_dim:n Used when an item to be stored is larger than \c_max_dim in absolute value; it is replaced by $\pm \c_max_dim$.

```

15461 \cs_new:Npn \__intarray_signed_max_dim:n #1
15462 { \int_value:w \int_compare:nNnT {#1} < 0 { - } \c_max_dim }

```

(End definition for __intarray_signed_max_dim:n.)

__intarray_bounds:NNnTF The functions \intarray_gset:Nnn and \intarray_item:Nn share bounds checking. **__intarray_bounds_error:NNn** The T branch is used if #3 is within bounds of the array #2.

```

15463 \cs_new:Npn \__intarray_bounds:NNnTF #1#2#3#4#5
15464 {
15465   \if_int_compare:w 1 > #3 \exp_stop_f:
15466     \__intarray_bounds_error:NNn #1 #2 {#3}
15467     #5
15468   \else:

```

```

15469     \if_int_compare:w #3 > \intarray_count:N #2 \exp_stop_f:
15470     \__intarray_bounds_error:NNn #1 #2 {#3}
15471     #5
15472     \else:
15473     #4
15474     \fi:
15475 \fi:
15476 }
15477 \cs_new:Npn \__intarray_bounds_error:NNn #1#2#3
15478 {
15479     #1 { kernel } { out-of-bounds }
15480     { \token_to_str:N #2 } {#3} { \intarray_count:N #2 }
15481 }

```

(End definition for __intarray_bounds:NNnTF and __intarray_bounds_error:NNn.)

\intarray_gset:Nnn

Set the appropriate \fontdimen. The __kernel_intarray_gset:Nnn function does not use \int_eval:n, namely its arguments must be suitable for \int_value:w. The user version checks the position and value are within bounds.

__kernel_intarray_gset:Nnn

__intarray_gset:Nnn

__intarray_gset_overflow:Nnn

```

15482 \cs_new_protected:Npn \__kernel_intarray_gset:Nnn #1#2#3
15483 { \__intarray_entry:w #2 #1 #3 \c__intarray_sp_dim }
15484 \cs_new_protected:Npn \intarray_gset:Nnn #1#2#3
15485 {
15486     \exp_after:wN \__intarray_gset:Nww
15487     \exp_after:wN #1
15488     \int_value:w \int_eval:n {#2} \exp_after:wN ;
15489     \int_value:w \int_eval:n {#3} ;
15490 }
15491 \cs_new_protected:Npn \__intarray_gset:Nww #1#2 ; #3 ;
15492 {
15493     \__intarray_bounds:NNnTF \__kernel_msg_error:nxxxx #1 {#2}
15494     {
15495         \__intarray_gset_overflow_test:nw {#3}
15496         \__kernel_intarray_gset:Nnn #1 {#2} {#3}
15497     }
15498     { }
15499 }
15500 \cs_if_exist:NTF \tex_ifabsnum:D
15501 {
15502     \cs_new_protected:Npn \__intarray_gset_overflow_test:nw #1
15503     {
15504         \tex_ifabsnum:D #1 > \c_max_dim
15505         \exp_after:wN \__intarray_gset_overflow:NNnn
15506         \fi:
15507     }
15508 }
15509 {
15510     \cs_new_protected:Npn \__intarray_gset_overflow_test:nw #1
15511     {
15512         \if_int_compare:w \int_abs:n {#1} > \c_max_dim
15513         \exp_after:wN \__intarray_gset_overflow:NNnn
15514         \fi:
15515     }
15516 }

```

```

15517 \cs_new_protected:Npn \__intarray_gset_overflow:NNnn #1#2#3#4
15518 {
15519   \__kernel_msg_error:nnxxxx { kernel } { overflow }
15520   { \token_to_str:N #2 } {#3} {#4} { \__intarray_signed_max_dim:n {#4} }
15521   #1 #2 {#3} { \__intarray_signed_max_dim:n {#4} }
15522 }

```

(End definition for `\intarray_gset:Nnn` and others. This function is documented on page 189.)

`\intarray_gzero:N` Set the appropriate `\fontdimen` to zero. No bound checking needed. The `\prg_replicate:nn` possibly uses quite a lot of memory, but this is somewhat comparable to the size of the array, and it is much faster than an `\int_step_inline:nn` loop.

```

15523 \cs_new_protected:Npn \intarray_gzero:N #1
15524 {
15525   \int_zero:N \l__intarray_loop_int
15526   \prg_replicate:nn { \intarray_count:N #1 }
15527   {
15528     \int_incr:N \l__intarray_loop_int
15529     \__intarray_entry:w \l__intarray_loop_int #1 \c_zero_dim
15530   }
15531 }

```

(End definition for `\intarray_gzero:N`. This function is documented on page 189.)

`\intarray_item:Nn` Get the appropriate `\fontdimen` and perform bound checks. The `__kernel_intarray_item:Nn` function omits bound checks and omits `\int_eval:n`, namely its argument must be a TeX integer suitable for `\int_value:w`.

```

15532 \cs_new:Npn \__kernel_intarray_item:Nn #1#2
15533 { \int_value:w \__intarray_entry:w #2 #1 }
15534 \cs_new:Npn \intarray_item:Nn #1#2
15535 {
15536   \exp_after:wN \__intarray_item:Nw
15537   \exp_after:wN #1
15538   \int_value:w \int_eval:n {#2} ;
15539 }
15540 \cs_new:Npn \__intarray_item:Nw #1#2 ;
15541 {
15542   \__intarray_bounds:NNnTF \__kernel_msg_expandable_error:nnfff #1 {#2}
15543   { \__kernel_intarray_item:Nn #1 {#2} }
15544   { 0 }
15545 }

```

(End definition for `\intarray_item:Nn`, `__kernel_intarray_item:Nn`, and `__intarray_item:Nn`. This function is documented on page 189.)

`\intarray_rand_item:N` Importantly, `\intarray_item:Nn` only evaluates its argument once.

```

15546 \cs_new:Npn \intarray_rand_item:N #1
15547 { \intarray_item:Nn #1 { \int_rand:n { \intarray_count:N #1 } } }

```

(End definition for `\intarray_rand_item:N`. This function is documented on page 189.)

23.3 Working with contents of integer arrays

At the time of writing these are candidates, but we need at least `\intarray_const_from_clist:Nn` in l3fp so before l3candidates.

`\intarray_const_from_clist:Nn`
`__intarray_const_from_clist:nN`

Similar to `\intarray_new:Nn` (which we don't use because when debugging is enabled that function checks the variable name starts with `g_`). We make use of the fact that `TEX` allows allocation of successive `\fontdimen` as long as no other font has been declared: no need to count the comma list items first. We need the code in `\intarray_gset:Nnn` that checks the item value is not too big, namely `__intarray_gset_overflow_test:nw`, but not the code that checks bounds. At the end, set the size of the intarray.

```

15548 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
15549 \cs_new_protected:Npn \intarray_const_from_clist:Nn #1#2
15550 {
15551   \__intarray_new:N #1
15552   \int_zero:N \l__intarray_loop_int
15553   \clist_map_inline:nn {#2}
15554     { \exp_args:Nf \__intarray_const_from_clist:nN { \int_eval:n {##1} } #1 }
15555   \__intarray_count:w #1 \l__intarray_loop_int
15556 }
15557 \cs_new_protected:Npn \__intarray_const_from_clist:nN #1#2
15558 {
15559   \int_incr:N \l__intarray_loop_int
15560   \__intarray_gset_overflow_test:nw {#1}
15561   \__kernel_intarray_gset:Nnn #2 \l__intarray_loop_int {#1}
15562 }

```

(End definition for `\intarray_const_from_clist:Nn` and `__intarray_const_from_clist:nN`. This function is documented on page 254.)

`\intarray_to_clist:N`
`__intarray_to_clist:Nn`
`__intarray_to_clist:w`

Loop through the array, putting a comma before each item. Remove the leading comma with `f`-expansion. We also use the auxiliary in `\intarray_show:N` with argument comma, space.

```

15563 \cs_new:Npn \intarray_to_clist:N #1 { \__intarray_to_clist:Nn #1 { , } }
15564 \cs_new:Npn \__intarray_to_clist:Nn #1#2
15565 {
15566   \int_compare:nNnF { \intarray_count:N #1 } = \c_zero_int
15567   {
15568     \exp_last_unbraced:Nf \use_none:n
15569       { \__intarray_to_clist:w 1 ; #1 {#2} \prg_break_point: }
15570   }
15571 }
15572 \cs_new:Npn \__intarray_to_clist:w #1 ; #2#3
15573 {
15574   \if_int_compare:w #1 > \__intarray_count:w #2
15575     \prg_break:n
15576   \fi:
15577   #3 \__kernel_intarray_item:Nn #2 {#1}
15578   \exp_after:wN \__intarray_to_clist:w
15579   \int_value:w \int_eval:w #1 + \c_one_int ; #2 {#3}
15580 }

```

(End definition for `\intarray_to_clist:N`, `__intarray_to_clist:Nn`, and `__intarray_to_clist:w`. This function is documented on page 254.)

`\intarray_show:N` Convert the list to a comma list (with spaces after each comma)

`\intarray_log:N`

```

15581 \cs_new_protected:Npn \intarray_show:N { \__intarray_show:NN \msg_show:nnxxxx }
15582 \cs_generate_variant:Nn \intarray_show:N { c }
15583 \cs_new_protected:Npn \intarray_log:N { \__intarray_show:NN \msg_log:nnxxxx }
15584 \cs_generate_variant:Nn \intarray_log:N { c }
15585 \cs_new_protected:Npn \__intarray_show:NN #1#2
15586 {
15587   \__kernel_chk_defined:NT #2
15588   {
15589     #1 { LaTeX/kernel } { show-intarray }
15590     { \token_to_str:N #2 }
15591     { \intarray_count:N #2 }
15592     { >~ \__intarray_to_clist:Nn #2 { , ~ } }
15593     { }
15594   }
15595 }

```

(End definition for `\intarray_show:N` and `\intarray_log:N`. These functions are documented on page 255.)

23.4 Random arrays

We only perform the bounds checks once. This is done by two `__intarray_gset_overflow_test:nw`, with an appropriate empty argument to avoid a spurious “at position #1” part in the error message. Then calculate the number of choices: this is at most $(2^{30} - 1) - (-(2^{30} - 1)) + 1 = 2^{31} - 1$, which just barely does not overflow. For small ranges use `__kernel_randint:n` (making sure to subtract 1 *before* adding the random number to the $\langle min \rangle$, to avoid overflow when $\langle min \rangle$ or $\langle max \rangle$ are $\pm \text{c_max_int}$), otherwise `__kernel_randint:nn`. Finally, if there are no random numbers do not define any of the auxiliaries.

```

15596 \cs_new_protected:Npn \intarray_gset_rand:Nn #1
15597 { \intarray_gset_rand:Nnn #1 { 1 } }
15598 \sys_if_rand_exist:TF
15599 {
15600   \cs_new_protected:Npn \intarray_gset_rand:Nnn #1#2#3
15601   {
15602     \__intarray_gset_rand:Nff #1
15603     { \int_eval:n {#2} } { \int_eval:n {#3} }
15604   }
15605   \cs_new_protected:Npn \__intarray_gset_rand:Nnn #1#2#3
15606   {
15607     \int_compare:nNnTF {#2} > {#3}
15608     {
15609       \__kernel_msg_expandable_error:nnnn
15610       { kernel } { randint-backward-range } {#2} {#3}
15611       \__intarray_gset_rand:Nnn #1 {#3} {#2}
15612     }
15613     {
15614       \__intarray_gset_overflow_test:nw {#2}
15615       \__intarray_gset_rand_auxi:Nnnn #1 { } {#2} {#3}
15616     }
15617   }
15618   \cs_generate_variant:Nn \__intarray_gset_rand:Nnn { Nff }

```

```

15619 \cs_new_protected:Npn \__intarray_gset_rand_auxi:Nnnn #1#2#3#4
15620 {
15621   \__intarray_gset_overflow_test:nw {#4}
15622   \__intarray_gset_rand_auxii:Nnnn #1 { } {#4} {#3}
15623 }
15624 \cs_new_protected:Npn \__intarray_gset_rand_auxii:Nnnn #1#2#3#4
15625 {
15626   \exp_args:NNf \__intarray_gset_rand_auxiii:Nnnn #1
15627   { \int_eval:n { #3 - #4 + 1 } } {#4} {#3}
15628 }
15629 \cs_new_protected:Npn \__intarray_gset_rand_auxiii:Nnnn #1#2#3#4
15630 {
15631   \exp_args:NNf \__intarray_gset_all_same:Nn #1
15632   {
15633     \int_compare:nNnTF {#2} > \c__kernel_randint_max_int
15634     {
15635       \exp_stop_f:
15636       \int_eval:n { \__kernel_randint:nn {#3} {#4} }
15637     }
15638     {
15639       \exp_stop_f:
15640       \int_eval:n { \__kernel_randint:n {#2} - 1 + #3 }
15641     }
15642   }
15643 }
15644 \cs_new_protected:Npn \__intarray_gset_all_same:Nn #1#2
15645 {
15646   \int_zero:N \l__intarray_loop_int
15647   \prg_replicate:nn { \intarray_count:N #1 }
15648   {
15649     \int_incr:N \l__intarray_loop_int
15650     \__kernel_intarray_gset:Nnn #1 \l__intarray_loop_int {#2}
15651   }
15652 }
15653 }
15654 {
15655   \cs_new_protected:Npn \intarray_gset_rand:Nnn #1#2#3
15656   {
15657     \__kernel_msg_error:nnn { kernel } { fp-no-random }
15658     { \intarray_gset_rand:Nnn #1 {#2} {#3} }
15659   }
15660 }

```

(End definition for `\intarray_gset_rand:Nn` and others. These functions are documented on page 254.)

15661 </initex | package>

24 l3fp implementation

Nothing to see here: everything is in the subfiles!

25 l3fp-aux implementation

15662 $\langle *initex \mid package \rangle$

15663 $\langle @@=fp \rangle$

25.1 Access to primitives

$\backslash_fp_int_eval:w$ Largely for performance reasons, we need to directly access primitives rather than use $\backslash_fp_int_eval_end:$ $\backslash_int_eval:n$. This happens *a lot*, so we use private names. The same is true for $\backslash_fp_int_to_roman:w$ $\backslash_romannumeral$, although it is used much less widely.

15664 $\backslash cs_new_eq:NN \backslash_fp_int_eval:w \backslash tex_numexpr:D$

15665 $\backslash cs_new_eq:NN \backslash_fp_int_eval_end: \backslash scan_stop:$

15666 $\backslash cs_new_eq:NN \backslash_fp_int_to_roman:w \backslash tex_romannumeral:D$

(End definition for $\backslash_fp_int_eval:w$, $\backslash_fp_int_eval_end:$, and $\backslash_fp_int_to_roman:w$.)

25.2 Internal representation

Internally, a floating point number $\langle X \rangle$ is a token list containing

$\backslash s_fp \backslash_fp_chk:w \langle case \rangle \langle sign \rangle \langle body \rangle ;$

Let us explain each piece separately.

Internal floating point numbers are used in expressions, and in this context are subject to **f**-expansion. They must leave a recognizable mark after **f**-expansion, to prevent the floating point number from being re-parsed. Thus, $\backslash s_fp$ is simply another name for $\backslash relax$.

When used directly without an accessor function, floating points should produce an error: this is the role of $\backslash_fp_chk:w$. We could make floating point variables be protected to prevent them from expanding under **x**-expansion, but it seems more convenient to treat them as a subcase of token list variables.

The (decimal part of the) IEEE-754-2008 standard requires the format to be able to represent special floating point numbers besides the usual positive and negative cases. We distinguish the various possibilities by their $\langle case \rangle$, which is a single digit:

0 zeros: $+0$ and -0 ,

1 “normal” numbers (positive and negative),

2 infinities: $+inf$ and $-inf$,

3 quiet and signalling **nan**.

The $\langle sign \rangle$ is 0 (positive) or 2 (negative), except in the case of **nan**, which have $\langle sign \rangle = 1$. This ensures that changing the $\langle sign \rangle$ digit to $2 - \langle sign \rangle$ is exactly equivalent to changing the sign of the number.

Special floating point numbers have the form

$\backslash s_fp \backslash_fp_chk:w \langle case \rangle \langle sign \rangle \backslash s_fp \dots ;$

where $\backslash s_fp \dots$ is a scan mark carrying information about how the number was formed (useful for debugging).

Normal floating point numbers ($\langle case \rangle = 1$) have the form

$\backslash s_fp \backslash_fp_chk:w 1 \langle sign \rangle \{ \langle exponent \rangle \} \{ \langle X_1 \rangle \} \{ \langle X_2 \rangle \} \{ \langle X_3 \rangle \} \{ \langle X_4 \rangle \} ;$

Table 3: Internal representation of floating point numbers.

Representation	Meaning
0 0 \s_fp_... ;	Positive zero.
0 2 \s_fp_... ;	Negative zero.
1 0 {\langle exponent\rangle} {\langle X_1\rangle} {\langle X_2\rangle} {\langle X_3\rangle} {\langle X_4\rangle} ;	Positive floating point.
1 2 {\langle exponent\rangle} {\langle X_1\rangle} {\langle X_2\rangle} {\langle X_3\rangle} {\langle X_4\rangle} ;	Negative floating point.
2 0 \s_fp_... ;	Positive infinity.
2 2 \s_fp_... ;	Negative infinity.
3 1 \s_fp_... ;	Quiet nan.
3 1 \s_fp_... ;	Signalling nan.

Here, the $\langle exponent \rangle$ is an integer, between -10000 and 10000 . The body consists in four blocks of exactly 4 digits, $0000 \leq \langle X_i \rangle \leq 9999$, and the floating point is

$$(-1)^{\langle sign \rangle / 2} \langle X_1 \rangle \langle X_2 \rangle \langle X_3 \rangle \langle X_4 \rangle \cdot 10^{\langle exponent \rangle - 16}$$

where we have concatenated the 16 digits. Currently, floating point numbers are normalized such that the $\langle exponent \rangle$ is minimal, in other words, $1000 \leq \langle X_1 \rangle \leq 9999$.

Calculations are done in base 10000, *i.e.* one myriad.

25.3 Using arguments and semicolons

_fp_use_none_stop_f:n This function removes an argument (typically a digit) and replaces it by \exp_stop_f:, a marker which stops f-type expansion.

```
15667 \cs_new:Npn \_fp\_use\_none\_stop\_f:n #1 { \exp\_stop\_f: }
```

(End definition for _fp_use_none_stop_f:n.)

_fp_use_s:n Those functions place a semicolon after one or two arguments (typically digits).

```
15668 \cs_new:Npn \_fp\_use\_s:n #1 { #1; }
15669 \cs_new:Npn \_fp\_use\_s:nn #1#2 { #1#2; }
```

(End definition for _fp_use_s:n and _fp_use_s:nn.)

_fp_use_none_until_s:w Those functions select specific arguments among a set of arguments delimited by a semicolon.

```
\_fp\_use\_i\_until\_s:nw
\_fp\_use\_ii\_until\_s:nnw
15670 \cs_new:Npn \_fp\_use\_none\_until\_s:w #1; { }
15671 \cs_new:Npn \_fp\_use\_i\_until\_s:nw #1#2; { #1 }
15672 \cs_new:Npn \_fp\_use\_ii\_until\_s:nnw #1#2#3; { #2 }
```

(End definition for _fp_use_none_until_s:w, _fp_use_i_until_s:nw, and _fp_use_ii_until_s:nnw.)

_fp_reverse_args:Nww Many internal functions take arguments delimited by semicolons, and it is occasionally useful to swap two such arguments.

```
15673 \cs_new:Npn \_fp\_reverse\_args:Nww #1 #2; #3; { #1 #3; #2; }
```

(End definition for _fp_reverse_args:Nww.)

`__fp_rrot:www` Rotate three arguments delimited by semicolons. This is the inverse (or the square) of the Forth primitive ROT, hence the name.

```
15674 \cs_new:Npn \__fp_rrot:www #1; #2; #3; { #2; #3; #1; }
```

(End definition for `__fp_rrot:www`.)

`__fp_use_i:ww` Many internal functions take arguments delimited by semicolons, and it is occasionally useful to remove one or two such arguments.

`__fp_use_i:www`

```
15675 \cs_new:Npn \__fp_use_i:ww #1; #2; { #1; }
```

```
15676 \cs_new:Npn \__fp_use_i:www #1; #2; #3; { #1; }
```

(End definition for `__fp_use_i:ww` and `__fp_use_i:www`.)

25.4 Constants, and structure of floating points

`__fp_misused:n` This receives a floating point object (floating point number or tuple) and generates an error stating that it was misused. This is called when for instance an `fp` variable is left in the input stream and its contents reach T_EX's stomach.

```
15677 \cs_new_protected:Npn \__fp_misused:n #1
```

```
15678 { \__kernel_msg_error:nnx { kernel } { misused-fp } { \fp_to_tl:n {#1} } }
```

(End definition for `__fp_misused:n`.)

`\s__fp` Floating points numbers all start with `\s__fp __fp_chk:w`, where `\s__fp` is equal to the T_EX primitive `\relax`, and `__fp_chk:w` is protected. The rest of the floating point number is made of characters (or `\relax`). This ensures that nothing expands under f-expansion, nor under x-expansion. However, when typeset, `\s__fp` does nothing, and `__fp_chk:w` is expanded. We define `__fp_chk:w` to produce an error.

`__fp_chk:w`

```
15679 \scan_new:N \s__fp
```

```
15680 \cs_new_protected:Npn \__fp_chk:w #1 ;
```

```
15681 { \__fp_misused:n { \s__fp \__fp_chk:w #1 ; } }
```

(End definition for `\s__fp` and `__fp_chk:w`.)

`\s__fp_mark` Aliases of `\tex_relax:D`, used to terminate expressions.

`\s__fp_stop`

```
15682 \scan_new:N \s__fp_mark
```

```
15683 \scan_new:N \s__fp_stop
```

(End definition for `\s__fp_mark` and `\s__fp_stop`.)

`\s__fp_invalid` A couple of scan marks used to indicate where special floating point numbers come from.

`\s__fp_underflow`

```
15684 \scan_new:N \s__fp_invalid
```

`\s__fp_overflow`

```
15685 \scan_new:N \s__fp_underflow
```

`\s__fp_division`

```
15686 \scan_new:N \s__fp_overflow
```

`\s__fp_exact`

```
15687 \scan_new:N \s__fp_division
```

```
15688 \scan_new:N \s__fp_exact
```

(End definition for `\s__fp_invalid` and others.)

`\c_zero_fp` The special floating points. We define the floating points here as “exact”.
`\c_minus_zero_fp`
`\c_inf_fp`
`\c_minus_inf_fp`
`\c_nan_fp`

```
15689 \tl_const:Nn \c_zero_fp { \s__fp \__fp_chk:w 0 0 \s__fp_exact ; }
```

```
15690 \tl_const:Nn \c_minus_zero_fp { \s__fp \__fp_chk:w 0 2 \s__fp_exact ; }
```

```
15691 \tl_const:Nn \c_inf_fp { \s__fp \__fp_chk:w 2 0 \s__fp_exact ; }
```

```
15692 \tl_const:Nn \c_minus_inf_fp { \s__fp \__fp_chk:w 2 2 \s__fp_exact ; }
```

```
15693 \tl_const:Nn \c_nan_fp { \s__fp \__fp_chk:w 3 1 \s__fp_exact ; }
```

(End definition for `\c_zero_fp` and others. These variables are documented on page 198.)

```

\c__fp_prec_int    The number of digits of floating points.
\c__fp_half_prec_int 15694 \int_const:Nn \c__fp_prec_int { 16 }
\c__fp_block_int   15695 \int_const:Nn \c__fp_half_prec_int { 8 }
                   15696 \int_const:Nn \c__fp_block_int { 4 }

```

(End definition for `\c__fp_prec_int`, `\c__fp_half_prec_int`, and `\c__fp_block_int`.)

```

\c__fp_myriad_int  Blocks have 4 digits so this integer is useful.
                   15697 \int_const:Nn \c__fp_myriad_int { 10000 }

```

(End definition for `\c__fp_myriad_int`.)

```

\c__fp_minus_min_exponent_int \c__fp_max_exponent_int Normal floating point numbers have an exponent between  $-\text{minus\_min\_exponent}$  and  $\text{max\_exponent}$  inclusive. Larger numbers are rounded to  $\pm\infty$ . Smaller numbers are rounded to  $\pm 0$ . It would be more natural to define a min_exponent with the opposite sign but that would waste one TEX count.

```

```

15698 \int_const:Nn \c__fp_minus_min_exponent_int { 10000 }
15699 \int_const:Nn \c__fp_max_exponent_int { 10000 }

```

(End definition for `\c__fp_minus_min_exponent_int` and `\c__fp_max_exponent_int`.)

```

\c__fp_max_exp_exponent_int If a number's exponent is larger than that, its exponential overflows/underflows.
15700 \int_const:Nn \c__fp_max_exp_exponent_int { 5 }

```

(End definition for `\c__fp_max_exp_exponent_int`.)

```

\c__fp_overflowing_fp A floating point number that is bigger than all normal floating point numbers. This replaces infinities when converting to formats that do not support infinities.

```

```

15701 \tl_const:Nx \c__fp_overflowing_fp
15702 {
15703   \s__fp \__fp_chk:w 1 0
15704   { \int_eval:n { \c__fp_max_exponent_int + 1 } }
15705   {1000} {0000} {0000} {0000} ;
15706 }

```

(End definition for `\c__fp_overflowing_fp`.)

```

\__fp_zero_fp:N In case of overflow or underflow, we have to output a zero or infinity with a given sign.
\__fp_inf_fp:N

```

```

15707 \cs_new:Npn \__fp_zero_fp:N #1
15708 { \s__fp \__fp_chk:w 0 #1 \s__fp_underflow ; }
15709 \cs_new:Npn \__fp_inf_fp:N #1
15710 { \s__fp \__fp_chk:w 2 #1 \s__fp_overflow ; }

```

(End definition for `__fp_zero_fp:N` and `__fp_inf_fp:N`.)

```

\__fp_exponent:w For normal numbers, the function expands to the exponent, otherwise to 0. This is used in l3str-format.

```

```

15711 \cs_new:Npn \__fp_exponent:w \s__fp \__fp_chk:w #1
15712 {
15713   \if_meaning:w 1 #1
15714   \exp_after:wN \__fp_use_ii_until_s:nnw
15715   \else:
15716   \exp_after:wN \__fp_use_i_until_s:nw
15717   \exp_after:wN 0
15718   \fi:
15719 }

```

When appearing in an integer expression or after `\int_value:w`, this expands to the sign opposite to `#1`, namely 0 (positive) is turned to 2 (negative), 1 (**nan**) to 1, and 2 to 0.

```
15720 \cs_new:Npn \__fp_neg_sign:N #1
15721 { \__fp_int_eval:w 2 - #1 \__fp_int_eval_end: }
```

25.5 Overflow, underflow, and exact zero

Expects the sign and the exponent in some order, then the significand (which we don't touch). Outputs the corresponding floating point number, possibly underflowed to ± 0 or overflowed to $\pm\infty$. The functions `_fp_underflow:w` and `_fp_overflow:w` are defined in `l3fp-traps`.

```

15722 \cs_new:Npn \__fp_sanitizew #1 #2;
15723 {
15724     \if_case:w
15725         \if_int_compare:w #2 > \c__fp_max_exponent_int 1 ~ \else:
15726         \if_int_compare:w #2 < - \c__fp_minus_min_exponent_int 2 ~ \else:
15727         \if_meaning:w 1 #1 3 ~ \fi: \fi: \fi: 0 ~
15728         \or: \exp_after:wN \__fp_overflow:w
15729         \or: \exp_after:wN \__fp_underflow:w
15730         \or: \exp_after:wN \__fp_sanitizew_zero:w
15731         \fi:
15732         \s__fp \__fp_chk:w 1 #1 {#2}
15733     }
15734 \cs_new:Npn \__fp_sanitizewN #1; #2 { \__fp_sanitizewN #2 #1; }
15735 \cs_new:Npn \__fp_sanitizew_zero:w \s__fp \__fp_chk:w #1 #2 #3;
15736 { \c_zero_fp }

```

25.6 Expanding after a floating point number

```

\__fp_exp_after_o:w <floating point>
\__fp_exp_after_f:nw {(tokens)} <floating point>

```

Places $\langle \textit{tokens} \rangle$ (empty in the case of `_fp_exp_after_o:w`) between the $\langle \textit{floating point} \rangle$ and the following tokens, then hits those tokens with `o` or `f`-expansion, and leaves the floating point number unchanged.

We first distinguish normal floating points, which have a significand, from the much simpler special floating points.

```

15737 \cs_new:Npn \__fp_exp_after_o:w \s__fp \__fp_chk:w #1
15738 {
15739     \if_meaning:w 1 #1
15740     \exp_after:wN \__fp_exp_after_normal:nNNw
15741     \else:
15742     \exp_after:wN \__fp_exp_after_special:nNNw
15743     \fi:
15744     { }
15745     #1
15746 }
15747 \cs_new:Npn \__fp_exp_after_f:nw #1 \s__fp \__fp_chk:w #2

```

```

15748 {
15749   \if_meaning:w 1 #2
15750   \exp_after:wN \_fp_exp_after_normal:nNNw
15751   \else:
15752     \exp_after:wN \_fp_exp_after_special:nNNw
15753   \fi:
15754   { \exp:w \exp_end_continue_f:w #1 }
15755   #2
15756 }

```

(End definition for _fp_exp_after_o:w and _fp_exp_after_f:nw.)

_fp_exp_after_special:nNNw _fp_exp_after_special:nNNw {⟨after⟩} ⟨case⟩ ⟨sign⟩ ⟨scan mark⟩ ;
Special floating point numbers are easy to jump over since they contain few tokens.

```

15757 \cs_new:Npn \_fp_exp_after_special:nNNw #1#2#3#4;
15758 {
15759   \exp_after:wN \s_fp
15760   \exp_after:wN \_fp_chk:w
15761   \exp_after:wN #2
15762   \exp_after:wN #3
15763   \exp_after:wN #4
15764   \exp_after:wN ;
15765   #1
15766 }

```

(End definition for _fp_exp_after_special:nNNw.)

_fp_exp_after_normal:nNNw For normal floating point numbers, life is slightly harder, since we have many tokens to jump over. Here it would be slightly better if the digits were not braced but instead were delimited arguments (for instance delimited by ,). That may be changed some day.

```

15767 \cs_new:Npn \_fp_exp_after_normal:nNNw #1 1 #2 #3 #4#5#6#7;
15768 {
15769   \exp_after:wN \_fp_exp_after_normal:Nwwwww
15770   \exp_after:wN #2
15771   \int_value:w #3 \exp_after:wN ;
15772   \int_value:w 1 #4 \exp_after:wN ;
15773   \int_value:w 1 #5 \exp_after:wN ;
15774   \int_value:w 1 #6 \exp_after:wN ;
15775   \int_value:w 1 #7 \exp_after:wN ; #1
15776 }
15777 \cs_new:Npn \_fp_exp_after_normal:Nwwwww
15778   #1 #2; 1 #3 ; 1 #4 ; 1 #5 ; 1 #6 ;
15779   { \s_fp \_fp_chk:w 1 #1 {#2} {#3} {#4} {#5} {#6} ; }

```

(End definition for _fp_exp_after_normal:nNNw.)

25.7 Other floating point types

\s_fp_tuple Floating point tuples take the form \s_fp_tuple _fp_tuple_chk:w { ⟨fp 1⟩ ⟨fp 2⟩
_fp_tuple_chk:w ... } ; where each ⟨fp⟩ is a floating point number or tuple, hence ends with ; itself. When
_c_fp_empty_tuple_fp a tuple is typeset, _fp_tuple_chk:w produces an error, just like usual floating point
numbers. Tuples may have zero or one element.

```

15780 \scan_new:N \s_fp_tuple
15781 \cs_new_protected:Npn \_fp_tuple_chk:w #1 ;

```

```

15782 { \__fp_misused:n { \s__fp_tuple \__fp_tuple_chk:w #1 ; } }
15783 \tl_const:Nn \c__fp_empty_tuple_fp
15784 { \s__fp_tuple \__fp_tuple_chk:w { } ; }

```

(End definition for \s__fp_tuple, __fp_tuple_chk:w, and \c__fp_empty_tuple_fp.)

__fp_tuple_count:w Count the number of items in a tuple of floating points by counting semicolons. The technique is very similar to \tl_count:n, but with the loop built-in. Checking for the end of the loop is done with the \use_none:n #1 construction.

```

15785 \cs_new:Npn \__fp_array_count:n #1
15786 { \__fp_tuple_count:w \s__fp_tuple \__fp_tuple_chk:w {#1} ; }
15787 \cs_new:Npn \__fp_tuple_count:w \s__fp_tuple \__fp_tuple_chk:w #1 ;
15788 {
15789   \int_value:w \__fp_int_eval:w 0
15790   \__fp_tuple_count_loop:Nw #1 { ? \prg_break: } ;
15791   \prg_break_point:
15792   \__fp_int_eval_end:
15793 }
15794 \cs_new:Npn \__fp_tuple_count_loop:Nw #1#2;
15795 { \use_none:n #1 + 1 \__fp_tuple_count_loop:Nw }

```

(End definition for __fp_tuple_count:w, __fp_array_count:n, and __fp_tuple_count_loop:Nw.)

__fp_if_type_fp:NTwFw Used as __fp_if_type_fp:NTwFw <marker> {<true code>} \s__fp {<false code>} \q_stop, this test whether the <marker> is \s__fp or not and runs the appropriate <code>. The very unusual syntax is for optimization purposes as that function is used for all floating point operations.

```

15796 \cs_new:Npn \__fp_if_type_fp:NTwFw #1 \s__fp #2 #3 \q_stop {#2}

```

(End definition for __fp_if_type_fp:NTwFw.)

__fp_array_if_all_fp:nTF True if all items are floating point numbers. Used for min.

```

\__fp_array_if_all_fp_loop:w
15797 \cs_new:Npn \__fp_array_if_all_fp:nTF #1
15798 {
15799   \__fp_array_if_all_fp_loop:w #1 { \s__fp \prg_break: } ;
15800   \prg_break_point: \use_i:nn
15801 }
15802 \cs_new:Npn \__fp_array_if_all_fp_loop:w #1#2 ;
15803 {
15804   \__fp_if_type_fp:NTwFw
15805   #1 \__fp_array_if_all_fp_loop:w
15806   \s__fp { \prg_break:n \use_iii:nnn }
15807   \q_stop
15808 }

```

(End definition for __fp_array_if_all_fp:nTF and __fp_array_if_all_fp_loop:w.)

__fp_type_from_scan:N Used as __fp_type_from_scan:N <token>. Grabs the pieces of the stringified <token> which lies after the first s__fp. If the <token> does not contain that string, the result is _?.

```

15809 \cs_new:Npn \__fp_type_from_scan:N #1
15810 {
15811   \__fp_if_type_fp:NTwFw
15812   #1 { }

```

```

15813     \s__fp { \__fp_type_from_scan_other:N #1 }
15814     \q_stop
15815   }
15816   \cs_new:Npx \__fp_type_from_scan_other:N #1
15817   {
15818     \exp_not:N \exp_after:wN \exp_not:N \__fp_type_from_scan:w
15819     \exp_not:N \token_to_str:N #1 \exp_not:N \q_mark
15820     \tl_to_str:n { s__fp _? } \exp_not:N \q_mark \exp_not:N \q_stop
15821   }
15822   \exp_last_unbraced:NNNNo
15823   \cs_new:Npn \__fp_type_from_scan:w #1
15824   { \tl_to_str:n { s__fp } } #2 \q_mark #3 \q_stop {#2}

```

(End definition for __fp_type_from_scan:N, __fp_type_from_scan_other:N, and __fp_type_from_scan:w.)

```

\__fp_change_func_type:NNN
\__fp_change_func_type_aux:w
  \__fp_change_func_type_chk:NNN

```

Arguments are $\langle type\ marker \rangle$ $\langle function \rangle$ $\langle recovery \rangle$. This gives the function obtained by placing the type after @@. If the function is not defined then $\langle recovery \rangle$ $\langle function \rangle$ is used instead; however that test is not run when the $\langle type\ marker \rangle$ is $\backslash s_fp$.

```

15825   \cs_new:Npn \__fp_change_func_type:NNN #1#2#3
15826   {
15827     \__fp_if_type_fp:NTwFw
15828     #1 #2
15829     \s__fp
15830     {
15831       \exp_after:wN \__fp_change_func_type_chk:NNN
15832       \cs:w
15833         __fp \__fp_type_from_scan_other:N #1
15834       \exp_after:wN \__fp_change_func_type_aux:w \token_to_str:N #2
15835       \cs_end:
15836       #2 #3
15837     }
15838     \q_stop
15839   }
15840   \exp_last_unbraced:NNNNo
15841   \cs_new:Npn \__fp_change_func_type_aux:w #1 { \tl_to_str:n { __fp } } { }
15842   \cs_new:Npn \__fp_change_func_type_chk:NNN #1#2#3
15843   {
15844     \if_meaning:w \scan_stop: #1
15845       \exp_after:wN #3 \exp_after:wN #2
15846     \else:
15847       \exp_after:wN #1
15848     \fi:
15849   }

```

(End definition for __fp_change_func_type:NNN, __fp_change_func_type_aux:w, and __fp_change_func_type_chk:NNN.)

```

\__fp_exp_after_any_f:Nnw
\__fp_exp_after_any_f:nw
\__fp_exp_after_stop_f:nw

```

The Nnw function simply dispatches to the appropriate $\backslash \text{__fp_exp_after}\dots_f:\text{nw}$ with “...” (either empty or $_ \langle type \rangle$) extracted from #1, which should start with $\backslash s_fp$. If it doesn’t start with $\backslash s_fp$ the function $\backslash \text{__fp_exp_after}_?_f:\text{nw}$ defined in `l3fp-parse` gives an error; another special $\langle type \rangle$ is `stop`, useful for loops, see below. The nw function has an important optimization for floating points numbers; it also fetches its type marker #2 from the floating point.

```

15850 \cs_new:Npn \__fp_exp_after_any_f:Nnw #1
15851 { \cs:w __fp_exp_after \__fp_type_from_scan_other:N #1 _f:nw \cs_end: }
15852 \cs_new:Npn \__fp_exp_after_any_f:nw #1#2
15853 {
15854   \__fp_if_type_fp:NTwFw
15855   #2 \__fp_exp_after_f:nw
15856   \s__fp { \__fp_exp_after_any_f:Nnw #2 }
15857   \q_stop
15858   {#1} #2
15859 }
15860 \cs_new_eq:NN \__fp_exp_after_stop_f:nw \use_none:nn

```

(End definition for __fp_exp_after_any_f:Nnw, __fp_exp_after_any_f:nw, and __fp_exp_after_stop_f:nw.)

__fp_exp_after_tuple_o:w The loop works by using the n argument of __fp_exp_after_any_f:nw to place the
__fp_exp_after_tuple_f:nw loop macro after the next item in the tuple and expand it.
__fp_exp_after_array_f:w

```

\__fp_exp_after_array_f:w
⟨fp1⟩ ;
...
⟨fpn⟩ ;
\s__fp_stop

```

```

15861 \cs_new:Npn \__fp_exp_after_tuple_o:w
15862 { \__fp_exp_after_tuple_f:nw { \exp_after:wN \exp_stop_f: } }
15863 \cs_new:Npn \__fp_exp_after_tuple_f:nw
15864 #1 \s__fp_tuple \__fp_tuple_chk:w #2 ;
15865 {
15866   \exp_after:wN \s__fp_tuple
15867   \exp_after:wN \__fp_tuple_chk:w
15868   \exp_after:wN {
15869     \exp:w \exp_end_continue_f:w
15870     \__fp_exp_after_array_f:w #2 \s__fp_stop
15871   \exp_after:wN }
15872   \exp_after:wN ;
15873   \exp:w \exp_end_continue_f:w #1
15874 }
15875 \cs_new:Npn \__fp_exp_after_array_f:w
15876 { \__fp_exp_after_any_f:nw { \__fp_exp_after_array_f:w } }

```

(End definition for __fp_exp_after_tuple_o:w, __fp_exp_after_tuple_f:nw, and __fp_exp_after_array_f:w.)

25.8 Packing digits

When a positive integer #1 is known to be less than 10⁸, the following trick splits it into two blocks of 4 digits, padding with zeros on the left.

```

\cs_new:Npn \pack:NNNNNw #1 #2#3#4#5 #6; { {#2#3#4#5} {#6} }
\exp_after:wN \pack:NNNNNw
\__fp_int_value:w \__fp_int_eval:w 1 0000 0000 + #1 ;

```


The idea is that adding 10^8 to the number ensures that it has exactly 9 digits, and can then easily find which digits correspond to what position in the number. Of course, this can be modified for any number of digits less or equal to 9 (we are limited by \TeX 's integers). This method is very heavily relied upon in `l3fp-basics`.

More specifically, the auxiliary inserts `+ #1#2#3#4#5 ; {#6}`, which allows us to compute several blocks of 4 digits in a nested manner, performing carries on the fly. Say we want to compute 12345×66778899 . With simplified names, we would do

```
\exp_after:wN \post_processing:w
\__fp_int_value:w \__fp_int_eval:w - 5 0000
\exp_after:wN \pack:NNNNNw
\__fp_int_value:w \__fp_int_eval:w 4 9995 0000
+ 12345 * 6677
\exp_after:wN \pack:NNNNNw
\__fp_int_value:w \__fp_int_eval:w 5 0000 0000
+ 12345 * 8899 ;
```

The `\exp_after:wN` triggers `\int_value:w __fp_int_eval:w`, which starts a first computation, whose initial value is -50000 (the “leading shift”). In that computation appears an `\exp_after:wN`, which triggers the nested computation `\int_value:w __fp_int_eval:w` with starting value 499950000 (the “middle shift”). That, in turn, expands `\exp_after:wN` which triggers the third computation. The third computation’s value is $500000000 + 12345 \times 8899$, which has 9 digits. Adding $5 \cdot 10^8$ to the product allowed us to know how many digits to expect as long as the numbers to multiply are not too big; it also works to some extent with negative results. The `pack` function puts the last 4 of those 9 digits into a brace group, moves the semi-colon delimiter, and inserts a `+`, which combines the carry with the previous computation. The shifts nicely combine into $500000000/10^4 + 499950000 = 500000000$. As long as the operands are in some range, the result of this second computation has 9 digits. The corresponding `pack` function, expanded after the result is computed, braces the last 4 digits, and leaves `+ <5 digits>` for the initial computation. The “leading shift” cancels the combination of the other shifts, and the `\post_processing:w` takes care of packing the last few digits.

Admittedly, this is quite intricate. It is probably the key in making `l3fp` as fast as other pure \TeX floating point units despite its increased precision. In fact, this is used so much that we provide different sets of packing functions and shifts, depending on ranges of input.

`__fp_pack:NNNNNw` This set of shifts allows for computations involving results in the range $[-4 \cdot 10^8, 5 \cdot 10^8 - 1]$. Shifted values all have exactly 9 digits.

```
15877 \int_const:Nn \c__fp_leading_shift_int { - 5 0000 }
15878 \int_const:Nn \c__fp_middle_shift_int { 5 0000 * 9999 }
15879 \int_const:Nn \c__fp_trailing_shift_int { 5 0000 * 10000 }
15880 \cs_new:Npn \__fp_pack:NNNNNw #1 #2#3#4#5 #6; { + #1#2#3#4#5 ; {#6} }
```

(End definition for `__fp_pack:NNNNNw` and others.)

`__fp_pack_big:NNNNNNw` This set of shifts allows for computations involving results in the range $[-5 \cdot 10^8, 6 \cdot 10^8 - 1]$ (actually a bit more). Shifted values all have exactly 10 digits. Note that the upper bound is due to \TeX 's limit of $2^{31} - 1$ on integers. The shifts are chosen to be roughly the mid-point of 10^9 and 2^{31} , the two bounds on 10-digit integers in \TeX .

```
15881 \int_const:Nn \c__fp_big_leading_shift_int { - 15 2374 }
```

```

15882 \int_const:Nn \c__fp_big_middle_shift_int { 15 2374 * 9999 }
15883 \int_const:Nn \c__fp_big_trailing_shift_int { 15 2374 * 10000 }
15884 \cs_new:Npn \__fp_pack_big:NNNNNNw #1#2 #3#4#5#6 #7;
15885 { + #1#2#3#4#5#6 ; {#7} }

```

(End definition for __fp_pack_big:NNNNNNw and others.)

```

\__fp_pack_Bigg:NNNNNNw
\c__fp_Bigg_trailing_shift_int
\c__fp_Bigg_middle_shift_int
\c__fp_Bigg_leading_shift_int

```

This set of shifts allows for computations with results in the range $[-1 \cdot 10^9, 147483647]$; the end-point is $2^{31} - 1 - 2 \cdot 10^9 \simeq 1.47 \cdot 10^8$. Shifted values all have exactly 10 digits.

```

15886 \int_const:Nn \c__fp_Bigg_leading_shift_int { - 20 0000 }
15887 \int_const:Nn \c__fp_Bigg_middle_shift_int { 20 0000 * 9999 }
15888 \int_const:Nn \c__fp_Bigg_trailing_shift_int { 20 0000 * 10000 }
15889 \cs_new:Npn \__fp_pack_Bigg:NNNNNNw #1#2 #3#4#5#6 #7;
15890 { + #1#2#3#4#5#6 ; {#7} }

```

(End definition for __fp_pack_Bigg:NNNNNNw and others.)

```
\__fp_pack_twice_four:wNNNNNNNN
```

__fp_pack_twice_four:wNNNNNNNN *<tokens>* ; *<≥ 8 digits>*

Grabs two sets of 4 digits and places them before the semi-colon delimiter. Putting several copies of this function before a semicolon packs more digits since each takes the digits packed by the others in its first argument.

```

15891 \cs_new:Npn \__fp_pack_twice_four:wNNNNNNNN #1; #2#3#4#5 #6#7#8#9
15892 { #1 {#2#3#4#5} {#6#7#8#9} ; }

```

(End definition for __fp_pack_twice_four:wNNNNNNNN.)

```
\__fp_pack_eight:wNNNNNNNN
```

__fp_pack_eight:wNNNNNNNN *<tokens>* ; *<≥ 8 digits>*

Grabs one set of 8 digits and places them before the semi-colon delimiter as a single group. Putting several copies of this function before a semicolon packs more digits since each takes the digits packed by the others in its first argument.

```

15893 \cs_new:Npn \__fp_pack_eight:wNNNNNNNN #1; #2#3#4#5 #6#7#8#9
15894 { #1 {#2#3#4#5#6#7#8#9} ; }

```

(End definition for __fp_pack_eight:wNNNNNNNN.)

```

\__fp_basics_pack_low:NNNNNw
\__fp_basics_pack_high:NNNNNw
\__fp_basics_pack_high_carry:w

```

Addition and multiplication of significands are done in two steps: first compute a (more or less) exact result, then round and pack digits in the final (braced) form. These functions take care of the packing, with special attention given to the case where rounding has caused a carry. Since rounding can only shift the final digit by 1, a carry always produces an exact power of 10. Thus, __fp_basics_pack_high_carry:w is always followed by four times {0000}.

This is used in l3fp-basics and l3fp-extended.

```

15895 \cs_new:Npn \__fp_basics_pack_low:NNNNNw #1 #2#3#4#5 #6;
15896 { + #1 - 1 ; {#2#3#4#5} {#6} ; }
15897 \cs_new:Npn \__fp_basics_pack_high:NNNNNw #1 #2#3#4#5 #6;
15898 {
15899   \if_meaning:w 2 #1
15900     \__fp_basics_pack_high_carry:w
15901   \fi:
15902   ; {#2#3#4#5} {#6}
15903 }
15904 \cs_new:Npn \__fp_basics_pack_high_carry:w \fi: ; #1
15905 { \fi: + 1 ; {1000} }

```

(End definition for `_fp_basics_pack_low:NNNNw`, `_fp_basics_pack_high:NNNNw`, and `_fp_basics_pack_high_carry:w`.)

This is used in `l3fp-basics` for additions and divisions. Their syntax is confusing, hence the name.

```

15906 \cs_new:Npn \_fp\_basics\_pack\_weird\_low:NNNNw #1 #2#3#4 #5;
15907 {
15908   \if_meaning:w 2 #1
15909     + 1
15910   \fi:
15911   \_fp\_int\_eval\_end:
15912   #2#3#4; {#5} ;
15913 }
15914 \cs_new:Npn \_fp\_basics\_pack\_weird\_high:NNNNNNNw
15915   1 #1#2#3#4 #5#6#7#8 #9; { ; {#1#2#3#4} {#5#6#7#8} {#9} }
```

(End definition for `_fp_basics_pack_weird_low:NNNNw` and `_fp_basics_pack_weird_high:NNNNNNNw`.)

25.9 Decimate (dividing by a power of 10)

`_fp_decimate:nNnnnn` $\{\langle shift \rangle\}$ $\langle f_1 \rangle$
 $\{\langle X_1 \rangle\}$ $\{\langle X_2 \rangle\}$ $\{\langle X_3 \rangle\}$ $\{\langle X_4 \rangle\}$

Each $\langle X_i \rangle$ consists in 4 digits exactly, and $1000 \leq \langle X_1 \rangle < 9999$. The first argument determines by how much we shift the digits. $\langle f_1 \rangle$ is called as follows:

$\langle f_1 \rangle$ $\langle rounding \rangle$ $\{\langle X'_1 \rangle\}$ $\{\langle X'_2 \rangle\}$ $\langle extra-digits \rangle$;

where $0 \leq \langle X'_i \rangle < 10^8 - 1$ are 8 digit integers, forming the truncation of our number. In other words,

$$\left(\sum_{i=1}^4 \langle X_i \rangle \cdot 10^{-4i} \cdot 10^{-\langle shift \rangle} \right) - (\langle X'_1 \rangle \cdot 10^{-8} + \langle X'_2 \rangle \cdot 10^{-16}) = 0. \langle extra-digits \rangle \cdot 10^{-16} \in [0, 10^{-16}).$$

To round properly later, we need to remember some information about the difference. The $\langle rounding \rangle$ digit is 0 if and only if the difference is exactly 0, and 5 if and only if the difference is exactly $0.5 \cdot 10^{-16}$. Otherwise, it is the (non-0, non-5) digit closest to 10^{17} times the difference. In particular, if the shift is 17 or more, all the digits are dropped, $\langle rounding \rangle$ is 1 (not 0), and $\langle X'_1 \rangle$ and $\langle X'_2 \rangle$ are both zero.

If the shift is 1, the $\langle rounding \rangle$ digit is simply the only digit that was pushed out of the brace groups (this is important for subtraction). It would be more natural for the $\langle rounding \rangle$ digit to be placed after the $\langle X'_i \rangle$, but the choice we make involves less reshuffling.

Note that this function treats negative $\langle shift \rangle$ as 0.

```

15916 \cs_new:Npn \_fp\_decimate:nNnnnn #1
15917 {
15918   \cs:w
15919   \_fp\_decimate\_
15920   \if_int_compare:w \_fp\_int\_eval:w #1 > \c\_fp\_prec\_int
15921     tiny
15922   \else:
15923     \_fp\_int\_to\_roman:w \_fp\_int\_eval:w #1
15924   \fi:
```

```

15925         :Nnnnn
15926     \cs_end:
15927 }

```

Each of the auxiliaries see the function $\langle f_1 \rangle$, followed by 4 blocks of 4 digits.

(End definition for `_fp_decimate:nNnnnn`.)

If the $\langle shift \rangle$ is zero, or too big, life is very easy.

```

\_fp_decimate_:Nnnnn
\_fp_decimate_tiny:Nnnnn
15928 \cs_new:Npn \_fp_decimate_:Nnnnn #1 #2#3#4#5
15929 { #1 0 {#2#3} {#4#5} ; }
15930 \cs_new:Npn \_fp_decimate_tiny:Nnnnn #1 #2#3#4#5
15931 { #1 1 { 0000 0000 } { 0000 0000 } 0 #2#3#4#5 ; }

```

(End definition for `_fp_decimate_:Nnnnn` and `_fp_decimate_tiny:Nnnnn`.)

```

\_fp_decimate_auxi:Nnnnn      \_fp_decimate_auxi:Nnnnn  $\langle f_1 \rangle$  { $\langle X_1 \rangle$ } { $\langle X_2 \rangle$ } { $\langle X_3 \rangle$ } { $\langle X_4 \rangle$ }
\_fp_decimate_auxii:Nnnnn
\_fp_decimate_auxiii:Nnnnn
\_fp_decimate_auxiv:Nnnnn
\_fp_decimate_auxv:Nnnnn
\_fp_decimate_auxvi:Nnnnn
\_fp_decimate_auxvii:Nnnnn
\_fp_decimate_auxviii:Nnnnn
\_fp_decimate_auxix:Nnnnn
\_fp_decimate_auxx:Nnnnn
\_fp_decimate_auxxi:Nnnnn
\_fp_decimate_auxxii:Nnnnn
\_fp_decimate_auxxiii:Nnnnn
\_fp_decimate_auxxiv:Nnnnn
\_fp_decimate_auxxv:Nnnnn
\_fp_decimate_auxxvi:Nnnnn

```

Shifting happens in two steps: compute the $\langle rounding \rangle$ digit, and repack digits into two blocks of 8. The sixteen functions are very similar, and defined through `_fp_tmp:w`. The arguments are as follows: #1 indicates which function is being defined; after one step of expansion, #2 yields the “extra digits” which are then converted by `_fp_round_digit:Nw` to the $\langle rounding \rangle$ digit (note the + separating blocks of digits to avoid overflowing TeX’s integers). This triggers the f-expansion of `_fp_decimate_pack:nnnnnnnnnw`,¹⁰ responsible for building two blocks of 8 digits, and removing the rest. For this to work, #3 alternates between braced and unbraced blocks of 4 digits, in such a way that the 5 first and 5 next token groups yield the correct blocks of 8 digits.

```

15932 \cs_new:Npn \_fp_tmp:w #1 #2 #3
15933 {
15934     \cs_new:cpn { \_fp_decimate_ #1 :Nnnnn } ##1 ##2##3##4##5
15935     {
15936         \exp_after:wN ##1
15937         \int_value:w
15938         \exp_after:wN \_fp_round_digit:Nw #2 ;
15939         \_fp_decimate_pack:nnnnnnnnnw #3 ;
15940     }
15941 }
15942 \_fp_tmp:w {i}   {\use_none:nnn    #50}{ 0{#2}#3{#4}#5          }
15943 \_fp_tmp:w {ii}  {\use_none:nn     #5 }{ 00{#2}#3{#4}#5          }
15944 \_fp_tmp:w {iii} {\use_none:n      #5 }{ 000{#2}#3{#4}#5          }
15945 \_fp_tmp:w {iv}  {                  #5 }{ {0000}#2{#3}#4 #5        }
15946 \_fp_tmp:w {v}   {\use_none:nnn    #4#5 }{ 0{0000}#2{#3}#4 #5      }
15947 \_fp_tmp:w {vi}  {\use_none:nn     #4#5 }{ 00{0000}#2{#3}#4 #5    }
15948 \_fp_tmp:w {vii} {\use_none:n      #4#5 }{ 000{0000}#2{#3}#4 #5    }
15949 \_fp_tmp:w {viii}{                  #4#5 }{ {0000}0000{#2}#3 #4 #5    }
15950 \_fp_tmp:w {ix}  {\use_none:nnn    #3#4+#5}{ 0{0000}0000{#2}#3 #4 #5    }
15951 \_fp_tmp:w {x}   {\use_none:nn     #3#4+#5}{ 00{0000}0000{#2}#3 #4 #5    }
15952 \_fp_tmp:w {xi}  {\use_none:n      #3#4+#5}{ 000{0000}0000{#2}#3 #4 #5    }
15953 \_fp_tmp:w {xii} {                  #3#4+#5}{ {0000}0000{0000}#2 #3 #4 #5    }
15954 \_fp_tmp:w {xiii}{\use_none:nnn    #2#3+#4#5}{ 0{0000}0000{0000}#2 #3 #4 #5    }
15955 \_fp_tmp:w {xiv} {\use_none:nn     #2#3+#4#5}{ 00{0000}0000{0000}#2 #3 #4 #5    }
15956 \_fp_tmp:w {xv}  {\use_none:n      #2#3+#4#5}{ 000{0000}0000{0000}#2 #3 #4 #5    }
15957 \_fp_tmp:w {xvi} {                  #2#3+#4#5}{ {0000}0000{0000}0000 #2 #3 #4 #5    }

```

¹⁰No, the argument spec is not a mistake: the function calls an auxiliary to do half of the job.

(End definition for `_fp_decimate_auxi:Nnnnn` and others.)

`_fp_decimate_pack:nnnnnnnnnw`

The computation of the *rounding* digit leaves an unfinished `\int_value:w`, which expands the following functions. This allows us to repack nicely the digits we keep. Those digits come as an alternation of unbraced and braced blocks of 4 digits, such that the first 5 groups of token consist in 4 single digits, and one brace group (in some order), and the next 5 have the same structure. This is followed by some digits and a semicolon.

```
15958 \cs_new:Npn \_fp_decimate_pack:nnnnnnnnnw #1#2#3#4#5
15959   { \_fp_decimate_pack:nnnnnw { #1#2#3#4#5 } }
15960 \cs_new:Npn \_fp_decimate_pack:nnnnnw #1 #2#3#4#5#6
15961   { {#1} {#2#3#4#5#6} }
```

(End definition for `_fp_decimate_pack:nnnnnnnnnw`.)

25.10 Functions for use within primitive conditional branches

The functions described in this section are not pretty and can easily be misused. When correctly used, each of them removes one `\fi:` as part of its parameter text, and puts one back as part of its replacement text.

Many computation functions in `l3fp` must perform tests on the type of floating points that they receive. This is often done in an `\if_case:w` statement or another conditional statement, and only a few cases lead to actual computations: most of the special cases are treated using a few standard functions which we define now. A typical use context for those functions would be

```
\if_case:w <integer> \exp_stop_f:
  \_fp_case_return_o:Nw <fp var>
\or: \_fp_case_use:nw {<some computation>}
\or: \_fp_case_return_same_o:w
\or: \_fp_case_return:nw {<something>}
\fi:
<junk>
<floating point>
```

In this example, the case 0 returns the floating point *<fp var>*, expanding once after that floating point. Case 1 does *<some computation>* using the *<floating point>* (presumably compute the operation requested by the user in that non-trivial case). Case 2 returns the *<floating point>* without modifying it, removing the *<junk>* and expanding once after. Case 3 closes the conditional, removes the *<junk>* and the *<floating point>*, and expands *<something>* next. In other cases, the “*<junk>*” is expanded, performing some other operation on the *<floating point>*. We provide similar functions with two trailing *<floating points>*.

`_fp_case_use:nw`

This function ends a `TEX` conditional, removes junk until the next floating point, and places its first argument before that floating point, to perform some operation on the floating point.

```
15962 \cs_new:Npn \_fp_case_use:nw #1#2 \fi: #3 \s_fp { \fi: #1 \s_fp }
```

(End definition for `_fp_case_use:nw`.)

`__fp_case_return:nw` This function ends a \TeX conditional, removes junk and a floating point, and places its first argument in the input stream. A quirk is that we don't define this function requiring a floating point to follow, simply anything ending in a semicolon. This, in turn, means that the *<junk>* may not contain semicolons.

```
15963 \cs_new:Npn \__fp_case_return:nw #1#2 \fi: #3 ; { \fi: #1 }
```

(End definition for `__fp_case_return:nw`.)

`__fp_case_return_o:Nw` This function ends a \TeX conditional, removes junk and a floating point, and returns its first argument (an *<fp var>*) then expands once after it.

```
15964 \cs_new:Npn \__fp_case_return_o:Nw #1#2 \fi: #3 \s__fp #4 ;
15965 { \fi: \exp_after:wN #1 }
```

(End definition for `__fp_case_return_o:Nw`.)

`__fp_case_return_same_o:w` This function ends a \TeX conditional, removes junk, and returns the following floating point, expanding once after it.

```
15966 \cs_new:Npn \__fp_case_return_same_o:w #1 \fi: #2 \s__fp
15967 { \fi: \__fp_exp_after_o:w \s__fp }
```

(End definition for `__fp_case_return_same_o:w`.)

`__fp_case_return_o:Nww` Same as `__fp_case_return_o:Nw` but with two trailing floating points.

```
15968 \cs_new:Npn \__fp_case_return_o:Nww #1#2 \fi: #3 \s__fp #4 ; #5 ;
15969 { \fi: \exp_after:wN #1 }
```

(End definition for `__fp_case_return_o:Nww`.)

`__fp_case_return_i_o:ww` Similar to `__fp_case_return_same_o:w`, but this returns the first or second of two trailing floating point numbers, expanding once after the result.

```
15970 \cs_new:Npn \__fp_case_return_i_o:ww #1 \fi: #2 \s__fp #3 ; \s__fp #4 ;
15971 { \fi: \__fp_exp_after_o:w \s__fp #3 ; }
15972 \cs_new:Npn \__fp_case_return_ii_o:ww #1 \fi: #2 \s__fp #3 ;
15973 { \fi: \__fp_exp_after_o:w }
```

(End definition for `__fp_case_return_i_o:ww` and `__fp_case_return_ii_o:ww`.)

25.11 Integer floating points

`__fp_int_p:w` Tests if the floating point argument is an integer. For normal floating point numbers, `__fp_int:wTF` this holds if the rounding digit resulting from `__fp_decimate:nNnnnn` is 0.

```
15974 \prg_new_conditional:Npnn \__fp_int:w \s__fp \__fp_chk:w #1 #2 #3 #4;
15975 { TF , T , F , p }
15976 {
15977   \if_case:w #1 \exp_stop_f:
15978     \prg_return_true:
15979   \or:
15980     \if_charcode:w 0
15981       \__fp_decimate:nNnnnn { \c__fp_prec_int - #3 }
15982       \__fp_use_i_until_s:nw #4
15983       \prg_return_true:
15984     \else:
15985       \prg_return_false:
15986     \fi:
```

```

15987     \else: \prg_return_false:
15988     \fi:
15989 }

```

(End definition for _fp_int:wTF.)

25.12 Small integer floating points

_fp_small_int:wTF Tests if the floating point argument is an integer or $\pm\infty$. If so, it is clipped to an integer in the range $[-10^8, 10^8]$ and fed as a braced argument to the *⟨true code⟩*. Otherwise, the *⟨false code⟩* is performed.

First filter special cases: zeros and infinities are integers, `nan` is not. For normal numbers, decimate. If the rounding digit is not 0 run the *⟨false code⟩*. If it is, then the integer is `#2 #3`; use `#3` if `#2` vanishes and otherwise `108`.

```

15990 \cs_new:Npn \_fp_small_int:wTF \s_fp \_fp_chk:w #1#2
15991 {
15992   \if_case:w #1 \exp_stop_f:
15993     \_fp_case_return:nw { \_fp_small_int_true:wTF 0 ; }
15994   \or:   \exp_after:wN \_fp_small_int_normal:NnwTF
15995   \or:
15996     \_fp_case_return:nw
15997     {
15998       \exp_after:wN \_fp_small_int_true:wTF \int_value:w
15999       \if_meaning:w 2 #2 - \fi: 1 0000 0000 ;
16000     }
16001   \else: \_fp_case_return:nw \use_ii:nn
16002   \fi:
16003   #2
16004 }
16005 \cs_new:Npn \_fp_small_int_true:wTF #1; #2#3 { #2 {#1} }
16006 \cs_new:Npn \_fp_small_int_normal:NnwTF #1#2#3;
16007 {
16008   \_fp_decimate:nNnnnn { \c_fp_prec_int - #2 }
16009   \_fp_small_int_test:NnnwNw
16010   #3 #1
16011 }
16012 \cs_new:Npn \_fp_small_int_test:NnnwNw #1#2#3#4; #5
16013 {
16014   \if_meaning:w 0 #1
16015     \exp_after:wN \_fp_small_int_true:wTF
16016     \int_value:w \if_meaning:w 2 #5 - \fi:
16017     \if_int_compare:w #2 > 0 \exp_stop_f:
16018       1 0000 0000
16019     \else:
16020       #3
16021     \fi:
16022     \exp_after:wN ;
16023   \else:
16024     \exp_after:wN \use_ii:nn
16025   \fi:
16026 }

```

(End definition for _fp_small_int:wTF and others.)

25.13 Fast string comparison

`__fp_str_if_eq:nn` A private version of the low-level string comparison function. As the nature of the arguments is restricted and as speed is of the essence, this version does not seek to deal with `#` tokens. No `l3sys` or `l3luatex` just yet so we have to define in terms of primitives.

```

16027 \sys_if_engine luatex:TF
16028 {
16029   \cs_new:Npn \__fp_str_if_eq:nn #1#2
16030   {
16031     \tex_directlua:D
16032     {
16033       l3kernel.strcmp
16034       (
16035         " \tex_luaescapestring:D {#1}",
16036         " \tex_luaescapestring:D {#2}"
16037       )
16038     }
16039   }
16040 }
16041 { \cs_new_eq:NN \__fp_str_if_eq:nn \tex_strcmp:D }

```

(End definition for `__fp_str_if_eq:nn`.)

25.14 Name of a function from its `l3fp`-parse name

`__fp_func_to_name:N` The goal is to convert for instance `__fp_sin_o:w` to `sin`. This is used in error messages
`__fp_func_to_name_aux:w` hence does not need to be fast.

```

16042 \cs_new:Npn \__fp_func_to_name:N #1
16043 {
16044   \exp_last_unbraced:Nf
16045   \__fp_func_to_name_aux:w { \cs_to_str:N #1 } X
16046 }
16047 \cs_set_protected:Npn \__fp_tmp:w #1 #2
16048 { \cs_new:Npn \__fp_func_to_name_aux:w ##1 #1 ##2 #2 ##3 X {##2} }
16049 \exp_args:Nff \__fp_tmp:w { \tl_to_str:n { __fp_ } }
16050 { \tl_to_str:n { _o: } }

```

(End definition for `__fp_func_to_name:N` and `__fp_func_to_name_aux:w`.)

25.15 Messages

Using a floating point directly is an error.

```

16051 \__kernel_msg_new:nnnn { kernel } { misused-fp }
16052 { A~floating~point~with~value~'~#1'~was~misused. }
16053 {
16054   To~obtain~the~value~of~a~floating~point~variable,~use~
16055   '\token_to_str:N \fp_to_decimal:N',~
16056   '\token_to_str:N \fp_to_tl:N',~or~other~
16057   conversion~functions.
16058 }
16059 </initex | package>

```


26 13fp-traps Implementation

16060 $\langle *initex \mid package \rangle$

16061 $\langle @@=fp \rangle$

Exceptions should be accessed by an `n`-type argument, among

- `invalid_operation`
- `division_by_zero`
- `overflow`
- `underflow`
- `inexact` (actually never used).

26.1 Flags

`flag_fp_invalid_operation`
`flag_fp_division_by_zero`
`flag_fp_overflow`
`flag_fp_underflow`

Flags to denote exceptions.

16062 `\flag_new:n { fp_invalid_operation }`
16063 `\flag_new:n { fp_division_by_zero }`
16064 `\flag_new:n { fp_overflow }`
16065 `\flag_new:n { fp_underflow }`

(End definition for flag `fp_invalid_operation` and others. These variables are documented on page 200.)

26.2 Traps

Exceptions can be trapped to obtain custom behaviour. When an invalid operation or a division by zero is trapped, the trap receives as arguments the result as an `N`-type floating point number, the function name (multiple letters for prefix operations, or a single symbol for infix operations), and the operand(s). When an overflow or underflow is trapped, the trap receives the resulting overly large or small floating point number if it is not too big, otherwise it receives $+\infty$. Currently, the `inexact` exception is entirely ignored.

The behaviour when an exception occurs is controlled by the definitions of the functions

- `__fp_invalid_operation:nnw,`
- `__fp_invalid_operation_o:Nww,`
- `__fp_invalid_operation_tl_o:ff,`
- `__fp_division_by_zero_o:Nnw,`
- `__fp_division_by_zero_o:NNww,`
- `__fp_overflow:w,`
- `__fp_underflow:w.`

Rather than changing them directly, we provide a user interface as `\fp_trap:nn { $\langle exception \rangle$ } { $\langle way of trapping \rangle$ }`, where the $\langle way of trapping \rangle$ is one of `error`, `flag`, or `none`.

We also provide `__fp_invalid_operation_o:nw`, defined in terms of `__fp_invalid_operation:nnw`.

\fp_trap:nn

```
16066 \cs_new_protected:Npn \fp_trap:nn #1#2
16067 {
16068   \cs_if_exist_use:cF { __fp_trap_#1_set_#2: }
16069   {
16070     \clist_if_in:nnTF
16071     { invalid_operation , division_by_zero , overflow , underflow }
16072     {#1}
16073     {
16074       \__kernel_msg_error:nnxx { kernel }
16075       { unknown-fpu-trap-type } {#1} {#2}
16076     }
16077     {
16078       \__kernel_msg_error:nnx
16079       { kernel } { unknown-fpu-exception } {#1}
16080     }
16081   }
16082 }
```

(End definition for \fp_trap:nn. This function is documented on page 200.)

_fp_trap_invalid_operation_set_error: We provide three types of trapping for invalid operations: either produce an error and
_fp_trap_invalid_operation_set_flag: raise the relevant flag; or only raise the flag; or don't even raise the flag. In most cases,
_fp_trap_invalid_operation_set_none: the function produces as a result its first argument, possibly with post-expansion.
_fp_trap_invalid_operation_set:N

```
16083 \cs_new_protected:Npn \__fp_trap_invalid_operation_set_error:
16084 { \__fp_trap_invalid_operation_set:N \prg_do_nothing: }
16085 \cs_new_protected:Npn \__fp_trap_invalid_operation_set_flag:
16086 { \__fp_trap_invalid_operation_set:N \use_none:nnnnn }
16087 \cs_new_protected:Npn \__fp_trap_invalid_operation_set_none:
16088 { \__fp_trap_invalid_operation_set:N \use_none:nnnnnnnn }
16089 \cs_new_protected:Npn \__fp_trap_invalid_operation_set:N #1
16090 {
16091   \exp_args:Nno \use:n
16092   { \cs_set:Npn \__fp_invalid_operation:nnw ##1##2##3; }
16093   {
16094     #1
16095     \__fp_error:nnfn { fp-invalid } {##2} { \fp_to_tl:n { ##3; } } { }
16096     \flag_raise_if_clear:n { fp_invalid_operation }
16097     ##1
16098   }
16099   \exp_args:Nno \use:n
16100   { \cs_set:Npn \__fp_invalid_operation_o:Nww ##1##2; ##3; }
16101   {
16102     #1
16103     \__fp_error:nffn { fp-invalid-ii }
16104     { \fp_to_tl:n { ##2; } } { \fp_to_tl:n { ##3; } } {##1}
16105     \flag_raise_if_clear:n { fp_invalid_operation }
16106     \exp_after:wN \c_nan_fp
16107   }
16108   \exp_args:Nno \use:n
16109   { \cs_set:Npn \__fp_invalid_operation_tl_o:ff ##1##2 }
16110   {
16111     #1
16112     \__fp_error:nffn { fp-invalid } {##1} {##2} { }
```

```

16113         \flag_raise_if_clear:n { fp_invalid_operation }
16114         \exp_after:wN \c_nan_fp
16115     }
16116 }

```

(End definition for `__fp_trap_invalid_operation_set_error:` and others.)

`__fp_trap_division_by_zero_set_error:` We provide three types of trapping for invalid operations and division by zero: either produce an error and raise the relevant flag; or only raise the flag; or don't even raise the flag. In all cases, the function must produce a result, namely its first argument, $\pm\infty$ or NaN.

```

16117 \cs_new_protected:Npn \__fp_trap_division_by_zero_set_error:
16118 { \__fp_trap_division_by_zero_set:N \prg_do_nothing: }
16119 \cs_new_protected:Npn \__fp_trap_division_by_zero_set_flag:
16120 { \__fp_trap_division_by_zero_set:N \use_none:nnnnn }
16121 \cs_new_protected:Npn \__fp_trap_division_by_zero_set_none:
16122 { \__fp_trap_division_by_zero_set:N \use_none:nnnnnnn }
16123 \cs_new_protected:Npn \__fp_trap_division_by_zero_set:N #1
16124 {
16125     \exp_args:Nno \use:n
16126     { \cs_set:Npn \__fp_division_by_zero_o:NNw ##1##2##3; }
16127     {
16128         #1
16129         \__fp_error:nfn { fp-zero-div } {##2} { \fp_to_tl:n { ##3; } } { }
16130         \flag_raise_if_clear:n { fp_division_by_zero }
16131         \exp_after:wN ##1
16132     }
16133     \exp_args:Nno \use:n
16134     { \cs_set:Npn \__fp_division_by_zero_o:NNww ##1##2##3; ##4; }
16135     {
16136         #1
16137         \__fp_error:nfn { fp-zero-div-ii }
16138         { \fp_to_tl:n { ##3; } } { \fp_to_tl:n { ##4; } } {##2}
16139         \flag_raise_if_clear:n { fp_division_by_zero }
16140         \exp_after:wN ##1
16141     }
16142 }

```

(End definition for `__fp_trap_division_by_zero_set_error:` and others.)

`__fp_trap_overflow_set_error:` Just as for invalid operations and division by zero, the three different behaviours are obtained by feeding `\prg_do_nothing:`, `\use_none:nnnnn` or `\use_none:nnnnnnn` to an auxiliary, with a further auxiliary common to overflow and underflow functions. In most cases, the argument of the `__fp_overflow:w` and `__fp_underflow:w` functions will be an (almost) normal number (with an exponent outside the allowed range), and the error message thus displays that number together with the result to which it overflowed or underflowed. For extreme cases such as `10 ** 1e9999`, the exponent would be too large for T_EX, and `__fp_overflow:w` receives $\pm\infty$ (`__fp_underflow:w` would receive ± 0); then we cannot do better than simply say an overflow or underflow occurred.

```

16143 \cs_new_protected:Npn \__fp_trap_overflow_set_error:
16144 { \__fp_trap_overflow_set:N \prg_do_nothing: }
16145 \cs_new_protected:Npn \__fp_trap_overflow_set_flag:
16146 { \__fp_trap_overflow_set:N \use_none:nnnnn }
16147 \cs_new_protected:Npn \__fp_trap_overflow_set_none:

```

```

16148 { \__fp_trap_overflow_set:N \use_none:nnnnnnn }
16149 \cs_new_protected:Npn \__fp_trap_overflow_set:N #1
16150 { \__fp_trap_overflow_set:NnNn #1 { overflow } \__fp_inf_fp:N { inf } }
16151 \cs_new_protected:Npn \__fp_trap_underflow_set_error:
16152 { \__fp_trap_underflow_set:N \prg_do_nothing: }
16153 \cs_new_protected:Npn \__fp_trap_underflow_set_flag:
16154 { \__fp_trap_underflow_set:N \use_none:nnnnn }
16155 \cs_new_protected:Npn \__fp_trap_underflow_set_none:
16156 { \__fp_trap_underflow_set:N \use_none:nnnnnnn }
16157 \cs_new_protected:Npn \__fp_trap_underflow_set:N #1
16158 { \__fp_trap_overflow_set:NnNn #1 { underflow } \__fp_zero_fp:N { 0 } }
16159 \cs_new_protected:Npn \__fp_trap_overflow_set:NnNn #1#2#3#4
16160 {
16161   \exp_args:Nno \use:n
16162   { \cs_set:cpn { \__fp_ #2 :w } \s__fp \__fp_chk:w ##1##2##3; }
16163   {
16164     #1
16165     \__fp_error:nffn
16166     { fp-flow \if_meaning:w 1 ##1 -to \fi: }
16167     { \fp_to_tl:n { \s__fp \__fp_chk:w ##1##2##3; } }
16168     { \token_if_eq_meaning:NNF 0 ##2 { - } #4 }
16169     {#2}
16170     \flag_raise_if_clear:n { fp_#2 }
16171     #3 ##2
16172   }
16173 }

```

(End definition for __fp_trap_overflow_set_error: and others.)

```

\__fp_invalid_operation:nnw Initialize the control sequences (to log properly their existence). Then set invalid operations
  \__fp_invalid_operation_o:Nnw to trigger an error, and division by zero, overflow, and underflow to act silently on
  \__fp_invalid_operation_tl_o:ff their flag.
\__fp_division_by_zero_o:Nnw
  \__fp_division_by_zero_o:NNww
  \__fp_overflow:w
  \__fp_underflow:w
16174 \cs_new:Npn \__fp_invalid_operation:nnw #1#2#3; { }
16175 \cs_new:Npn \__fp_invalid_operation_o:Nnw #1#2; #3; { }
16176 \cs_new:Npn \__fp_invalid_operation_tl_o:ff #1 #2 { }
16177 \cs_new:Npn \__fp_division_by_zero_o:Nnw #1#2#3; { }
16178 \cs_new:Npn \__fp_division_by_zero_o:NNww #1#2#3; #4; { }
16179 \cs_new:Npn \__fp_overflow:w { }
16180 \cs_new:Npn \__fp_underflow:w { }
16181 \fp_trap:nn { invalid_operation } { error }
16182 \fp_trap:nn { division_by_zero } { flag }
16183 \fp_trap:nn { overflow } { flag }
16184 \fp_trap:nn { underflow } { flag }

```

(End definition for __fp_invalid_operation:nnw and others.)

```

\__fp_invalid_operation_o:nw Convenient short-hands for returning \c_nan_fp for a unary or binary operation, and
\__fp_invalid_operation_o:fw expanding after.
16185 \cs_new:Npn \__fp_invalid_operation_o:nw
16186 { \__fp_invalid_operation:nnw { \exp_after:wN \c_nan_fp } }
16187 \cs_generate_variant:Nn \__fp_invalid_operation_o:nw { f }

```

(End definition for __fp_invalid_operation_o:nw.)

26.3 Errors

```

\__fp_error:nnnn
\__fp_error:nnfn 16188 \cs_new:Npn \__fp_error:nnnn
\__fp_error:nffn 16189 { \__kernel_msg_expandable_error:nnnnn { kernel } }
\__fp_error:nfff 16190 \cs_generate_variant:Nn \__fp_error:nnnn { nnf, nff , nfff }

(End definition for \__fp_error:nnnn.)

```

26.4 Messages

Some messages.

```

16191 \__kernel_msg_new:nnnn { kernel } { unknown-fpu-exception }
16192 {
16193   The~FPU~exception~'#1'~is~not~known:~
16194   that~trap~will~never~be~triggered.
16195 }
16196 {
16197   The~only~exceptions~to~which~traps~can~be~attached~are \
16198   \iow_indent:n
16199   {
16200     * ~ invalid_operation \
16201     * ~ division_by_zero \
16202     * ~ overflow \
16203     * ~ underflow
16204   }
16205 }
16206 \__kernel_msg_new:nnnn { kernel } { unknown-fpu-trap-type }
16207 { The~FPU~trap~type~'#2'~is~not~known. }
16208 {
16209   The~trap~type~must~be~one~of \
16210   \iow_indent:n
16211   {
16212     * ~ error \
16213     * ~ flag \
16214     * ~ none
16215   }
16216 }
16217 \__kernel_msg_new:nnn { kernel } { fp-flow }
16218 { An ~ #3 ~ occurred. }
16219 \__kernel_msg_new:nnn { kernel } { fp-flow-to }
16220 { #1 ~ #3 ed ~ to ~ #2 . }
16221 \__kernel_msg_new:nnn { kernel } { fp-zero-div }
16222 { Division~by~zero~in~ #1 (#2) }
16223 \__kernel_msg_new:nnn { kernel } { fp-zero-div-ii }
16224 { Division~by~zero~in~ (#1) #3 (#2) }
16225 \__kernel_msg_new:nnn { kernel } { fp-invalid }
16226 { Invalid~operation~ #1 (#2) }
16227 \__kernel_msg_new:nnn { kernel } { fp-invalid-ii }
16228 { Invalid~operation~ (#1) #3 (#2) }
16229 \__kernel_msg_new:nnn { kernel } { fp-unknown-type }
16230 { Unknown~type~for~'#1' }
16231 </initex | package>

```

27 13fp-round implementation

```

16232 (*initex | package)
16233 (@@=fp)

\__fp_parse_word_trunc:N
\__fp_parse_word_floor:N
\__fp_parse_word_ceil:N
16234 \cs_new:Npn \__fp_parse_word_trunc:N
16235 { \__fp_parse_function:NNN \__fp_round_o:Nw \__fp_round_to_zero:NNN }
16236 \cs_new:Npn \__fp_parse_word_floor:N
16237 { \__fp_parse_function:NNN \__fp_round_o:Nw \__fp_round_to_ninf:NNN }
16238 \cs_new:Npn \__fp_parse_word_ceil:N
16239 { \__fp_parse_function:NNN \__fp_round_o:Nw \__fp_round_to_pinf:NNN }

(End definition for \__fp_parse_word_trunc:N, \__fp_parse_word_floor:N, and \__fp_parse_word_ceil:N.)

```

```

\__fp_parse_word_round:N
\__fp_parse_round:Nw
16240 \cs_new:Npn \__fp_parse_word_round:N #1#2
16241 {
16242   \__fp_parse_function:NNN
16243   \__fp_round_o:Nw \__fp_round_to_nearest:NNN #1
16244   #2
16245 }
16246 \cs_new:Npn \__fp_parse_round:Nw #1 #2 \__fp_round_to_nearest:NNN #3#4
16247 { #2 #1 #3 }
16248

(End definition for \__fp_parse_word_round:N and \__fp_parse_round:Nw.)

```

27.1 Rounding tools

\c__fp_five_int This is used as the half-point for which numbers are rounded up/down.

```

16249 \int_const:Nn \c__fp_five_int { 5 }

```

(End definition for \c__fp_five_int.)

Floating point operations often yield a result that cannot be exactly represented in a significand with 16 digits. In that case, we need to round the exact result to a representable number. The IEEE standard defines four rounding modes:

- Round to nearest: round to the representable floating point number whose absolute difference with the exact result is the smallest. If the exact result lies exactly at the mid-point between two consecutive representable floating point numbers, round to the floating point number whose last digit is even.
- Round towards negative infinity: round to the greatest floating point number not larger than the exact result.
- Round towards zero: round to a floating point number with the same sign as the exact result, with the largest absolute value not larger than the absolute value of the exact result.
- Round towards positive infinity: round to the least floating point number not smaller than the exact result.

This is not fully implemented in l3fp yet, and transcendental functions fall back on the “round to nearest” mode. All rounding for basic algebra is done through the functions defined in this module, which can be redefined to change their rounding behaviour (but there is not interface for that yet).

The rounding tools available in this module are many variations on a base function `__fp_round:NNN`, which expands to `0\exp_stop_f:` or `1\exp_stop_f:` depending on whether the final result should be rounded up or down.

- `__fp_round:NNN <sign> <digit1> <digit2>` can expand to `0\exp_stop_f:` or `1\exp_stop_f:.`
- `__fp_round_s:NNNw <sign> <digit1> <digit2> <more digits>;` can expand to `0\exp_stop_f:;` or `1\exp_stop_f:;`
- `__fp_round_neg:NNN <sign> <digit1> <digit2>` can expand to `0\exp_stop_f:` or `1\exp_stop_f:.`

See implementation comments for details on the syntax.

```
\__fp_round:NNN
\__fp_round_to_nearest:NNN
  \__fp_round_to_nearest_ninf:NNN
  \__fp_round_to_nearest_zero:NNN
  \__fp_round_to_nearest_pinf:NNN
\__fp_round_to_ninf:NNN
\__fp_round_to_zero:NNN
\__fp_round_to_pinf:NNN
```

`__fp_round:NNN <final sign> <digit1> <digit2>`
If rounding the number $\langle final\ sign \rangle \langle digit_1 \rangle . \langle digit_2 \rangle$ to an integer rounds it towards zero (truncates it), this function expands to `0\exp_stop_f:`, and otherwise to `1\exp_stop_f:.` Typically used within the scope of an `__fp_int_eval:w`, to add 1 if needed, and thereby round correctly. The result depends on the rounding mode.

It is very important that $\langle final\ sign \rangle$ be the final sign of the result. Otherwise, the result would be incorrect in the case of rounding towards $-\infty$ or towards $+\infty$. Also recall that $\langle final\ sign \rangle$ is 0 for positive, and 2 for negative.

By default, the functions below return `0\exp_stop_f:`, but this is superseded by `__fp_round_return_one:`, which instead returns `1\exp_stop_f:`, expanding everything and removing `0\exp_stop_f:` in the process. In the case of rounding towards $\pm\infty$ or towards 0, this is not really useful, but it prepares us for the “round to nearest, ties to even” mode.

The “round to nearest” mode is the default. If the $\langle digit_2 \rangle$ is larger than 5, then round up. If it is less than 5, round down. If it is exactly 5, then round such that $\langle digit_1 \rangle$ plus the result is even. In other words, round up if $\langle digit_1 \rangle$ is odd.

The “round to nearest” mode has three variants, which differ in how ties are rounded: down towards $-\infty$, truncated towards 0, or up towards $+\infty$.

```
16250 \cs_new:Npn \__fp_round_return_one:
16251   { \exp_after:wN 1 \exp_after:wN \exp_stop_f: \exp:w }
16252 \cs_new:Npn \__fp_round_to_ninf:NNN #1 #2 #3
16253   {
16254     \if_meaning:w 2 #1
16255     \if_int_compare:w #3 > 0 \exp_stop_f:
16256       \__fp_round_return_one:
16257     \fi:
16258     \fi:
16259     0 \exp_stop_f:
16260   }
16261 \cs_new:Npn \__fp_round_to_zero:NNN #1 #2 #3 { 0 \exp_stop_f: }
16262 \cs_new:Npn \__fp_round_to_pinf:NNN #1 #2 #3
16263   {
16264     \if_meaning:w 0 #1
16265     \if_int_compare:w #3 > 0 \exp_stop_f:
```

```

16266         \_fp_round_return_one:
16267         \fi:
16268         \fi:
16269         0 \exp_stop_f:
16270     }
16271 \cs_new:Npn \_fp_round_to_nearest:NNN #1 #2 #3
16272 {
16273     \if_int_compare:w #3 > \c__fp_five_int
16274         \_fp_round_return_one:
16275     \else:
16276         \if_meaning:w 5 #3
16277         \if_int_odd:w #2 \exp_stop_f:
16278         \_fp_round_return_one:
16279         \fi:
16280         \fi:
16281     \fi:
16282     0 \exp_stop_f:
16283 }
16284 \cs_new:Npn \_fp_round_to_nearest_ninf:NNN #1 #2 #3
16285 {
16286     \if_int_compare:w #3 > \c__fp_five_int
16287         \_fp_round_return_one:
16288     \else:
16289         \if_meaning:w 5 #3
16290         \if_meaning:w 2 #1
16291         \_fp_round_return_one:
16292         \fi:
16293         \fi:
16294     \fi:
16295     0 \exp_stop_f:
16296 }
16297 \cs_new:Npn \_fp_round_to_nearest_zero:NNN #1 #2 #3
16298 {
16299     \if_int_compare:w #3 > \c__fp_five_int
16300         \_fp_round_return_one:
16301     \fi:
16302     0 \exp_stop_f:
16303 }
16304 \cs_new:Npn \_fp_round_to_nearest_pinf:NNN #1 #2 #3
16305 {
16306     \if_int_compare:w #3 > \c__fp_five_int
16307         \_fp_round_return_one:
16308     \else:
16309         \if_meaning:w 5 #3
16310         \if_meaning:w 0 #1
16311         \_fp_round_return_one:
16312         \fi:
16313         \fi:
16314     \fi:
16315     0 \exp_stop_f:
16316 }
16317 \cs_new_eq:NN \_fp_round:NNN \_fp_round_to_nearest:NNN

```

(End definition for _fp_round:NNN and others.)

_fp_round_s:NNNw

_fp_round_s:NNNw <final sign> <digit> <more digits> ;

Similar to _fp_round:NNN, but with an extra semicolon, this function expands to 0\exp_stop_f:; if rounding <final sign><digit>.<more digits> to an integer truncates, and to 1\exp_stop_f:; otherwise. The <more digits> part must be a digit, followed by something that does not overflow a \int_use:N _fp_int_eval:w construction. The only relevant information about this piece is whether it is zero or not.

```

16318 \cs_new:Npn \_fp_round_s:NNNw #1 #2 #3 #4;
16319 {
16320   \exp_after:wN \_fp_round:NNN
16321   \exp_after:wN #1
16322   \exp_after:wN #2
16323   \int_value:w \_fp_int_eval:w
16324   \if_int_odd:w 0 \if_meaning:w 0 #3 1 \fi:
16325   \if_meaning:w 5 #3 1 \fi:
16326   \exp_stop_f:
16327   \if_int_compare:w \_fp_int_eval:w #4 > 0 \exp_stop_f:
16328   1 +
16329   \fi:
16330   \fi:
16331   #3
16332   ;
16333 }

```

(End definition for _fp_round_s:NNNw.)

_fp_round_digit:Nw

\int_value:w _fp_round_digit:Nw <digit> <intexpr> ;

This function should always be called within an \int_value:w or _fp_int_eval:w expansion; it may add an extra _fp_int_eval:w, which means that the integer or integer expression should not be ended with a synonym of \relax, but with a semi-colon for instance.

```

16334 \cs_new:Npn \_fp_round_digit:Nw #1 #2;
16335 {
16336   \if_int_odd:w \if_meaning:w 0 #1 1 \else:
16337   \if_meaning:w 5 #1 1 \else:
16338   0 \fi: \fi: \exp_stop_f:
16339   \if_int_compare:w \_fp_int_eval:w #2 > 0 \exp_stop_f:
16340   \_fp_int_eval:w 1 +
16341   \fi:
16342   \fi:
16343   #1
16344 }

```

(End definition for _fp_round_digit:Nw.)

_fp_round_neg:NNN

_fp_round_neg:NNN <final sign> <digit₁> <digit₂>

_fp_round_to_nearest_neg:NNN

This expands to 0\exp_stop_f: or 1\exp_stop_f: after doing the following test.

_fp_round_to_nearest_ninf_neg:NNN

Starting from a number of the form <final sign>0.<15 digits><digit₁> with exactly 15 (non-all-zero) digits before <digit₁>, subtract from it <final sign>0.0...0<digit₂>, where there are 16 zeros. If in the current rounding mode the result should be rounded down, then this function returns 1\exp_stop_f:. Otherwise, i.e., if the result is rounded back to the first operand, then this function returns 0\exp_stop_f:.

_fp_round_to_nearest_zero_neg:NNN

_fp_round_to_nearest_pinf_neg:NNN

_fp_round_to_ninf_neg:NNN

_fp_round_to_zero_neg:NNN

_fp_round_to_pinf_neg:NNN

It turns out that this negative “round to nearest” is identical to the positive one. And this is the default mode.

```

16345 \cs_new_eq:NN \__fp_round_to_ninf_neg:NNN \__fp_round_to_pinf:NNN
16346 \cs_new:Npn \__fp_round_to_zero_neg:NNN #1 #2 #3
16347 {
16348     \if_int_compare:w #3 > 0 \exp_stop_f:
16349     \__fp_round_return_one:
16350     \fi:
16351     0 \exp_stop_f:
16352 }
16353 \cs_new_eq:NN \__fp_round_to_pinf_neg:NNN \__fp_round_to_ninf:NNN
16354 \cs_new_eq:NN \__fp_round_to_nearest_neg:NNN \__fp_round_to_nearest:NNN
16355 \cs_new_eq:NN \__fp_round_to_nearest_ninf_neg:NNN
16356 \__fp_round_to_nearest_pinf:NNN
16357 \cs_new:Npn \__fp_round_to_nearest_zero_neg:NNN #1 #2 #3
16358 {
16359     \if_int_compare:w #3 < \c__fp_five_int \else:
16360     \__fp_round_return_one:
16361     \fi:
16362     0 \exp_stop_f:
16363 }
16364 \cs_new_eq:NN \__fp_round_to_nearest_pinf_neg:NNN
16365 \__fp_round_to_nearest_ninf:NNN
16366 \cs_new_eq:NN \__fp_round_neg:NNN \__fp_round_to_nearest_neg:NNN

```

(End definition for __fp_round_neg:NNN and others.)

27.2 The round function

__fp_round_o:Nw
__fp_round_aux_o:Nw

First check that all arguments are floating point numbers. The `trunc`, `ceil` and `floor` functions expect one or two arguments (the second is 0 by default), and the `round` function also accepts a third argument (`nan` by default), which changes `#1` from `__fp_round_to_nearest:NNN` to one of its analogues.

```

16367 \cs_new:Npn \__fp_round_o:Nw #1
16368 {
16369     \__fp_parse_function_all_fp_o:fnw
16370     { \__fp_round_name_from_cs:N #1 }
16371     { \__fp_round_aux_o:Nw #1 }
16372 }
16373 \cs_new:Npn \__fp_round_aux_o:Nw #1#2 @
16374 {
16375     \if_case:w
16376     \__fp_int_eval:w \__fp_array_count:n {#2} \__fp_int_eval_end:
16377     \__fp_round_no_arg_o:Nw #1 \exp:w
16378     \or: \__fp_round:Nwn #1 #2 {0} \exp:w
16379     \or: \__fp_round:Nww #1 #2 \exp:w
16380     \else: \__fp_round:Nwww #1 #2 @ \exp:w
16381     \fi:
16382     \exp_after:wN \exp_end:
16383 }

```

(End definition for __fp_round_o:Nw and __fp_round_aux_o:Nw.)

__fp_round_no_arg_o:Nw

```

16384 \cs_new:Npn \__fp_round_no_arg_o:Nw #1
16385 {

```

```

16386 \cs_if_eq:NNTF #1 \__fp_round_to_nearest:NNN
16387 { \__fp_error:nnnn { fp-num-args } { round () } { 1 } { 3 } }
16388 {
16389   \__fp_error:nffn { fp-num-args }
16390   { \__fp_round_name_from_cs:N #1 () } { 1 } { 2 }
16391 }
16392 \exp_after:wN \c_nan_fp
16393 }

```

(End definition for __fp_round_no_arg_o:Nw.)

__fp_round:Nwww Having three arguments is only allowed for round, not trunc, ceil, floor, so check for that case. If all is well, construct one of __fp_round_to_nearest:NNN, __fp_round_to_nearest_zero:NNN, __fp_round_to_nearest_ninf:NNN, __fp_round_to_nearest_pinf:NNN and act accordingly.

```

16394 \cs_new:Npn \__fp_round:Nwww #1#2 ; #3 ; \s__fp \__fp_chk:w #4#5#6 ; #7 @
16395 {
16396   \cs_if_eq:NNTF #1 \__fp_round_to_nearest:NNN
16397   {
16398     \tl_if_empty:nTF {#7}
16399     {
16400       \exp_args:Nc \__fp_round:Nww
16401       {
16402         __fp_round_to_nearest
16403         \if_meaning:w 0 #4 _zero \else:
16404         \if_case:w #5 \exp_stop_f: _pinf \or: \else: _ninf \fi: \fi:
16405         :NNN
16406       }
16407       #2 ; #3 ;
16408     }
16409     {
16410       \__fp_error:nnnn { fp-num-args } { round () } { 1 } { 3 }
16411       \exp_after:wN \c_nan_fp
16412     }
16413   }
16414   {
16415     \__fp_error:nffn { fp-num-args }
16416     { \__fp_round_name_from_cs:N #1 () } { 1 } { 2 }
16417     \exp_after:wN \c_nan_fp
16418   }
16419 }

```

(End definition for __fp_round:Nwww.)

__fp_round_name_from_cs:N

```

16420 \cs_new:Npn \__fp_round_name_from_cs:N #1
16421 {
16422   \cs_if_eq:NNTF #1 \__fp_round_to_zero:NNN { trunc }
16423   {
16424     \cs_if_eq:NNTF #1 \__fp_round_to_ninf:NNN { floor }
16425     {
16426       \cs_if_eq:NNTF #1 \__fp_round_to_pinf:NNN { ceil }
16427       { round }
16428     }
16429   }

```

```

16429     }
16430 }

```

(End definition for _fp_round_name_from_cs:N.)

```

    \_fp_round:Nww
    \_fp_round:Nwn
    \_fp_round_normal:NwNNnw
    \_fp_round_normal:NnnwNNnn
    \_fp_round_pack:Nw
    \_fp_round_normal:NNwNnn
    \_fp_round_normal_end:wwNnn
    \_fp_round_special:NwwNnn
    \_fp_round_special_aux:Nw
16431 \cs_new:Npn \_fp_round:Nww #1#2 ; #3 ;
16432 {
16433     \_fp_small_int:wTF #3; { \_fp_round:Nwn #1#2; }
16434     {
16435         \_fp_invalid_operation_tl_o:ff
16436         { \_fp_round_name_from_cs:N #1 }
16437         { \_fp_array_to_clist:n { #2; #3; } }
16438     }
16439 }
16440 \cs_new:Npn \_fp_round:Nwn #1 \s_fp \_fp_chk:w #2#3#4; #5
16441 {
16442     \if_meaning:w 1 #2
16443     \exp_after:wN \_fp_round_normal:NwNNnw
16444     \exp_after:wN #1
16445     \int_value:w #5
16446     \else:
16447     \exp_after:wN \_fp_exp_after_o:w
16448     \fi:
16449     \s_fp \_fp_chk:w #2#3#4;
16450 }
16451 \cs_new:Npn \_fp_round_normal:NwNNnw #1#2 \s_fp \_fp_chk:w 1#3#4#5;
16452 {
16453     \_fp_decimate:nNnnnn { \c_fp_prec_int - #4 - #2 }
16454     \_fp_round_normal:NnnwNNnn #5 #1 #3 {#4} {#2}
16455 }
16456 \cs_new:Npn \_fp_round_normal:NnnwNNnn #1#2#3#4; #5#6
16457 {
16458     \exp_after:wN \_fp_round_normal:NNwNnn
16459     \int_value:w \_fp_int_eval:w
16460     \if_int_compare:w #2 > 0 \exp_stop_f:
16461     1 \int_value:w #2
16462     \exp_after:wN \_fp_round_pack:Nw
16463     \int_value:w \_fp_int_eval:w 1#3 +
16464     \else:
16465     \if_int_compare:w #3 > 0 \exp_stop_f:
16466     1 \int_value:w #3 +
16467     \fi:
16468     \fi:
16469     \exp_after:wN #5
16470     \exp_after:wN #6
16471     \use_none:nnnnnn #3
16472     #1
16473     \_fp_int_eval_end:
16474     0000 0000 0000 0000 ; #6
16475 }
16476 \cs_new:Npn \_fp_round_pack:Nw #1
16477 { \if_meaning:w 2 #1 + 1 \fi: \_fp_int_eval_end: }
16478 \cs_new:Npn \_fp_round_normal:NNwNnn #1 #2

```

```

16479 {
16480   \if_meaning:w 0 #2
16481   \exp_after:wN \__fp_round_special:NwwNnn
16482   \exp_after:wN #1
16483   \fi:
16484   \__fp_pack_twice_four:wNNNNNNNN
16485   \__fp_pack_twice_four:wNNNNNNNN
16486   \__fp_round_normal_end:wwNnn
16487   ; #2
16488 }
16489 \cs_new:Npn \__fp_round_normal_end:wwNnn #1;#2;#3#4#5
16490 {
16491   \exp_after:wN \__fp_exp_after_o:w \exp:w \exp_end_continue_f:w
16492   \__fp_sanitiz:Nw #3 #4 ; #1 ;
16493 }
16494 \cs_new:Npn \__fp_round_special:NwwNnn #1#2;#3;#4#5#6
16495 {
16496   \if_meaning:w 0 #1
16497   \__fp_case_return:nw
16498   { \exp_after:wN \__fp_zero_fp:N \exp_after:wN #4 }
16499   \else:
16500   \exp_after:wN \__fp_round_special_aux:Nw
16501   \exp_after:wN #4
16502   \int_value:w \__fp_int_eval:w 1
16503   \if_meaning:w 1 #1 -#6 \else: +#5 \fi:
16504   \fi:
16505   ;
16506 }
16507 \cs_new:Npn \__fp_round_special_aux:Nw #1#2;
16508 {
16509   \exp_after:wN \__fp_exp_after_o:w \exp:w \exp_end_continue_f:w
16510   \__fp_sanitiz:Nw #1#2; {1000}{0000}{0000}{0000};
16511 }

```

(End definition for `__fp_round:Nww` and others.)

```
16512 </initex | package>
```

28 13fp-parse implementation

```
16513 <*:initex | package>
```

```
16514 <@@=fp>
```

28.1 Work plan

The task at hand is non-trivial, and some previous failed attempts show that the code leads to unreadable logs, so we had better get it (almost) right the first time. Let us first describe our goal, then discuss the design precisely before writing any code.

In this file at least, a *floating point object* is a floating point number or tuple. This can be extended to anything that starts with `\s__fp` or `\s__fp_⟨type⟩` and ends with `;` with some internal structure that depends on the *⟨type⟩*.

```
\__fp_parse:n      \__fp_parse:n {⟨fpexpr⟩}
```

Evaluates the *floating point expression* and leaves the result in the input stream as a floating point object. This function forms the basis of almost all public `l3fp` functions. During evaluation, each token is fully `f`-expanded.

`__fp_parse_o:n` does the same but expands once after its result.

T_EXhackers note: Registers (integers, toks, etc.) are automatically unpacked, without requiring a function such as `\int_use:N`. Invalid tokens remaining after `f`-expansion lead to unrecoverable low-level T_EX errors.

(End definition for `__fp_parse:n`.)

Floating point expressions are composed of numbers, given in various forms, infix operators, such as `+`, `**`, or `,` (which joins two numbers into a list), and prefix operators, such as the unary `-`, functions, or opening parentheses. Here is a list of precedences which control the order of evaluation (some distinctions are irrelevant for the order of evaluation, but serve as signals), from the tightest binding to the loosest binding.

- | | |
|------------------------------------|--|
| <code>\c__fp_prec_func_int</code> | 16 Function calls. |
| <code>\c__fp_prec_hatii_int</code> | 13/14 Binary <code>**</code> and <code>^</code> (right to left). |
| <code>\c__fp_prec_hat_int</code> | 12 Unary <code>+</code> , <code>-</code> , <code>!</code> (right to left). |
| <code>\c__fp_prec_not_int</code> | 11 Juxtaposition (implicit <code>*</code>) with no parenthesis. |
| <code>\c__fp_prec_juxt_int</code> | 10 Binary <code>*</code> and <code>/</code> . |
| <code>\c__fp_prec_times_int</code> | 9 Binary <code>+</code> and <code>-</code> . |
| <code>\c__fp_prec_plus_int</code> | 7 Comparisons. |
| <code>\c__fp_prec_comp_int</code> | 6 Logical <code>and</code> , denoted by <code>&&</code> . |
| <code>\c__fp_prec_and_int</code> | 5 Logical <code>or</code> , denoted by <code> </code> . |
| <code>\c__fp_prec_or_int</code> | 4 Ternary operator <code>?:</code> , piece <code>?</code> . |
| <code>\c__fp_prec_quest_int</code> | 3 Ternary operator <code>?:</code> , piece <code>:</code> . |
| <code>\c__fp_prec_colon_int</code> | 2 Commas. |
| <code>\c__fp_prec_comma_int</code> | 1 Place where a comma is allowed and generates a tuple. |
| <code>\c__fp_prec_tuple_int</code> | 0 Start and end of the expression. |
| <code>\c__fp_prec_end_int</code> | |

```

16515 \int_const:Nn \c__fp_prec_func_int { 16 }
16516 \int_const:Nn \c__fp_prec_hatii_int { 14 }
16517 \int_const:Nn \c__fp_prec_hat_int { 13 }
16518 \int_const:Nn \c__fp_prec_not_int { 12 }
16519 \int_const:Nn \c__fp_prec_juxt_int { 11 }
16520 \int_const:Nn \c__fp_prec_times_int { 10 }
16521 \int_const:Nn \c__fp_prec_plus_int { 9 }
16522 \int_const:Nn \c__fp_prec_comp_int { 7 }
16523 \int_const:Nn \c__fp_prec_and_int { 6 }
16524 \int_const:Nn \c__fp_prec_or_int { 5 }
16525 \int_const:Nn \c__fp_prec_quest_int { 4 }

```

```

16526 \int_const:Nn \c__fp_prec_colon_int { 3 }
16527 \int_const:Nn \c__fp_prec_comma_int { 2 }
16528 \int_const:Nn \c__fp_prec_tuple_int { 1 }
16529 \int_const:Nn \c__fp_prec_end_int { 0 }

```

(End definition for `\c__fp_prec_func_int` and others.)

28.1.1 Storing results

The main question in parsing expressions expandably is to decide where to put the intermediate results computed for various subexpressions.

One option is to store the values at the start of the expression, and carry them together as the first argument of each macro. However, we want to `f-expand` tokens one by one in the expression (as `\int_eval:n` does), and with this approach, expanding the next unread token forces us to jump with `\exp_after:wN` over every value computed earlier in the expression. With this approach, the run-time grows at least quadratically in the length of the expression, if not as its cube (inserting the `\exp_after:wN` is tricky and slow).

A second option is to place those values at the end of the expression. Then expanding the next unread token is straightforward, but this still hits a performance issue: for long expressions we would be reaching all the way to the end of the expression at every step of the calculation. The run-time is again quadratic.

A variation of the above attempts to place the intermediate results which appear when computing a parenthesized expression near the closing parenthesis. This still lets us expand tokens as we go, and avoids performance problems as long as there are enough parentheses. However, it would be better to avoid requiring the closing parenthesis to be present as soon as the corresponding opening parenthesis is read: the closing parenthesis may still be hidden in a macro yet to be expanded.

Hence, we need to go for some fine expansion control: the result is stored *before* the start!

Let us illustrate this idea in a simple model: adding positive integers which may be resulting from the expansion of macros, or may be values of registers. Assume that one number, say, 12345, has already been found, and that we want to parse the next number. The current status of the code may look as follows.

```

\exp_after:wN \add:ww \int_value:w 12345 \exp_after:wN ;
\exp:w \operand:w <stuff>

```

One step of expansion expands `\exp_after:wN`, which triggers the primitive `\int_value:w`, which reads the five digits we have already found, 12345. This integer is unfinished, causing the second `\exp_after:wN` to expand, and to trigger the construction `\exp:w`, which expands `\operand:w`, defined to read what follows and make a number out of it, then leave `\exp_end:`, the number, and a semicolon in the input stream. Once `\operand:w` is done expanding, we obtain essentially

```

\exp_after:wN \add:ww \int_value:w 12345 ;
\exp:w \exp_end: 333444 ;

```

where in fact `\exp_after:wN` has already been expanded, `\int_value:w` has already seen 12345, and `\exp:w` is still looking for a number. It finds `\exp_end:`, hence expands to nothing. Now, `\int_value:w` sees the `;`, which cannot be part of a number. The expansion stops, and we are left with

`\add:ww 12345 ; 333444 ;`

which can safely perform the addition by grabbing two arguments delimited by `;`.

If we were to continue parsing the expression, then the following number should also be cleaned up before the next use of a binary operation such as `\add:ww`. Just like `\int_value:w 12345 \exp_after:wN ;` expanded what follows once, we need `\add:ww` to do the calculation, and in the process to expand the following once. This is also true in our real application: all the functions of the form `__fp_..._o:ww` expand what follows once. This comes at the cost of leaving tokens in the input stack, and we need to be careful not to waste this memory. All of our discussion above is nice but simplistic, as operations should not simply be performed in the order they appear.

28.1.2 Precedence and infix operators

The various operators we will encounter have different precedences, which influence the order of calculations: $1 + 2 \times 3 = 1 + (2 \times 3)$ because \times has a higher precedence than $+$. The true analog of our macro `\operand:w` must thus take care of that. When looking for an operand, it needs to perform calculations until reaching an operator which has lower precedence than the one which called `\operand:w`. This means that `\operand:w` must know what the previous binary operator is, or rather, its precedence: we thus rename it `\operand:Nw`. Let us describe as an example how we plan to do the calculation $41 - 2^3 * 4 + 5$. More precisely we describe how to perform the first operation in this expression. Here, we abuse notations: the first argument of `\operand:Nw` should be an integer constant (`\c__fp_prec_plus_int, ...`) equal to the precedence of the given operator, not directly the operator itself.

- Clean up 41 and find `-`. We call `\operand:Nw -` to find the second operand.
- Clean up 2 and find `^`.
- Compare the precedences of `-` and `^`. Since the latter is higher, we need to compute the exponentiation. For this, find the second operand with a nested call to `\operand:Nw ^`.
- Clean up 3 and find `*`.
- Compare the precedences of `^` and `*`. Since the former is higher, `\operand:Nw ^` has found the second operand of the exponentiation, which is computed: $2^3 = 8$.
- We now have $41 - 8 * 4 + 5$, and `\operand:Nw -` is still looking for a second operand for the subtraction. Is it 8?
- Compare the precedences of `-` and `*`. Since the latter is higher, we are not done with 8. Call `\operand:Nw *` to find the second operand of the multiplication.
- Clean up 4, and find `+`.
- Compare the precedences of `*` and `+`. Since the former is higher, `\operand:Nw *` has found the second operand of the multiplication, which is computed: $8 * 4 = 32$.
- We now have $41 - 32 + 5$, and `\operand:Nw -` is still looking for a second operand for the subtraction. Is it 32?
- Compare the precedences of `-` and `+`. Since they are equal, `\operand:Nw -` has found the second operand for the subtraction, which is computed: $41 - 32 = 9$.

- We now have 9+5.

The procedure above stops short of performing all computations, but adding a surrounding call to `\operand:Nw` with a very low precedence ensures that all computations are performed before `\operand:Nw` is done. Adding a trailing marker with the same very low precedence prevents the surrounding `\operand:Nw` from going beyond the marker.

The pattern above to find an operand for a given operator, is to find one number and the next operator, then compare precedences to know if the next computation should be done. If it should, then perform it after finding its second operand, and look at the next operator, then compare precedences to know if the next computation should be done. This continues until we find that the next computation should not be done. Then, we stop.

We are now ready to get a bit more technical and describe which of the `l3fp-parse` functions correspond to each step above.

First, `__fp_parse_operand:Nw` is the `\operand:Nw` function above, with small modifications due to expansion issues discussed later. We denote by $\langle precedence \rangle$ the argument of `__fp_parse_operand:Nw`, that is, the precedence of the binary operator whose operand we are trying to find. The basic action is to read numbers from the input stream. This is done by `__fp_parse_one:Nw`. A first approximation of this function is that it reads one $\langle number \rangle$, performing no computation, and finds the following binary $\langle operator \rangle$. Then it expands to

$$\langle number \rangle \\ _fp_parse_infix_ \langle operator \rangle :N \langle precedence \rangle$$

expanding the `infix` auxiliary before leaving the above in the input stream.

We now explain the `infix` auxiliaries. We need some flexibility in how we treat the case of equal precedences: most often, the first operation encountered should be performed, such as $1-2-3$ being computed as $(1-2)-3$, but 2^3^4 should be evaluated as $2^{(3^4)}$ instead. For this reason, and to support the equivalence between `**` and `^` more easily, each binary operator is converted to a control sequence `__fp_parse_infix_ \langle operator \rangle :N` when it is encountered for the first time. Instead of passing both precedences to a test function to do the comparison steps above, we pass the $\langle precedence \rangle$ (of the earlier operator) to the `infix` auxiliary for the following $\langle operator \rangle$, to know whether to perform the computation of the $\langle operator \rangle$. If it should not be performed, the `infix` auxiliary expands to

$$@ _use_none:n _fp_parse_infix_ \langle operator \rangle :N$$

and otherwise it calls `__fp_parse_operand:Nw` with the precedence of the $\langle operator \rangle$ to find its second operand $\langle number_2 \rangle$ and the next $\langle operator_2 \rangle$, and expands to

$$@ _fp_parse_apply_binary:NwNwN \\ \langle operator \rangle \langle number_2 \rangle \\ @ _fp_parse_infix_ \langle operator_2 \rangle :N$$

The `infix` function is responsible for comparing precedences, but cannot directly call the computation functions, because the first operand $\langle number \rangle$ is before the `infix` function in the input stream. This is why we stop the expansion here and give control to another function to close the loop.

A definition of `__fp_parse_operand:Nw \langle precedence \rangle` with some of the expansion control removed is

```

\exp_after:wN \__fp_parse_continue:NwN
\exp_after:wN <precedence>
\exp:w \exp_end_continue_f:w
\__fp_parse_one:Nw <precedence>

```

This expands `__fp_parse_one:Nw <precedence>` completely, which finds a number, wraps the next `<operator>` into an infix function, feeds this function the `<precedence>`, and expands it, yielding either

```

\__fp_parse_continue:NwN <precedence>
<number> @
\use_none:n \__fp_parse_infix_<operator>:N

```

or

```

\__fp_parse_continue:NwN <precedence>
<number> @
\__fp_parse_apply_binary:NwNwN
<operator> <number_2>
@ \__fp_parse_infix_<operator_2>:N

```

The definition of `__fp_parse_continue:NwN` is then very simple:

```

\cs_new:Npn \__fp_parse_continue:NwN #1#2#3 { #3 #1 #2 @ }

```

In the first case, `#3` is `\use_none:n`, yielding

```

\use_none:n <precedence> <number> @
\__fp_parse_infix_<operator>:N

```

then `<number> @ __fp_parse_infix_<operator>:N`. In the second case, `#3` is `__fp_parse_apply_binary:NwNwN`, whose role is to compute `<number> <operator> <number_2>` and to prepare for the next comparison of precedences: first we get

```

\__fp_parse_apply_binary:NwNwN
<precedence> <number> @
<operator> <number_2>
@ \__fp_parse_infix_<operator_2>:N

```

then

```

\exp_after:wN \__fp_parse_continue:NwN
\exp_after:wN <precedence>
\exp:w \exp_end_continue_f:w
\__fp_<operator>_o:ww <number> <number_2>
\exp:w \exp_end_continue_f:w
\__fp_parse_infix_<operator_2>:N <precedence>

```

where `__fp_<operator>_o:ww` computes `<number> <operator> <number_2>` and expands after the result, thus triggers the comparison of the precedence of the `<operator_2>` and the `<precedence>`, continuing the loop.

We have introduced the most important functions here, and the next few paragraphs we describe various subtleties.

28.1.3 Prefix operators, parentheses, and functions

Prefix operators (unary $-$, $+$, $!$) and parentheses are taken care of by the same mechanism, and functions (`sin`, `exp`, etc.) as well. Finding the argument of the unary $-$, for instance, is very similar to grabbing the second operand of a binary infix operator, with a subtle precedence explained below. Once that operand is found, the operator can be applied to it (for the unary $-$, this simply flips the sign). A left parenthesis is just a prefix operator with a very low precedence equal to that of the closing parenthesis (which is treated as an infix operator, since it normally appears just after numbers), so that all computations are performed until the closing parenthesis. The prefix operator associated to the left parenthesis does not alter its argument, but it removes the closing parenthesis (with some checks).

Prefix operators are the reason why we only summarily described the function `_fp_parse_one:Nw` earlier. This function is responsible for reading in the input stream the first possible $\langle number \rangle$ and the next infix $\langle operator \rangle$. If what follows `_fp_parse_one:Nw` $\langle precedence \rangle$ is a prefix operator, then we must find the operand of this prefix operator through a nested call to `_fp_parse_operand:Nw` with the appropriate precedence, then apply the operator to the operand found to yield the result of `_fp_parse_one:Nw`. So far, all is simple.

The unary operators $+$, $-$, $!$ complicate things a little bit: $-3**2$ should be $-(3^2) = -9$, and not $(-3)^2 = 9$. This would easily be done by giving $-$ a lower precedence, equal to that of the infix $+$ and $-$. Unfortunately, this fails in cases such as $3**-2*4$, yielding $3^{-2 \times 4}$ instead of the correct $3^{-2} \times 4$. A second attempt would be to call `_fp_parse_operand:Nw` with the $\langle precedence \rangle$ of the previous operator, but $0>-2+3$ is then parsed as $0>-(2+3)$: the addition is performed because it binds more tightly than the comparison which precedes $-$. The correct approach is for a unary $-$ to perform operations whose precedence is greater than both that of the previous operation, and that of the unary $-$ itself. The unary $-$ is given a precedence higher than multiplication and division. This does not lead to any surprising result, since $-(x/y) = (-x)/y$ and similarly for multiplication, and it reduces the number of nested calls to `_fp_parse_operand:Nw`.

Functions are implemented as prefix operators with very high precedence, so that their argument is the first number that can possibly be built.

Note that contrarily to the `infix` functions discussed earlier, the `prefix` functions do perform tests on the previous $\langle precedence \rangle$ to decide whether to find an argument or not, since we know that we need a number, and must never stop there.

28.1.4 Numbers and reading tokens one by one

So far, we have glossed over one important point: what is a “number”? A number is typically given in the form $\langle significand \rangle \mathbf{e} \langle exponent \rangle$, where the $\langle significand \rangle$ is any non-empty string composed of decimal digits and at most one decimal separator (a period), the exponent “ $\mathbf{e} \langle exponent \rangle$ ” is optional and is composed of an exponent mark `e` followed by a possibly empty string of signs $+$ or $-$ and a non-empty string of decimal digits. The $\langle significand \rangle$ can also be an integer, dimension, skip, or muskip variable, in which case dimensions are converted from points (or mu units) to floating points, and the $\langle exponent \rangle$ can also be an integer variable. Numbers can also be given as floating point variables, or as named constants such as `nan`, `inf` or `pi`. We may add more types in the future.

When `_fp_parse_one:Nw` is looking for a “number”, here is what happens.

- If the next token is a control sequence with the meaning of `\scan_stop:`, it can be: `\s__fp`, in which case our job is done, as what follows is an internal floating point number, or `\s__fp_mark`, in which case the expression has come to an early end, as we are still looking for a number here, or something else, in which case we consider the control sequence to be a bad variable resulting from c-expansion.
- If the next token is a control sequence with a different meaning, we assume that it is a register, unpack it with `\tex_the:D`, and use its value (in `pt` for dimensions and `skips`, `mu` for muskips) as the *significand* of a number: we look for an exponent.
- If the next token is a digit, we remove any leading zeros, then read a significand larger than 1 if the next character is a digit, read a significand smaller than 1 if the next character is a period, or we have found a significand equal to 0 otherwise, and look for an exponent.
- If the next token is a letter, we collect more letters until the first non-letter: the resulting word may denote a function such as `asin`, a constant such as `pi` or be unknown. In the first case, we call `__fp_parse_operand:Nw` to find the argument of the function, then apply the function, before declaring that we are done. Otherwise, we are done, either with the value of the constant, or with the value `nan` for unknown words.
- If the next token is anything else, we check whether it is a known prefix operator, in which case `__fp_parse_operand:Nw` finds its operand. If it is not known, then either a number is missing (if the token is a known infix operator) or the token is simply invalid in floating point expressions.

Once a number is found, `__fp_parse_one:Nw` also finds an infix operator. This goes as follows.

- If the next token is a control sequence, it could be the special marker `\s__fp_mark`, and otherwise it is a case of juxtaposing numbers, such as `2\c_zero_int`, with an implied multiplication.
- If the next token is a letter, it is also a case of juxtaposition, as letters cannot be proper infix operators.
- Otherwise (including in the case of digits), if the token is a known infix operator, the appropriate `__fp_infix_<operator>:N` function is built, and if it does not exist, we complain. In particular, the juxtaposition `\c_zero_int 2` is disallowed.

In the above, we need to test whether a character token `#1` is a digit:

```
\if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
  is a digit
\else:
  not a digit
\fi:
```

To exclude 0, replace 9 by 10. The use of `\token_to_str:N` ensures that a digit with any catcode is detected. To test if a character token is a letter, we need to work with its character code, testing if ‘`#1`’ lies in [65, 90] (uppercase letters) or [97, 112] (lowercase letters)

```

\if_int_compare:w \__fp_int_eval:w
  ( '#1 \if_int_compare:w '#1 > 'Z - 32 \fi: ) / 26 = 3 \exp_stop_f:
  is a letter
\else:
  not a letter
\fi:

```

At all steps, we try to accept all category codes: when #1 is kept to be used later, it is almost always converted to category code other through `\token_to_str:N`. More precisely, catcodes {3, 6, 7, 8, 11, 12} should work without trouble, but not {1, 2, 4, 10, 13}, and of course {0, 5, 9} cannot become tokens.

Floating point expressions should behave as much as possible like ε -TeX-based integer expressions and dimension expressions. In particular, `f`-expansion should be performed as the expression is read, token by token, forcing the expansion of protected macros, and ignoring spaces. One advantage of expanding at every step is that restricted expandable functions can then be used in floating point expressions just as they can be in other kinds of expressions. Problematically, spaces stop `f`-expansion: for instance, the macro `\X` below would not be expanded if we simply performed `f`-expansion.

```

\DeclareDocumentCommand {\test} {m} { \fp_eval:n {#1} }
\ExplSyntaxOff
\test { 1 + \X }

```

Of course, spaces typically do not appear in a code setting, but may very easily come in document-level input, from which some expressions may come. To avoid this problem, at every step, we do essentially what `\use:f` would do: take an argument, put it back in the input stream, then `f`-expand it. This is not a complete solution, since a macro's expansion could contain leading spaces which would stop the `f`-expansion before further macro calls are performed. However, in practice it should be enough: in particular, floating point numbers are correctly expanded to the underlying `\s__fp ...` structure. The `f`-expansion is performed by `__fp_parse_expand:w`.

28.2 Main auxiliary functions

```

\__fp_parse_operand:Nw \exp:w \__fp_parse_operand:Nw <precedence> \__fp_parse_expand:w
Reads the "...", performing every computation with a precedence higher than
<precedence>, then expands to

```

```

<result> @ \__fp_parse_infix_<operation>:N ...

```

where the `<operation>` is the first operation with a lower precedence, possibly `end`, and the `"..."` start just after the `<operation>`.

(End definition for `__fp_parse_operand:Nw`.)

```

\__fp_parse_infix_+:N \__fp_parse_infix_+:N <precedence> ...
If + has a precedence higher than the <precedence>, cleans up a second <operand> and
finds the <operation_2> which follows, and expands to

```

```

@ \__fp_parse_apply_binary:NwNw + <operand> @ \__fp_parse_infix_<operation_2>:N
...

```

Otherwise expands to

```
@ \use_none:n \__fp_parse_infix_+:N ...
```

A similar function exists for each infix operator.

(End definition for __fp_parse_infix_+:N.)

```
\__fp_parse_one:Nw \__fp_parse_one:Nw <precedence> ...
```

Cleans up one or two operands depending on how the precedence of the next operation compares to the *<precedence>*. If the following *<operation>* has a precedence higher than *<precedence>*, expands to

```
<operand1> @ \__fp_parse_apply_binary:NwNwN <operation> <operand2> @
\__fp_parse_infix_<operation2>:N ...
```

and otherwise expands to

```
<operand> @ \use_none:n \__fp_parse_infix_<operation>:N ...
```

(End definition for __fp_parse_one:Nw.)

28.3 Helpers

```
\__fp_parse_expand:w \exp:w \__fp_parse_expand:w <tokens>
```

This function must always come within a `\exp:w` expansion. The *<tokens>* should be the part of the expression that we have not yet read. This requires in particular closing all conditionals properly before expanding.

```
16530 \cs_new:Npn \__fp_parse_expand:w #1 { \exp_end_continue_f:w #1 }
```

(End definition for __fp_parse_expand:w.)

```
\_fp_parse_return_semicolon:w
```

This very odd function swaps its position with the following `\fi:` and removes `__fp_parse_expand:w` normally responsible for expansion. That turns out to be useful.

```
16531 \cs_new:Npn \_fp_parse_return_semicolon:w
16532   #1 \fi: \__fp_parse_expand:w { \fi: ; #1 }
```

(End definition for _fp_parse_return_semicolon:w.)

```
\__fp_parse_digits_vii:N
\_fp_parse_digits_vi:N
\_fp_parse_digits_v:N
\_fp_parse_digits_iv:N
\_fp_parse_digits_iii:N
\_fp_parse_digits_ii:N
\_fp_parse_digits_i:N
\_fp_parse_digits_:N
```

These functions must be called within an `\int_value:w` or `__fp_int_eval:w` construction. The first token which follows must be `f`-expanded prior to calling those functions. The functions read tokens one by one, and output digits into the input stream, until meeting a non-digit, or up to a number of digits equal to their index. The full expansion is

```
<digits> ; <filling 0> ; <length>
```

where *<filling 0>* is a string of zeros such that *<digits>* *<filling 0>* has the length given by the index of the function, and *<length>* is the number of zeros in the *<filling 0>* string. Each function puts a digit into the input stream and calls the next function, until we find a non-digit. We are careful to pass the tested tokens through `\token_to_str:N` to normalize their category code.

```
16533 \cs_set_protected:Npn \__fp_tmp:w #1 #2 #3
16534   {
16535     \cs_new:cpn { \_fp_parse_digits_ #1 :N } ##1
16536     {
```

```

16537     \if_int_compare:w 9 < 1 \token_to_str:N ##1 \exp_stop_f:
16538     \token_to_str:N ##1 \exp_after:wN #2 \exp:w
16539     \else:
16540     \__fp_parse_return_semicolon:w #3 ##1
16541     \fi:
16542     \__fp_parse_expand:w
16543   }
16544 }
16545 \__fp_tmp:w {vii} \__fp_parse_digits_vi:N { 0000000 ; 7 }
16546 \__fp_tmp:w {vi} \__fp_parse_digits_v:N { 000000 ; 6 }
16547 \__fp_tmp:w {v} \__fp_parse_digits_iv:N { 00000 ; 5 }
16548 \__fp_tmp:w {iv} \__fp_parse_digits_iii:N { 0000 ; 4 }
16549 \__fp_tmp:w {iii} \__fp_parse_digits_ii:N { 000 ; 3 }
16550 \__fp_tmp:w {ii} \__fp_parse_digits_i:N { 00 ; 2 }
16551 \__fp_tmp:w {i} \__fp_parse_digits_:N { 0 ; 1 }
16552 \cs_new:Npn \__fp_parse_digits_:N { ; ; 0 }

```

(End definition for `__fp_parse_digits_vii:N` and others.)

28.4 Parsing one number

`__fp_parse_one:Nw` This function finds one number, and packs the symbol which follows in an `__fp_parse_infix_...` csname. #1 is the previous *<precedence>*, and #2 the first token of the operand. We distinguish four cases: #2 is equal to `\scan_stop:` in meaning, #2 is a different control sequence, #2 is a digit, and #2 is something else (this last case is split further later). Despite the earlier `f`-expansion, #2 may still be expandable if it was protected by `\exp_not:N`, as may happen with the L^AT_EX 2_ε command `\protect`. Using a well placed `\reverse_if:N`, this case is sent to `__fp_parse_one_fp:NN` which deals with it robustly.

```

16553 \cs_new:Npn \__fp_parse_one:Nw #1 #2
16554 {
16555   \if_catcode:w \scan_stop: \exp_not:N #2
16556   \exp_after:wN \if_meaning:w \exp_not:N #2 #2 \else:
16557   \exp_after:wN \reverse_if:N
16558   \fi:
16559   \if_meaning:w \scan_stop: #2
16560   \exp_after:wN \exp_after:wN
16561   \exp_after:wN \__fp_parse_one_fp:NN
16562   \else:
16563   \exp_after:wN \exp_after:wN
16564   \exp_after:wN \__fp_parse_one_register:NN
16565   \fi:
16566   \else:
16567   \if_int_compare:w 9 < 1 \token_to_str:N #2 \exp_stop_f:
16568   \exp_after:wN \exp_after:wN
16569   \exp_after:wN \__fp_parse_one_digit:NN
16570   \else:
16571   \exp_after:wN \exp_after:wN
16572   \exp_after:wN \__fp_parse_one_other:NN
16573   \fi:
16574   \fi:
16575   #1 #2
16576 }

```

(End definition for `_fp_parse_one:Nw`.)

`_fp_parse_one_fp:NN`
`_fp_exp_after_mark_f:nw`
`_fp_exp_after_?_f:nw`

This function receives a $\langle precedence \rangle$ and a control sequence equal to `\scan_stop:` in meaning. There are three cases.

- `\s_fp` starts a floating point number, and we call `_fp_exp_after_f:nw`, which f-expands after the floating point.
- `\s_fp_mark` is a premature end, we call `_fp_exp_after_mark_f:nw`, which triggers an fp-early-end error.
- For a control sequence not containing `\s_fp`, we call `_fp_exp_after_?_f:nw`, causing a bad-variable error.

This scheme is extensible: additional types can be added by starting the variables with a scan mark of the form `\s_fp_⟨type⟩` and defining `_fp_exp_after_⟨type⟩_f:nw`. In all cases, we make sure that the second argument of `_fp_parse_infix:NN` is correctly expanded. A special case only enabled in L^AT_EX 2_ε is that if `\protect` is encountered then the error message mentions the control sequence which follows it rather than `\protect` itself. The test for L^AT_EX 2_ε uses `\@unexpandable@protect` rather than `\protect` because `\protect` is often `\scan_stop:` hence “does not exist”.

```

16577 \cs_new:Npn \_fp_parse_one_fp:NN #1
16578 {
16579   \_fp_exp_after_any_f:nw
16580   {
16581     \exp_after:wN \_fp_parse_infix:NN
16582     \exp_after:wN #1 \exp:w \_fp_parse_expand:w
16583   }
16584 }
16585 \cs_new:Npn \_fp_exp_after_mark_f:nw #1
16586 {
16587   \int_case:nnF { \exp_after:wN \use_i:nnn \use_none:nnn #1 }
16588   {
16589     \c\_fp_prec_comma_int { }
16590     \c\_fp_prec_tuple_int { }
16591     \c\_fp_prec_end_int
16592     {
16593       \exp_after:wN \c\_fp_empty_tuple_fp
16594       \exp:w \exp_end_continue_f:w
16595     }
16596   }
16597   {
16598     \_kernel_msg_expandable_error:nn { kernel } { fp-early-end }
16599     \exp_after:wN \c\_nan_fp \exp:w \exp_end_continue_f:w
16600   }
16601   #1
16602 }
16603 \cs_new:cpn { \_fp_exp_after_?_f:nw } #1#2
16604 {
16605   \_kernel_msg_expandable_error:nnn { kernel } { bad-variable }
16606   {#2}
16607   \exp_after:wN \c\_nan_fp \exp:w \exp_end_continue_f:w #1
16608 }
16609 (*package)

```



```

16610 \cs_set_protected:Npn \__fp_tmp:w #1
16611 {
16612   \cs_if_exist:NT #1
16613   {
16614     \cs_gset:cpn { __fp_exp_after_?_f:nw } ##1##2
16615     {
16616       \exp_after:wN \c_nan_fp \exp:w \exp_end_continue_f:w ##1
16617       \str_if_eq:nnTF {##2} { \protect }
16618       {
16619         \cs_if_eq:NNTF ##2 #1 { \use_i:nn } { \use:n }
16620         {
16621           \__kernel_msg_expandable_error:nnn { kernel }
16622           { fp-robust-cmd }
16623         }
16624       }
16625       {
16626         \__kernel_msg_expandable_error:nnn { kernel }
16627         { bad-variable } {##2}
16628       }
16629     }
16630   }
16631 }
16632 \exp_args:Nc \__fp_tmp:w { @unexpandable@protect }
16633 </package>

```

(End definition for __fp_parse_one_fp:NN, __fp_exp_after_mark_f:nw, and __fp_exp_after_?_f:nw.)

```

\__fp_parse_one_register:NN
  \__fp_parse_one_register_aux:Nw
\__fp_parse_one_register_auxii:wwwNw
  \__fp_parse_one_register_int:www
  \__fp_parse_one_register_mu:www
  \__fp_parse_one_register_dim:ww

```

This is called whenever #2 is a control sequence other than \scan_stop: in meaning. We special-case \wd, \ht, \dp (see later) and otherwise assume that it is a register, but carefully unpack it with \tex_the:D within braces. First, we find the exponent following #2. Then we unpack #2 with \tex_the:D, and the auxii auxiliary distinguishes integer registers from dimensions/skips from muskips, according to the presence of a period and/or of pt. For integers, simply convert $\langle value \rangle e \langle exponent \rangle$ to a floating point number with __fp_parse:n (this is somewhat wasteful). For other registers, the decimal rounding provided by TeX does not accurately represent the binary value that it manipulates, so we extract this binary value as a number of scaled points with \int_value:w \dim_to_decimal_in_sp:n { $\langle decimal value \rangle$ pt }, and use an auxiliary of \dim_to_fp:n, which performs the multiplication by 2^{-16} , correctly rounded.

```

16634 \cs_new:Npn \__fp_parse_one_register:NN #1#2
16635 {
16636   \exp_after:wN \__fp_parse_infix_after_operand:NwN
16637   \exp_after:wN #1
16638   \exp:w \exp_end_continue_f:w
16639   \__fp_parse_one_register_special:N #2
16640   \exp_after:wN \__fp_parse_one_register_aux:Nw
16641   \exp_after:wN #2
16642   \int_value:w
16643   \exp_after:wN \__fp_parse_exponent:N
16644   \exp:w \__fp_parse_expand:w
16645 }
16646 \cs_new:Npx \__fp_parse_one_register_aux:Nw #1
16647 {
16648   \exp_not:n

```

```

16649     {
16650       \exp_after:wN \use:nn
16651       \exp_after:wN \__fp_parse_one_register_auxii:wwwNw
16652     }
16653     \exp_not:N \exp_after:wN { \exp_not:N \tex_the:D #1 }
16654     ; \exp_not:N \__fp_parse_one_register_dim:ww
16655     \tl_to_str:n { pt } ; \exp_not:N \__fp_parse_one_register_mu:www
16656     . \tl_to_str:n { pt } ; \exp_not:N \__fp_parse_one_register_int:www
16657     \exp_not:N \q_stop
16658   }
16659   \exp_args:Nno \use:nn
16660   { \cs_new:Npn \__fp_parse_one_register_auxii:wwwNw #1 . #2 }
16661   { \tl_to_str:n { pt } #3 ; #4#5 \q_stop }
16662   { #4 #1.#2; }
16663   \exp_args:Nno \use:nn
16664   { \cs_new:Npn \__fp_parse_one_register_mu:www #1 }
16665   { \tl_to_str:n { mu } ; #2 ; }
16666   { \__fp_parse_one_register_dim:ww #1 ; }
16667   \cs_new:Npn \__fp_parse_one_register_int:www #1; #2.; #3;
16668   { \__fp_parse:n { #1 e #3 } }
16669   \cs_new:Npn \__fp_parse_one_register_dim:ww #1; #2;
16670   {
16671     \exp_after:wN \__fp_from_dim_test:ww
16672     \int_value:w #2 \exp_after:wN ,
16673     \int_value:w \dim_to_decimal_in_sp:n { #1 pt } ;
16674   }

```

(End definition for `__fp_parse_one_register:NN` and others.)

`__fp_parse_one_register_special:N` The `\wd`, `\dp`, `\ht` primitives expect an integer argument. We abuse the exponent parser to find the integer argument: simply include the exponent marker `e`. Once that “exponent” is found, use `\tex_the:D` to find the box dimension and then copy what we did for dimensions.

```

16675 \cs_new:Npn \__fp_parse_one_register_special:N #1
16676 {
16677   \if_meaning:w \box_wd:N #1 \__fp_parse_one_register_wd:w \fi:
16678   \if_meaning:w \box_ht:N #1 \__fp_parse_one_register_wd:w \fi:
16679   \if_meaning:w \box_dp:N #1 \__fp_parse_one_register_wd:w \fi:
16680   \if_meaning:w \infty #1
16681     \__fp_parse_one_register_math:NNw \infty #1
16682   \fi:
16683   \if_meaning:w \pi #1
16684     \__fp_parse_one_register_math:NNw \pi #1
16685   \fi:
16686 }
16687 \cs_new:Npn \__fp_parse_one_register_math:NNw
16688 #1#2#3#4 \__fp_parse_expand:w
16689 {
16690   #3
16691   \str_if_eq:nnTF {#1} {#2}
16692   {
16693     \__kernel_msg_expandable_error:nnn
16694     { kernel } { fp-infty-pi } {#1}
16695     \c_nan_fp

```

```

16696     }
16697     { #4 \__fp_parse_expand:w }
16698   }
16699   \cs_new:Npn \__fp_parse_one_register_wd:w
16700     #1#2 \exp_after:wN #3#4 \__fp_parse_expand:w
16701   {
16702     #1
16703     \exp_after:wN \__fp_parse_one_register_wd:Nw
16704     #4 \__fp_parse_expand:w e
16705   }
16706   \cs_new:Npn \__fp_parse_one_register_wd:Nw #1#2 ;
16707   {
16708     \exp_after:wN \__fp_from_dim_test:ww
16709     \exp_after:wN 0 \exp_after:wN ,
16710     \int_value:w \dim_to_decimal_in_sp:n { #1 #2 } ;
16711   }

```

(End definition for __fp_parse_one_register_special:N and others.)

__fp_parse_one_digit:NN A digit marks the beginning of an explicit floating point number. Once the number is found, we catch the case of overflow and underflow with __fp_sanitize:wN, then __fp_parse_infix_after_operand:NwN expands __fp_parse_infix:NN after the number we find, to wrap the following infix operator as required. Finding the number itself begins by removing leading zeros: further steps are described later.

```

16712 \cs_new:Npn \__fp_parse_one_digit:NN #1
16713 {
16714   \exp_after:wN \__fp_parse_infix_after_operand:NwN
16715   \exp_after:wN #1
16716   \exp:w \exp_end_continue_f:w
16717   \exp_after:wN \__fp_sanitize:wN
16718   \int_value:w \__fp_int_eval:w 0 \__fp_parse_trim_zeros:N
16719 }

```

(End definition for __fp_parse_one_digit:NN.)

__fp_parse_one_other:NN For this function, #2 is a character token which is not a digit. If it is an ASCII letter, __fp_parse_letters:N beyond this one and give the result to __fp_parse_word:Nw. Otherwise, the character is assumed to be a prefix operator, and we build __fp_parse_prefix_{operator}:Nw.

```

16720 \cs_new:Npn \__fp_parse_one_other:NN #1 #2
16721 {
16722   \if_int_compare:w
16723     \__fp_int_eval:w
16724     ( '#2 \if_int_compare:w '#2 > 'Z - 32 \fi: ) / 26
16725     = 3 \exp_stop_f:
16726   \exp_after:wN \__fp_parse_word:Nw
16727   \exp_after:wN #1
16728   \exp_after:wN #2
16729   \exp:w \exp_after:wN \__fp_parse_letters:N
16730   \exp:w
16731   \else:
16732     \exp_after:wN \__fp_parse_prefix:NNN
16733     \exp_after:wN #1
16734     \exp_after:wN #2

```

```

16735     \cs:w
16736     __fp_parse_prefix_ \token_to_str:N #2 :Nw
16737     \exp_after:wN
16738     \cs_end:
16739     \exp:w
16740     \fi:
16741     \__fp_parse_expand:w
16742 }

```

(End definition for __fp_parse_one_other:NN.)

__fp_parse_word:Nw
__fp_parse_letters:N

Finding letters is a simple recursion. Once __fp_parse_letters:N has done its job, we try to build a control sequence from the word #2. If it is a known word, then the corresponding action is taken, and otherwise, we complain about an unknown word, yield \c_nan_fp, and look for the following infix operator. Note that the unknown word could be a mistyped function as well as a mistyped constant, so there is no way to tell whether to look for arguments; we do not. The standard requires “inf” and “infinity” and “nan” to be recognized regardless of case, but we probably don’t want to allow every l3fp word to have an arbitrary mixture of lower and upper case, so we test and use a differently-named control sequence.

```

16743 \cs_new:Npn \__fp_parse_word:Nw #1#2;
16744 {
16745     \cs_if_exist_use:cF { __fp_parse_word_#2:N }
16746     {
16747         \cs_if_exist_use:cF
16748         { __fp_parse_caseless_ \str_fold_case:n {#2} :N }
16749         {
16750             \__kernel_msg_expandable_error:nnn
16751             { kernel } { unknown-fp-word } {#2}
16752             \exp_after:wN \c_nan_fp \exp:w \exp_end_continue_f:w
16753             \__fp_parse_infix:NN
16754         }
16755     }
16756     #1
16757 }
16758 \cs_new:Npn \__fp_parse_letters:N #1
16759 {
16760     \exp_end_continue_f:w
16761     \if_int_compare:w
16762     \if_catcode:w \scan_stop: \exp_not:N #1
16763     0
16764     \else:
16765         \__fp_int_eval:w
16766         ( '#1 \if_int_compare:w '#1 > 'Z - 32 \fi: ) / 26
16767         \fi:
16768         = 3 \exp_stop_f:
16769         \exp_after:wN #1
16770         \exp:w \exp_after:wN \__fp_parse_letters:N
16771         \exp:w
16772     \else:
16773         \__fp_parse_return_semicolon:w #1
16774         \fi:
16775         \__fp_parse_expand:w
16776 }

```

(End definition for `_fp_parse_word:Nw` and `_fp_parse_letters:N`.)

`_fp_parse_prefix:NNN` For this function, #1 is the previous *<precedence>*, #2 is the operator just seen, and #3 is a control sequence which implements the operator if it is a known operator. If this control sequence is `\scan_stop:`, then the operator is in fact unknown. Either the expression is missing a number there (if the operator is valid as an infix operator), and we put `nan`, wrapping the infix operator in a `cname` as appropriate, or the character is simply invalid in floating point expressions, and we continue looking for a number, starting again from `_fp_parse_one:Nw`.

`_fp_parse_prefix_unknown:NNN`

```

16777 \cs_new:Npn \_fp_parse_prefix:NNN #1#2#3
16778 {
16779   \if_meaning:w \scan_stop: #3
16780     \exp_after:wN \_fp_parse_prefix_unknown:NNN
16781     \exp_after:wN #2
16782   \fi:
16783   #3 #1
16784 }
16785 \cs_new:Npn \_fp_parse_prefix_unknown:NNN #1#2#3
16786 {
16787   \cs_if_exist:cTF { \_fp_parse_infix_ \token_to_str:N #1 :N }
16788   {
16789     \_kernel_msg_expandable_error:nnn
16790     { kernel } { fp-missing-number } {#1}
16791     \exp_after:wN \c_nan_fp \exp:w \exp_end_continue_f:w
16792     \_fp_parse_infix:NN #3 #1
16793   }
16794   {
16795     \_kernel_msg_expandable_error:nnn
16796     { kernel } { fp-unknown-symbol } {#1}
16797     \_fp_parse_one:Nw #3
16798   }
16799 }
```

(End definition for `_fp_parse_prefix:NNN` and `_fp_parse_prefix_unknown:NNN`.)

28.4.1 Numbers: trimming leading zeros

Numbers are parsed as follows: first we trim leading zeros, then if the next character is a digit, start reading a significand ≥ 1 with the set of functions `_fp_parse_large...`; if it is a period, the significand is < 1 ; and otherwise it is zero. In the second case, trim additional zeros after the period, counting them for an exponent shift $\langle exp_1 \rangle < 0$, then read the significand with the set of functions `_fp_parse_small...`. Once the significand is read, read the exponent if `e` is present.

`_fp_parse_trim_zeros:N`
`_fp_parse_trim_end:w`

This function expects an already expanded token. It removes any leading zero, then distinguishes three cases: if the first non-zero token is a digit, then call `_fp_parse_large:N` (the significand is ≥ 1); if it is `.`, then continue trimming zeros with `_fp_parse_strim_zeros:N`; otherwise, our number is exactly zero, and we call `_fp_parse_zero:` to take care of that case.

```

16800 \cs_new:Npn \_fp_parse_trim_zeros:N #1
16801 {
16802   \if:w 0 \exp_not:N #1
16803     \exp_after:wN \_fp_parse_trim_zeros:N
```

```

16804         \exp:w
16805     \else:
16806         \if:w . \exp_not:N #1
16807             \exp_after:wN \__fp_parse_strim_zeros:N
16808             \exp:w
16809         \else:
16810             \__fp_parse_trim_end:w #1
16811         \fi:
16812     \fi:
16813     \__fp_parse_expand:w
16814 }
16815 \cs_new:Npn \__fp_parse_trim_end:w #1 \fi: \fi: \__fp_parse_expand:w
16816 {
16817     \fi:
16818     \fi:
16819     \if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
16820         \exp_after:wN \__fp_parse_large:N
16821     \else:
16822         \exp_after:wN \__fp_parse_zero:
16823     \fi:
16824     #1
16825 }

```

(End definition for __fp_parse_trim_zeros:N and __fp_parse_trim_end:w.)

__fp_parse_strim_zeros:N If we have removed all digits until a period (or if the body started with a period), then
 __fp_parse_strim_end:w enter the “small_trim” loop which outputs −1 for each removed 0. Those −1 are added to an integer expression waiting for the exponent. If the first non-zero token is a digit, call __fp_parse_small:N (our significand is smaller than 1), and otherwise, the number is an exact zero. The name `strim` stands for “small trim”.

```

16826 \cs_new:Npn \__fp_parse_strim_zeros:N #1
16827 {
16828     \if:w 0 \exp_not:N #1
16829         - 1
16830         \exp_after:wN \__fp_parse_strim_zeros:N \exp:w
16831     \else:
16832         \__fp_parse_strim_end:w #1
16833     \fi:
16834     \__fp_parse_expand:w
16835 }
16836 \cs_new:Npn \__fp_parse_strim_end:w #1 \fi: \__fp_parse_expand:w
16837 {
16838     \fi:
16839     \if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
16840         \exp_after:wN \__fp_parse_small:N
16841     \else:
16842         \exp_after:wN \__fp_parse_zero:
16843     \fi:
16844     #1
16845 }

```

(End definition for __fp_parse_strim_zeros:N and __fp_parse_strim_end:w.)

__fp_parse_zero: After reading a significand of 0, find any exponent, then put a sign of 1 for __fp-sanitize:wN, which removes everything and leaves an exact zero.

```

16846 \cs_new:Npn \__fp_parse_zero:
16847 {
16848   \exp_after:wN ; \exp_after:wN 1
16849   \int_value:w \__fp_parse_exponent:N
16850 }

```

(End definition for __fp_parse_zero:.)

28.4.2 Number: small significand

__fp_parse_small:N This function is called after we have passed the decimal separator and removed all leading zeros from the significand. It is followed by a non-zero digit (with any catcode). The goal is to read up to 16 digits. But we can't do that all at once, because \int_value:w (which allows us to collect digits and continue expanding) can only go up to 9 digits. Hence we grab digits in two steps of 8 digits. Since #1 is a digit, read seven more digits using __fp_parse_digits_vii:N. The small_leading auxiliary leaves those digits in the \int_value:w, and grabs some more, or stops if there are no more digits. Then the pack_leading auxiliary puts the various parts in the appropriate order for the processing further up.

```

16851 \cs_new:Npn \__fp_parse_small:N #1
16852 {
16853   \exp_after:wN \__fp_parse_pack_leading:NNNNNww
16854   \int_value:w \__fp_int_eval:w 1 \token_to_str:N #1
16855   \exp_after:wN \__fp_parse_small_leading:wwNN
16856   \int_value:w 1
16857   \exp_after:wN \__fp_parse_digits_vii:N
16858   \exp:w \__fp_parse_expand:w
16859 }

```

(End definition for __fp_parse_small:N.)

__fp_parse_small_leading:wwNN __fp_parse_small_leading:wwNN 1 <digits> ; <zeros> ; <number of zeros>

We leave <digits> <zeros> in the input stream: the functions used to grab digits are such that this constitutes digits 1 through 8 of the significand. Then prepare to pack 8 more digits, with an exponent shift of zero (this shift is used in the case of a large significand). If #4 is a digit, leave it behind for the packing function, and read 6 more digits to reach a total of 15 digits: further digits are involved in the rounding. Otherwise put 8 zeros in to complete the significand, then look for an exponent.

```

16860 \cs_new:Npn \__fp_parse_small_leading:wwNN 1 #1 ; #2; #3 #4
16861 {
16862   #1 #2
16863   \exp_after:wN \__fp_parse_pack_trailing:NNNNNNww
16864   \exp_after:wN 0
16865   \int_value:w \__fp_int_eval:w 1
16866   \if_int_compare:w 9 < 1 \token_to_str:N #4 \exp_stop_f:
16867     \token_to_str:N #4
16868     \exp_after:wN \__fp_parse_small_trailing:wwNN
16869     \int_value:w 1
16870     \exp_after:wN \__fp_parse_digits_vi:N
16871     \exp:w
16872   \else:
16873     0000 0000 \__fp_parse_exponent:Nw #4
16874   \fi:

```

(End definition for _fp_parse_small_leading:wwNN.)

Leave digits 10 to 15 (arguments #1 and #2) in the input stream. If the *<next token>* is a digit, it is the 16th digit, we keep it, then the `small_round` auxiliary considers this digit and all further digits to perform the rounding: the function expands to nothing, to `+0` or to `+1`. Otherwise, there is no 16-th digit, so we put a 0, and look for an exponent.

(End definition for _fp_parse_small_trailing:wwNN.)

Those functions are expanded after all the digits are found, we took care of the rounding, as well as the exponent. The last argument is the exponent. The previous five arguments are 8 digits which we pack in groups of 4, and the argument before that is 1, except in the rare case where rounding lead to a carry, in which case the argument is 2. The `trailing` function has an exponent shift as its first argument, which we add to the exponent found in the `e...` syntax. If the trailing digits cause a carry, the integer expression for the leading digits is incremented (+1 in the code below). If the leading digits propagate this carry all the way up, the function `_fp_parse_pack_carry:w` increments the exponent, and changes the significand from 0000... to 1000...: this is simple because such a carry can only occur to give rise to a power of 10.

(End definition for _fp_parse_pack_trailing:NNNNNNww, _fp_parse_pack_leading:NNNNNNww, and _fp_parse_pack_carry:w.)

28.4.3 Number: large significand

Parsing a significand larger than 1 is a little bit more difficult than parsing small significands. We need to count the number of digits before the decimal separator, and add that to the final exponent. We also need to test for the presence of a dot each time we run out of digits, and branch to the appropriate `parse_small` function in those cases.

`_fp_parse_large:N` This function is followed by the first non-zero digit of a “large” significand (≥ 1). It is called within an integer expression for the exponent. Grab up to 7 more digits, for a total of 8 digits.

```

16903 \cs_new:Npn \_fp_parse_large:N #1
16904 {
16905   \exp_after:wN \_fp_parse_large_leading:wwNN
16906   \int_value:w 1 \token_to_str:N #1
16907   \exp_after:wN \_fp_parse_digits_vii:N
16908   \exp:w \_fp_parse_expand:w
16909 }

```

(End definition for `_fp_parse_large:N`.)

`_fp_parse_large_leading:wwNN` `_fp_parse_large_leading:wwNN 1 <digits> ; <zeros> ; <number of zeros>`
`<next token>`

We shift the exponent by the number of digits in #1, namely the target number, 8, minus the *<number of zeros>* (number of digits missing). Then prepare to pack the 8 first digits. If the *<next token>* is a digit, read up to 6 more digits (digits 10 to 15). If it is a period, try to grab the end of our 8 first digits, branching to the `small` functions since the number of digit does not affect the exponent anymore. Finally, if this is the end of the significand, insert the *<zeros>* to complete the 8 first digits, insert 8 more, and look for an exponent.

```

16910 \cs_new:Npn \_fp_parse_large_leading:wwNN 1 #1 ; #2; #3 #4
16911 {
16912   + \c__fp_half_prec_int - #3
16913   \exp_after:wN \_fp_parse_pack_leading:NNNNNww
16914   \int_value:w \_fp_int_eval:w 1 #1
16915   \if_int_compare:w 9 < 1 \token_to_str:N #4 \exp_stop_f:
16916     \exp_after:wN \_fp_parse_large_trailing:wwNN
16917     \int_value:w 1 \token_to_str:N #4
16918     \exp_after:wN \_fp_parse_digits_vi:N
16919     \exp:w
16920   \else:
16921     \if:w . \exp_not:N #4
16922       \exp_after:wN \_fp_parse_small_leading:wwNN
16923       \int_value:w 1
16924       \cs:w
16925         \_fp_parse_digits_
16926         \_fp_int_to_roman:w #3
16927         :N \exp_after:wN
16928       \cs_end:
16929       \exp:w
16930     \else:
16931       #2
16932       \exp_after:wN \_fp_parse_pack_trailing:NNNNNNww
16933       \exp_after:wN 0

```

```

16934         \int_value:w 1 0000 0000
16935         \__fp_parse_exponent:Nw #4
16936         \fi:
16937     \fi:
16938     \__fp_parse_expand:w
16939 }

```

(End definition for __fp_parse_large_leading:wwNN.)

```

\__fp_parse_large_trailing:wwNN    \__fp_parse_large_trailing:wwNN 1 <digits> ; <zeros> ; <number of zeros>
                                   <next token>

```

We have just read 15 digits. If the *<next token>* is a digit, then the exponent shift caused by this block of 8 digits is 8, first argument to the `pack_trailing` function. We keep the *<digits>* and this 16-th digit, and find how this should be rounded using `__fp_parse_large_round:NN`. Otherwise, the exponent shift is the number of *<digits>*, 7 minus the *<number of zeros>*, and we test for a decimal point. This case happens in 123451234512345.67 with exactly 15 digits before the decimal separator. Then branch to the appropriate `small` auxiliary, grabbing a few more digits to complement the digits we already grabbed. Finally, if this is truly the end of the significand, look for an exponent after using the *<zeros>* and providing a 16-th digit of 0.

```

16940 \cs_new:Npn \__fp_parse_large_trailing:wwNN 1 #1 ; #2; #3 #4
16941 {
16942     \if_int_compare:w 9 < 1 \token_to_str:N #4 \exp_stop_f:
16943     \exp_after:wN \__fp_parse_pack_trailing:NNNNNNnw
16944     \exp_after:wN \c__fp_half_prec_int
16945     \int_value:w \__fp_int_eval:w 1 #1 \token_to_str:N #4
16946     \exp_after:wN \__fp_parse_large_round:NN
16947     \exp_after:wN #4
16948     \exp:w
16949     \else:
16950     \exp_after:wN \__fp_parse_pack_trailing:NNNNNNnw
16951     \int_value:w \__fp_int_eval:w 7 - #3 \exp_stop_f:
16952     \int_value:w \__fp_int_eval:w 1 #1
16953     \if:w . \exp_not:N #4
16954     \exp_after:wN \__fp_parse_small_trailing:wwNN
16955     \int_value:w 1
16956     \cs:w
16957         __fp_parse_digits_
16958         \__fp_int_to_roman:w #3
16959         :N \exp_after:wN
16960     \cs_end:
16961     \exp:w
16962     \else:
16963     #2 0 \__fp_parse_exponent:Nw #4
16964     \fi:
16965 \fi:
16966 \__fp_parse_expand:w
16967 }

```

(End definition for __fp_parse_large_trailing:wwNN.)

28.4.4 Number: beyond 16 digits, rounding

`__fp_parse_round_loop:N` This loop is called when rounding a number (whether the mantissa is small or large).
`__fp_parse_round_up:N` It should appear in an integer expression. This function reads digits one by one, until reaching a non-digit, and adds 1 to the integer expression for each digit. If all digits found are 0, the function ends the expression by ;0, otherwise by ;1. This is done by switching the loop to `round_up` at the first non-zero digit, thus we avoid to test whether digits are 0 or not once we see a first non-zero digit.

```

16968 \cs_new:Npn \__fp_parse_round_loop:N #1
16969 {
16970   \if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
16971     + 1
16972   \if:w 0 \token_to_str:N #1
16973     \exp_after:wN \__fp_parse_round_loop:N
16974     \exp:w
16975   \else:
16976     \exp_after:wN \__fp_parse_round_up:N
16977     \exp:w
16978   \fi:
16979 \else:
16980   \__fp_parse_return_semicolon:w 0 #1
16981 \fi:
16982 \__fp_parse_expand:w
16983 }
16984 \cs_new:Npn \__fp_parse_round_up:N #1
16985 {
16986   \if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
16987     + 1
16988   \exp_after:wN \__fp_parse_round_up:N
16989   \exp:w
16990 \else:
16991   \__fp_parse_return_semicolon:w 1 #1
16992 \fi:
16993 \__fp_parse_expand:w
16994 }

```

(End definition for `__fp_parse_round_loop:N` and `__fp_parse_round_up:N`.)

`__fp_parse_round_after:wN` After the loop `__fp_parse_round_loop:N`, this function fetches an exponent with `__fp_parse_exponent:N`, and combines it with the number of digits counted by `__fp_parse_round_loop:N`. At the same time, the result 0 or 1 is added to the surrounding integer expression.

```

16995 \cs_new:Npn \__fp_parse_round_after:wN #1; #2
16996 {
16997   + #2 \exp_after:wN ;
16998   \int_value:w \__fp_int_eval:w #1 + \__fp_parse_exponent:N
16999 }

```

(End definition for `__fp_parse_round_after:wN`.)

`__fp_parse_small_round:NN` Here, #1 is the digit that we are currently rounding (we only care whether it is even or odd).
`__fp_parse_round_after:wN` If #2 is not a digit, then fetch an exponent and expand to ;*exponent* only. Otherwise, we expand to +0 or +1, then ;*exponent*. To decide which, call `__fp_round_s:NNNw` to know whether to round up, giving it as arguments a sign 0 (all explicit

numbers are positive), the digit #1 to round, the first following digit #2, and either +0 or +1 depending on whether the following digits are all zero or not. This last argument is obtained by `__fp_parse_round_loop:N`, whose number of digits we discard by multiplying it by 0. The exponent which follows the number is also fetched by `__fp_parse_round_after:wN`.

```

17000 \cs_new:Npn \__fp_parse_small_round:NN #1#2
17001 {
17002   \if_int_compare:w 9 < 1 \token_to_str:N #2 \exp_stop_f:
17003   +
17004   \exp_after:wN \__fp_round_s:NNNw
17005   \exp_after:wN 0
17006   \exp_after:wN #1
17007   \exp_after:wN #2
17008   \int_value:w \__fp_int_eval:w
17009   \exp_after:wN \__fp_parse_round_after:wN
17010   \int_value:w \__fp_int_eval:w 0 * \__fp_int_eval:w 0
17011   \exp_after:wN \__fp_parse_round_loop:N
17012   \exp:w
17013   \else:
17014     \__fp_parse_exponent:Nw #2
17015   \fi:
17016   \__fp_parse_expand:w
17017 }

```

(End definition for `__fp_parse_small_round:NN` and `__fp_parse_round_after:wN`.)

```

\__fp_parse_large_round:NN
  \__fp_parse_large_round_test:NN
  \__fp_parse_large_round_aux:wNN

```

Large numbers are harder to round, as there may be a period in the way. Again, #1 is the digit that we are currently rounding (we only care whether it is even or odd). If there are no more digits (#2 is not a digit), then we must test for a period: if there is one, then switch to the rounding function for small significands, otherwise fetch an exponent. If there are more digits (#2 is a digit), then round, checking with `__fp_parse_round_loop:N` if all further digits vanish, or some are non-zero. This loop is not enough, as it is stopped by a period. After the loop, the `aux` function tests for a period: if it is present, then we must continue looking for digits, this time discarding the number of digits we find.

```

17018 \cs_new:Npn \__fp_parse_large_round:NN #1#2
17019 {
17020   \if_int_compare:w 9 < 1 \token_to_str:N #2 \exp_stop_f:
17021   +
17022   \exp_after:wN \__fp_round_s:NNNw
17023   \exp_after:wN 0
17024   \exp_after:wN #1
17025   \exp_after:wN #2
17026   \int_value:w \__fp_int_eval:w
17027   \exp_after:wN \__fp_parse_large_round_aux:wNN
17028   \int_value:w \__fp_int_eval:w 1
17029   \exp_after:wN \__fp_parse_round_loop:N
17030   \else: %^^A could be dot, or e, or other
17031     \exp_after:wN \__fp_parse_large_round_test:NN
17032     \exp_after:wN #1
17033     \exp_after:wN #2
17034   \fi:
17035 }

```

```

17036 \cs_new:Npn \__fp_parse_large_round_test:NN #1#2
17037 {
17038   \if:w . \exp_not:N #2
17039     \exp_after:wN \__fp_parse_small_round:NN
17040     \exp_after:wN #1
17041     \exp:w
17042   \else:
17043     \__fp_parse_exponent:Nw #2
17044   \fi:
17045   \__fp_parse_expand:w
17046 }
17047 \cs_new:Npn \__fp_parse_large_round_aux:wNN #1 ; #2 #3
17048 {
17049   + #2
17050   \exp_after:wN \__fp_parse_round_after:wN
17051   \int_value:w \__fp_int_eval:w #1
17052   \if:w . \exp_not:N #3
17053     + 0 * \__fp_int_eval:w 0
17054     \exp_after:wN \__fp_parse_round_loop:N
17055     \exp:w \exp_after:wN \__fp_parse_expand:w
17056   \else:
17057     \exp_after:wN ;
17058     \exp_after:wN 0
17059     \exp_after:wN #3
17060   \fi:
17061 }

```

(End definition for `__fp_parse_large_round:NN`, `__fp_parse_large_round_test:NN`, and `__fp_parse_large_round_aux:wNN`.)

28.4.5 Number: finding the exponent

Expansion is a little bit tricky here, in part because we accept input where multiplication is implicit.

```

\__fp_parse:n { 3.2 erf(0.1) }
\__fp_parse:n { 3.2 e1_my_int }
\__fp_parse:n { 3.2 \c_pi_fp }

```

The first case indicates that just looking one character ahead for an “e” is not enough, since we would mistake the function `erf` for an exponent of “`rf`”. An alternative would be to look two tokens ahead and check if what follows is a sign or a digit, considering in that case that we must be finding an exponent. But taking care of the second case requires that we unpack registers after `e`. However, blindly expanding the two tokens ahead completely would break the third example (unpacking is even worse). Indeed, in the course of reading `3.2`, `\c_pi_fp` is expanded to `\s__fp __fp_chk:w 1 0 {-1} {3141}` \cdots ; and `\s__fp` stops the expansion. Expanding two tokens ahead would then force the expansion of `__fp_chk:w` (despite it being protected), and that function tries to produce an error.

What can we do? Really, the reason why this last case breaks is that just as \TeX does, we should read ahead as little as possible. Here, the only case where there may be an exponent is if the first token ahead is `e`. Then we expand (and possibly unpack) the second token.

`__fp_parse_exponent:Nw` This auxiliary is convenient to smuggle some material through `\fi:` ending conditional processing. We place those `\fi:` (argument #2) at a very odd place because this allows us to insert `__fp_int_eval:w ...` there if needed.

```

17062 \cs_new:Npn \__fp_parse_exponent:Nw #1 #2 \__fp_parse_expand:w
17063 {
17064     \exp_after:wN ;
17065     \int_value:w #2 \__fp_parse_exponent:N #1
17066 }

```

(End definition for __fp_parse_exponent:Nw.)

`__fp_parse_exponent:N` This function should be called within an `\int_value:w` expansion (or within an integer expression). It leaves digits of the exponent behind it in the input stream, and terminates the expansion with a semicolon. If there is no `e`, leave an exponent of 0. If there is an `e`, expand the next token to run some tests on it. The first rough test is that if the character code of #1 is greater than that of 9 (largest code valid for an exponent, less than any code valid for an identifier), there was in fact no exponent; otherwise, we search for the sign of the exponent.

```

17067 \cs_new:Npn \__fp_parse_exponent:N #1
17068 {
17069     \if:w e \exp_not:N #1
17070         \exp_after:wN \__fp_parse_exponent_aux:N
17071         \exp:w
17072     \else:
17073         0 \__fp_parse_return_semicolon:w #1
17074     \fi:
17075     \__fp_parse_expand:w
17076 }
17077 \cs_new:Npn \__fp_parse_exponent_aux:N #1
17078 {
17079     \if_int_compare:w \if_catcode:w \scan_stop: \exp_not:N #1
17080         0 \else: '#1 \fi: > '9 \exp_stop_f:
17081         0 \exp_after:wN ; \exp_after:wN e
17082     \else:
17083         \exp_after:wN \__fp_parse_exponent_sign:N
17084     \fi:
17085     #1
17086 }

```

(End definition for __fp_parse_exponent:N and __fp_parse_exponent_aux:N.)

`__fp_parse_exponent_sign:N` Read signs one by one (if there is any).

```

17087 \cs_new:Npn \__fp_parse_exponent_sign:N #1
17088 {
17089     \if:w + \if:w - \exp_not:N #1 + \fi: \token_to_str:N #1
17090         \exp_after:wN \__fp_parse_exponent_sign:N
17091         \exp:w \exp_after:wN \__fp_parse_expand:w
17092     \else:
17093         \exp_after:wN \__fp_parse_exponent_body:N
17094         \exp_after:wN #1
17095     \fi:
17096 }

```

(End definition for __fp_parse_exponent_sign:N.)

`_fp_parse_exponent_body:N` An exponent can be an explicit integer (most common case), or various other things (most of which are invalid).

```

17097 \cs_new:Npn \_fp_parse_exponent_body:N #1
17098 {
17099   \if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
17100     \token_to_str:N #1
17101     \exp_after:wN \_fp_parse_exponent_digits:N
17102     \exp:w
17103   \else:
17104     \_fp_parse_exponent_keep:NTF #1
17105     { \_fp_parse_return_semicolon:w #1 }
17106     {
17107       \exp_after:wN ;
17108       \exp:w
17109     }
17110   \fi:
17111   \_fp_parse_expand:w
17112 }

```

(End definition for `_fp_parse_exponent_body:N`.)

`_fp_parse_exponent_digits:N` Read digits one by one, and leave them behind in the input stream. When finding a non-digit, stop, and insert a semicolon. Note that we do not check for overflow of the exponent, hence there can be a `TeX` error. It is mostly harmless, except when parsing `0e9876543210`, which should be a valid representation of 0, but is not.

```

17113 \cs_new:Npn \_fp_parse_exponent_digits:N #1
17114 {
17115   \if_int_compare:w 9 < 1 \token_to_str:N #1 \exp_stop_f:
17116     \token_to_str:N #1
17117     \exp_after:wN \_fp_parse_exponent_digits:N
17118     \exp:w
17119   \else:
17120     \_fp_parse_return_semicolon:w #1
17121   \fi:
17122   \_fp_parse_expand:w
17123 }

```

(End definition for `_fp_parse_exponent_digits:N`.)

`_fp_parse_exponent_keep:N` This is the last building block for parsing exponents. The argument `#1` is already fully expanded, and neither `+` nor `-` nor a digit. It can be:

- `\s_fp`, marking the start of an internal floating point, invalid here;
- another control sequence equal to `\relax`, probably a bad variable;
- a register: in this case we make sure that it is an integer register, not a dimension;
- a character other than `+`, `-` or digits, again, an error.

```

17124 \prg_new_conditional:Npnn \_fp_parse_exponent_keep:N #1 { TF }
17125 {
17126   \if_catcode:w \scan_stop: \exp_not:N #1
17127     \if_meaning:w \scan_stop: #1
17128     \if_int_compare:w

```

```

17129         \_fp_str_if_eq:nn { \s\_fp } { \exp_not:N #1 }
17130         = 0 \exp_stop_f:
17131     0
17132     \_kernel_msg_expandable_error:nnn
17133     { kernel } { fp-after-e } { floating-point~ }
17134     \prg_return_true:
17135 \else:
17136     0
17137     \_kernel_msg_expandable_error:nnn
17138     { kernel } { bad-variable } { #1 }
17139     \prg_return_false:
17140 \fi:
17141 \else:
17142     \if_int_compare:w
17143         \_fp_str_if_eq:nn { \int_value:w #1 } { \tex_the:D #1 }
17144         = 0 \exp_stop_f:
17145         \int_value:w #1
17146     \else:
17147         0
17148         \_kernel_msg_expandable_error:nnn
17149         { kernel } { fp-after-e } { dimension~#1 }
17150     \fi:
17151     \prg_return_false:
17152 \fi:
17153 \else:
17154     0
17155     \_kernel_msg_expandable_error:nnn
17156     { kernel } { fp-missing } { exponent }
17157     \prg_return_true:
17158 \fi:
17159 }

```

(End definition for _fp_parse_exponent_keep:NTF.)

28.5 Constants, functions and prefix operators

28.5.1 Prefix operators

_fp_parse_prefix_+:Nw A unary + does nothing: we should continue looking for a number.

```

17160 \cs_new_eq:cN { \_fp_parse_prefix_+:Nw } \_fp_parse_one:Nw

```

(End definition for _fp_parse_prefix_+:Nw.)

_fp_parse_apply_function:NNwN Here, #1 is a precedence, #2 is some extra data used by some functions, #3 is *e.g.*, _fp_sin_o:w, and expands once after the calculation, #4 is the operand, and #5 is a _fp_parse_infix...:N function. We feed the data #2, and the argument #4, to the function #3, which expands \exp:w thus the infix function #5.

```

17161 \cs_new:Npn \_fp_parse_apply_function:NNwN #1#2#3#4#5
17162 {
17163     #3 #2 #4 @
17164     \exp:w \exp_end_continue_f:w #5 #1
17165 }

```

(End definition for _fp_parse_apply_function:NNwN.)


```

\__fp_parse_apply_unary:NNWwN
\__fp_parse_apply_unary_chk:NwNw
\__fp_parse_apply_unary_chk:nNNWw
\__fp_parse_apply_unary_type:NNN
\__fp_parse_apply_unary_error:NNw

```

In contrast to `__fp_parse_apply_function:NNWwN`, this checks that the operand #4 is a single argument (namely there is a single `;`). We use the fact that any floating point starts with a “safe” token like `\s__fp`. If there is no argument produce the `fp-no-arg` error; if there are at least two produce `fp-multi-arg`. For the error message extract the mathematical function name (such as `sin`) from the `expl3` function that computes it, such as `__fp_sin_o:w`.

In addition, since there is a single argument we can dispatch on type and check that the resulting function exists. This catches things like `sin((1,2))` where it does not make sense to take the sine of a tuple.

```

17166 \cs_new:Npn \__fp_parse_apply_unary:NNWwN #1#2#3#4#5
17167 {
17168   \__fp_parse_apply_unary_chk:NwNw #4 @ ; . \q_stop
17169   \__fp_parse_apply_unary_type:NNN
17170   #3 #2 #4 @
17171   \exp:w \exp_end_continue_f:w #5 #1
17172 }
17173 \cs_new:Npn \__fp_parse_apply_unary_chk:NwNw #1#2 ; #3#4 \q_stop
17174 {
17175   \if_meaning:w @ #3 \else:
17176     \token_if_eq_meaning:NNTF . #3
17177     { \__fp_parse_apply_unary_chk:nNNNNw { no } }
17178     { \__fp_parse_apply_unary_chk:nNNNNw { multi } }
17179   \fi:
17180 }
17181 \cs_new:Npn \__fp_parse_apply_unary_chk:nNNNNw #1#2#3#4#5#6 @
17182 {
17183   #2
17184   \__fp_error:nffn { fp-#1-arg } { \__fp_func_to_name:N #4 } { } { }
17185   \exp_after:wN #4 \exp_after:wN #5 \c_nan_fp @
17186 }
17187 \cs_new:Npn \__fp_parse_apply_unary_type:NNN #1#2#3
17188 {
17189   \__fp_change_func_type:NNN #3 #1 \__fp_parse_apply_unary_error:NNw
17190   #2 #3
17191 }
17192 \cs_new:Npn \__fp_parse_apply_unary_error:NNw #1#2#3 @
17193 { \__fp_invalid_operation_o:fw { \__fp_func_to_name:N #1 } #3 }

```

(End definition for `__fp_parse_apply_unary:NNWwN` and others.)

```

\__fp_parse_prefix_-:Nw
\__fp_parse_prefix_!:Nw

```

The unary `-` and boolean not are harder: we parse the operand using a precedence equal to the maximum of the previous precedence ##1 and the precedence `\c__fp_prec_not_int` of the unary operator, then call the appropriate `__fp_⟨operation⟩_o:w` function, where the `⟨operation⟩` is `set_sign` or `not`.

```

17194 \cs_set_protected:Npn \__fp_tmp:w #1#2#3#4
17195 {
17196   \cs_new:cpn { \__fp_parse_prefix_ #1 :Nw } ##1
17197   {
17198     \exp_after:wN \__fp_parse_apply_unary:NNWwN
17199     \exp_after:wN ##1
17200     \exp_after:wN #4
17201     \exp_after:wN #3
17202     \exp:w

```

```

17203         \if_int_compare:w #2 < ##1
17204         \__fp_parse_operand:Nw ##1
17205         \else:
17206         \__fp_parse_operand:Nw #2
17207         \fi:
17208         \__fp_parse_expand:w
17209     }
17210 }
17211 \__fp_tmp:w - \c__fp_prec_not_int \__fp_set_sign_o:w 2
17212 \__fp_tmp:w ! \c__fp_prec_not_int \__fp_not_o:w ?

```

(End definition for __fp_parse_prefix -:Nw and __fp_parse_prefix !:Nw.)

__fp_parse_prefix .:Nw Numbers which start with a decimal separator (a period) end up here. Of course, we do not look for an operand, but for the rest of the number. This function is very similar to __fp_parse_one_digit:NN but calls __fp_parse_strim_zeros:N to trim zeros after the decimal point, rather than the trim_zeros function for zeros before the decimal point.

```

17213 \cs_new:cpn { __fp_parse_prefix .:Nw } #1
17214 {
17215     \exp_after:wN \__fp_parse_infix_after_operand:NwN
17216     \exp_after:wN #1
17217     \exp:w \exp_end_continue_f:w
17218     \exp_after:wN \__fp_sanitizew
17219     \int_value:w \__fp_int_eval:w 0 \__fp_parse_strim_zeros:N
17220 }

```

(End definition for __fp_parse_prefix .:Nw.)

__fp_parse_prefix (:Nw __fp_parse_lparen_after:NwN The left parenthesis is treated as a unary prefix operator because it appears in exactly the same settings. If the previous precedence is \c__fp_prec_func_int we are parsing arguments of a function and commas should not build tuples; otherwise commas should build tuples. We distinguish these cases by precedence: \c__fp_prec_comma_int for the case of arguments, \c__fp_prec_tuple_int for the case of tuples. Once the operand is found, the lparen_after auxiliary makes sure that there was a closing parenthesis (otherwise it complains), and leaves in the input stream an operand, fetching the following infix operator.

```

17221 \cs_new:cpn { __fp_parse_prefix (:Nw } #1
17222 {
17223     \exp_after:wN \__fp_parse_lparen_after:NwN
17224     \exp_after:wN #1
17225     \exp:w
17226     \if_int_compare:w #1 = \c__fp_prec_func_int
17227     \__fp_parse_operand:Nw \c__fp_prec_comma_int
17228     \else:
17229     \__fp_parse_operand:Nw \c__fp_prec_tuple_int
17230     \fi:
17231     \__fp_parse_expand:w
17232 }
17233 \cs_new:Npx \__fp_parse_lparen_after:NwN #1#2 @ #3
17234 {
17235     \exp_not:N \token_if_eq_meaning:NNTF #3
17236     \exp_not:c { __fp_parse_infix_):N }
17237     {

```

```

17238 \exp_not:N \__fp_exp_after_array_f:w #2 \s__fp_stop
17239 \exp_not:N \exp_after:wN
17240 \exp_not:N \__fp_parse_infix_after_paren:NN
17241 \exp_not:N \exp_after:wN #1
17242 \exp_not:N \exp:w
17243 \exp_not:N \__fp_parse_expand:w
17244 }
17245 {
17246 \exp_not:N \__kernel_msg_expandable_error:nnn
17247 { kernel } { fp-missing } { ) }
17248 \exp_not:N \tl_if_empty:nT {#2} \exp_not:N \c__fp_empty_tuple_fp
17249 #2 @
17250 \exp_not:N \use_none:n #3
17251 }
17252 }

```

(End definition for __fp_parse_prefix_(:Nw and __fp_parse_lparen_after:NwN.)

__fp_parse_prefix_):Nw The right parenthesis can appear as a prefix in two similar cases: in an empty tuple or tuple ending with a comma, or in an empty argument list or argument list ending with a comma, such as in `max(1,2,)` or in `rand()`.

```

17253 \cs_new:cpn { __fp_parse_prefix_):Nw } #1
17254 {
17255 \if_int_compare:w #1 = \c__fp_prec_comma_int
17256 \else:
17257 \if_int_compare:w #1 = \c__fp_prec_tuple_int
17258 \exp_after:wN \c__fp_empty_tuple_fp \exp:w
17259 \else:
17260 \__kernel_msg_expandable_error:nnn
17261 { kernel } { fp-missing-number } { ) }
17262 \exp_after:wN \c_nan_fp \exp:w
17263 \fi:
17264 \exp_end_continue_f:w
17265 \fi:
17266 \__fp_parse_infix_after_paren:NN #1 )
17267 }

```

(End definition for __fp_parse_prefix_):Nw.)

28.5.2 Constants

__fp_parse_word_inf:N Some words correspond to constant floating points. The floating point constant is left as a result of __fp_parse_one:Nw after expanding __fp_parse_infix:NN.

__fp_parse_word_nan:N

__fp_parse_word_pi:N

__fp_parse_word_deg:N

__fp_parse_word_true:N

__fp_parse_word_false:N

```

17268 \cs_set_protected:Npn \__fp_tmp:w #1 #2
17269 {
17270 \cs_new:cpn { __fp_parse_word_#1:N }
17271 { \exp_after:wN #2 \exp:w \exp_end_continue_f:w \__fp_parse_infix:NN }
17272 }
17273 \__fp_tmp:w { inf } \c_inf_fp
17274 \__fp_tmp:w { nan } \c_nan_fp
17275 \__fp_tmp:w { pi } \c_pi_fp
17276 \__fp_tmp:w { deg } \c_one_degree_fp
17277 \__fp_tmp:w { true } \c_one_fp
17278 \__fp_tmp:w { false } \c_zero_fp

```

(End definition for `_fp_parse_word_inf:N` and others.)

`_fp_parse_caseless_inf:N` Copies of `_fp_parse_word_...:N` commands, to allow arbitrary case as mandated by the standard.

```

\fp_parse_caseless_infinity:N
\fp_parse_caseless_nan:N
17279 \cs_new_eq:NN \_fp_parse_caseless_inf:N \_fp_parse_word_inf:N
17280 \cs_new_eq:NN \_fp_parse_caseless_infinity:N \_fp_parse_word_inf:N
17281 \cs_new_eq:NN \_fp_parse_caseless_nan:N \_fp_parse_word_nan:N

```

(End definition for `_fp_parse_caseless_inf:N`, `_fp_parse_caseless_infinity:N`, and `_fp_parse_caseless_nan:N`.)

`_fp_parse_word_pt:N` Dimension units are also floating point constants but their value is not stored as a floating point constant. We give the values explicitly here.

```

\fp_parse_word_in:N
\fp_parse_word_pc:N
\fp_parse_word_cm:N
\fp_parse_word_mm:N
\fp_parse_word_dd:N
\fp_parse_word_cc:N
\fp_parse_word_nd:N
\fp_parse_word_nc:N
\fp_parse_word_bp:N
\fp_parse_word_sp:N
17282 \cs_set_protected:Npn \_fp_tmp:w #1 #2
17283 {
17284   \cs_new:cpn { \_fp_parse_word_#1:N }
17285   {
17286     \_fp_exp_after_f:nw { \_fp_parse_infix:NN }
17287     \s__fp \_fp_chk:w 10 #2 ;
17288   }
17289 }
17290 \_fp_tmp:w {pt} { {1} {1000} {0000} {0000} {0000} }
17291 \_fp_tmp:w {in} { {2} {7227} {0000} {0000} {0000} }
17292 \_fp_tmp:w {pc} { {2} {1200} {0000} {0000} {0000} }
17293 \_fp_tmp:w {cm} { {2} {2845} {2755} {9055} {1181} }
17294 \_fp_tmp:w {mm} { {1} {2845} {2755} {9055} {1181} }
17295 \_fp_tmp:w {dd} { {1} {1070} {0085} {6496} {0630} }
17296 \_fp_tmp:w {cc} { {2} {1284} {0102} {7795} {2756} }
17297 \_fp_tmp:w {nd} { {1} {1066} {9783} {4645} {6693} }
17298 \_fp_tmp:w {nc} { {2} {1280} {3740} {1574} {8031} }
17299 \_fp_tmp:w {bp} { {1} {1003} {7500} {0000} {0000} }
17300 \_fp_tmp:w {sp} { {-4} {1525} {8789} {0625} {0000} }

```

(End definition for `_fp_parse_word_pt:N` and others.)

`_fp_parse_word_em:N` The font-dependent units `em` and `ex` must be evaluated on the fly. We reuse an auxiliary of `\dim_to_fp:n`.

```

\fp_parse_word_ex:N
17301 \tl_map_inline:nn { {em} {ex} }
17302 {
17303   \cs_new:cpn { \_fp_parse_word_#1:N }
17304   {
17305     \exp_after:wN \_fp_from_dim_test:ww
17306     \exp_after:wN 0 \exp_after:wN ,
17307     \int_value:w \dim_to_decimal_in_sp:n { 1 #1 } \exp_after:wN ;
17308     \exp:w \exp_end_continue_f:w \_fp_parse_infix:NN
17309   }
17310 }

```

(End definition for `_fp_parse_word_em:N` and `_fp_parse_word_ex:N`.)

28.5.3 Functions

```

\__fp_parse_unary_function:NNN
\__fp_parse_function:NNN
17311 \cs_new:Npn \__fp_parse_unary_function:NNN #1#2#3
17312 {
17313   \exp_after:wN \__fp_parse_apply_unary:NNNwN
17314   \exp_after:wN #3
17315   \exp_after:wN #2
17316   \exp_after:wN #1
17317   \exp:w
17318   \__fp_parse_operand:Nw \c__fp_prec_func_int \__fp_parse_expand:w
17319 }
17320 \cs_new:Npn \__fp_parse_function:NNN #1#2#3
17321 {
17322   \exp_after:wN \__fp_parse_apply_function:NNNwN
17323   \exp_after:wN #3
17324   \exp_after:wN #2
17325   \exp_after:wN #1
17326   \exp:w
17327   \__fp_parse_operand:Nw \c__fp_prec_func_int \__fp_parse_expand:w
17328 }

```

(End definition for `__fp_parse_unary_function:NNN` and `__fp_parse_function:NNN`.)

28.6 Main functions

`__fp_parse:n` Start an `\exp:w` expansion so that `__fp_parse:n` expands in two steps. The `__fp_parse_operand:Nw` function performs computations until reaching an operation with precedence `\c__fp_prec_end_int` or less, namely, the end of the expression. The marker `\s__fp_mark` indicates that the next token is an already parsed version of an infix operator, and `__fp_parse_infix_end:N` has infinitely negative precedence. Finally, clean up a (well-defined) set of extra tokens and stop the initial expansion with `\exp_end:.`

```

17329 \cs_new:Npn \__fp_parse:n #1
17330 {
17331   \exp:w
17332   \exp_after:wN \__fp_parse_after:ww
17333   \exp:w
17334   \__fp_parse_operand:Nw \c__fp_prec_end_int
17335   \__fp_parse_expand:w #1
17336   \s__fp_mark \__fp_parse_infix_end:N
17337   \s__fp_stop
17338   \exp_end:
17339 }
17340 \cs_new:Npn \__fp_parse_after:ww
17341   #1@ \__fp_parse_infix_end:N \s__fp_stop #2 { #2 #1 }
17342 \cs_new:Npn \__fp_parse_o:n #1
17343 {
17344   \exp:w
17345   \exp_after:wN \__fp_parse_after:ww
17346   \exp:w
17347   \__fp_parse_operand:Nw \c__fp_prec_end_int
17348   \__fp_parse_expand:w #1
17349   \s__fp_mark \__fp_parse_infix_end:N
17350   \s__fp_stop

```

```

17351     {
17352         \exp_end_continue_f:w
17353         \__fp_exp_after_any_f:nw { \exp_after:wN \exp_stop_f: }
17354     }
17355 }

```

(End definition for __fp_parse:n, __fp_parse_o:n, and __fp_parse_after:ww.)

__fp_parse_operand:Nw This is just a shorthand which sets up both __fp_parse_continue:NwN and __fp_parse_one:Nw with the same precedence. Note the trailing \exp:w.

```

17356 \cs_new:Npn \__fp_parse_operand:Nw #1
17357 {
17358     \exp_end_continue_f:w
17359     \exp_after:wN \__fp_parse_continue:NwN
17360     \exp_after:wN #1
17361     \exp:w \exp_end_continue_f:w
17362     \exp_after:wN \__fp_parse_one:Nw
17363     \exp_after:wN #1
17364     \exp:w
17365 }
17366 \cs_new:Npn \__fp_parse_continue:NwN #1 #2 @ #3 { #3 #1 #2 @ }

```

(End definition for __fp_parse_operand:Nw and __fp_parse_continue:NwN.)

_fp_parse_apply_binary:NwNwN Receives $\langle precedence \rangle \langle operand_1 \rangle @ \langle operation \rangle \langle operand_2 \rangle @ \langle infix command \rangle$. Builds the appropriate call to the $\langle operation \rangle$ #3, dispatching on both types. If the resulting control sequence does not exist, the operation is not allowed.

This is redefined in l3fp-extras.

```

17367 \cs_new:Npn \_fp_parse_apply_binary:NwNwN #1 #2#3@ #4 #5#6@ #7
17368 {
17369     \exp_after:wN \_fp_parse_continue:NwN
17370     \exp_after:wN #1
17371     \exp:w \exp_end_continue_f:w
17372     \exp_after:wN \_fp_parse_apply_binary_chk:NN
17373     \cs:w
17374         \_fp
17375         \__fp_type_from_scan:N #2
17376         _#4
17377         \__fp_type_from_scan:N #5
17378         _o:ww
17379     \cs_end:
17380     #4
17381     #2#3 #5#6
17382     \exp:w \exp_end_continue_f:w #7 #1
17383 }
17384 \cs_new:Npn \_fp_parse_apply_binary_chk:NN #1#2
17385 {
17386     \if_meaning:w \scan_stop: #1
17387         \_fp_parse_apply_binary_error:NNN #2
17388     \fi:
17389     #1
17390 }
17391 \cs_new:Npn \_fp_parse_apply_binary_error:NNN #1#2#3
17392 {

```

```

17393     #2
17394     \__fp_invalid_operation_o:Nww #1
17395 }

```

(End definition for __fp_parse_apply_binary:NwNwN, __fp_parse_apply_binary_chk:NN, and __fp_parse_apply_binary_error:NNN.)

__fp_binary_type_o:Nww
__fp_binary_rev_type_o:Nww

Applies the operator #1 to its two arguments, dispatching according to their types, and expands once after the result. The rev version swaps its arguments before doing this.

```

17396 \cs_new:Npn \__fp_binary_type_o:Nww #1 #2#3 ; #4
17397 {
17398     \exp_after:wN \__fp_parse_apply_binary_chk:NN
17399     \cs:w
17400     __fp
17401     \__fp_type_from_scan:N #2
17402     _ #1
17403     \__fp_type_from_scan:N #4
17404     _o:ww
17405     \cs_end:
17406     #1
17407     #2 #3 ; #4
17408 }
17409 \cs_new:Npn \__fp_binary_rev_type_o:Nww #1 #2#3 ; #4#5 ;
17410 {
17411     \exp_after:wN \__fp_parse_apply_binary_chk:NN
17412     \cs:w
17413     __fp
17414     \__fp_type_from_scan:N #4
17415     _ #1
17416     \__fp_type_from_scan:N #2
17417     _o:ww
17418     \cs_end:
17419     #1
17420     #4 #5 ; #2 #3 ;
17421 }

```

(End definition for __fp_binary_type_o:Nww and __fp_binary_rev_type_o:Nww.)

28.7 Infix operators

__fp_parse_infix_after_operand:NwN

```

17422 \cs_new:Npn \__fp_parse_infix_after_operand:NwN #1 #2;
17423 {
17424     \__fp_exp_after_f:nw { \__fp_parse_infix:NN #1 }
17425     #2;
17426 }
17427 \cs_new:Npn \__fp_parse_infix:NN #1 #2
17428 {
17429     \if_catcode:w \scan_stop: \exp_not:N #2
17430     \if_int_compare:w
17431         \__fp_str_if_eq:nn { \s__fp_mark } { \exp_not:N #2 }
17432         = 0 \exp_stop_f:
17433     \exp_after:wN \exp_after:wN
17434     \exp_after:wN \__fp_parse_infix_mark:NNN

```

```

17435 \else:
17436 \exp_after:wN \exp_after:wN
17437 \exp_after:wN \_fp_parse_infix_juxt:N
17438 \fi:
17439 \else:
17440 \if_int_compare:w
17441 \_fp_int_eval:w
17442 ( '#2 \if_int_compare:w '#2 > 'Z - 32 \fi: ) / 26
17443 = 3 \exp_stop_f:
17444 \exp_after:wN \exp_after:wN
17445 \exp_after:wN \_fp_parse_infix_juxt:N
17446 \else:
17447 \exp_after:wN \_fp_parse_infix_check:NNN
17448 \cs:w
17449 \_fp_parse_infix_ \token_to_str:N #2 :N
17450 \exp_after:wN \exp_after:wN \exp_after:wN
17451 \cs_end:
17452 \fi:
17453 \fi:
17454 #1
17455 #2
17456 }
17457 \cs_new:Npn \_fp_parse_infix_check:NNN #1#2#3
17458 {
17459 \if_meaning:w \scan_stop: #1
17460 \_kernel_msg_expandable_error:nnn
17461 { kernel } { fp-missing } { * }
17462 \exp_after:wN \_fp_parse_infix_mul:N
17463 \exp_after:wN #2
17464 \exp_after:wN #3
17465 \else:
17466 \exp_after:wN #1
17467 \exp_after:wN #2
17468 \exp:w \exp_after:wN \_fp_parse_expand:w
17469 \fi:
17470 }

```

(End definition for _fp_parse_infix_after_operand:NwN.)

_fp_parse_infix_after_paren:NN Variant of _fp_parse_infix:NN for use after a closing parenthesis. The only difference is that _fp_parse_infix_juxt:N is replaced by _fp_parse_infix_mul:N.

```

17471 \cs_new:Npn \_fp_parse_infix_after_paren:NN #1 #2
17472 {
17473 \if_catcode:w \scan_stop: \exp_not:N #2
17474 \if_int_compare:w
17475 \_fp_str_if_eq:nn { \s_fp_mark } { \exp_not:N #2 }
17476 = 0 \exp_stop_f:
17477 \exp_after:wN \exp_after:wN
17478 \exp_after:wN \_fp_parse_infix_mark:NNN
17479 \else:
17480 \exp_after:wN \exp_after:wN
17481 \exp_after:wN \_fp_parse_infix_mul:N
17482 \fi:
17483 \else:

```



```

17484 \if_int_compare:w
17485 \__fp_int_eval:w
17486 ( '#2 \if_int_compare:w '#2 > 'Z - 32 \fi: ) / 26
17487 = 3 \exp_stop_f:
17488 \exp_after:wN \exp_after:wN
17489 \exp_after:wN \__fp_parse_infix_mul:N
17490 \else:
17491 \exp_after:wN \__fp_parse_infix_check:NNN
17492 \cs:w
17493 \__fp_parse_infix_ \token_to_str:N #2 :N
17494 \exp_after:wN \exp_after:wN \exp_after:wN
17495 \cs_end:
17496 \fi:
17497 \fi:
17498 #1
17499 #2
17500 }

```

(End definition for __fp_parse_infix_after_paren:NN.)

28.7.1 Closing parentheses and commas

__fp_parse_infix_mark:NNN As an infix operator, \s__fp_mark means that the next token (#3) has already gone through __fp_parse_infix:NN and should be provided the precedence #1. The scan mark #2 is discarded.

```

17501 \cs_new:Npn \__fp_parse_infix_mark:NNN #1#2#3 { #3 #1 }

```

(End definition for __fp_parse_infix_mark:NNN.)

__fp_parse_infix_end:N This one is a little bit odd: force every previous operator to end, regardless of the precedence.

```

17502 \cs_new:Npn \__fp_parse_infix_end:N #1
17503 { @ \use_none:n \__fp_parse_infix_end:N }

```

(End definition for __fp_parse_infix_end:N.)

__fp_parse_infix_):N This is very similar to __fp_parse_infix_end:N, complaining about an extra closing parenthesis if the previous operator was the beginning of the expression, with precedence \c__fp_prec_end_int.

```

17504 \cs_set_protected:Npn \__fp_tmp:w #1
17505 {
17506   \cs_new:Npn #1 ##1
17507   {
17508     \if_int_compare:w ##1 > \c__fp_prec_end_int
17509     \exp_after:wN @
17510     \exp_after:wN \use_none:n
17511     \exp_after:wN #1
17512   \else:
17513     \__kernel_msg_expandable_error:nnn { kernel } { fp-extra } { ) }
17514     \exp_after:wN \__fp_parse_infix:NN
17515     \exp_after:wN ##1
17516     \exp:w \exp_after:wN \__fp_parse_expand:w
17517   \fi:
17518 }

```

```

17519     }
17520 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_):N }

```

(End definition for __fp_parse_infix_):N.)

```

\__fp_parse_infix_,:N
\__fp_parse_infix_comma:w
\__fp_parse_apply_comma:NwNwN

```

As for other infix operations, if the previous operations has higher precedence the comma waits. Otherwise we call __fp_parse_operand:Nw to read more comma-delimited arguments that __fp_parse_infix_comma:w simply concatenates into a @-delimited array. The first comma in a tuple that is not a function argument is distinguished: in that case call __fp_parse_apply_comma:NwNwN whose job is to convert the first item of the tuple and an array of the remaining items into a tuple. In contrast to __fp_parse_apply_binary:NwNwN this function's operands are not single-object arrays.

```

17521 \cs_set_protected:Npn \__fp_tmp:w #1
17522 {
17523   \cs_new:Npn #1 ##1
17524   {
17525     \if_int_compare:w ##1 > \c__fp_prec_comma_int
17526     \exp_after:wN @
17527     \exp_after:wN \use_none:n
17528     \exp_after:wN #1
17529   \else:
17530     \if_int_compare:w ##1 < \c__fp_prec_comma_int
17531     \exp_after:wN @
17532     \exp_after:wN \__fp_parse_apply_comma:NwNwN
17533     \exp_after:wN ,
17534     \exp:w
17535   \else:
17536     \exp_after:wN \__fp_parse_infix_comma:w
17537     \exp:w
17538   \fi:
17539   \__fp_parse_operand:Nw \c__fp_prec_comma_int
17540   \exp_after:wN \__fp_parse_expand:w
17541   \fi:
17542   }
17543 }
17544 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_,:N }
17545 \cs_new:Npn \__fp_parse_infix_comma:w #1 @
17546 { #1 @ \use_none:n }
17547 \cs_new:Npn \__fp_parse_apply_comma:NwNwN #1 #2@ #3 #4@ #5
17548 {
17549   \exp_after:wN \__fp_parse_continue:NwN
17550   \exp_after:wN #1
17551   \exp:w \exp_end_continue_f:w
17552   \__fp_exp_after_tuple_f:nw { }
17553   \s__fp_tuple \__fp_tuple_chk:w { #2 #4 } ;
17554   #5 #1
17555 }

```

(End definition for __fp_parse_infix_,:N, __fp_parse_infix_comma:w, and __fp_parse_apply_comma:NwNwN.)

28.7.2 Usual infix operators

```

\__fp_parse_infix_+:N
\__fp_parse_infix_-:N
\__fp_parse_infix_juxt:N
\__fp_parse_infix_/:N
\__fp_parse_infix_mul:N
\__fp_parse_infix_and:N
\__fp_parse_infix_or:N
\__fp_parse_infix_^:N

```

As described in the “work plan”, each infix operator has an associated \..._infix... function, a computing function, and precedence, given as arguments to __fp_tmp:w.

Using the general mechanism for arithmetic operations. The power operation must be associative in the opposite order from all others. For this, we use two distinct precedences.

```

17556 \cs_set_protected:Npn \__fp_tmp:w #1#2#3#4
17557 {
17558   \cs_new:Npn #1 ##1
17559   {
17560     \if_int_compare:w ##1 < #3
17561       \exp_after:wN @
17562       \exp_after:wN \__fp_parse_apply_binary:NwNwN
17563       \exp_after:wN #2
17564       \exp:w
17565       \__fp_parse_operand:Nw #4
17566       \exp_after:wN \__fp_parse_expand:w
17567     \else:
17568       \exp_after:wN @
17569       \exp_after:wN \use_none:n
17570       \exp_after:wN #1
17571     \fi:
17572   }
17573 }
17574 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_~:N } ^
17575   \c__fp_prec_hatii_int \c__fp_prec_hat_int
17576 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_juxt:N } *
17577   \c__fp_prec_juxt_int \c__fp_prec_juxt_int
17578 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_/:N } /
17579   \c__fp_prec_times_int \c__fp_prec_times_int
17580 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_mul:N } *
17581   \c__fp_prec_times_int \c__fp_prec_times_int
17582 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix -:N } -
17583   \c__fp_prec_plus_int \c__fp_prec_plus_int
17584 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix +:N } +
17585   \c__fp_prec_plus_int \c__fp_prec_plus_int
17586 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_and:N } &
17587   \c__fp_prec_and_int \c__fp_prec_and_int
17588 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_or:N } |
17589   \c__fp_prec_or_int \c__fp_prec_or_int

```

(End definition for __fp_parse_infix_+:N and others.)

28.7.3 Juxtaposition

__fp_parse_infix_(:N When an opening parenthesis appears where we expect an infix operator, we compute the product of the previous operand and the contents of the parentheses using __fp_parse_infix_mul:N.

```

17590 \cs_new:cpn { __fp_parse_infix_(:N } #1
17591   { \__fp_parse_infix_mul:N #1 ( }

```

(End definition for __fp_parse_infix_(:N.)

28.7.4 Multi-character cases

__fp_parse_infix_*:N

```

17592 \cs_set_protected:Npn \__fp_tmp:w #1
17593 {

```

```

17594 \cs_new:cpn { __fp_parse_infix_*.N } ##1##2
17595 {
17596   \if:w * \exp_not:N ##2
17597     \exp_after:wN #1
17598     \exp_after:wN ##1
17599   \else:
17600     \exp_after:wN \__fp_parse_infix_mul:N
17601     \exp_after:wN ##1
17602     \exp_after:wN ##2
17603   \fi:
17604 }
17605 }
17606 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_^.N }

```

(End definition for __fp_parse_infix_*.N.)

__fp_parse_infix_|:Nw
 __fp_parse_infix_&:Nw

```

17607 \cs_set_protected:Npn \__fp_tmp:w #1#2#3
17608 {
17609   \cs_new:Npn #1 ##1##2
17610   {
17611     \if:w #2 \exp_not:N ##2
17612       \exp_after:wN #1
17613       \exp_after:wN ##1
17614       \exp:w \exp_after:wN \__fp_parse_expand:w
17615     \else:
17616       \exp_after:wN #3
17617       \exp_after:wN ##1
17618       \exp_after:wN ##2
17619     \fi:
17620   }
17621 }
17622 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_|:N } | \__fp_parse_infix_or:N
17623 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_&:N } & \__fp_parse_infix_and:N

```

(End definition for __fp_parse_infix_|:Nw and __fp_parse_infix_&:Nw.)

28.7.5 Ternary operator

__fp_parse_infix_?:N
 __fp_parse_infix_:N

```

17624 \cs_set_protected:Npn \__fp_tmp:w #1#2#3#4
17625 {
17626   \cs_new:Npn #1 ##1
17627   {
17628     \if_int_compare:w ##1 < \c__fp_prec_quest_int
17629       #4
17630       \exp_after:wN @
17631       \exp_after:wN #2
17632       \exp:w
17633       \__fp_parse_operand:Nw #3
17634       \exp_after:wN \__fp_parse_expand:w
17635     \else:
17636       \exp_after:wN @
17637       \exp_after:wN \use_none:n

```

```

17638         \exp_after:wN #1
17639         \fi:
17640     }
17641 }
17642 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_?:N }
17643   \__fp_ternary:NwwN \c__fp_prec_quest_int { }
17644 \exp_args:Nc \__fp_tmp:w { __fp_parse_infix_:N }
17645   \__fp_ternary_auxii:NwwN \c__fp_prec_colon_int
17646   {
17647     \__kernel_msg_expandable_error:nnnn
17648     { kernel } { fp-missing } { ? } { ~for~?: }
17649   }

```

(End definition for __fp_parse_infix_?:N and __fp_parse_infix_:N.)

28.7.6 Comparisons

```

\__fp_parse_infix_<:N
\__fp_parse_infix_=:N
\__fp_parse_infix_>:N
\__fp_parse_infix_!:N
\__fp_parse_excl_error:
\__fp_parse_compare:NNNNNNN
  \__fp_parse_compare_auxi:NNNNNNN
  \__fp_parse_compare_auxii:NNNNN
  \__fp_parse_compare_end:NNNNw
  \__fp_compare:wNNNNw
17650 \cs_new:cpn { __fp_parse_infix_<:N } #1
17651   { \__fp_parse_compare:NNNNNNN #1 1 0 0 0 0 < }
17652 \cs_new:cpn { __fp_parse_infix_=:N } #1
17653   { \__fp_parse_compare:NNNNNNN #1 1 0 0 0 0 = }
17654 \cs_new:cpn { __fp_parse_infix_>:N } #1
17655   { \__fp_parse_compare:NNNNNNN #1 1 0 0 0 0 > }
17656 \cs_new:cpn { __fp_parse_infix_!:N } #1
17657   {
17658     \exp_after:wN \__fp_parse_compare:NNNNNNN
17659     \exp_after:wN #1
17660     \exp_after:wN 0
17661     \exp_after:wN 1
17662     \exp_after:wN 1
17663     \exp_after:wN 1
17664     \exp_after:wN 1
17665   }
17666 \cs_new:Npn \__fp_parse_excl_error:
17667   {
17668     \__kernel_msg_expandable_error:nnnn
17669     { kernel } { fp-missing } { = } { ~after~!. }
17670   }
17671 \cs_new:Npn \__fp_parse_compare:NNNNNNN #1
17672   {
17673     \if_int_compare:w #1 < \c__fp_prec_comp_int
17674       \exp_after:wN \__fp_parse_compare_auxi:NNNNNNN
17675       \exp_after:wN \__fp_parse_excl_error:
17676     \else:
17677       \exp_after:wN @
17678       \exp_after:wN \use_none:n
17679       \exp_after:wN \__fp_parse_compare:NNNNNNN
17680     \fi:
17681   }
17682 \cs_new:Npn \__fp_parse_compare_auxi:NNNNNNN #1#2#3#4#5#6#7
17683   {
17684     \if_case:w
17685       \__fp_int_eval:w \exp_after:wN ‘ \token_to_str:N #7 - ‘<

```

```

17686         \__fp_int_eval_end:
17687         \__fp_parse_compare_auxii:NNNNN #2#2#4#5#6
17688     \or: \__fp_parse_compare_auxii:NNNNN #2#3#2#5#6
17689     \or: \__fp_parse_compare_auxii:NNNNN #2#3#4#2#6
17690     \or: \__fp_parse_compare_auxii:NNNNN #2#3#4#5#2
17691     \else: #1 \__fp_parse_compare_end:NNNNw #3#4#5#6#7
17692     \fi:
17693 }
17694 \cs_new:Npn \__fp_parse_compare_auxii:NNNNN #1#2#3#4#5
17695 {
17696     \exp_after:wN \__fp_parse_compare_auxi:NNNNNNN
17697     \exp_after:wN \prg_do_nothing:
17698     \exp_after:wN #1
17699     \exp_after:wN #2
17700     \exp_after:wN #3
17701     \exp_after:wN #4
17702     \exp_after:wN #5
17703     \exp:w \exp_after:wN \__fp_parse_expand:w
17704 }
17705 \cs_new:Npn \__fp_parse_compare_end:NNNNw #1#2#3#4#5 \fi:
17706 {
17707     \fi:
17708     \exp_after:wN @
17709     \exp_after:wN \__fp_parse_apply_compare:NwNNNNNNwN
17710     \exp_after:wN \c_one_fp
17711     \exp_after:wN #1
17712     \exp_after:wN #2
17713     \exp_after:wN #3
17714     \exp_after:wN #4
17715     \exp:w
17716     \__fp_parse_operand:Nw \c__fp_prec_comp_int \__fp_parse_expand:w #5
17717 }
17718 \cs_new:Npn \__fp_parse_apply_compare:NwNNNNNNwN
17719     #1 #2@ #3 #4#5#6#7 #8@ #9
17720 {
17721     \if_int_odd:w
17722         \if_meaning:w \c_zero_fp #3
17723         0
17724     \else:
17725         \if_case:w \__fp_compare_back_any:ww #8 #2 \exp_stop_f:
17726         #5 \or: #6 \or: #7 \else: #4
17727     \fi:
17728     \fi:
17729     \exp_stop_f:
17730     \exp_after:wN \__fp_parse_apply_compare_aux:NNwN
17731     \exp_after:wN \c_one_fp
17732 \else:
17733     \exp_after:wN \__fp_parse_apply_compare_aux:NNwN
17734     \exp_after:wN \c_zero_fp
17735 \fi:
17736 #1 #8 #9
17737 }
17738 \cs_new:Npn \__fp_parse_apply_compare_aux:NNwN #1 #2 #3; #4
17739 {

```

```

17740 \if_meaning:w \_fp_parse_compare:NNNNNN #4
17741 \exp_after:wN \_fp_parse_continue_compare:NNwNN
17742 \exp_after:wN #1
17743 \exp_after:wN #2
17744 \exp:w \exp_end_continue_f:w
17745 \_fp_exp_after_o:w #3;
17746 \exp:w \exp_end_continue_f:w
17747 \else:
17748 \exp_after:wN \_fp_parse_continue:NwN
17749 \exp_after:wN #2
17750 \exp:w \exp_end_continue_f:w
17751 \exp_after:wN #1
17752 \exp:w \exp_end_continue_f:w
17753 \fi:
17754 #4 #2
17755 }
17756 \cs_new:Npn \_fp_parse_continue_compare:NNwNN #1#2 #3@ #4#5
17757 { #4 #2 #3@ #1 }

```

(End definition for `_fp_parse_infix_<:N` and others.)

28.8 Tools for functions

`_fp_parse_function_all_fp_o:fnw` Followed by $\{\langle function\ name\rangle\}\{\langle code\rangle\}\langle float\ array\rangle @$ this checks all floats are floating point numbers (no tuples).

```

17758 \cs_new:Npn \_fp_parse_function_all_fp_o:fnw #1#2#3 @
17759 {
17760 \_fp_array_if_all_fp:nTF {#3}
17761 { #2 #3 @ }
17762 {
17763 \_fp_error:nffn { fp-bad-args }
17764 {#1}
17765 { \fp_to_tl:n { \s__fp_tuple \_fp_tuple_chk:w {#3} ; } }
17766 { }
17767 \exp_after:wN \c_nan_fp
17768 }
17769 }

```

(End definition for `_fp_parse_function_all_fp_o:fnw`.)

`_fp_parse_function_one_two:nnw` This is followed by $\{\langle function\ name\rangle\}\{\langle code\rangle\}\langle float\ array\rangle @$. It checks that the $\langle float\ array\rangle$ consists of one or two floating point numbers (not tuples), then leaves the $\langle code\rangle$ (if there is one float) or its tail (if there are two floats) followed by the $\langle float\ array\rangle$. The $\langle code\rangle$ should start with a single token such as `_fp_atan_default:w` that deals with the single-float case.

The first `_fp_if_type_fp:NTwFw` test catches the case of no argument and the case of a tuple argument. The next one distinguishes the case of a single argument (no error, just add `\c_one_fp`) from a tuple second argument. Finally check there is no further argument.

```

17770 \cs_new:Npn \_fp_parse_function_one_two:nnw #1#2#3
17771 {
17772 \_fp_if_type_fp:NTwFw
17773 #3 { } \s__fp \_fp_parse_function_one_two_error_o:w \q_stop

```

```

17774     \__fp_parse_function_one_two_aux:nnw {#1} {#2} #3
17775   }
17776 \cs_new:Npn \__fp_parse_function_one_two_error_o:w #1#2#3#4 @
17777 {
17778     \__fp_error:nffn { fp-bad-args }
17779     {#2}
17780     { \fp_to_tl:n { \s__fp_tuple \__fp_tuple_chk:w {#4} ; } }
17781     { }
17782     \exp_after:wN \c_nan_fp
17783 }
17784 \cs_new:Npn \__fp_parse_function_one_two_aux:nnw #1#2 #3; #4
17785 {
17786     \__fp_if_type_fp:NTwFw
17787     #4 { }
17788     \s__fp
17789     {
17790         \if_meaning:w @ #4
17791         \exp_after:wN \use_iv:nnnn
17792         \fi:
17793         \__fp_parse_function_one_two_error_o:w
17794     }
17795     \q_stop
17796     \__fp_parse_function_one_two_auxii:nnw {#1} {#2} #3; #4
17797 }
17798 \cs_new:Npn \__fp_parse_function_one_two_auxii:nnw #1#2#3; #4; #5
17799 {
17800     \if_meaning:w @ #5 \else:
17801     \exp_after:wN \__fp_parse_function_one_two_error_o:w
17802     \fi:
17803     \use_ii:nn {#1} { \use_none:n #2 } #3; #4; #5
17804 }

```

(End definition for __fp_parse_function_one_two:nnw and others.)

__fp_tuple_map_o:nw Apply #1 to all items in the following tuple and expand once afterwards. The code #1
 __fp_tuple_map_loop_o:nw should itself expand once after its result.

```

17805 \cs_new:Npn \__fp_tuple_map_o:nw #1 \s__fp_tuple \__fp_tuple_chk:w #2 ;
17806 {
17807     \exp_after:wN \s__fp_tuple
17808     \exp_after:wN \__fp_tuple_chk:w
17809     \exp_after:wN {
17810         \exp:w \exp_end_continue_f:w
17811         \__fp_tuple_map_loop_o:nw {#1} #2
17812         { \s__fp \prg_break: } ;
17813         \prg_break_point:
17814         \exp_after:wN } \exp_after:wN ;
17815     }
17816 \cs_new:Npn \__fp_tuple_map_loop_o:nw #1#2#3 ;
17817 {
17818     \use_none:n #2
17819     #1 #2 #3 ;
17820     \exp:w \exp_end_continue_f:w
17821     \__fp_tuple_map_loop_o:nw {#1}
17822 }

```


(End definition for _fp_tuple_map_o:nw and _fp_tuple_map_loop_o:nw.)

_fp_tuple_mapthread_o:nww Apply #1 to pairs of items in the two following tuples and expand once afterwards.

```

\_fp_tuple_mapthread_loop_o:nw
17823 \cs_new:Npn \_fp_tuple_mapthread_o:nww #1
17824   \s__fp_tuple \_fp_tuple_chk:w #2 ;
17825   \s__fp_tuple \_fp_tuple_chk:w #3 ;
17826   {
17827     \exp_after:wN \s__fp_tuple
17828     \exp_after:wN \_fp_tuple_chk:w
17829     \exp_after:wN {
17830       \exp:w \exp_end_continue_f:w
17831       \_fp_tuple_mapthread_loop_o:nw {#1}
17832       #2 { \s__fp \prg_break: } ; @
17833       #3 { \s__fp \prg_break: } ;
17834       \prg_break_point:
17835       \exp_after:wN } \exp_after:wN ;
17836     }
17837 \cs_new:Npn \_fp_tuple_mapthread_loop_o:nw #1#2#3 ; #4 @ #5#6 ;
17838   {
17839     \use_none:n #2
17840     \use_none:n #5
17841     #1 #2 #3 ; #5 #6 ;
17842     \exp:w \exp_end_continue_f:w
17843     \_fp_tuple_mapthread_loop_o:nw {#1} #4 @
17844   }
```

(End definition for _fp_tuple_mapthread_o:nww and _fp_tuple_mapthread_loop_o:nw.)

28.9 Messages

```

17845 \__kernel_msg_new:nnn { kernel } { fp-deprecated }
17846   { '#1'~deprecated;~use~'#2' }
17847 \__kernel_msg_new:nnn { kernel } { unknown-fp-word }
17848   { Unknown~fp~word~#1. }
17849 \__kernel_msg_new:nnn { kernel } { fp-missing }
17850   { Missing~#1~inserted #2. }
17851 \__kernel_msg_new:nnn { kernel } { fp-extra }
17852   { Extra~#1~ignored. }
17853 \__kernel_msg_new:nnn { kernel } { fp-early-end }
17854   { Premature~end~in~fp~expression. }
17855 \__kernel_msg_new:nnn { kernel } { fp-after-e }
17856   { Cannot~use~#1 after~'e'. }
17857 \__kernel_msg_new:nnn { kernel } { fp-missing-number }
17858   { Missing~number~before~'#1'. }
17859 \__kernel_msg_new:nnn { kernel } { fp-unknown-symbol }
17860   { Unknown~symbol~#1~ignored. }
17861 \__kernel_msg_new:nnn { kernel } { fp-extra-comma }
17862   { Unexpected~comma~turned~to~nan~result. }
17863 \__kernel_msg_new:nnn { kernel } { fp-no-arg }
17864   { #1~got~no~argument;~used~nan. }
17865 \__kernel_msg_new:nnn { kernel } { fp-multi-arg }
17866   { #1~got~more~than~one~argument;~used~nan. }
17867 \__kernel_msg_new:nnn { kernel } { fp-num-args }
17868   { #1~expects~between~#2~and~#3~arguments. }
```

```

17869 \__kernel_msg_new:nnn { kernel } { fp-bad-args }
17870 { Arguments~in~#1#2~are~invalid. }
17871 \__kernel_msg_new:nnn { kernel } { fp-infty-pi }
17872 { Math~command~#1 is~not~an~fp }
17873 (*package)
17874 \cs_if_exist:cT { @unexpandable@protect }
17875 {
17876   \__kernel_msg_new:nnn { kernel } { fp-robust-cmd }
17877   { Robust~command~#1 invalid~in~fp~expression! }
17878 }
17879 </package>
17880 </initex | package>

```

29 l3fp-assign implementation

```

17881 (*initex | package)
17882 @@=fp

```

29.1 Assigning values

\fp_new:N Floating point variables are initialized to be +0.

```

17883 \cs_new_protected:Npn \fp_new:N #1
17884 { \cs_new_eq:NN #1 \c_zero_fp }
17885 \cs_generate_variant:Nn \fp_new:N {c}

```

(End definition for \fp_new:N. This function is documented on page 192.)

\fp_set:Nn Simply use __fp_parse:n within various f-expanding assignments.

```

\fp_set:cn 17886 \cs_new_protected:Npn \fp_set:Nn #1#2
\fp_gset:Nn 17887 { \tl_set:Nx #1 { \exp_not:f { \__fp_parse:n {#2} } } }
\fp_gset:cn 17888 \cs_new_protected:Npn \fp_gset:Nn #1#2
\fp_const:Nn 17889 { \tl_gset:Nx #1 { \exp_not:f { \__fp_parse:n {#2} } } }
\fp_const:cn 17890 \cs_new_protected:Npn \fp_const:Nn #1#2
17891 { \tl_const:Nx #1 { \exp_not:f { \__fp_parse:n {#2} } } }
17892 \cs_generate_variant:Nn \fp_set:Nn {c}
17893 \cs_generate_variant:Nn \fp_gset:Nn {c}
17894 \cs_generate_variant:Nn \fp_const:Nn {c}

```

(End definition for \fp_set:Nn, \fp_gset:Nn, and \fp_const:Nn. These functions are documented on page 193.)

\fp_set_eq:NN Copying a floating point is the same as copying the underlying token list.

```

\fp_set_eq:cn 17895 \cs_new_eq:NN \fp_set_eq:NN \tl_set_eq:NN
\fp_set_eq:Nc 17896 \cs_new_eq:NN \fp_gset_eq:NN \tl_gset_eq:NN
\fp_set_eq:cc 17897 \cs_generate_variant:Nn \fp_set_eq:NN { c , Nc , cc }
\fp_gset_eq:NN 17898 \cs_generate_variant:Nn \fp_gset_eq:NN { c , Nc , cc }

```

(End definition for \fp_set_eq:NN and \fp_gset_eq:NN. These functions are documented on page 193.)

\fp_gset_eq:cn Setting a floating point to zero: copy \c_zero_fp.

```

\fp_zero:c 17899 \cs_new_protected:Npn \fp_zero:N #1 { \fp_set_eq:NN #1 \c_zero_fp }
\fp_gzero:N 17900 \cs_new_protected:Npn \fp_gzero:N #1 { \fp_gset_eq:NN #1 \c_zero_fp }
\fp_gzero:c 17901 \cs_generate_variant:Nn \fp_zero:N { c }
17902 \cs_generate_variant:Nn \fp_gzero:N { c }

```

(End definition for `\fp_zero:N` and `\fp_gzero:N`. These functions are documented on page 192.)

```

\fp_zero_new:N Set the floating point to zero, or define it if needed.
\fp_zero_new:c 17903 \cs_new_protected:Npn \fp_zero_new:N #1
\fp_gzero_new:N 17904 { \fp_if_exist:NTF #1 { \fp_zero:N #1 } { \fp_new:N #1 } }
\fp_gzero_new:c 17905 \cs_new_protected:Npn \fp_gzero_new:N #1
17906 { \fp_if_exist:NTF #1 { \fp_gzero:N #1 } { \fp_new:N #1 } }
17907 \cs_generate_variant:Nn \fp_zero_new:N { c }
17908 \cs_generate_variant:Nn \fp_gzero_new:N { c }

```

(End definition for `\fp_zero_new:N` and `\fp_gzero_new:N`. These functions are documented on page 193.)

29.2 Updating values

These match the equivalent functions in `l3int` and `l3skip`.

```

\fp_add:Nn For the sake of error recovery we should not simply set #1 to #1 ± (#2): for instance, if #2
\fp_add:cn is 0)+2, the parsing error would be raised at the last closing parenthesis rather than at
\fp_gadd:Nn the closing parenthesis in the user argument. Thus we evaluate #2 instead of just putting
\fp_gadd:cn parentheses. As an optimization we use \__fp_parse:n rather than \fp_eval:n, which
\fp_sub:Nn would convert the result away from the internal representation and back.
\fp_sub:cn 17909 \cs_new_protected:Npn \fp_add:Nn { \__fp_add:NNNn \fp_set:Nn + }
\fp_gsub:Nn 17910 \cs_new_protected:Npn \fp_gadd:Nn { \__fp_add:NNNn \fp_gset:Nn + }
\fp_gsub:cn 17911 \cs_new_protected:Npn \fp_sub:Nn { \__fp_add:NNNn \fp_set:Nn - }
\__fp_add:NNNn 17912 \cs_new_protected:Npn \fp_gsub:Nn { \__fp_add:NNNn \fp_gset:Nn - }
17913 \cs_new_protected:Npn \__fp_add:NNNn #1#2#3#4
17914 { #1 #3 { #3 #2 \__fp_parse:n {#4} } }
17915 \cs_generate_variant:Nn \fp_add:Nn { c }
17916 \cs_generate_variant:Nn \fp_gadd:Nn { c }
17917 \cs_generate_variant:Nn \fp_sub:Nn { c }
17918 \cs_generate_variant:Nn \fp_gsub:Nn { c }

```

(End definition for `\fp_add:Nn` and others. These functions are documented on page 193.)

29.3 Showing values

```

\fp_show:N This shows the result of computing its argument by passing the right data to \tl_show:n
\fp_show:c or \tl_log:n.
\fp_log:N 17919 \cs_new_protected:Npn \fp_show:N { \__fp_show:NN \tl_show:n }
\fp_log:c 17920 \cs_generate_variant:Nn \fp_show:N { c }
\__fp_show:NN 17921 \cs_new_protected:Npn \fp_log:N { \__fp_show:NN \tl_log:n }
17922 \cs_generate_variant:Nn \fp_log:N { c }
17923 \cs_new_protected:Npn \__fp_show:NN #1#2
17924 {
17925   \__kernel_chk_defined:NT #2
17926   { \exp_args:Nx #1 { \token_to_str:N #2 = \fp_to_tl:N #2 } }
17927 }

```

(End definition for `\fp_show:N`, `\fp_log:N`, and `__fp_show:NN`. These functions are documented on page 200.)

\fp_show:n Use general tools.

\fp_log:n

```
17928 \cs_new_protected:Npn \fp_show:n
17929 { \msg_show_eval:Nn \fp_to_tl:n }
17930 \cs_new_protected:Npn \fp_log:n
17931 { \msg_log_eval:Nn \fp_to_tl:n }
```

(End definition for `\fp_show:n` and `\fp_log:n`. These functions are documented on page 200.)

29.4 Some useful constants and scratch variables

\c_one_fp Some constants.

\c_e_fp

```
17932 \fp_const:Nn \c_e_fp { 2.718 2818 2845 9045 }
17933 \fp_const:Nn \c_one_fp { 1 }
```

(End definition for `\c_one_fp` and `\c_e_fp`. These variables are documented on page 198.)

\c_pi_fp We simply round π to and $\pi/180$ to 16 significant digits.

\c_one_degree_fp

```
17934 \fp_const:Nn \c_pi_fp { 3.141 5926 5358 9793 }
17935 \fp_const:Nn \c_one_degree_fp { 0.0 1745 3292 5199 4330 }
```

(End definition for `\c_pi_fp` and `\c_one_degree_fp`. These variables are documented on page 199.)

\l_tmpa_fp Scratch variables are simply initialized there.

\l_tmpb_fp

```
17936 \fp_new:N \l_tmpa_fp
17937 \fp_new:N \l_tmpb_fp
17938 \fp_new:N \g_tmpa_fp
17939 \fp_new:N \g_tmpb_fp
```

(End definition for `\l_tmpa_fp` and others. These variables are documented on page 199.)

17940 `\</initex | package>`

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17941 `*initex | package>`

17942 `<@@=fp>`

__fp_parse_word_max:N Those functions may receive a variable number of arguments.

__fp_parse_word_min:N

```
17943 \cs_new:Npn \__fp_parse_word_max:N
17944 { \__fp_parse_function:NNN \__fp_minmax_o:Nw 2 }
17945 \cs_new:Npn \__fp_parse_word_min:N
17946 { \__fp_parse_function:NNN \__fp_minmax_o:Nw 0 }
```

(End definition for `__fp_parse_word_max:N` and `__fp_parse_word_min:N`.)

30.1 Syntax of internal functions

- `__fp_compare_npos:nwnw` $\{\langle expo_1 \rangle\} \langle body_1 \rangle ; \{\langle expo_2 \rangle\} \langle body_2 \rangle ;$
- `__fp_minmax_o:Nw` $\langle sign \rangle \langle floating\ point\ array \rangle$
- `__fp_not_o:w ?` $\langle floating\ point\ array \rangle$ (with one floating point number only)
- `__fp_&_o:ww` $\langle floating\ point \rangle \langle floating\ point \rangle$
- `__fp_|_o:ww` $\langle floating\ point \rangle \langle floating\ point \rangle$
- `__fp_ternary:NwwN`, `__fp_ternary_auxi:NwwN`, `__fp_ternary_auxii:NwwN` have to be understood.

30.2 Existence test

`\fp_if_exist_p:n` Copies of the `cs` functions defined in `l3basics`.
`\fp_if_exist_p:c` 17947 `\prg_new_eq_conditional:NNn \fp_if_exist:N \cs_if_exist:N { TF , T , F , p }`
`\fp_if_exist:nTF` 17948 `\prg_new_eq_conditional:NNn \fp_if_exist:c \cs_if_exist:c { TF , T , F , p }`
`\fp_if_exist:cTF` (End definition for `\fp_if_exist:nTF`. This function is documented on page 195.)

30.3 Comparison

`\fp_compare_p:n` Within floating point expressions, comparison operators are treated as operations, so we
`\fp_compare:nTF` evaluate #1, then compare with ± 0 . Tuples are true.
`__fp_compare_return:w` 17949 `\prg_new_conditional:Npnn \fp_compare:n #1 { p , T , F , TF }`
17950 `{`
17951 `\exp_after:wN __fp_compare_return:w`
17952 `\exp:w \exp_end_continue_f:w __fp_parse:n {#1}`
17953 `}`
17954 `\cs_new:Npn __fp_compare_return:w #1#2#3;`
17955 `{`
17956 `\if_charcode:w 0`
17957 `__fp_if_type_fp:NTwFw`
17958 `#1 { \use_i_delimit_by_q_stop:nw #3 \q_stop }`
17959 `\s__fp 1 \q_stop`
17960 `\prg_return_false:`
17961 `\else:`
17962 `\prg_return_true:`
17963 `\fi:`
17964 `}`
(End definition for `\fp_compare:nTF` and `__fp_compare_return:w`. This function is documented on page 196.)

`\fp_compare_p:nNn` Evaluate #1 and #3, using an auxiliary to expand both, and feed the two floating point
`\fp_compare:nNnTF` numbers swapped to `__fp_compare_back_any:ww`, defined below. Compare the result
`__fp_compare_aux:wn` with ‘#2-‘=, which is -1 for $<$, 0 for $=$, 1 for $>$ and 2 for $?$.
17965 `\prg_new_conditional:Npnn \fp_compare:nNn #1#2#3 { p , T , F , TF }`
17966 `{`
17967 `\if_int_compare:w`
17968 `\exp_after:wN __fp_compare_aux:wn`
17969 `\exp:w \exp_end_continue_f:w __fp_parse:n {#1} {#3}`

```

17970         = \_fp_int_eval:w '#2 - '=' \_fp_int_eval_end:
17971         \prg_return_true:
17972     \else:
17973         \prg_return_false:
17974     \fi:
17975 }
17976 \cs_new:Npn \_fp_compare_aux:wn #1; #2
17977 {
17978     \exp_after:wN \_fp_compare_back_any:ww
17979     \exp:w \exp_end_continue_f:w \_fp_parse:n {#2} #1;
17980 }

```

(End definition for \fp_compare:nNnTF and _fp_compare_aux:wn. This function is documented on page 195.)

```

\_fp_compare_back_any:ww    \_fp_compare_back_any:ww <y> ; <x> ;
\_fp_compare_back:ww        Expands (in the same way as \int_eval:n) to -1 if  $x < y$ , 0 if  $x = y$ , 1 if  $x > y$ ,
\_fp_compare_nan:w          and 2 otherwise (denoted as  $x?y$ ). If either operand is nan, stop the comparison with
                            \_fp_compare_nan:w returning 2. If  $x$  is negative, swap the outputs 1 and -1 (i.e., >
                            and <); we can henceforth assume that  $x \geq 0$ . If  $y \geq 0$ , and they have the same type,
                            either they are normal and we compare them with \_fp_compare_npos:nwnw, or they
                            are equal. If  $y \geq 0$ , but of a different type, the highest type is a larger number. Finally,
                            if  $y \leq 0$ , then  $x > y$ , unless both are zero.
17981 \cs_new:Npn \_fp_compare_back_any:ww #1#2; #3
17982 {
17983     \_fp_if_type_fp:NTwFw
17984     #1 { \_fp_if_type_fp:NTwFw #3 \use_i:nn \s__fp \use_ii:nn \q_stop }
17985     \s__fp \use_ii:nn \q_stop
17986     \_fp_compare_back:ww
17987     {
17988         \cs:w
17989         __fp
17990         \_fp_type_from_scan:N #1
17991         _compare_back
17992         \_fp_type_from_scan:N #3
17993         :ww
17994     \cs_end:
17995     }
17996     #1#2 ; #3
17997 }
17998 \cs_new:Npn \_fp_compare_back:ww
17999     \s__fp \_fp_chk:w #1 #2 #3;
18000     \s__fp \_fp_chk:w #4 #5 #6;
18001 {
18002     \int_value:w
18003     \if_meaning:w 3 #1 \exp_after:wN \_fp_compare_nan:w \fi:
18004     \if_meaning:w 3 #4 \exp_after:wN \_fp_compare_nan:w \fi:
18005     \if_meaning:w 2 #5 - \fi:
18006     \if_meaning:w #2 #5
18007         \if_meaning:w #1 #4
18008             \if_meaning:w 1 #1
18009                 \_fp_compare_npos:nwnw #6; #3;
18010             \else:
18011                 0

```

```

18012         \fi:
18013     \else:
18014         \if_int_compare:w #4 < #1 - \fi: 1
18015     \fi:
18016 \else:
18017     \if_int_compare:w #1#4 = 0 \exp_stop_f:
18018         0
18019     \else:
18020         1
18021     \fi:
18022 \fi:
18023 \exp_stop_f:
18024 }
18025 \cs_new:Npn \__fp_compare_nan:w #1 \fi: \exp_stop_f: { 2 \exp_stop_f: }

```

(End definition for __fp_compare_back_any:ww, __fp_compare_back:ww, and __fp_compare_nan:w.)

__fp_compare_back_tuple:ww Tuple and floating point numbers are not comparable so return 2 in mixed cases or
__fp_tuple_compare_back:ww when tuples have a different number of items. Otherwise compare pairs of items with
__fp_tuple_compare_back_tuple:ww __fp_compare_back_any:ww and if any don't match return 2 (as \int_value:w 02
__fp_tuple_compare_back_loop:w \exp_stop_f:).

```

18026 \cs_new:Npn \__fp_compare_back_tuple:ww #1; #2; { 2 }
18027 \cs_new:Npn \__fp_tuple_compare_back:ww #1; #2; { 2 }
18028 \cs_new:Npn \__fp_tuple_compare_back_tuple:ww
18029     \s__fp_tuple \__fp_tuple_chk:w #1;
18030     \s__fp_tuple \__fp_tuple_chk:w #2;
18031     {
18032         \int_compare:nNnTF { \__fp_array_count:n {#1} } =
18033             { \__fp_array_count:n {#2} }
18034             {
18035                 \int_value:w 0
18036                 \__fp_tuple_compare_back_loop:w
18037                     #1 { \s__fp \prg_break: } ; @
18038                     #2 { \s__fp \prg_break: } ;
18039                 \prg_break_point:
18040                 \exp_stop_f:
18041             }
18042             { 2 }
18043     }
18044 \cs_new:Npn \__fp_tuple_compare_back_loop:w #1#2 ; #3 @ #4#5 ;
18045     {
18046         \use_none:n #1
18047         \use_none:n #4
18048         \if_int_compare:w
18049             \__fp_compare_back_any:ww #1 #2 ; #4 #5 ; = 0 \exp_stop_f:
18050         \else:
18051             2 \exp_after:wN \prg_break:
18052         \fi:
18053         \__fp_tuple_compare_back_loop:w #3 @
18054     }

```

(End definition for __fp_compare_back_tuple:ww and others.)

```

\__fp_compare_npos:nwnw \__fp_compare_npos:nwnw {<expo1>} <body1> ; {<expo2>} <body2> ;
\__fp_compare_significand:nnnnnnnn

```

Within an `\int_value:w ... \exp_stop_f:` construction, this expands to 0 if the two numbers are equal, -1 if the first is smaller, and 1 if the first is bigger. First compare the exponents: the larger one denotes the larger number. If they are equal, we must compare significands. If both the first 8 digits and the next 8 digits coincide, the numbers are equal. If only the first 8 digits coincide, the next 8 decide. Otherwise, the first 8 digits are compared.

```

18055 \cs_new:Npn \__fp_compare_npos:nwnw #1#2; #3#4;
18056 {
18057   \if_int_compare:w #1 = #3 \exp_stop_f:
18058     \__fp_compare_significand:nnnnnnnn #2 #4
18059   \else:
18060     \if_int_compare:w #1 < #3 - \fi: 1
18061   \fi:
18062 }
18063 \cs_new:Npn \__fp_compare_significand:nnnnnnnn #1#2#3#4#5#6#7#8
18064 {
18065   \if_int_compare:w #1#2 = #5#6 \exp_stop_f:
18066     \if_int_compare:w #3#4 = #7#8 \exp_stop_f:
18067     0
18068   \else:
18069     \if_int_compare:w #3#4 < #7#8 - \fi: 1
18070   \fi:
18071   \else:
18072     \if_int_compare:w #1#2 < #5#6 - \fi: 1
18073   \fi:
18074 }

```

(End definition for `__fp_compare_npos:nwnw` and `__fp_compare_significand:nnnnnnnn`.)

30.4 Floating point expression loops

`\fp_do_until:nn` These are quite easy given the above functions. The `do_until` and `do_while` versions execute the body, then test. The `until_do` and `while_do` do it the other way round.

```

\fp_do_while:nn
\fp_until_do:nn
\fp_while_do:nn
18075 \cs_new:Npn \fp_do_until:nn #1#2
18076 {
18077   #2
18078   \fp_compare:nF {#1}
18079   { \fp_do_until:nn {#1} {#2} }
18080 }
18081 \cs_new:Npn \fp_do_while:nn #1#2
18082 {
18083   #2
18084   \fp_compare:nT {#1}
18085   { \fp_do_while:nn {#1} {#2} }
18086 }
18087 \cs_new:Npn \fp_until_do:nn #1#2
18088 {
18089   \fp_compare:nF {#1}
18090   {
18091     #2
18092     \fp_until_do:nn {#1} {#2}
18093   }
18094 }

```



```

18095 \cs_new:Npn \fp_while_do:nn #1#2
18096 {
18097   \fp_compare:nT {#1}
18098   {
18099     #2
18100     \fp_while_do:nn {#1} {#2}
18101   }
18102 }

```

(End definition for `\fp_do_until:nn` and others. These functions are documented on page 197.)

`\fp_do_until:nNnn` As above but not using the `nNn` syntax.

```

\fp_do_while:nNnn 18103 \cs_new:Npn \fp_do_until:nNnn #1#2#3#4
\fp_until_do:nNnn 18104 {
\fp_while_do:nNnn 18105   #4
18106   \fp_compare:nNnF {#1} #2 {#3}
18107   { \fp_do_until:nNnn {#1} #2 {#3} {#4} }
18108 }
18109 \cs_new:Npn \fp_do_while:nNnn #1#2#3#4
18110 {
18111   #4
18112   \fp_compare:nNnT {#1} #2 {#3}
18113   { \fp_do_while:nNnn {#1} #2 {#3} {#4} }
18114 }
18115 \cs_new:Npn \fp_until_do:nNnn #1#2#3#4
18116 {
18117   \fp_compare:nNnF {#1} #2 {#3}
18118   {
18119     #4
18120     \fp_until_do:nNnn {#1} #2 {#3} {#4}
18121   }
18122 }
18123 \cs_new:Npn \fp_while_do:nNnn #1#2#3#4
18124 {
18125   \fp_compare:nNnT {#1} #2 {#3}
18126   {
18127     #4
18128     \fp_while_do:nNnn {#1} #2 {#3} {#4}
18129   }
18130 }

```

(End definition for `\fp_do_until:nNnn` and others. These functions are documented on page 196.)

`\fp_step_function:nnnN` The approach here is somewhat similar to `\int_step_function:nnnN`. There are two subtleties: we use the internal parser `__fp_parse:n` to avoid converting back and forth from the internal representation; and (due to rounding) even a non-zero step does not guarantee that the loop counter increases.

```

\fp_step_function:nnnc 18131 \cs_new:Npn \fp_step_function:nnnN #1#2#3
  \__fp_step:wwwN 18132 {
  \__fp_step_fp:wwwN 18133   \exp_after:wN \__fp_step:wwwN
  \__fp_step:NnnnnN 18134   \exp:w \exp_end_continue_f:w \__fp_parse_o:n {#1}
  \__fp_step:NfnnnN 18135   \exp:w \exp_end_continue_f:w \__fp_parse_o:n {#2}
  18136   \exp:w \exp_end_continue_f:w \__fp_parse:n {#3}
  18137 }

```

```

18138 \cs_generate_variant:Nn \fp_step_function:nnnN { nnnn }
18139 % \end{macrocode}
18140 % Only floating point numbers (not tuples) are allowed arguments.
18141 % Only \enquote{normal} floating points (not $\pm 0$,
18142 % $\pm\texttt{inf}$, $\texttt{nan}$) can be used as step; if positive,
18143 % call \cs{__fp_step:NnnnnN} with argument |>| otherwise~|<|. This
18144 % function has one more argument than its integer counterpart, namely
18145 % the previous value, to catch the case where the loop has made no
18146 % progress. Conversion to decimal is done just before calling the
18147 % user's function.
18148 % \begin{macrocode}
18149 \cs_new:Npn \__fp_step:wwwN #1#2; #3#4; #5#6; #7
18150 {
18151   \__fp_if_type_fp:NTwFw #1 { } \s__fp \prg_break: \q_stop
18152   \__fp_if_type_fp:NTwFw #3 { } \s__fp \prg_break: \q_stop
18153   \__fp_if_type_fp:NTwFw #5 { } \s__fp \prg_break: \q_stop
18154   \use_i:nnnn { \__fp_step_fp:wwwN #1#2; #3#4; #5#6; #7 }
18155   \prg_break_point:
18156   \use:n
18157   {
18158     \__fp_error:nfff { fp-step-tuple } { \fp_to_tl:n { #1#2 ; } }
18159     { \fp_to_tl:n { #3#4 ; } } { \fp_to_tl:n { #5#6 ; } }
18160   }
18161 }
18162 \cs_new:Npn \__fp_step_fp:wwwN #1 ; \s__fp \__fp_chk:w #2#3#4 ; #5; #6
18163 {
18164   \token_if_eq_meaning:NNTF #2 1
18165   {
18166     \token_if_eq_meaning:NNTF #3 0
18167     { \__fp_step:NnnnnN > }
18168     { \__fp_step:NnnnnN < }
18169   }
18170   {
18171     \token_if_eq_meaning:NNTF #2 0
18172     {
18173       \__kernel_msg_expandable_error:nnn { kernel }
18174       { zero-step } {#6}
18175     }
18176     {
18177       \__fp_error:nnfn { fp-bad-step } { }
18178       { \fp_to_tl:n { \s__fp \__fp_chk:w #2#3#4 ; } } {#6}
18179     }
18180     \use_none:nnnnn
18181   }
18182   { #1 ; } { \c_nan_fp } { \s__fp \__fp_chk:w #2#3#4 ; } { #5 ; } #6
18183 }
18184 \cs_new:Npn \__fp_step:NnnnnN #1#2#3#4#5#6
18185 {
18186   \fp_compare:nNnTF {#2} = {#3}
18187   {
18188     \__fp_error:nffn { fp-tiny-step }
18189     { \fp_to_tl:n {#3} } { \fp_to_tl:n {#4} } {#6}
18190   }
18191   {

```

```

18192     \fp_compare:nNnF {#2} #1 {#5}
18193     {
18194         \exp_args:Nf #6 { \__fp_to_decimal_dispatch:w #2 }
18195         \__fp_step:NfnNnN
18196         #1 { \__fp_parse:n { #2 + #4 } } {#2} {#4} {#5} #6
18197     }
18198 }
18199 }
18200 \cs_generate_variant:Nn \__fp_step:NnnnnN { Nf }

```

(End definition for `\fp_step_function:nnnN` and others. This function is documented on page 198.)

`\fp_step_inline:nnnn` As for `\int_step_inline:nnnn`, create a global function and apply it, following up with
`\fp_step_variable:nnnNn` a break point.

```

\__fp_step:NNnnnn
18201 \cs_new_protected:Npn \fp_step_inline:nnnn
18202 {
18203     \int_gincr:N \g__kernel_prg_map_int
18204     \exp_args:NNc \__fp_step:NNnnnn
18205     \cs_gset_protected:Npn
18206     { \__fp_map_ \int_use:N \g__kernel_prg_map_int :w }
18207 }
18208 \cs_new_protected:Npn \fp_step_variable:nnnNn #1#2#3#4#5
18209 {
18210     \int_gincr:N \g__kernel_prg_map_int
18211     \exp_args:NNc \__fp_step:NNnnnn
18212     \cs_gset_protected:Npx
18213     { \__fp_map_ \int_use:N \g__kernel_prg_map_int :w }
18214     {#1} {#2} {#3}
18215     {
18216         \tl_set:Nn \exp_not:N #4 {##1}
18217         \exp_not:n {#5}
18218     }
18219 }
18220 \cs_new_protected:Npn \__fp_step:NNnnnn #1#2#3#4#5#6
18221 {
18222     #1 #2 ##1 {#6}
18223     \fp_step_function:nnnN {#3} {#4} {#5} #2
18224     \prg_break_point:Nn \scan_stop: { \int_gdecr:N \g__kernel_prg_map_int }
18225 }

```

(End definition for `\fp_step_inline:nnnn`, `\fp_step_variable:nnnNn`, and `__fp_step:NNnnnn`. These functions are documented on page 198.)

```

18226 \__kernel_msg_new:nnn { kernel } { fp-step-tuple }
18227 { Tuple~argument~in~fp_step...~{#1}{#2}{#3}. }
18228 \__kernel_msg_new:nnn { kernel } { fp-bad-step }
18229 { Invalid~step~size~#2~in~step~function~#3. }
18230 \__kernel_msg_new:nnn { kernel } { fp-tiny-step }
18231 { Tiny~step~size~( #1 + #2 = #1 ) ~in~step~function~#3. }

```

30.5 Extrema

`__fp_minmax_o:Nw` First check all operands are floating point numbers. The argument #1 is 2 to find the
`__fp_minmax_aux_o:Nw` maximum of an array #2 of floating point numbers, and 0 to find the minimum. We
read numbers sequentially, keeping track of the largest (smallest) number found so far. If

numbers are equal (for instance ± 0), the first is kept. We append $-\infty$ (∞), for the case of an empty array. Since no number is smaller (larger) than that, this additional item only affects the maximum (minimum) in the case of `max()` and `min()` with no argument. The weird fp-like trailing marker breaks the loop correctly: see the precise definition of `__fp_minmax_loop:Nww`.

```

18232 \cs_new:Npn \__fp_minmax_o:Nw #1
18233 {
18234   \__fp_parse_function_all_fp_o:fnw
18235   { \token_if_eq_meaning:NNTF 0 #1 { min } { max } }
18236   { \__fp_minmax_aux_o:Nw #1 }
18237 }
18238 \cs_new:Npn \__fp_minmax_aux_o:Nw #1#2 @
18239 {
18240   \if_meaning:w 0 #1
18241     \exp_after:wN \__fp_minmax_loop:Nww \exp_after:wN +
18242   \else:
18243     \exp_after:wN \__fp_minmax_loop:Nww \exp_after:wN -
18244   \fi:
18245   #2
18246   \s_fp \__fp_chk:w 2 #1 \s_fp_exact ;
18247   \s_fp \__fp_chk:w { 3 \__fp_minmax_break_o:w } ;
18248 }

```

(End definition for `__fp_minmax_o:Nw` and `__fp_minmax_aux_o:Nw`.)

`__fp_minmax_loop:Nww`

The first argument is `-` or `+` to denote the case where the currently largest (smallest) number found (first floating point argument) should be replaced by the new number (second floating point argument). If the new number is `nan`, keep that as the extremum, unless that extremum is already a `nan`. Otherwise, compare the two numbers. If the new number is larger (in the case of `max`) or smaller (in the case of `min`), the test yields `true`, and we keep the second number as a new maximum; otherwise we keep the first number. Then loop.

```

18249 \cs_new:Npn \__fp_minmax_loop:Nww
18250   #1 \s_fp \__fp_chk:w #2#3; \s_fp \__fp_chk:w #4#5;
18251 {
18252   \if_meaning:w 3 #4
18253     \if_meaning:w 3 #2
18254       \__fp_minmax_auxi:ww
18255     \else:
18256       \__fp_minmax_auxii:ww
18257     \fi:
18258   \else:
18259     \if_int_compare:w
18260       \__fp_compare_back:ww
18261       \s_fp \__fp_chk:w #4#5;
18262       \s_fp \__fp_chk:w #2#3;
18263       = #1 1 \exp_stop_f:
18264       \__fp_minmax_auxii:ww
18265     \else:
18266       \__fp_minmax_auxi:ww
18267     \fi:
18268   \fi:
18269   \__fp_minmax_loop:Nww #1

```

```

18270     \s__fp \__fp_chk:w #2#3;
18271     \s__fp \__fp_chk:w #4#5;
18272 }

```

(End definition for __fp_minmax_loop:Nww.)

```

\__fp_minmax_auxi:ww Keep the first/second number, and remove the other.
\__fp_minmax_auxii:ww
18273 \cs_new:Npn \__fp_minmax_auxi:ww #1 \fi: \fi: #2 \s__fp #3 ; \s__fp #4;
18274 { \fi: \fi: #2 \s__fp #3 ; }
18275 \cs_new:Npn \__fp_minmax_auxii:ww #1 \fi: \fi: #2 \s__fp #3 ;
18276 { \fi: \fi: #2 }

```

(End definition for __fp_minmax_auxi:ww and __fp_minmax_auxii:ww.)

__fp_minmax_break_o:w This function is called from within an \if_meaning:w test. Skip to the end of the tests, close the current test with \fi:, clean up, and return the appropriate number with one post-expansion.

```

18277 \cs_new:Npn \__fp_minmax_break_o:w #1 \fi: \fi: #2 \s__fp #3; #4;
18278 { \fi: \__fp_exp_after_o:w \s__fp #3; }

```

(End definition for __fp_minmax_break_o:w.)

30.6 Boolean operations

__fp_not_o:w Return true or false, with two expansions, one to exit the conditional, and one to please l3fp-parse. The first argument is provided by l3fp-parse and is ignored.

```

\__fp_tuple_not_o:w
18279 \cs_new:Npn \__fp_not_o:w #1 \s__fp \__fp_chk:w #2#3; @
18280 {
18281   \if_meaning:w 0 #2
18282     \exp_after:wN \exp_after:wN \exp_after:wN \c_one_fp
18283   \else:
18284     \exp_after:wN \exp_after:wN \exp_after:wN \c_zero_fp
18285   \fi:
18286 }
18287 \cs_new:Npn \__fp_tuple_not_o:w #1 @ { \exp_after:wN \c_zero_fp }

```

(End definition for __fp_not_o:w and __fp_tuple_not_o:w.)

__fp_&_o:w For and, if the first number is zero, return it (with the same sign). Otherwise, return the second one. For or, the logic is reversed: if the first number is non-zero, return it, otherwise return the second number: we achieve that by hi-jacking __fp_&_o:ww, inserting an extra argument, \else:, before \s__fp. In all cases, expand after the floating point number.

```

\__fp_tuple_&_o:ww
\__fp_&_tuple_o:ww
\__fp_tuple_&_tuple_o:ww
\__fp_|_o:ww
\__fp_tuple_|_o:ww
\__fp_|_tuple_o:ww
\__fp_tuple_|_tuple_o:ww
\__fp_and_return:wNw
18288 \group_begin:
18289   \char_set_catcode_letter:N &
18290   \char_set_catcode_letter:N |
18291   \cs_new:Npn \__fp_&_o:ww #1 \s__fp \__fp_chk:w #2#3;
18292   {
18293     \if_meaning:w 0 #2 #1
18294       \__fp_and_return:wNw \s__fp \__fp_chk:w #2#3;
18295     \fi:
18296     \__fp_exp_after_o:w
18297   }
18298   \cs_new:Npn \__fp_&_tuple_o:ww #1 \s__fp \__fp_chk:w #2#3;

```

```

18299 {
18300     \if_meaning:w 0 #2 #1
18301     \__fp_and_return:wNw \s__fp \__fp_chk:w #2#3;
18302     \fi:
18303     \__fp_exp_after_tuple_o:w
18304 }
18305 \cs_new:Npn \__fp_tuple_&_o:ww #1; { \__fp_exp_after_o:w }
18306 \cs_new:Npn \__fp_tuple_&_tuple_o:ww #1; { \__fp_exp_after_tuple_o:w }
18307 \cs_new:Npn \__fp_|_o:ww { \__fp_&_o:ww \else: }
18308 \cs_new:Npn \__fp_|_tuple_o:ww { \__fp_&_tuple_o:ww \else: }
18309 \cs_new:Npn \__fp_tuple_|_o:ww #1; #2; { \__fp_exp_after_tuple_o:w #1; }
18310 \cs_new:Npn \__fp_tuple_|_tuple_o:ww #1; #2;
18311 { \__fp_exp_after_tuple_o:w #1; }
18312 \group_end:
18313 \cs_new:Npn \__fp_and_return:wNw #1; \fi: #2;
18314 { \fi: \__fp_exp_after_o:w #1; }

```

(End definition for __fp_&_o:ww and others.)

30.7 Ternary operator

```

\__fp_ternary:NwN
\__fp_ternary_auxi:NwN
\__fp_ternary_auxii:NwN

```

The first function receives the test and the true branch of the ?: ternary operator. It calls __fp_ternary_auxii:NwN if the test branch is a floating point number ± 0 , and otherwise calls __fp_ternary_auxi:NwN. These functions select one of their two arguments.

```

18315 \cs_new:Npn \__fp_ternary:NwN #1 #2#3@ #4@ #5
18316 {
18317     \if_meaning:w \__fp_parse_infix_:N #5
18318     \if_charcode:w 0
18319         \__fp_if_type_fp:NTwFw
18320         #2 { \use_i:nn \use_i_delimit_by_q_stop:nw #3 \q_stop }
18321         \s__fp 1 \q_stop
18322         \exp_after:wN \exp_after:wN \exp_after:wN \__fp_ternary_auxii:NwN
18323     \else:
18324         \exp_after:wN \exp_after:wN \exp_after:wN \__fp_ternary_auxi:NwN
18325     \fi:
18326     \exp_after:wN #1
18327     \exp:w \exp_end_continue_f:w
18328     \__fp_exp_after_array_f:w #4 \s__fp_stop
18329     \exp_after:wN @
18330     \exp:w
18331     \__fp_parse_operand:Nw \c__fp_prec_colon_int
18332     \__fp_parse_expand:w
18333 \else:
18334     \__kernel_msg_expandable_error:nnnn
18335     { kernel } { fp-missing } { : } { ~for~?: }
18336     \exp_after:wN \__fp_parse_continue:NwN
18337     \exp_after:wN #1
18338     \exp:w \exp_end_continue_f:w
18339     \__fp_exp_after_array_f:w #4 \s__fp_stop
18340     \exp_after:wN #5
18341     \exp_after:wN #1
18342 \fi:
18343 }

```

```

18344 \cs_new:Npn \__fp_ternary_auxi:NwwN #1#2@#3@#4
18345 {
18346   \exp_after:wN \__fp_parse_continue:NwN
18347   \exp_after:wN #1
18348   \exp:w \exp_end_continue_f:w
18349   \__fp_exp_after_array_f:w #2 \s__fp_stop
18350   #4 #1
18351 }
18352 \cs_new:Npn \__fp_ternary_auxii:NwwN #1#2@#3@#4
18353 {
18354   \exp_after:wN \__fp_parse_continue:NwN
18355   \exp_after:wN #1
18356   \exp:w \exp_end_continue_f:w
18357   \__fp_exp_after_array_f:w #3 \s__fp_stop
18358   #4 #1
18359 }

```

(End definition for `__fp_ternary:NwwN`, `__fp_ternary_auxi:NwwN`, and `__fp_ternary_auxii:NwwN`.)

```
18360 </initex | package>
```

31 l3fp-basics Implementation

```
18361 <*initex | package>
```

```
18362 <@@=fp>
```

The `l3fp-basics` module implements addition, subtraction, multiplication, and division of two floating points, and the absolute value and sign-changing operations on one floating point. All operations implemented in this module yield the outcome of rounding the infinitely precise result of the operation to the nearest floating point.

Some algorithms used below end up being quite similar to some described in “What Every Computer Scientist Should Know About Floating Point Arithmetic”, by David Goldberg, which can be found at <http://cr.yp.to/2005-590/goldberg.pdf>.

Unary functions.

```

\__fp_parse_word_abs:N
\__fp_parse_word_logb:N
\__fp_parse_word_sign:N
\__fp_parse_word_sqrt:N
18363 \cs_new:Npn \__fp_parse_word_abs:N
18364 { \__fp_parse_unary_function:NNN \__fp_set_sign_o:w 0 }
18365 \cs_new:Npn \__fp_parse_word_logb:N
18366 { \__fp_parse_unary_function:NNN \__fp_logb_o:w ? }
18367 \cs_new:Npn \__fp_parse_word_sign:N
18368 { \__fp_parse_unary_function:NNN \__fp_sign_o:w ? }
18369 \cs_new:Npn \__fp_parse_word_sqrt:N
18370 { \__fp_parse_unary_function:NNN \__fp_sqrt_o:w ? }

```

(End definition for `__fp_parse_word_abs:N` and others.)

31.1 Addition and subtraction

We define here two functions, `__fp_-o:ww` and `__fp_+o:ww`, which perform the subtraction and addition of their two floating point operands, and expand the tokens following the result once.

A more obscure function, `__fp_add_big_i_o:wNww`, is used in `l3fp-expo`.

The logic goes as follows:

- `__fp_-_o:ww` calls `__fp+_o:ww` to do the work, with the sign of the second operand flipped;
- `__fp+_o:ww` dispatches depending on the type of floating point, calling specialized auxiliaries;
- in all cases except summing two normal floating point numbers, we return one or the other operands depending on the signs, or detect an invalid operation in the case of $\infty - \infty$;
- for normal floating point numbers, compare the signs;
- to add two floating point numbers of the same sign or of opposite signs, shift the significand of the smaller one to match the bigger one, perform the addition or subtraction of significands, check for a carry, round, and pack using the `__fp-basics_pack_...` functions.

The trickiest part is to round correctly when adding or subtracting normal floating point numbers.

31.1.1 Sign, exponent, and special numbers

`__fp_-_o:ww` The `__fp+_o:ww` auxiliary has a hook: it takes one argument between the first `\s__fp` and `__fp_chk:w`, which is applied to the sign of the second operand. Positioning the hook there means that `__fp+_o:ww` can still perform the sanity check that it was followed by `\s__fp`.

```

18371 \cs_new:cpx { __fp_-_o:ww } \s__fp
18372 {
18373   \exp_not:c { __fp+_o:ww }
18374   \exp_not:n { \s__fp \__fp_neg_sign:N }
18375 }
```

(End definition for `__fp_-_o:ww`.)

`__fp+_o:ww` This function is either called directly with an empty `#1` to compute an addition, or it is called by `__fp_-_o:ww` with `__fp_neg_sign:N` as `#1` to compute a subtraction, in which case the second operand's sign should be changed. If the $\langle types \rangle$ `#2` and `#4` are the same, dispatch to case `#2` (0, 1, 2, or 3), where we call specialized functions: thanks to `\int_value:w`, those receive the tweaked $\langle sign_2 \rangle$ (expansion of `#1#5`) as an argument. If the $\langle types \rangle$ are distinct, the result is simply the floating point number with the highest $\langle type \rangle$. Since case 3 (used for two `nan`) also picks the first operand, we can also use it when $\langle type_1 \rangle$ is greater than $\langle type_2 \rangle$. Also note that we don't need to worry about $\langle sign_2 \rangle$ in that case since the second operand is discarded.

```

18376 \cs_new:cpn { __fp+_o:ww }
18377   \s__fp #1 \__fp_chk:w #2 #3 ; \s__fp \__fp_chk:w #4 #5
18378 {
18379   \if_case:w
18380     \if_meaning:w #2 #4
18381     #2
18382   \else:
18383     \if_int_compare:w #2 > #4 \exp_stop_f:
18384     3
18385   \else:
```



```

18386         4
18387         \fi:
18388         \fi:
18389         \exp_stop_f:
18390         \exp_after:wN \__fp_add_zeros_o:Nww \int_value:w
18391     \or: \exp_after:wN \__fp_add_normal_o:Nww \int_value:w
18392     \or: \exp_after:wN \__fp_add_inf_o:Nww \int_value:w
18393     \or: \__fp_case_return_i_o:ww
18394     \else: \exp_after:wN \__fp_add_return_ii_o:Nww \int_value:w
18395     \fi:
18396     #1 #5
18397     \s__fp \__fp_chk:w #2 #3 ;
18398     \s__fp \__fp_chk:w #4 #5
18399 }

```

(End definition for __fp_+_o:ww.)

__fp_add_return_ii_o:Nww Ignore the first operand, and return the second, but using the sign #1 rather than #4. As usual, expand after the floating point.

```

18400 \cs_new:Npn \__fp_add_return_ii_o:Nww #1 #2 ; \s__fp \__fp_chk:w #3 #4
18401 { \__fp_exp_after_o:w \s__fp \__fp_chk:w #3 #1 }

```

(End definition for __fp_add_return_ii_o:Nww.)

__fp_add_zeros_o:Nww Adding two zeros yields \c_zero_fp, except if both zeros were -0 .

```

18402 \cs_new:Npn \__fp_add_zeros_o:Nww #1 \s__fp \__fp_chk:w 0 #2
18403 {
18404     \if_int_compare:w #2 #1 = 20 \exp_stop_f:
18405     \exp_after:wN \__fp_add_return_ii_o:Nww
18406     \else:
18407     \__fp_case_return_i_o:ww
18408     \fi:
18409     #1
18410     \s__fp \__fp_chk:w 0 #2
18411 }

```

(End definition for __fp_add_zeros_o:Nww.)

__fp_add_inf_o:Nww If both infinities have the same sign, just return that infinity, otherwise, it is an invalid operation. We find out if that invalid operation is an addition or a subtraction by testing whether the tweaked $\langle sign_2 \rangle$ (#1) and the $\langle sign_2 \rangle$ (#4) are identical.

```

18412 \cs_new:Npn \__fp_add_inf_o:Nww
18413     #1 \s__fp \__fp_chk:w 2 #2 #3; \s__fp \__fp_chk:w 2 #4
18414 {
18415     \if_meaning:w #1 #2
18416     \__fp_case_return_i_o:ww
18417     \else:
18418     \__fp_case_use:nw
18419     {
18420     \exp_last_unbraced:Nf \__fp_invalid_operation_o:Nww
18421     { \token_if_eq_meaning:NNTF #1 #4 + - }
18422     }
18423     \fi:
18424     \s__fp \__fp_chk:w 2 #2 #3;
18425     \s__fp \__fp_chk:w 2 #4
18426 }

```

(End definition for _fp_add_inf_o:Nww.)

```
\_fp_add_normal_o:Nww \_fp_add_normal_o:Nww <sign2> \s\_fp \_fp_chk:w 1 <sign1> <exp1>
<body1> ; \s\_fp \_fp_chk:w 1 <initial sign2> <exp2> <body2> ;
```

We now have two normal numbers to add, and we have to check signs and exponents more carefully before performing the addition.

```
18427 \cs_new:Npn \_fp_add_normal_o:Nww #1 \s\_fp \_fp_chk:w 1 #2
18428 {
18429   \if_meaning:w #1#2
18430     \exp_after:wN \_fp_add_npos_o:NnwNnw
18431   \else:
18432     \exp_after:wN \_fp_sub_npos_o:NnwNnw
18433   \fi:
18434   #2
18435 }
```

(End definition for _fp_add_normal_o:Nww.)

31.1.2 Absolute addition

In this subsection, we perform the addition of two positive normal numbers.

```
\_fp_add_npos_o:NnwNnw \_fp_add_npos_o:NnwNnw <sign1> <exp1> <body1> ; \s\_fp \_fp_chk:w 1
<initial sign2> <exp2> <body2> ;
```

Since we are doing an addition, the final sign is $\langle sign_1 \rangle$. Start an $_fp_int_eval:w$, responsible for computing the exponent: the result, and the $\langle final\ sign \rangle$ are then given to $_fp_sanitize:Nw$ which checks for overflow. The exponent is computed as the largest exponent #2 or #5, incremented if there is a carry. To add the significands, we decimate the smaller number by the difference between the exponents. This is done by $_fp_add_big_i:wNnw$ or $_fp_add_big_ii:wNnw$. We need to bring the final sign with us in the midst of the calculation to round properly at the end.

```
18436 \cs_new:Npn \_fp_add_npos_o:NnwNnw #1#2#3 ; \s\_fp \_fp_chk:w 1 #4 #5
18437 {
18438   \exp_after:wN \_fp_sanitize:Nw
18439   \exp_after:wN #1
18440   \int_value:w \_fp_int_eval:w
18441   \if_int_compare:w #2 > #5 \exp_stop_f:
18442     #2
18443     \exp_after:wN \_fp_add_big_i_o:wNnw \int_value:w -
18444   \else:
18445     #5
18446     \exp_after:wN \_fp_add_big_ii_o:wNnw \int_value:w
18447   \fi:
18448   \_fp_int_eval:w #5 - #2 ; #1 #3;
18449 }
```

(End definition for _fp_add_npos_o:NnwNnw.)

```
\_fp_add_big_i_o:wNnw \_fp_add_big_i_o:wNnw <shift> ; <final sign> <body1> ; <body2> ;
\_fp_add_big_ii_o:wNnw Used in l3fp-expo. Shift the significand of the small number, then add with \_fp_
add_significand_o:NnnwnnnnN.
```

```
18450 \cs_new:Npn \_fp_add_big_i_o:wNnw #1; #2 #3; #4;
18451 {
```

```

18452     \__fp_decimate:nNnnnn {#1}
18453     \__fp_add_significand_o:NnnwnnnnN
18454     #4
18455     #3
18456     #2
18457   }
18458 \cs_new:Npn \__fp_add_big_ii_o:wNww #1; #2 #3; #4;
18459 {
18460     \__fp_decimate:nNnnnn {#1}
18461     \__fp_add_significand_o:NnnwnnnnN
18462     #3
18463     #4
18464     #2
18465 }

```

(End definition for __fp_add_big_i_o:wNww and __fp_add_big_ii_o:wNww.)

```

\__fp_add_significand_o:NnnwnnnnN     \__fp_add_significand_o:NnnwnnnnN <rounding digit> {\langle Y'_1 \rangle} {\langle Y'_2 \rangle}
\__fp_add_significand_pack:NNNNNNN    <extra-digits> ; {\langle X_1 \rangle} {\langle X_2 \rangle} {\langle X_3 \rangle} {\langle X_4 \rangle} <final sign>
\__fp_add_significand_test_o:N

```

To round properly, we must know at which digit the rounding should occur. This requires to know whether the addition produces an overall carry or not. Thus, we do the computation now and check for a carry, then go back and do the rounding. The rounding may cause a carry in very rare cases such as $0.99 \dots 95 \rightarrow 1.00 \dots 0$, but this situation always give an exact power of 10, for which it is easy to correct the result at the end.

```

18466 \cs_new:Npn \__fp_add_significand_o:NnnwnnnnN #1 #2#3 #4; #5#6#7#8
18467 {
18468     \exp_after:wN \__fp_add_significand_test_o:N
18469     \int_value:w \__fp_int_eval:w 1#5#6 + #2
18470     \exp_after:wN \__fp_add_significand_pack:NNNNNNN
18471     \int_value:w \__fp_int_eval:w 1#7#8 + #3 ; #1
18472 }
18473 \cs_new:Npn \__fp_add_significand_pack:NNNNNNN #1 #2#3#4#5#6#7
18474 {
18475     \if_meaning:w 2 #1
18476     + 1
18477     \fi:
18478     ; #2 #3 #4 #5 #6 #7 ;
18479 }
18480 \cs_new:Npn \__fp_add_significand_test_o:N #1
18481 {
18482     \if_meaning:w 2 #1
18483     \exp_after:wN \__fp_add_significand_carry_o:wwwNN
18484     \else:
18485     \exp_after:wN \__fp_add_significand_no_carry_o:wwwNN
18486     \fi:
18487 }

```

(End definition for __fp_add_significand_o:NnnwnnnnN, __fp_add_significand_pack:NNNNNNN, and __fp_add_significand_test_o:N.)

```

\__fp_add_significand_no_carry_o:wwwNN     \__fp_add_significand_no_carry_o:wwwNN <8d> ; <6d> ; <2d> ; <rounding
digit> <sign>

```

If there's no carry, grab all the digits again and round. The packing function __fp_basics_pack_high:NNNNNw takes care of the case where rounding brings a carry.

```

18488 \cs_new:Npn \__fp_add_significand_no_carry_o:wwwNN
18489   #1; #2; #3#4 ; #5#6
18490   {
18491     \exp_after:wN \__fp_basics_pack_high:NNNNNw
18492     \int_value:w \__fp_int_eval:w 1 #1
18493     \exp_after:wN \__fp_basics_pack_low:NNNNNw
18494     \int_value:w \__fp_int_eval:w 1 #2 #3#4
18495     + \__fp_round:NNN #6 #4 #5
18496     \exp_after:wN ;
18497   }

```

(End definition for __fp_add_significand_no_carry_o:wwwNN.)

__fp_add_significand_carry_o:wwwNN $\langle 8d \rangle$; $\langle 6d \rangle$; $\langle 2d \rangle$; $\langle \text{rounding digit} \rangle$ $\langle \text{sign} \rangle$

The case where there is a carry is very similar. Rounding can even raise the first digit from 1 to 2, but we don't care.

```

18498 \cs_new:Npn \__fp_add_significand_carry_o:wwwNN
18499   #1; #2; #3#4; #5#6
18500   {
18501     + 1
18502     \exp_after:wN \__fp_basics_pack_weird_high:NNNNNNNNw
18503     \int_value:w \__fp_int_eval:w 1 1 #1
18504     \exp_after:wN \__fp_basics_pack_weird_low:NNNNNw
18505     \int_value:w \__fp_int_eval:w 1 #2#3 +
18506     \exp_after:wN \__fp_round:NNN
18507     \exp_after:wN #6
18508     \exp_after:wN #3
18509     \int_value:w \__fp_round_digit:Nw #4 #5 ;
18510     \exp_after:wN ;
18511   }

```

(End definition for __fp_add_significand_carry_o:wwwNN.)

31.1.3 Absolute subtraction

__fp_sub_npos_o:NnwNnw $\langle \text{sign}_1 \rangle$ $\langle \text{exp}_1 \rangle$ $\langle \text{body}_1 \rangle$; \s__fp __fp_chk:w 1
 __fp_sub_eq_o:Nwnnw $\langle \text{initial sign}_2 \rangle$ $\langle \text{exp}_2 \rangle$ $\langle \text{body}_2 \rangle$;
 __fp_sub_npos_ii_o:Nwnnw

Rounding properly in some modes requires to know what the sign of the result will be. Thus, we start by comparing the exponents and significands. If the numbers coincide, return zero. If the second number is larger, swap the numbers and call __fp_sub_npos_i_o:Nwnnw with the opposite of $\langle \text{sign}_1 \rangle$.

```

18512 \cs_new:Npn \__fp_sub_npos_o:NnwNnw #1#2#3; \s__fp \__fp_chk:w 1 #4#5#6;
18513   {
18514     \if_case:w \__fp_compare_npos:nwnw {#2} #3; {#5} #6; \exp_stop_f:
18515     \exp_after:wN \__fp_sub_eq_o:Nwnnw
18516     \or:
18517     \exp_after:wN \__fp_sub_npos_i_o:Nwnnw
18518     \else:
18519     \exp_after:wN \__fp_sub_npos_ii_o:Nwnnw
18520     \fi:
18521     #1 {#2} #3; {#5} #6;
18522   }
18523 \cs_new:Npn \__fp_sub_eq_o:Nwnnw #1#2; #3; { \exp_after:wN \c_zero_fp }

```

```

18524 \cs_new:Npn \__fp_sub_npos_ii_o:Nnwnw #1 #2; #3;
18525 {
18526   \exp_after:wN \__fp_sub_npos_i_o:Nnwnw
18527   \int_value:w \__fp_neg_sign:N #1
18528   #3; #2;
18529 }

```

(End definition for __fp_sub_npos_o:NnwNnw, __fp_sub_eq_o:Nnwnw, and __fp_sub_npos_ii_o:Nnwnw.)

__fp_sub_npos_i_o:Nnwnw

After the computation is done, __fp_sanitize:Nw checks for overflow/underflow. It expects the $\langle final\ sign \rangle$ and the $\langle exponent \rangle$ (delimited by ;). Start an integer expression for the exponent, which starts with the exponent of the largest number, and may be decreased if the two numbers are very close. If the two numbers have the same exponent, call the **near** auxiliary. Otherwise, decimate y , then call the **far** auxiliary to evaluate the difference between the two significands. Note that we decimate by 1 less than one could expect.

```

18530 \cs_new:Npn \__fp_sub_npos_i_o:Nnwnw #1 #2#3; #4#5;
18531 {
18532   \exp_after:wN \__fp_sanitize:Nw
18533   \exp_after:wN #1
18534   \int_value:w \__fp_int_eval:w
18535   #2
18536   \if_int_compare:w #2 = #4 \exp_stop_f:
18537   \exp_after:wN \__fp_sub_back_near_o:nnnnnnnnN
18538   \else:
18539   \exp_after:wN \__fp_decimate:nNnnnn \exp_after:wN
18540   { \int_value:w \__fp_int_eval:w #2 - #4 - 1 \exp_after:wN }
18541   \exp_after:wN \__fp_sub_back_far_o:NnnwnnnnnN
18542   \fi:
18543   #5
18544   #3
18545   #1
18546 }

```

(End definition for __fp_sub_npos_i_o:Nnwnw.)

__fp_sub_back_near_o:nnnnnnnnN
 __fp_sub_back_near_pack:NNNNNNw
 __fp_sub_back_near_after:wNNNNw

__fp_sub_back_near_o:nnnnnnnnN $\{\langle Y_1 \rangle\} \{\langle Y_2 \rangle\} \{\langle Y_3 \rangle\} \{\langle Y_4 \rangle\} \{\langle X_1 \rangle\}$
 $\{\langle X_2 \rangle\} \{\langle X_3 \rangle\} \{\langle X_4 \rangle\} \langle final\ sign \rangle$

In this case, the subtraction is exact, so we discard the $\langle final\ sign \rangle$ #9. The very large shifts of 10^9 and $1.1 \cdot 10^9$ are unnecessary here, but allow the auxiliaries to be reused later. Each integer expression produces a 10 digit result. If the resulting 16 digits start with a 0, then we need to shift the group, padding with trailing zeros.

```

18547 \cs_new:Npn \__fp_sub_back_near_o:nnnnnnnnN #1#2#3#4 #5#6#7#8 #9
18548 {
18549   \exp_after:wN \__fp_sub_back_near_after:wNNNNw
18550   \int_value:w \__fp_int_eval:w 10#5#6 - #1#2 - 11
18551   \exp_after:wN \__fp_sub_back_near_pack:NNNNNNw
18552   \int_value:w \__fp_int_eval:w 11#7#8 - #3#4 \exp_after:wN ;
18553 }
18554 \cs_new:Npn \__fp_sub_back_near_pack:NNNNNNw #1#2#3#4#5#6#7 ;
18555 { + #1#2 ; {#3#4#5#6} {#7} ; }
18556 \cs_new:Npn \__fp_sub_back_near_after:wNNNNw 10 #1#2#3#4 #5 ;
18557 {
18558   \if_meaning:w 0 #1

```

```

18559      \exp_after:wN \__fp_sub_back_shift:wnnnn
18560      \fi:
18561      ; {#1#2#3#4} {#5}
18562    }

```

(End definition for __fp_sub_back_near_o:nnnnnnnnN, __fp_sub_back_near_pack:NNNNNNw, and __fp_sub_back_near_after:wNNNNw.)

```

\__fp_sub_back_shift:wnnnn
\__fp_sub_back_shift_ii:ww
\__fp_sub_back_shift_iii:NNNNNNNNw
\__fp_sub_back_shift_iv:nnnnw

```

__fp_sub_back_shift:wnnnn ; {⟨ Z_1 ⟩} {⟨ Z_2 ⟩} {⟨ Z_3 ⟩} {⟨ Z_4 ⟩} ;

This function is called with $\langle Z_1 \rangle \leq 999$. Act with `\number` to trim leading zeros from $\langle Z_1 \rangle$ $\langle Z_2 \rangle$ (we don't do all four blocks at once, since non-zero blocks would then overflow $\text{T}_{\text{E}}\text{X}$'s integers). If the first two blocks are zero, the auxiliary receives an empty `#1` and trims `#2#30` from leading zeros, yielding a total shift between 7 and 16 to the exponent. Otherwise we get the shift from `#1` alone, yielding a result between 1 and 6. Once the exponent is taken care of, trim leading zeros from `#1#2#3` (when `#1` is empty, the space before `#2#3` is ignored), get four blocks of 4 digits and finally clean up. Trailing zeros are added so that digits can be grabbed safely.

```

18563 \cs_new:Npn \__fp_sub_back_shift:wnnnn ; #1#2
18564 {
18565   \exp_after:wN \__fp_sub_back_shift_ii:ww
18566   \int_value:w #1 #2 0 ;
18567 }
18568 \cs_new:Npn \__fp_sub_back_shift_ii:ww #1 0 ; #2#3 ;
18569 {
18570   \if_meaning:w @ #1 @
18571   - 7
18572   - \exp_after:wN \use_i:nnn
18573   \exp_after:wN \__fp_sub_back_shift_iii:NNNNNNNNw
18574   \int_value:w #2#3 0 ~ 123456789;
18575   \else:
18576   - \__fp_sub_back_shift_iii:NNNNNNNNw #1 123456789;
18577   \fi:
18578   \exp_after:wN \__fp_pack_twice_four:wNNNNNNNNN
18579   \exp_after:wN \__fp_pack_twice_four:wNNNNNNNNN
18580   \exp_after:wN \__fp_sub_back_shift_iv:nnnnw
18581   \exp_after:wN ;
18582   \int_value:w
18583   #1 ~ #2#3 0 ~ 0000 0000 0000 000 ;
18584 }
18585 \cs_new:Npn \__fp_sub_back_shift_iii:NNNNNNNNw #1#2#3#4#5#6#7#8#9; {#8}
18586 \cs_new:Npn \__fp_sub_back_shift_iv:nnnnw #1 ; #2 ; { ; #1 ; }

```

(End definition for __fp_sub_back_shift:wnnnn and others.)

```
\__fp_sub_back_far_o:NnnwnnnnnN
```

__fp_sub_back_far_o:NnnwnnnnnN $\langle \textit{rounding} \rangle$ {⟨ Y'_1 ⟩} {⟨ Y'_2 ⟩}
 $\langle \textit{extra-digits} \rangle$; {⟨ X_1 ⟩} {⟨ X_2 ⟩} {⟨ X_3 ⟩} {⟨ X_4 ⟩} $\langle \textit{final sign} \rangle$

If the difference is greater than $10^{\langle \textit{expo}_x \rangle}$, call the `very_far` auxiliary. If the result is less than $10^{\langle \textit{expo}_x \rangle}$, call the `not_far` auxiliary. If it is too close a call to know yet, namely if $1 \langle Y'_1 \rangle \langle Y'_2 \rangle = \langle X_1 \rangle \langle X_2 \rangle \langle X_3 \rangle \langle X_4 \rangle 0$, then call the `quite_far` auxiliary. We use the odd combination of space and semi-colon delimiters to allow the `not_far` auxiliary to grab each piece individually, the `very_far` auxiliary to use `__fp_pack_eight:wNNNNNNNNN`, and the `quite_far` to ignore the significands easily (using the `;` delimiter).

```
18587 \cs_new:Npn \__fp_sub_back_far_o:NnnwnnnnnN #1 #2#3 #4; #5#6#7#8
```

```

18588 {
18589   \if_case:w
18590     \if_int_compare:w 1 #2 = #5#6 \use_i:nnnn #7 \exp_stop_f:
18591       \if_int_compare:w #3 = \use_none:n #7#8 0 \exp_stop_f:
18592         0
18593       \else:
18594         \if_int_compare:w #3 > \use_none:n #7#8 0 - \fi: 1
18595       \fi:
18596     \else:
18597       \if_int_compare:w 1 #2 > #5#6 \use_i:nnnn #7 - \fi: 1
18598     \fi:
18599   \exp_stop_f:
18600     \exp_after:wN \__fp_sub_back_quite_far_o:wwNN
18601   \or:   \exp_after:wN \__fp_sub_back_very_far_o:wwwNN
18602   \else: \exp_after:wN \__fp_sub_back_not_far_o:wwwNN
18603   \fi:
18604   #2 ~ #3 ; #5 #6 ~ #7 #8 ; #1
18605 }

```

(End definition for __fp_sub_back_far_o:NnnwnnnnN.)

__fp_sub_back_quite_far_o:wwNN
__fp_sub_back_quite_far_ii:NN

The easiest case is when $x - y$ is extremely close to a power of 10, namely the first digit of x is 1, and all others vanish when subtracting y . Then the *rounding* #3 and the *final sign* #4 control whether we get 1 or 0.9999999999999999. In the usual round-to-nearest mode, we get 1 whenever the *rounding* digit is less than or equal to 5 (remember that the *rounding* digit is only equal to 5 if there was no further non-zero digit).

```

18606 \cs_new:Npn \__fp_sub_back_quite_far_o:wwNN #1; #2; #3#4
18607 {
18608   \exp_after:wN \__fp_sub_back_quite_far_ii:NN
18609   \exp_after:wN #3
18610   \exp_after:wN #4
18611 }
18612 \cs_new:Npn \__fp_sub_back_quite_far_ii:NN #1#2
18613 {
18614   \if_case:w \__fp_round_neg:NNN #2 0 #1
18615     \exp_after:wN \use_i:nn
18616   \else:
18617     \exp_after:wN \use_ii:nn
18618   \fi:
18619   { ; {1000} {0000} {0000} {0000} ; }
18620   { - 1 ; {9999} {9999} {9999} {9999} ; }
18621 }

```

(End definition for __fp_sub_back_quite_far_o:wwNN and __fp_sub_back_quite_far_ii:NN.)

__fp_sub_back_not_far_o:wwwNN

In the present case, x and y have different exponents, but y is large enough that $x - y$ has a smaller exponent than x . Decrement the exponent (with -1). Then proceed in a way similar to the *near* auxiliaries seen earlier, but multiplying x by 10 (#30 and #40 below), and with the added quirk that the *rounding* digit has to be taken into account. Namely, we may have to decrease the result by one unit if __fp_round_neg:NNN returns 1. This function expects the *final sign* #6, the last digit of 1100000000+#40-#2, and the *rounding* digit. Instead of redoing the computation for the second argument, we note that __fp_round_neg:NNN only cares about its parity, which is identical to that of the last digit of #2.

```

18622 \cs_new:Npn \__fp_sub_back_not_far_o:wwwNN #1 ~ #2; #3 ~ #4; #5#6
18623 {
18624   - 1
18625   \exp_after:wN \__fp_sub_back_near_after:wNNNNw
18626   \int_value:w \__fp_int_eval:w 1#30 - #1 - 11
18627   \exp_after:wN \__fp_sub_back_near_pack:NNNNNNw
18628   \int_value:w \__fp_int_eval:w 11 0000 0000 + #40 - #2
18629   - \exp_after:wN \__fp_round_neg:NNN
18630   \exp_after:wN #6
18631   \use_none:nnnnnnn #2 #5
18632   \exp_after:wN ;
18633 }

```

(End definition for __fp_sub_back_not_far_o:wwwNN.)

__fp_sub_back_very_far_o:wwwNN
__fp_sub_back_very_far_ii_o:nnNwwNN

The case where $x - y$ and x have the same exponent is a bit more tricky, mostly because it cannot reuse the same auxiliaries. Shift the y significand by adding a leading 0. Then the logic is similar to the `not_far` functions above. Rounding is a bit more complicated: we have two *rounding* digits `#3` and `#6` (from the decimation, and from the new shift) to take into account, and getting the parity of the main result requires a computation. The first `\int_value:w` triggers the second one because the number is unfinished; we can thus not use 0 in place of 2 there.

```

18634 \cs_new:Npn \__fp_sub_back_very_far_o:wwwNN #1#2#3#4#5#6#7
18635 {
18636   \__fp_pack_eight:wNNNNNNNN
18637   \__fp_sub_back_very_far_ii_o:nnNwwNN
18638   { 0 #1#2#3 #4#5#6#7 }
18639   ;
18640 }
18641 \cs_new:Npn \__fp_sub_back_very_far_ii_o:nnNwwNN #1#2 ; #3 ; #4 ~ #5; #6#7
18642 {
18643   \exp_after:wN \__fp_basics_pack_high:NNNNNw
18644   \int_value:w \__fp_int_eval:w 1#4 - #1 - 1
18645   \exp_after:wN \__fp_basics_pack_low:NNNNNw
18646   \int_value:w \__fp_int_eval:w 2#5 - #2
18647   - \exp_after:wN \__fp_round_neg:NNN
18648   \exp_after:wN #7
18649   \int_value:w
18650   \if_int_odd:w \__fp_int_eval:w #5 - #2 \__fp_int_eval_end:
18651   1 \else: 2 \fi:
18652   \int_value:w \__fp_round_digit:Nw #3 #6 ;
18653   \exp_after:wN ;
18654 }

```

(End definition for __fp_sub_back_very_far_o:wwwNN and __fp_sub_back_very_far_ii_o:nnNwwNN.)

31.2 Multiplication

31.2.1 Signs, and special numbers

__fp*_o:ww

We go through an auxiliary, which is common with `__fp/_o:ww`. The first argument is the operation, used for the invalid operation exception. The second is inserted in a formula to dispatch cases slightly differently between multiplication and division. The

third is the operation for normal floating points. The fourth is there for extra cases needed in `__fp_/_o:ww`.

```

18655 \cs_new:cpn { __fp*_o:ww }
18656 {
18657   \__fp_mul_cases_o:NnNnw
18658   *
18659   { - 2 + }
18660   \__fp_mul_npos_o:Nww
18661   { }
18662 }

```

(End definition for `__fp*_o:ww`.)

`__fp_mul_cases_o:nNnww` Split into 10 cases (12 for division). If both numbers are normal, go to case 0 (same sign) or case 1 (opposite signs): in both cases, call `__fp_mul_npos_o:Nww` to do the work. If the first operand is `nan`, go to case 2, in which the second operand is discarded; if the second operand is `nan`, go to case 3, in which the first operand is discarded (note the weird interaction with the final test on signs). Then we separate the case where the first number is normal and the second is zero: this goes to cases 4 and 5 for multiplication, 10 and 11 for division. Otherwise, we do a computation which dispatches the products $0 \times 0 = 0 \times 1 = 1 \times 0 = 0$ to case 4 or 5 depending on the combined sign, the products $0 \times \infty$ and $\infty \times 0$ to case 6 or 7 (invalid operation), and the products $1 \times \infty = \infty \times 1 = \infty \times \infty = \infty$ to cases 8 and 9. Note that the code for these two cases (which return $\pm\infty$) is inserted as argument #4, because it differs in the case of divisions.

```

18663 \cs_new:Npn \__fp_mul_cases_o:NnNnw
18664 #1#2#3#4 \s__fp \__fp_chk:w #5#6#7; \s__fp \__fp_chk:w #8#9
18665 {
18666   \if_case:w \__fp_int_eval:w
18667     \if_int_compare:w #5 #8 = 11 ~
18668     1
18669   \else:
18670     \if_meaning:w 3 #8
18671     3
18672   \else:
18673     \if_meaning:w 3 #5
18674     2
18675   \else:
18676     \if_int_compare:w #5 #8 = 10 ~
18677     9 #2 - 2
18678   \else:
18679     (#5 #2 #8) / 2 * 2 + 7
18680   \fi:
18681   \fi:
18682   \fi:
18683   \fi:
18684   \if_meaning:w #6 #9 - 1 \fi:
18685   \__fp_int_eval_end:
18686   \__fp_case_use:nw { #3 0 }
18687 \or: \__fp_case_use:nw { #3 2 }
18688 \or: \__fp_case_return_i_o:ww
18689 \or: \__fp_case_return_ii_o:ww
18690 \or: \__fp_case_return_o:Nww \c_zero_fp
18691 \or: \__fp_case_return_o:Nww \c_minus_zero_fp

```

```

18692 \or: \__fp_case_use:nw { \__fp_invalid_operation_o:Nww #1 }
18693 \or: \__fp_case_use:nw { \__fp_invalid_operation_o:Nww #1 }
18694 \or: \__fp_case_return_o:Nww \c_inf_fp
18695 \or: \__fp_case_return_o:Nww \c_minus_inf_fp
18696 #4
18697 \fi:
18698 \s__fp \__fp_chk:w #5 #6 #7;
18699 \s__fp \__fp_chk:w #8 #9
18700 }

```

(End definition for __fp_mul_cases_o:nNnnww.)

31.2.2 Absolute multiplication

In this subsection, we perform the multiplication of two positive normal numbers.

```

\__fp_mul_npos_o:Nww \__fp_mul_npos_o:Nww <final sign> \s__fp \__fp_chk:w 1 <sign1> {<exp1>}
<body1> ; \s__fp \__fp_chk:w 1 <sign2> {<exp2>} <body2> ;

```

After the computation, __fp_sanitize:Nw checks for overflow or underflow. As we did for addition, __fp_int_eval:w computes the exponent, catching any shift coming from the computation in the significand. The <final sign> is needed to do the rounding properly in the significand computation. We setup the post-expansion here, triggered by __fp_mul_significand_o:nnnnNnnnn.

This is also used in l3fp-convert.

```

18701 \cs_new:Npn \__fp_mul_npos_o:Nww
18702 #1 \s__fp \__fp_chk:w #2 #3 #4 #5 ; \s__fp \__fp_chk:w #6 #7 #8 #9 ;
18703 {
18704 \exp_after:wN \__fp_sanitize:Nw
18705 \exp_after:wN #1
18706 \int_value:w \__fp_int_eval:w
18707 #4 + #8
18708 \__fp_mul_significand_o:nnnnNnnnn #5 #1 #9
18709 }

```

(End definition for __fp_mul_npos_o:Nww.)

```

\__fp_mul_significand_o:nnnnNnnnn \__fp_mul_significand_o:nnnnNnnnn {<X1>} {<X2>} {<X3>} {<X4>} <sign>
\__fp_mul_significand_drop:NNNNNw {<Y1>} {<Y2>} {<Y3>} {<Y4>}
\__fp_mul_significand_keep:NNNNNw

```

Note the three semicolons at the end of the definition. One is for the last __fp_mul_significand_drop:NNNNNw; one is for __fp_round_digit:Nw later on; and one, preceded by \exp_after:wN, which is correctly expanded (within an __fp_int_eval:w), is used by __fp_basics_pack_low:NNNNNw.

The product of two 16 digit integers has 31 or 32 digits, but it is impossible to know which one before computing. The place where we round depends on that number of digits, and may depend on all digits until the last in some rare cases. The approach is thus to compute the 5 first blocks of 4 digits (the first one is between 100 and 9999 inclusive), and a compact version of the remaining 3 blocks. Afterwards, the number of digits is known, and we can do the rounding within yet another set of __fp_int_eval:w.

```

18710 \cs_new:Npn \__fp_mul_significand_o:nnnnNnnnn #1#2#3#4 #5 #6#7#8#9
18711 {
18712 \exp_after:wN \__fp_mul_significand_test_f:NNN
18713 \exp_after:wN #5
18714 \int_value:w \__fp_int_eval:w 99990000 + #1#6 +

```

```

18715 \exp_after:wN \_fp_mul_significand_keep:NNNNNw
18716 \int_value:w \_fp_int_eval:w 99990000 + #1*#7 + #2*#6 +
18717 \exp_after:wN \_fp_mul_significand_keep:NNNNNw
18718 \int_value:w \_fp_int_eval:w 99990000 + #1*#8 + #2*#7 + #3*#6 +
18719 \exp_after:wN \_fp_mul_significand_drop:NNNNNw
18720 \int_value:w \_fp_int_eval:w 99990000 + #1*#9 + #2*#8 +
18721 #3*#7 + #4*#6 +
18722 \exp_after:wN \_fp_mul_significand_drop:NNNNNw
18723 \int_value:w \_fp_int_eval:w 99990000 + #2*#9 + #3*#8 +
18724 #4*#7 +
18725 \exp_after:wN \_fp_mul_significand_drop:NNNNNw
18726 \int_value:w \_fp_int_eval:w 99990000 + #3*#9 + #4*#8 +
18727 \exp_after:wN \_fp_mul_significand_drop:NNNNNw
18728 \int_value:w \_fp_int_eval:w 100000000 + #4*#9 ;
18729 ; \exp_after:wN ;
18730 }
18731 \cs_new:Npn \_fp_mul_significand_drop:NNNNNw #1#2#3#4#5 #6;
18732 { #1#2#3#4#5 ; + #6 }
18733 \cs_new:Npn \_fp_mul_significand_keep:NNNNNw #1#2#3#4#5 #6;
18734 { #1#2#3#4#5 ; #6 ; }

```

(End definition for `_fp_mul_significand_o:nnnnNnnnn`, `_fp_mul_significand_drop:NNNNNw`, and `_fp_mul_significand_keep:NNNNNw`.)

```

\_fp_mul_significand_test_f:NNN \_fp_mul_significand_test_f:NNN <sign> 1 <digits 1–8> ; <digits 9–12> ;
<digits 13–16> ; + <digits 17–20> + <digits 21–24> + <digits 25–28> + <digits
29–32> ; \exp_after:wN ;

```

If the *<digit 1>* is non-zero, then for rounding we only care about the digits 16 and 17, and whether further digits are zero or not (check for exact ties). On the other hand, if *<digit 1>* is zero, we care about digits 17 and 18, and whether further digits are zero.

```

18735 \cs_new:Npn \_fp_mul_significand_test_f:NNN #1 #2 #3
18736 {
18737   \if_meaning:w 0 #3
18738     \exp_after:wN \_fp_mul_significand_small_f:NNwwwN
18739   \else:
18740     \exp_after:wN \_fp_mul_significand_large_f:NwwNNNN
18741   \fi:
18742   #1 #3
18743 }

```

(End definition for `_fp_mul_significand_test_f:NNN`.)

`_fp_mul_significand_large_f:NwwNNNN` In this branch, *<digit 1>* is non-zero. The result is thus *<digits 1–16>*, plus some rounding which depends on the digits 16, 17, and whether all subsequent digits are zero or not. Here, `_fp_round_digit:Nw` takes digits 17 and further (as an integer expression), and replaces it by a *<rounding digit>*, suitable for `_fp_round:NNN`.

```

18744 \cs_new:Npn \_fp_mul_significand_large_f:NwwNNNN #1 #2; #3; #4#5#6#7; +
18745 {
18746   \exp_after:wN \_fp_basics_pack_high:NNNNNw
18747   \int_value:w \_fp_int_eval:w 1#2
18748   \exp_after:wN \_fp_basics_pack_low:NNNNNw
18749   \int_value:w \_fp_int_eval:w 1#3#4#5#6#7
18750   + \exp_after:wN \_fp_round:NNN
18751   \exp_after:wN #1

```

```

18752         \exp_after:wN #7
18753         \int_value:w \__fp_round_digit:Nw
18754     }

```

(End definition for `__fp_mul_significand_large_f:NwwNNNN`.)

`__fp_mul_significand_small_f:NNwwN`

In this branch, $\langle digit\ 1 \rangle$ is zero. Our result is thus $\langle digits\ 2\text{--}17 \rangle$, plus some rounding which depends on the digits 17, 18, and whether all subsequent digits are zero or not. The 8 digits 1#3 are followed, after expansion of the `small_pack` auxiliary, by the next digit, to form a 9 digit number.

```

18755 \cs_new:Npn \__fp_mul_significand_small_f:NNwwN #1 #2#3; #4#5; #6; + #7
18756 {
18757     - 1
18758     \exp_after:wN \__fp_basics_pack_high:NNNNw
18759     \int_value:w \__fp_int_eval:w 1#3#4
18760     \exp_after:wN \__fp_basics_pack_low:NNNNw
18761     \int_value:w \__fp_int_eval:w 1#5#6#7
18762     + \exp_after:wN \__fp_round:NNN
18763     \exp_after:wN #1
18764     \exp_after:wN #7
18765     \int_value:w \__fp_round_digit:Nw
18766 }

```

(End definition for `__fp_mul_significand_small_f:NNwwN`.)

31.3 Division

31.3.1 Signs, and special numbers

Time is now ripe to tackle the hardest of the four elementary operations: division.

`__fp_/_o:ww`

Filtering special floating point is very similar to what we did for multiplications, with a few variations. Invalid operation exceptions display `/` rather than `*`. In the formula for dispatch, we replace `- 2 +` by `-`. The case of normal numbers is treated using `__fp_div_npos_o:Nww` rather than `__fp_mul_npos_o:Nww`. There are two additional cases: if the first operand is normal and the second is a zero, then the division by zero exception is raised: cases 10 and 11 of the `\if_case:w` construction in `__fp_mul_cases_o:NnNww` are provided as the fourth argument here.

```

18767 \cs_new:cpn { __fp_/_o:ww }
18768 {
18769     \__fp_mul_cases_o:NnNww
18770     /
18771     { - }
18772     \__fp_div_npos_o:Nww
18773     {
18774         \or:
18775         \__fp_case_use:nw
18776         { \__fp_division_by_zero_o:NNww \c_inf_fp / }
18777         \or:
18778         \__fp_case_use:nw
18779         { \__fp_division_by_zero_o:NNww \c_minus_inf_fp / }
18780     }
18781 }

```

(End definition for `_fp_/_o:ww`.)

```
\_fp_div_npos_o:Nww \_fp_div_npos_o:Nww <final sign> \s\_fp \_fp_chk:w 1 <sign_A> {\<exp A>}
{\<A_1>} {\<A_2>} {\<A_3>} {\<A_4>} ; \s\_fp \_fp_chk:w 1 <sign_Z> {\<exp Z>}
{\<Z_1>} {\<Z_2>} {\<Z_3>} {\<Z_4>} ;
```

We want to compute A/Z . As for multiplication, `_fp_sanitize:Nw` checks for overflow or underflow; we provide it with the *final sign*, and an integer expression in which we compute the exponent. We set up the arguments of `_fp_div_significand_i_o:wnnw`, namely an integer $\langle y \rangle$ obtained by adding 1 to the first 5 digits of Z (explanation given soon below), then the four $\{\langle A_i \rangle\}$, then the four $\{\langle Z_i \rangle\}$, a semi-colon, and the *final sign*, used for rounding at the end.

```
18782 \cs_new:Npn \_fp_div_npos_o:Nww
18783   #1 \s\_fp \_fp_chk:w 1 #2 #3 #4 ; \s\_fp \_fp_chk:w 1 #5 #6 #7#8#9;
18784   {
18785     \exp_after:wN \_fp\_sanitize:Nw
18786     \exp_after:wN #1
18787     \int_value:w \_fp\_int\_eval:w
18788     #3 - #6
18789     \exp_after:wN \_fp\_div\_significand\_i_o:wnnw
18790     \int_value:w \_fp\_int\_eval:w #7 \use_i:nnnn #8 + 1 ;
18791     #4
18792     {\#7}{\#8}\#9 ;
18793     #1
18794   }
```

(End definition for `_fp_div_npos_o:Nww`.)

31.3.2 Work plan

In this subsection, we explain how to avoid overflowing $\text{T}_{\text{E}}\text{X}$'s integers when performing the division of two positive normal numbers.

We are given two numbers, $A = 0.A_1A_2A_3A_4$ and $Z = 0.Z_1Z_2Z_3Z_4$, in blocks of 4 digits, and we know that the first digits of A_1 and of Z_1 are non-zero. To compute A/Z , we proceed as follows.

- Find an integer $Q_A \simeq 10^4 A/Z$.
- Replace A by $B = 10^4 A - Q_A Z$.
- Find an integer $Q_B \simeq 10^4 B/Z$.
- Replace B by $C = 10^4 B - Q_B Z$.
- Find an integer $Q_C \simeq 10^4 C/Z$.
- Replace C by $D = 10^4 C - Q_C Z$.
- Find an integer $Q_D \simeq 10^4 D/Z$.
- Consider $E = 10^4 D - Q_D Z$, and ensure correct rounding.

The result is then $Q = 10^{-4}Q_A + 10^{-8}Q_B + 10^{-12}Q_C + 10^{-16}Q_D + \text{rounding}$. Since the Q_i are integers, B , C , D , and E are all exact multiples of 10^{-16} , in other words, computing with 16 digits after the decimal separator yields exact results. The problem is the risk of overflow: in general B , C , D , and E may be greater than 1.

Unfortunately, things are not as easy as they seem. In particular, we want all intermediate steps to be positive, since negative results would require extra calculations at the end. This requires that $Q_A \leq 10^4 A/Z$ etc. A reasonable attempt would be to define Q_A as

$$\backslash\text{int_eval:n}\left\{\frac{A_1 A_2}{Z_1 + 1} - 1\right\} \leq 10^4 \frac{A}{Z}$$

Subtracting 1 at the end takes care of the fact that $\varepsilon\text{-TeX}$'s $\backslash_fp_int_eval:w$ rounds divisions instead of truncating (really, $1/2$ would be sufficient, but we work with integers). We add 1 to Z_1 because $Z_1 \leq 10^4 Z < Z_1 + 1$ and we need Q_A to be an underestimate. However, we are now underestimating Q_A too much: it can be wrong by up to 100, for instance when $Z = 0.1$ and $A \simeq 1$. Then B could take values up to 10 (maybe more), and a few steps down the line, we would run into arithmetic overflow, since TeX can only handle integers less than roughly $2 \cdot 10^9$.

A better formula is to take

$$Q_A = \backslash\text{int_eval:n}\left\{\frac{10 \cdot A_1 A_2}{\lfloor 10^{-3} \cdot Z_1 Z_2 \rfloor + 1} - 1\right\}.$$

This is always less than $10^9 A / (10^5 Z)$, as we wanted. In words, we take the 5 first digits of Z into account, and the 8 first digits of A , using 0 as a 9-th digit rather than the true digit for efficiency reasons. We shall prove that using this formula to define all the Q_i avoids any overflow. For convenience, let us denote

$$y = \lfloor 10^{-3} \cdot Z_1 Z_2 \rfloor + 1,$$

so that, taking into account the fact that $\varepsilon\text{-TeX}$ rounds ties away from zero,

$$\begin{aligned} Q_A &= \left\lfloor \frac{A_1 A_2 0}{y} - \frac{1}{2} \right\rfloor \\ &> \frac{A_1 A_2 0}{y} - \frac{3}{2}. \end{aligned}$$

Note that $10^4 < y \leq 10^5$, and $999 \leq Q_A \leq 99989$. Also note that this formula does not cause an overflow as long as $A < (2^{31} - 1)/10^9 \simeq 2.147 \dots$, since the numerator involves an integer slightly smaller than $10^9 A$.

Let us bound B :

$$\begin{aligned} 10^5 B &= A_1 A_2 0 + 10 \cdot 0.A_3 A_4 - 10 \cdot Z_1.Z_2 Z_3 Z_4 \cdot Q_A \\ &< A_1 A_2 0 \cdot \left(1 - 10 \cdot \frac{Z_1.Z_2 Z_3 Z_4}{y}\right) + \frac{3}{2} \cdot 10 \cdot Z_1.Z_2 Z_3 Z_4 + 10 \\ &\leq \frac{A_1 A_2 0 \cdot (y - 10 \cdot Z_1.Z_2 Z_3 Z_4)}{y} + \frac{3}{2}y + 10 \\ &\leq \frac{A_1 A_2 0 \cdot 1}{y} + \frac{3}{2}y + 10 \leq \frac{10^9 A}{y} + 1.6 \cdot y. \end{aligned}$$

At the last step, we hide 10 into the second term for later convenience. The same reasoning yields

$$\begin{aligned} 10^5 B &< 10^9 A/y + 1.6y, \\ 10^5 C &< 10^9 B/y + 1.6y, \\ 10^5 D &< 10^9 C/y + 1.6y, \\ 10^5 E &< 10^9 D/y + 1.6y. \end{aligned}$$

The goal is now to prove that none of B , C , D , and E can go beyond $(2^{31} - 1)/10^9 = 2.147 \dots$.

Combining the various inequalities together with $A < 1$, we get

$$\begin{aligned} 10^5 B &< 10^9/y + 1.6y, \\ 10^5 C &< 10^{13}/y^2 + 1.6(y + 10^4), \\ 10^5 D &< 10^{17}/y^3 + 1.6(y + 10^4 + 10^8/y), \\ 10^5 E &< 10^{21}/y^4 + 1.6(y + 10^4 + 10^8/y + 10^{12}/y^2). \end{aligned}$$

All of those bounds are convex functions of y (since every power of y involved is convex, and the coefficients are positive), and thus maximal at one of the end-points of the allowed range $10^4 < y \leq 10^5$. Thus,

$$\begin{aligned} 10^5 B &< \max(1.16 \cdot 10^5, 1.7 \cdot 10^5), \\ 10^5 C &< \max(1.32 \cdot 10^5, 1.77 \cdot 10^5), \\ 10^5 D &< \max(1.48 \cdot 10^5, 1.777 \cdot 10^5), \\ 10^5 E &< \max(1.64 \cdot 10^5, 1.7777 \cdot 10^5). \end{aligned}$$

All of those bounds are less than $2.147 \cdot 10^5$, and we are thus within \TeX 's bounds in all cases!

We later need to have a bound on the Q_i . Their definitions imply that $Q_A < 10^9 A/y - 1/2 < 10^5 A$ and similarly for the other Q_i . Thus, all of them are less than 177770.

The last step is to ensure correct rounding. We have

$$A/Z = \sum_{i=1}^4 (10^{-4i} Q_i) + 10^{-16} E/Z$$

exactly. Furthermore, we know that the result is in $[0.1, 10)$, hence will be rounded to a multiple of 10^{-16} or of 10^{-15} , so we only need to know the integer part of E/Z , and a “rounding” digit encoding the rest. Equivalently, we need to find the integer part of $2E/Z$, and determine whether it was an exact integer or not (this serves to detect ties). Since

$$\frac{2E}{Z} = 2 \frac{10^5 E}{10^5 Z} \leq 2 \frac{10^5 E}{10^4} < 36,$$

this integer part is between 0 and 35 inclusive. We let ε -TeX round

$$P = \text{\int_eval:n} \left\{ \frac{2 \cdot E_1 E_2}{Z_1 Z_2} \right\},$$

which differs from $2E/Z$ by at most

$$\frac{1}{2} + 2 \left| \frac{E}{Z} - \frac{E}{10^{-8} Z_1 Z_2} \right| + 2 \left| \frac{10^8 E - E_1 E_2}{Z_1 Z_2} \right| < 1,$$

($1/2$ comes from ε -TeX's rounding) because each absolute value is less than 10^{-7} . Thus P is either the correct integer part, or is off by 1; furthermore, if $2E/Z$ is an integer, $P = 2E/Z$. We will check the sign of $2E - PZ$. If it is negative, then $E/Z \in ((P-1)/2, P/2)$. If it is zero, then $E/Z = P/2$. If it is positive, then $E/Z \in (P/2, (P+1)/2)$. In each case, we know how to round to an integer, depending on the parity of P , and the rounding mode.

31.3.3 Implementing the significand division

`_fp_div_significand_i_o:wnnw`

`_fp_div_significand_i_o:wnnw` $\langle y \rangle$; $\{\langle A_1 \rangle\}$ $\{\langle A_2 \rangle\}$ $\{\langle A_3 \rangle\}$ $\{\langle A_4 \rangle\}$
 $\{\langle Z_1 \rangle\}$ $\{\langle Z_2 \rangle\}$ $\{\langle Z_3 \rangle\}$ $\{\langle Z_4 \rangle\}$; $\langle sign \rangle$

Compute $10^6 + Q_A$ (a 7 digit number thanks to the shift), unbrace $\langle A_1 \rangle$ and $\langle A_2 \rangle$, and prepare the $\langle continuation \rangle$ arguments for 4 consecutive calls to `_fp_div_significand_calc:wnnnnnnnn`. Each of these calls needs $\langle y \rangle$ (#1), and it turns out that we need post-expansion there, hence the `\int_value:w`. Here, #4 is six brace groups, which give the six first n-type arguments of the `calc` function.

```

18795 \cs_new:Npn \_fp\_div\_significand\_i\_o:wnnw #1 ; #2#3 #4 ;
18796 {
18797   \exp\_after:wN \_fp\_div\_significand\_test\_o:w
18798   \int\_value:w \_fp\_int\_eval:w
18799   \exp\_after:wN \_fp\_div\_significand\_calc:wnnnnnnnn
18800   \int\_value:w \_fp\_int\_eval:w 999999 + #2 #3 0 / #1 ;
18801   #2 #3 ;
18802   #4
18803   { \exp\_after:wN \_fp\_div\_significand\_ii:wN \int\_value:w #1 }
18804   { \exp\_after:wN \_fp\_div\_significand\_ii:wN \int\_value:w #1 }
18805   { \exp\_after:wN \_fp\_div\_significand\_ii:wN \int\_value:w #1 }
18806   { \exp\_after:wN \_fp\_div\_significand\_iii:wnnnnnn \int\_value:w #1 }
18807 }

```

(End definition for `_fp_div_significand_i_o:wnnw`.)

`_fp_div_significand_calc:wnnnnnnnn`
`_fp_div_significand_calc_i:wnnnnnnnn`
`_fp_div_significand_calc_ii:wnnnnnnnn`

`_fp_div_significand_calc:wnnnnnnnn` $\langle 10^6 + Q_A \rangle$; $\langle A_1 \rangle$ $\langle A_2 \rangle$; $\{\langle A_3 \rangle\}$
 $\{\langle A_4 \rangle\}$ $\{\langle Z_1 \rangle\}$ $\{\langle Z_2 \rangle\}$ $\{\langle Z_3 \rangle\}$ $\{\langle Z_4 \rangle\}$ $\{\langle continuation \rangle\}$

expands to

$\langle 10^6 + Q_A \rangle$ $\langle continuation \rangle$; $\langle B_1 \rangle$ $\langle B_2 \rangle$; $\{\langle B_3 \rangle\}$ $\{\langle B_4 \rangle\}$ $\{\langle Z_1 \rangle\}$ $\{\langle Z_2 \rangle\}$ $\{\langle Z_3 \rangle\}$
 $\{\langle Z_4 \rangle\}$

where $B = 10^4 A - Q_A \cdot Z$. This function is also used to compute C , D , E (with the input shifted accordingly), and is used in `l3fp-expo`.

We know that $0 < Q_A < 1.8 \cdot 10^5$, so the product of Q_A with each Z_i is within TeX's bounds. However, it is a little bit too large for our purposes: we would not be able to

use the usual trick of adding a large power of 10 to ensure that the number of digits is fixed.

The bound on Q_A , implies that $10^6 + Q_A$ starts with the digit 1, followed by 0 or 1. We test, and call different auxiliaries for the two cases. An earlier implementation did the tests within the computation, but since we added a *continuation*, this is not possible because the macro has 9 parameters.

The result we want is then (the overall power of 10 is arbitrary):

$$10^{-4}(\#2 - \#1 \cdot \#5 - 10 \cdot \langle i \rangle \cdot \#5\#6) + 10^{-8}(\#3 - \#1 \cdot \#6 - 10 \cdot \langle i \rangle \cdot \#7) \\ + 10^{-12}(\#4 - \#1 \cdot \#7 - 10 \cdot \langle i \rangle \cdot \#8) + 10^{-16}(-\#1 \cdot \#8),$$

where $\langle i \rangle$ stands for the 10^5 digit of Q_A , which is 0 or 1, and $\#1$, $\#2$, *etc.* are the parameters of either auxiliary. The factors of 10 come from the fact that $Q_A = 10 \cdot 10^4 \cdot \langle i \rangle + \#1$. As usual, to combine all the terms, we need to choose some shifts which must ensure that the number of digits of the second, third, and fourth terms are each fixed. Here, the positive contributions are at most 10^8 and the negative contributions can go up to 10^9 . Indeed, for the auxiliary with $\langle i \rangle = 1$, $\#1$ is at most 80000, leading to contributions of at worse $-8 \cdot 10^8 4$, while the other negative term is very small $< 10^6$ (except in the first expression, where we don't care about the number of digits); for the auxiliary with $\langle i \rangle = 0$, $\#1$ can go up to 99999, but there is no other negative term. Hence, a good choice is $2 \cdot 10^9$, which produces totals in the range $[10^9, 2.1 \cdot 10^9]$. We are flirting with TeX's limits once more.

```

18808 \cs_new:Npn \__fp_div_significand_calc:wwnnnnnnn 1#1
18809 {
18810   \if_meaning:w 1 #1
18811     \exp_after:wN \__fp_div_significand_calc_i:wwnnnnnnn
18812   \else:
18813     \exp_after:wN \__fp_div_significand_calc_ii:wwnnnnnnn
18814   \fi:
18815 }
18816 \cs_new:Npn \__fp_div_significand_calc_i:wwnnnnnnn
18817 #1; #2; #3#4 #5#6#7#8 #9
18818 {
18819   1 1 #1
18820   #9 \exp_after:wN ;
18821   \int_value:w \__fp_int_eval:w \c__fp_Bigg_leading_shift_int
18822     + #2 - #1 * #5 - #5#60
18823   \exp_after:wN \__fp_pack_Bigg:NNNNNNw
18824   \int_value:w \__fp_int_eval:w \c__fp_Bigg_middle_shift_int
18825     + #3 - #1 * #6 - #70
18826   \exp_after:wN \__fp_pack_Bigg:NNNNNNw
18827   \int_value:w \__fp_int_eval:w \c__fp_Bigg_middle_shift_int
18828     + #4 - #1 * #7 - #80
18829   \exp_after:wN \__fp_pack_Bigg:NNNNNNw
18830   \int_value:w \__fp_int_eval:w \c__fp_Bigg_trailing_shift_int
18831     - #1 * #8 ;
18832   {#5}{#6}{#7}{#8}
18833 }
18834 \cs_new:Npn \__fp_div_significand_calc_ii:wwnnnnnnn
18835 #1; #2; #3#4 #5#6#7#8 #9
18836 {
18837   1 0 #1

```

```

18838      #9 \exp_after:wN ;
18839      \int_value:w \_fp_int_eval:w \c\_fp_Bigg_leading_shift_int
18840      + #2 - #1 * #5
18841      \exp_after:wN \_fp_pack_Bigg:NNNNNNw
18842      \int_value:w \_fp_int_eval:w \c\_fp_Bigg_middle_shift_int
18843      + #3 - #1 * #6
18844      \exp_after:wN \_fp_pack_Bigg:NNNNNNw
18845      \int_value:w \_fp_int_eval:w \c\_fp_Bigg_middle_shift_int
18846      + #4 - #1 * #7
18847      \exp_after:wN \_fp_pack_Bigg:NNNNNNw
18848      \int_value:w \_fp_int_eval:w \c\_fp_Bigg_trailing_shift_int
18849      - #1 * #8 ;
18850      {#5}{#6}{#7}{#8}
18851    }

```

(End definition for _fp_div_significand_calc:wwnnnnnn, _fp_div_significand_calc_i:wwnnnnnn, and _fp_div_significand_calc_ii:wwnnnnnn.)

```

\_fp_div_significand_ii:wnn      \_fp_div_significand_ii:wnn <y> ; <B1> ; {<B2>} {<B3>} {<B4>} {<Z1>}
                                {<Z2>} {<Z3>} {<Z4>} <continuations> <sign>

```

Compute Q_B by evaluating $\langle B_1 \rangle \langle B_2 \rangle 0 / y - 1$. The result is output to the left, in an `_fp_int_eval:w` which we start now. Once that is evaluated (and the other Q_i also, since later expansions are triggered by this one), a packing auxiliary takes care of placing the digits of Q_B in an appropriate way for the final addition to obtain Q . This auxiliary is also used to compute Q_C and Q_D with the inputs C and D instead of B .

```

18852 \cs_new:Npn \_fp_div_significand_ii:wnn #1; #2;#3
18853 {
18854   \exp_after:wN \_fp_div_significand_pack:NNN
18855   \int_value:w \_fp_int_eval:w
18856   \exp_after:wN \_fp_div_significand_calc:wwnnnnnn
18857   \int_value:w \_fp_int_eval:w 999999 + #2 #3 0 / #1 ; #2 #3 ;
18858 }

```

(End definition for _fp_div_significand_ii:wnn.)

```

\_fp_div_significand_iii:wwnnnnn \_fp_div_significand_iii:wwnnnnn <y> ; <E1> ; {<E2>} {<E3>} {<E4>}
                                {<Z1>} {<Z2>} {<Z3>} {<Z4>} <sign>

```

We compute $P \simeq 2E/Z$ by rounding $2E_1E_2/Z_1Z_2$. Note the first 0, which multiplies Q_D by 10: we later add (roughly) $5 \cdot P$, which amounts to adding $P/2 \simeq E/Z$ to Q_D , the appropriate correction from a hypothetical Q_E .

```

18859 \cs_new:Npn \_fp_div_significand_iii:wwnnnnn #1; #2;#3#4#5 #6#7
18860 {
18861   0
18862   \exp_after:wN \_fp_div_significand_iv:wwnnnnnnn
18863   \int_value:w \_fp_int_eval:w ( 2 * #2 #3 ) / #6 #7 ; % <- P
18864   #2 ; {#3} {#4} {#5}
18865   {#6} {#7}
18866 }

```

(End definition for _fp_div_significand_iii:wwnnnnn.)

```

\_fp_div_significand_iv:wwnnnnnnn \_fp_div_significand_iv:wwnnnnnnn <P> ; <E1> ; {<E2>} {<E3>} {<E4>}
\_fp_div_significand_v:NNw      {<Z1>} {<Z2>} {<Z3>} {<Z4>} <sign>
\_fp_div_significand_vi:Nw

```

This adds to the current expression $(10^7 + 10 \cdot Q_D)$ a contribution of $5 \cdot P + \text{sign}(T)$ with $T = 2E - PZ$. This amounts to adding $P/2$ to Q_D , with an extra *rounding* digit. This *rounding* digit is 0 or 5 if T does not contribute, *i.e.*, if $0 = T = 2E - PZ$, in other words if $10^{16}A/Z$ is an integer or half-integer. Otherwise it is in the appropriate range, $[1, 4]$ or $[6, 9]$. This is precise enough for rounding purposes (in any mode).

It seems an overkill to compute T exactly as I do here, but I see no faster way right now.

Once more, we need to be careful and show that the calculation $\#1 \cdot \#6\#7$ below does not cause an overflow: naively, P can be up to 35, and $\#6\#7$ up to 10^8 , but both cannot happen simultaneously. To show that things are fine, we split in two (non-disjoint) cases.

- For $P < 10$, the product obeys $P \cdot \#6\#7 < 10^8 \cdot P < 10^9$.
- For large $P \geq 3$, the rounding error on P , which is at most 1, is less than a factor of 2, hence $P \leq 4E/Z$. Also, $\#6\#7 \leq 10^8 \cdot Z$, hence $P \cdot \#6\#7 \leq 4E \cdot 10^8 < 10^9$.

Both inequalities could be made tighter if needed.

Note however that $P \cdot \#8\#9$ may overflow, since the two factors are now independent, and the result may reach $3.5 \cdot 10^9$. Thus we compute the two lower levels separately. The rest is standard, except that we use $+$ as a separator (ending integer expressions explicitly). T is negative if the first character is $-$, it is positive if the first character is neither 0 nor $-$. It is also positive if the first character is 0 and second argument of `__fp_div_significand_vi:Nw`, a sum of several terms, is also zero. Otherwise, there was an exact agreement: $T = 0$.

```

18867 \cs_new:Npn \__fp_div_significand_iv:wwnnnnnnn #1; #2;#3#4#5 #6#7#8#9
18868 {
18869   + 5 * #1
18870   \exp_after:wN \__fp_div_significand_vi:Nw
18871   \int_value:w \__fp_int_eval:w -20 + 2*#2#3 - #1*#6#7 +
18872   \exp_after:wN \__fp_div_significand_v:NN
18873   \int_value:w \__fp_int_eval:w 199980 + 2*#4 - #1*#8 +
18874   \exp_after:wN \__fp_div_significand_v:NN
18875   \int_value:w \__fp_int_eval:w 200000 + 2*#5 - #1*#9 ;
18876 }
18877 \cs_new:Npn \__fp_div_significand_v:NN #1#2 { #1#2 \__fp_int_eval_end: + }
18878 \cs_new:Npn \__fp_div_significand_vi:Nw #1#2;
18879 {
18880   \if_meaning:w 0 #1
18881     \if_int_compare:w \__fp_int_eval:w #2 > 0 + 1 \fi:
18882   \else:
18883     \if_meaning:w - #1 - \else: + \fi: 1
18884   \fi:
18885   ;
18886 }

```

(End definition for `__fp_div_significand_iv:wwnnnnnnn`, `__fp_div_significand_v:NNw`, and `__fp_div_significand_vi:Nw`.)

`__fp_div_significand_pack:NNN`

At this stage, we are in the following situation: \TeX is in the process of expanding several integer expressions, thus functions at the bottom expand before those above.

```

    \_fp_div_significand_test_o:w 106 + QA \_fp_div_significand_-
    pack:NNN 106 + QB \_fp_div_significand_pack:NNN 106 + QC \_fp_-
    div_significand_pack:NNN 107 + 10 · QD + 5 · P + ε ; ⟨sign⟩

```

Here, $\varepsilon = \text{sign}(T)$ is 0 in case $2E = PZ$, 1 in case $2E > PZ$, which means that P was the correct value, but not with an exact quotient, and -1 if $2E < PZ$, i.e., P was an overestimate. The packing function we define now does nothing special: it removes the 10^6 and carries two digits (for the 10^5 's and the 10^4 's).

```

18887 \cs_new:Npn \_fp_div_significand_pack:NNN 1 #1 #2 { + #1 #2 ; }

```

(End definition for `_fp_div_significand_pack:NNN`.)

```

\_fp_div_significand_test_o:w    \_fp_div_significand_test_o:w 1 0 ⟨5d⟩ ;  ⟨4d⟩ ; ⟨4d⟩ ; ⟨5d⟩ ; ⟨sign⟩

```

The reason we know that the first two digits are 1 and 0 is that the final result is known to be between 0.1 (inclusive) and 10, hence \widetilde{Q}_A (the tilde denoting the contribution from the other Q_i) is at most 99999, and $10^6 + \widetilde{Q}_A = 10 \dots$.

It is now time to round. This depends on how many digits the final result will have.

```

18888 \cs_new:Npn \_fp_div_significand_test_o:w 10 #1
18889 {
18890   \if_meaning:w 0 #1
18891     \exp_after:wN \_fp_div_significand_small_o:wwwNNNNwN
18892   \else:
18893     \exp_after:wN \_fp_div_significand_large_o:wwwNNNNwN
18894   \fi:
18895   #1
18896 }

```

(End definition for `_fp_div_significand_test_o:w`.)

```

\_fp_div_significand_small_o:wwwNNNNwN    \_fp_div_significand_small_o:wwwNNNNwN 0 ⟨4d⟩ ;  ⟨4d⟩ ; ⟨4d⟩ ; ⟨5d⟩
; ⟨final sign⟩

```

Standard use of the functions `_fp_basics_pack_low:NNNNw` and `_fp_basics_pack_high:NNNNw`. We finally get to use the *⟨final sign⟩* which has been sitting there for a while.

```

18897 \cs_new:Npn \_fp_div_significand_small_o:wwwNNNNwN
18898   0 #1; #2; #3; #4#5#6#7#8; #9
18899 {
18900   \exp_after:wN \_fp_basics_pack_high:NNNNw
18901   \int_value:w \_fp_int_eval:w 1 #1#2
18902   \exp_after:wN \_fp_basics_pack_low:NNNNw
18903   \int_value:w \_fp_int_eval:w 1 #3#4#5#6#7
18904   + \_fp_round:NNN #9 #7 #8
18905   \exp_after:wN ;
18906 }

```

(End definition for `_fp_div_significand_small_o:wwwNNNNwN`.)

```

\_fp_div_significand_large_o:wwwNNNNwN    \_fp_div_significand_large_o:wwwNNNNwN ⟨5d⟩ ;  ⟨4d⟩ ; ⟨4d⟩ ; ⟨5d⟩ ;
⟨sign⟩

```

We know that the final result cannot reach 10, hence `1#1#2`, together with contributions from the level below, cannot reach $2 \cdot 10^9$. For rounding, we build the *⟨rounding digit⟩* from the last two of our 18 digits.

```

18907 \cs_new:Npn \_fp_div_significand_large_o:wwwNNNNwN

```

```

18908     #1; #2; #3; #4#5#6#7#8; #9
18909     {
18910         + 1
18911         \exp_after:wN \_fp_basics_pack_weird_high:NNNNNNNNw
18912         \int_value:w \_fp_int_eval:w 1 #1 #2
18913         \exp_after:wN \_fp_basics_pack_weird_low:NNNNw
18914         \int_value:w \_fp_int_eval:w 1 #3 #4 #5 #6 +
18915         \exp_after:wN \_fp_round:NNN
18916         \exp_after:wN #9
18917         \exp_after:wN #6
18918         \int_value:w \_fp_round_digit:Nw #7 #8 ;
18919         \exp_after:wN ;
18920     }

```

(End definition for `_fp_div_significand_large_o:wwwNNNNwN`.)

31.4 Square root

`_fp_sqrt_o:w` Zeros are unchanged: $\sqrt{-0} = -0$ and $\sqrt{+0} = +0$. Negative numbers (other than -0) have no real square root. Positive infinity, and `nan`, are unchanged. Finally, for normal positive numbers, there is some work to do.

```

18921 \cs_new:Npn \_fp_sqrt_o:w #1 \s_fp \_fp_chk:w #2#3#4; @
18922 {
18923     \if_meaning:w 0 #2 \_fp_case_return_same_o:w \fi:
18924     \if_meaning:w 2 #3
18925         \_fp_case_use:nw { \_fp_invalid_operation_o:nw { sqrt } }
18926     \fi:
18927     \if_meaning:w 1 #2 \else: \_fp_case_return_same_o:w \fi:
18928     \_fp_sqrt_npos_o:w
18929     \s_fp \_fp_chk:w #2 #3 #4;
18930 }

```

(End definition for `_fp_sqrt_o:w`.)

`_fp_sqrt_npos_o:w` Prepare `_fp_sanitize:Nw` to receive the final sign 0 (the result is always positive) and the exponent, equal to half of the exponent #1 of the argument. If the exponent #1 is even, find a first approximation of the square root of the significand $10^8 a_1 + a_2 = 10^8 \#2\#3 + \#4\#5$ through Newton's method, starting at $x = 57234133 \simeq 10^{7.75}$. Otherwise, first shift the significand of the argument by one digit, getting $a'_1 \in [10^6, 10^7)$ instead of $[10^7, 10^8)$, then use Newton's method starting at $17782794 \simeq 10^{7.25}$.

```

18931 \cs_new:Npn \_fp_sqrt_npos_o:w \s_fp \_fp_chk:w 1 0 #1#2#3#4#5;
18932 {
18933     \exp_after:wN \_fp_sanitize:Nw
18934     \exp_after:wN 0
18935     \int_value:w \_fp_int_eval:w
18936     \if_int_odd:w #1 \exp_stop_f:
18937         \exp_after:wN \_fp_sqrt_npos_auxi_o:wwnnN
18938     \fi:
18939     #1 / 2
18940     \_fp_sqrt_Newton_o:wnn 56234133; 0; {#2#3} {#4#5} 0
18941 }
18942 \cs_new:Npn \_fp_sqrt_npos_auxi_o:wwnnN #1 / 2 #2; 0; #3#4#5
18943 {
18944     ( #1 + 1 ) / 2

```

```

18945 \__fp_pack_eight:wNNNNNNNN
18946 \__fp_sqrt_npos_auxii_o:wNNNNNNNN
18947 ;
18948 0 #3 #4
18949 }
18950 \cs_new:Npn \__fp_sqrt_npos_auxii_o:wNNNNNNNN #1; #2#3#4#5#6#7#8#9
18951 { \__fp_sqrt_Newton_o:wnn 17782794; 0; {#1} {#2#3#4#5#6#7#8#9} }

```

(End definition for `__fp_sqrt_npos_o:w`, `__fp_sqrt_npos_auxi_o:wnnnN`, and `__fp_sqrt_npos_auxii_o:wNNNNNNNN`.)

`__fp_sqrt_Newton_o:wnn` Newton's method maps $x \mapsto [(x + [10^8 a_1/x])/2]$ in each iteration, where $[b/c]$ denotes ε -TeX's division. This division rounds the real number b/c to the closest integer, rounding ties away from zero, hence when c is even, $b/c - 1/2 + 1/c \leq [b/c] \leq b/c + 1/2$ and when c is odd, $b/c - 1/2 + 1/(2c) \leq [b/c] \leq b/c + 1/2 - 1/(2c)$. For all c , $b/c - 1/2 + 1/(2c) \leq [b/c] \leq b/c + 1/2$.

Let us prove that the method converges when implemented with ε -TeX integer division, for any $10^6 \leq a_1 < 10^8$ and starting value $10^6 \leq x < 10^8$. Using the inequalities above and the arithmetic–geometric inequality $(x + t)/2 \geq \sqrt{xt}$ for $t = 10^8 a_1/x$, we find

$$x' = \left\lfloor \frac{x + [10^8 a_1/x]}{2} \right\rfloor \geq \frac{x + 10^8 a_1/x - 1/2 + 1/(2x)}{2} \geq \sqrt{10^8 a_1} - \frac{1}{4} + \frac{1}{4x}.$$

After any step of iteration, we thus have $\delta = x - \sqrt{10^8 a_1} \geq -0.25 + 0.25 \cdot 10^{-8}$. The new difference $\delta' = x' - \sqrt{10^8 a_1}$ after one step is bounded above as

$$x' - \sqrt{10^8 a_1} \leq \frac{x + 10^8 a_1/x + 1/2}{2} + \frac{1}{2} - \sqrt{10^8 a_1} \leq \frac{\delta}{2} \frac{\delta}{\sqrt{10^8 a_1} + \delta} + \frac{3}{4}.$$

For $\delta > 3/2$, this last expression is $\leq \delta/2 + 3/4 < \delta$, hence δ decreases at each step: since all x are integers, δ must reach a value $-1/4 < \delta \leq 3/2$. In this range of values, we get $\delta' \leq \frac{3}{4} \frac{3}{2\sqrt{10^8 a_1}} + \frac{3}{4} \leq 0.75 + 1.125 \cdot 10^{-7}$. We deduce that the difference $\delta = x - \sqrt{10^8 a_1}$ eventually reaches a value in the interval $[-0.25 + 0.25 \cdot 10^{-8}, 0.75 + 11.25 \cdot 10^{-8}]$, whose width is $1 + 11 \cdot 10^{-8}$. The corresponding interval for x may contain two integers, hence x might oscillate between those two values.

However, the fact that $x \mapsto x - 1$ and $x - 1 \mapsto x$ puts stronger constraints, which are not compatible: the first implies

$$x + [10^8 a_1/x] \leq 2x - 2$$

hence $10^8 a_1/x \leq x - 3/2$, while the second implies

$$x - 1 + [10^8 a_1/(x - 1)] \geq 2x - 1$$

hence $10^8 a_1/(x - 1) \geq x - 1/2$. Combining the two inequalities yields $x^2 - 3x/2 \geq 10^8 a_1 \geq x - 3x/2 + 1/2$, which cannot hold. Therefore, the iteration always converges to a single integer x . To stop the iteration when two consecutive results are equal, the function `__fp_sqrt_Newton_o:wnn` receives the newly computed result as `#1`, the previous result as `#2`, and a_1 as `#3`. Note that ε -TeX combines the computation of a multiplication and a following division, thus avoiding overflow in `#3 * 100000000 / #1`. In any case, the result is within $[10^7, 10^8]$.

```

18952 \cs_new:Npn \__fp_sqrt_Newton_o:wnn #1; #2; #3

```

```

18953 {
18954   \if_int_compare:w #1 = #2 \exp_stop_f:
18955     \exp_after:wN \__fp_sqrt_auxi_o:NNNNwnnN
18956     \int_value:w \__fp_int_eval:w 9999 9999 +
18957     \exp_after:wN \__fp_use_none_until_s:w
18958   \fi:
18959   \exp_after:wN \__fp_sqrt_Newton_o:wnn
18960   \int_value:w \__fp_int_eval:w (#1 + #3 * 1 0000 0000 / #1) / 2 ;
18961   #1; {#3}
18962 }

```

(End definition for __fp_sqrt_Newton_o:wnn.)

__fp_sqrt_auxi_o:NNNNwnnN

This function is followed by $10^8 + x - 1$, which has 9 digits starting with 1, then ; $\{\langle a_1 \rangle\} \{\langle a_2 \rangle\} \langle a' \rangle$. Here, $x \simeq \sqrt{10^8 a_1}$ and we want to estimate the square root of $a = 10^{-8} a_1 + 10^{-16} a_2 + 10^{-17} a'$. We set up an initial underestimate

$$y = (x - 1)10^{-8} + 0.2499998875 \cdot 10^{-8} \lesssim \sqrt{a}.$$

From the inequalities shown earlier, we know that $y \leq \sqrt{10^{-8} a_1} \leq \sqrt{a}$ and that $\sqrt{10^{-8} a_1} \leq y + 10^{-8} + 11 \cdot 10^{-16}$ hence (using $0.1 \leq y \leq \sqrt{a} \leq 1$)

$$a - y^2 \leq 10^{-8} a_1 + 10^{-8} - y^2 \leq (y + 10^{-8} + 11 \cdot 10^{-16})^2 - y^2 + 10^{-8} < 3.2 \cdot 10^{-8},$$

and $\sqrt{a} - y = (a - y^2)/(\sqrt{a} + y) \leq 16 \cdot 10^{-8}$. Next, __fp_sqrt_auxii_o:NnnnnnnnnN is called several times to get closer and closer underestimates of \sqrt{a} . By construction, the underestimates y are always increasing, $a - y^2 < 3.2 \cdot 10^{-8}$ for all. Also, $y < 1$.

```

18963 \cs_new:Npn \__fp_sqrt_auxi_o:NNNNwnnN 1 #1#2#3#4#5;
18964 {
18965   \__fp_sqrt_auxii_o:NnnnnnnnnN
18966   \__fp_sqrt_auxiii_o:wnnnnnnnnn
18967   {#1#2#3#4} {#5} {2499} {9988} {7500}
18968 }

```

(End definition for __fp_sqrt_auxi_o:NNNNwnnN.)

__fp_sqrt_auxii_o:NnnnnnnnnN

This receives a continuation function #1, then five blocks of 4 digits for y , then two 8-digit blocks and a single digit for a . A common estimate of $\sqrt{a} - y = (a - y^2)/(\sqrt{a} + y)$ is $(a - y^2)/(2y)$, which leads to alternating overestimates and underestimates. We tweak this, to only work with underestimates (no need then to worry about signs in the computation). Each step finds the largest integer $j \leq 6$ such that $10^{4j}(a - y^2) < 2 \cdot 10^8$, then computes the integer (with ε -TeX's rounding division)

$$10^{4j} z = \left[(10^{4j}(a - y^2)) - 257 \right] \cdot (0.5 \cdot 10^8) \Big/ \lfloor 10^8 y + 1 \rfloor.$$

The choice of j ensures that $10^{4j} z < 2 \cdot 10^8 \cdot 0.5 \cdot 10^8 / 10^7 = 10^9$, thus $10^9 + 10^{4j} z$ has exactly 10 digits, does not overflow TeX's integer range, and starts with 1. Incidentally, since all $a - y^2 \leq 3.2 \cdot 10^{-8}$, we know that $j \geq 3$.

Let us show that z is an underestimate of $\sqrt{a} - y$. On the one hand, $\sqrt{a} - y \leq 16 \cdot 10^{-8}$ because this holds for the initial y and values of y can only increase. On the other hand, the choice of j implies that $\sqrt{a} - y \leq 5(\sqrt{a} + y)(\sqrt{a} - y) = 5(a - y^2) < 10^{9-4j}$. For $j = 3$,

the first bound is better, while for larger j , the second bound is better. For all $j \in [3, 6]$, we find $\sqrt{a} - y < 16 \cdot 10^{-2j}$. From this, we deduce that

$$10^{4j}(\sqrt{a} - y) = \frac{10^{4j}(a - y^2 - (\sqrt{a} - y)^2)}{2y} \geq \frac{\lfloor 10^{4j}(a - y^2) \rfloor - 257}{2 \cdot 10^{-8} \lfloor 10^8 y + 1 \rfloor} + \frac{1}{2}$$

where we have replaced the bound $10^{4j}(16 \cdot 10^{-2j}) = 256$ by 257 and extracted the corresponding term $1/(2 \cdot 10^{-8} \lfloor 10^8 y + 1 \rfloor) \geq 1/2$. Given that ε -TeX's integer division obeys $\lfloor b/c \rfloor \leq b/c + 1/2$, we deduce that $10^{4j}z \leq 10^{4j}(\sqrt{a} - y)$, hence $y + z \leq \sqrt{a}$ is an underestimate of \sqrt{a} , as claimed. One implementation detail: because the computation involves $-4 \cdot 4 - 2 \cdot 3 \cdot 5 - 2 \cdot 2 \cdot 6$ which may be as low as $-5 \cdot 10^8$, we need to use the `pack_big` functions, and the big shifts.

```

18969 \cs_new:Npn \__fp_sqrt_auxii_o:NnnnnnnN #1 #2#3#4#5#6 #7#8#9
18970 {
18971   \exp_after:wN #1
18972   \int_value:w \__fp_int_eval:w \c__fp_big_leading_shift_int
18973     + #7 - #2 * #2
18974   \exp_after:wN \__fp_pack_big:NNNNNNw
18975   \int_value:w \__fp_int_eval:w \c__fp_big_middle_shift_int
18976     - 2 * #2 * #3
18977   \exp_after:wN \__fp_pack_big:NNNNNNw
18978   \int_value:w \__fp_int_eval:w \c__fp_big_middle_shift_int
18979     + #8 - #3 * #3 - 2 * #2 * #4
18980   \exp_after:wN \__fp_pack_big:NNNNNNw
18981   \int_value:w \__fp_int_eval:w \c__fp_big_middle_shift_int
18982     - 2 * #3 * #4 - 2 * #2 * #5
18983   \exp_after:wN \__fp_pack_big:NNNNNNw
18984   \int_value:w \__fp_int_eval:w \c__fp_big_middle_shift_int
18985     + #9 000 0000 - #4 * #4 - 2 * #3 * #5 - 2 * #2 * #6
18986   \exp_after:wN \__fp_pack_big:NNNNNNw
18987   \int_value:w \__fp_int_eval:w \c__fp_big_middle_shift_int
18988     - 2 * #4 * #5 - 2 * #3 * #6
18989   \exp_after:wN \__fp_pack_big:NNNNNNw
18990   \int_value:w \__fp_int_eval:w \c__fp_big_middle_shift_int
18991     - #5 * #5 - 2 * #4 * #6
18992   \exp_after:wN \__fp_pack_big:NNNNNNw
18993   \int_value:w \__fp_int_eval:w
18994     \c__fp_big_middle_shift_int
18995     - 2 * #5 * #6
18996   \exp_after:wN \__fp_pack_big:NNNNNNw
18997   \int_value:w \__fp_int_eval:w
18998     \c__fp_big_trailing_shift_int
18999     - #6 * #6 ;
19000   % (
19001   - 257 ) * 5000 0000 / (#2#3 + 1) + 10 0000 0000 ;
19002   {#2}{#3}{#4}{#5}{#6} {#7}{#8}{#9}
19003 }

```

(End definition for `__fp_sqrt_auxii_o:NnnnnnnN`.)

```

\__fp_sqrt_auxiii_o:wnnnnnnnN
\__fp_sqrt_auxiv_o:NNNNNNw
\__fp_sqrt_auxv_o:NNNNNNw
\__fp_sqrt_auxvi_o:NNNNNNw
\__fp_sqrt_auxvii_o:NNNNNNw

```

We receive here the difference $a - y^2 = d = \sum_i d_i \cdot 10^{-4i}$, as $\langle d_2 \rangle$; $\{\langle d_3 \rangle\} \dots \{\langle d_{10} \rangle\}$, where each block has 4 digits, except $\langle d_2 \rangle$. This function finds the largest $j \leq 6$ such that $10^{4j}(a - y^2) < 2 \cdot 10^8$, then leaves an open parenthesis and the integer $\lfloor 10^{4j}(a - y^2) \rfloor$

in an integer expression. The closing parenthesis is provided by the caller `__fp_sqrt_auxii_o:NnnnnnnnN`, which completes the expression

$$10^{4j}z = \left[([10^{4j}(a - y^2)] - 257) \cdot (0.5 \cdot 10^8) / [10^8y + 1] \right]$$

for an estimate of $10^{4j}(\sqrt{a} - y)$. If $d_2 \geq 2$, $j = 3$ and the `auxiv` auxiliary receives $10^{12}z$. If $d_2 \leq 1$ but $10^4d_2 + d_3 \geq 2$, $j = 4$ and the `auxv` auxiliary is called, and receives $10^{16}z$, and so on. In all those cases, the `auxviii` auxiliary is set up to add z to y , then go back to the `auxii` step with continuation `auxiii` (the function we are currently describing). The maximum value of j is 6, regardless of whether $10^{12}d_2 + 10^8d_3 + 10^4d_4 + d_5 \geq 1$. In this last case, we detect when $10^{24}z < 10^7$, which essentially means $\sqrt{a} - y \lesssim 10^{-17}$: once this threshold is reached, there is enough information to find the correctly rounded \sqrt{a} with only one more call to `__fp_sqrt_auxii_o:NnnnnnnnN`. Note that the iteration cannot be stuck before reaching $j = 6$, because for $j < 6$, one has $2 \cdot 10^8 \leq 10^{4(j+1)}(a - y^2)$, hence

$$10^{4j}z \geq \frac{(20000 - 257)(0.5 \cdot 10^8)}{[10^8y + 1]} \geq (20000 - 257) \cdot 0.5 > 0.$$

```

19004 \cs_new:Npn \__fp_sqrt_auxiii_o:wnnnnnnnn
19005   #1; #2#3#4#5#6#7#8#9
19006   {
19007     \if_int_compare:w #1 > 1 \exp_stop_f:
19008       \exp_after:wN \__fp_sqrt_auxiv_o:NNNNNw
19009       \int_value:w \__fp_int_eval:w (#1#2 %)
19010     \else:
19011       \if_int_compare:w #1#2 > 1 \exp_stop_f:
19012         \exp_after:wN \__fp_sqrt_auxv_o:NNNNNw
19013         \int_value:w \__fp_int_eval:w (#1#2#3 %)
19014       \else:
19015         \if_int_compare:w #1#2#3 > 1 \exp_stop_f:
19016           \exp_after:wN \__fp_sqrt_auxvi_o:NNNNNw
19017           \int_value:w \__fp_int_eval:w (#1#2#3#4 %)
19018         \else:
19019           \exp_after:wN \__fp_sqrt_auxvii_o:NNNNNw
19020           \int_value:w \__fp_int_eval:w (#1#2#3#4#5 %)
19021         \fi:
19022       \fi:
19023     \fi:
19024   }
19025 \cs_new:Npn \__fp_sqrt_auxiv_o:NNNNNw 1#1#2#3#4#5#6;
19026   { \__fp_sqrt_auxviii_o:nnnnnnn {#1#2#3#4#5#6} {00000000} }
19027 \cs_new:Npn \__fp_sqrt_auxv_o:NNNNNw 1#1#2#3#4#5#6;
19028   { \__fp_sqrt_auxviii_o:nnnnnnn {000#1#2#3#4#5} {#60000} }
19029 \cs_new:Npn \__fp_sqrt_auxvi_o:NNNNNw 1#1#2#3#4#5#6;
19030   { \__fp_sqrt_auxviii_o:nnnnnnn {0000000#1} {#2#3#4#5#6} }
19031 \cs_new:Npn \__fp_sqrt_auxvii_o:NNNNNw 1#1#2#3#4#5#6;
19032   {
19033     \if_int_compare:w #1#2 = 0 \exp_stop_f:
19034       \exp_after:wN \__fp_sqrt_auxx_o:Nnnnnnnn
19035     \fi:
19036     \__fp_sqrt_auxviii_o:nnnnnnn {00000000} {000#1#2#3#4#5}
19037   }

```

(End definition for `__fp_sqrt_auxiii_o:wnnnnnnnn` and others.)

`__fp_sqrt_auxviii_o:nnnnnnn` Simply add the two 8-digit blocks of z , aligned to the last four of the five 4-digit blocks of y , then call the `auxii` auxiliary to evaluate $y'^2 = (y + z)^2$.

```

19038 \cs_new:Npn \__fp_sqrt_auxviii_o:nnnnnnn #1#2 #3#4#5#6#7
19039 {
19040   \exp_after:wN \__fp_sqrt_auxix_o:wnwnw
19041   \int_value:w \__fp_int_eval:w #3
19042   \exp_after:wN \__fp_basics_pack_low:NNNNw
19043   \int_value:w \__fp_int_eval:w #1 + 1#4#5
19044   \exp_after:wN \__fp_basics_pack_low:NNNNw
19045   \int_value:w \__fp_int_eval:w #2 + 1#6#7 ;
19046 }
19047 \cs_new:Npn \__fp_sqrt_auxix_o:wnwnw #1; #2#3; #4#5;
19048 {
19049   \__fp_sqrt_auxii_o:NnnnnnnnN
19050   \__fp_sqrt_auxiii_o:wnnnnnnnn {#1}{#2}{#3}{#4}{#5}
19051 }

```

(End definition for `__fp_sqrt_auxviii_o:nnnnnnn` and `__fp_sqrt_auxix_o:wnwnw`.)

`__fp_sqrt_auxx_o:Nnnnnnnn` At this stage, $j = 6$ and $10^{24}z < 10^7$, hence
`__fp_sqrt_auxxi_o:wnnnN`

$$10^7 + 1/2 > 10^{24}z + 1/2 \geq (10^{24}(a - y^2) - 258) \cdot (0.5 \cdot 10^8) / (10^8y + 1),$$

then $10^{24}(a - y^2) - 258 < 2(10^7 + 1/2)(y + 10^{-8})$, and

$$10^{24}(a - y^2) < (10^7 + 1290.5)(1 + 10^{-8}/y)(2y) < (10^7 + 1290.5)(1 + 10^{-7})(y + \sqrt{a}),$$

which finally implies $0 \leq \sqrt{a} - y < 0.2 \cdot 10^{-16}$. In particular, y is an underestimate of \sqrt{a} and $y + 0.5 \cdot 10^{-16}$ is a (strict) overestimate. There is at exactly one multiple m of $0.5 \cdot 10^{-16}$ in the interval $[y, y + 0.5 \cdot 10^{-16})$. If $m^2 > a$, then the square root is inexact and is obtained by rounding $m - \epsilon$ to a multiple of 10^{-16} (the precise shift $0 < \epsilon < 0.5 \cdot 10^{-16}$ is irrelevant for rounding). If $m^2 = a$ then the square root is exactly m , and there is no rounding. If $m^2 < a$ then we round $m + \epsilon$. For now, discard a few irrelevant arguments `#1`, `#2`, `#3`, and find the multiple of $0.5 \cdot 10^{-16}$ within $[y, y + 0.5 \cdot 10^{-16})$; rather, only the last 4 digits `#8` of y are considered, and we do not perform any carry yet. The `auxxi` auxiliary sets up `auxii` with a continuation function `auxxii` instead of `auxiii` as before. To prevent `auxii` from giving a negative results $a - m^2$, we compute $a + 10^{-16} - m^2$ instead, always positive since $m < \sqrt{a} + 0.5 \cdot 10^{-16}$ and $a \leq 1 - 10^{-16}$.

```

19052 \cs_new:Npn \__fp_sqrt_auxx_o:Nnnnnnnn #1#2#3 #4#5#6#7#8
19053 {
19054   \exp_after:wN \__fp_sqrt_auxxi_o:wnnnN
19055   \int_value:w \__fp_int_eval:w
19056   (#8 + 2499) / 5000 * 5000 ;
19057   {#4} {#5} {#6} {#7} ;
19058 }
19059 \cs_new:Npn \__fp_sqrt_auxxi_o:wnnnN #1; #2; #3#4#5
19060 {
19061   \__fp_sqrt_auxii_o:NnnnnnnnN
19062   \__fp_sqrt_auxxii_o:nnnnnnnnw
19063   #2 {#1}
19064   {#3} { #4 + 1 } #5
19065 }

```

(End definition for _fp_sqrt_auxx_o:nnnnnnnw and _fp_sqrt_auxxi_o:wnnnN.)

_fp_sqrt_auxxii_o:nnnnnnnnnw
_fp_sqrt_auxxiii_o:w

The difference $0 \leq a + 10^{-16} - m^2 \leq 10^{-16} + (\sqrt{a} - m)(\sqrt{a} + m) \leq 2 \cdot 10^{-16}$ was just computed: its first 8 digits vanish, as do the next four, #1, and most of the following four, #2. The guess m is an overestimate if $a + 10^{-16} - m^2 < 10^{-16}$, that is, #1#2 vanishes. Otherwise it is an underestimate, unless $a + 10^{-16} - m^2 = 10^{-16}$ exactly. For an underestimate, call the auxxiv function with argument 9998. For an exact result call it with 9999, and for an overestimate call it with 10000.

```

19066 \cs_new:Npn \_fp_sqrt_auxxii_o:nnnnnnnnw 0; #1#2#3#4#5#6#7#8 #9;
19067 {
19068   \if_int_compare:w #1#2 > 0 \exp_stop_f:
19069   \if_int_compare:w #1#2 = 1 \exp_stop_f:
19070   \if_int_compare:w #3#4 = 0 \exp_stop_f:
19071   \if_int_compare:w #5#6 = 0 \exp_stop_f:
19072   \if_int_compare:w #7#8 = 0 \exp_stop_f:
19073   \_fp_sqrt_auxxiii_o:w
19074   \fi:
19075   \fi:
19076   \fi:
19077   \fi:
19078   \exp_after:wN \_fp_sqrt_auxxiv_o:wnnnnnnnnN
19079   \int_value:w 9998
19080   \else:
19081   \exp_after:wN \_fp_sqrt_auxxiv_o:wnnnnnnnnN
19082   \int_value:w 10000
19083   \fi:
19084   ;
19085 }
19086 \cs_new:Npn \_fp_sqrt_auxxiii_o:w \fi: \fi: \fi: \fi: #1 \fi: ;
19087 {
19088   \fi: \fi: \fi: \fi: \fi:
19089   \_fp_sqrt_auxxiv_o:wnnnnnnnnN 9999 ;
19090 }

```

(End definition for _fp_sqrt_auxxii_o:nnnnnnnnw and _fp_sqrt_auxxiii_o:w.)

_fp_sqrt_auxxiv_o:wnnnnnnnnN

This receives 9998, 9999 or 10000 as #1 when m is an underestimate, exact, or an overestimate, respectively. Then comes m as five blocks of 4 digits, but where the last block #6 may be 0, 5000, or 10000. In the latter case, we need to add a carry, unless m is an overestimate (#1 is then 10000). Then comes a as three arguments. Rounding is done by _fp_round:NNN, whose first argument is the final sign 0 (square roots are positive). We fake its second argument. It should be the last digit kept, but this is only used when ties are “rounded to even”, and only when the result is exactly half-way between two representable numbers rational square roots of numbers with 16 significant digits have: this situation never arises for the square root, as any exact square root of a 16 digit number has at most 8 significant digits. Finally, the last argument is the next digit, possibly shifted by 1 when there are further nonzero digits. This is achieved by _fp_round_digit:Nw, which receives (after removal of the 10000’s digit) one of 0000, 0001, 4999, 5000, 5001, or 9999, which it converts to 0, 1, 4, 5, 6, and 9, respectively.

```

19091 \cs_new:Npn \_fp_sqrt_auxxiv_o:wnnnnnnnnN #1; #2#3#4#5#6 #7#8#9
19092 {
19093   \exp_after:wN \_fp_basics_pack_high:NNNNNw
19094   \int_value:w \_fp_int_eval:w 1 0000 0000 + #2#3

```

```

19095     \exp_after:wN \__fp_basics_pack_low:NNNNNw
19096     \int_value:w \__fp_int_eval:w 1 0000 0000
19097         + #4#5
19098     \if_int_compare:w #6 > #1 \exp_stop_f: + 1 \fi:
19099     + \exp_after:wN \__fp_round:NNN
19100     \exp_after:wN 0
19101     \exp_after:wN 0
19102     \int_value:w
19103     \exp_after:wN \use_i:nn
19104     \exp_after:wN \__fp_round_digit:Nw
19105     \int_value:w \__fp_int_eval:w #6 + 19999 - #1 ;
19106     \exp_after:wN ;
19107 }

```

(End definition for __fp_sqrt_auxxiv_o:wnnnnnnnnN.)

31.5 About the sign and exponent

__fp_logb_o:w The exponent of a normal number is its *<exponent>* minus one.

```

\__fp_logb_aux_o:w
19108 \cs_new:Npn \__fp_logb_o:w ? \s__fp \__fp_chk:w #1#2; @
19109 {
19110     \if_case:w #1 \exp_stop_f:
19111         \__fp_case_use:nw
19112         { \__fp_division_by_zero_o:Nnw \c_minus_inf_fp { logb } }
19113     \or: \exp_after:wN \__fp_logb_aux_o:w
19114     \or: \__fp_case_return_o:Nw \c_inf_fp
19115     \else: \__fp_case_return_same_o:w
19116     \fi:
19117     \s__fp \__fp_chk:w #1 #2;
19118 }
19119 \cs_new:Npn \__fp_logb_aux_o:w \s__fp \__fp_chk:w #1 #2 #3 #4 ;
19120 {
19121     \exp_after:wN \__fp_parse:n \exp_after:wN
19122     { \int_value:w \int_eval:w #3 - 1 \exp_after:wN }
19123 }

```

(End definition for __fp_logb_o:w and __fp_logb_aux_o:w.)

__fp_sign_o:w Find the sign of the floating point: nan, +0, -0, +1 or -1.

```

\__fp_sign_aux_o:w
19124 \cs_new:Npn \__fp_sign_o:w ? \s__fp \__fp_chk:w #1#2; @
19125 {
19126     \if_case:w #1 \exp_stop_f:
19127         \__fp_case_return_same_o:w
19128     \or: \exp_after:wN \__fp_sign_aux_o:w
19129     \or: \exp_after:wN \__fp_sign_aux_o:w
19130     \else: \__fp_case_return_same_o:w
19131     \fi:
19132     \s__fp \__fp_chk:w #1 #2;
19133 }
19134 \cs_new:Npn \__fp_sign_aux_o:w \s__fp \__fp_chk:w #1 #2 #3 ;
19135 { \exp_after:wN \__fp_set_sign_o:w \exp_after:wN #2 \c_one_fp @ }

```

(End definition for __fp_sign_o:w and __fp_sign_aux_o:w.)

`_fp_set_sign_o:w` This function is used for the unary minus and for `abs`. It leaves the sign of `nan` invariant, turns negative numbers (sign 2) to positive numbers (sign 0) and positive numbers (sign 0) to positive or negative numbers depending on #1. It also expands after itself in the input stream, just like `_fp+_o:ww`.

```

19136 \cs_new:Npn \_fp_set_sign_o:w #1 \s__fp \_fp_chk:w #2#3#4; @
19137 {
19138     \exp_after:wN \_fp_exp_after_o:w
19139     \exp_after:wN \s__fp
19140     \exp_after:wN \_fp_chk:w
19141     \exp_after:wN #2
19142     \int_value:w
19143     \if_case:w #3 \exp_stop_f: #1 \or: 1 \or: 0 \fi: \exp_stop_f:
19144     #4;
19145 }

```

(End definition for `_fp_set_sign_o:w`.)

31.6 Operations on tuples

`_fp_tuple_set_sign_o:w` Two cases: `abs(<tuple>)` for which #1 is 0 (invalid for tuples) and `-<tuple>` for which #1 is 2. In that case, map over all items in the tuple an auxiliary that dispatches to the type-appropriate sign-flipping function.

```

\__fp_tuple_set_sign_aux_o:Nnw
\_fp_tuple_set_sign_aux_o:w
19146 \cs_new:Npn \_fp_tuple_set_sign_o:w #1
19147 {
19148     \if_meaning:w 2 #1
19149     \exp_after:wN \_fp_tuple_set_sign_aux_o:Nnw
19150     \fi:
19151     \_fp_invalid_operation_o:nw { abs }
19152 }
19153 \cs_new:Npn \_fp_tuple_set_sign_aux_o:Nnw #1#2#3 @
19154 { \_fp_tuple_map_o:nw \_fp_tuple_set_sign_aux_o:w #3 }
19155 \cs_new:Npn \_fp_tuple_set_sign_aux_o:w #1#2 ;
19156 {
19157     \_fp_change_func_type:NNN #1 \_fp_set_sign_o:w
19158     \_fp_parse_apply_unary_error:NNw
19159     2 #1 #2 ; @
19160 }

```

(End definition for `_fp_tuple_set_sign_o:w`, `_fp_tuple_set_sign_aux_o:Nnw`, and `_fp_tuple_set_sign_aux_o:w`.)

`_fp*_tuple_o:ww` For `<number>*<tuple>` and `<tuple>*<number>` and `<tuple>/<number>`, loop through the `<tuple>` some code that multiplies or divides by the appropriate `<number>`. Importantly we need to dispatch according to the type, and we make sure to apply the operator in the correct order.

```

\_fp_tuple*_o:ww
\_fp_tuple/_o:ww
19161 \cs_new:cpn { \_fp*_tuple_o:ww } #1 ;
19162 { \_fp_tuple_map_o:nw { \_fp_binary_type_o:Nnw * #1 ; } }
19163 \cs_new:cpn { \_fp_tuple*_o:ww } #1 ; #2 ;
19164 { \_fp_tuple_map_o:nw { \_fp_binary_rev_type_o:Nnw * #2 ; } #1 ; }
19165 \cs_new:cpn { \_fp_tuple/_o:ww } #1 ; #2 ;
19166 { \_fp_tuple_map_o:nw { \_fp_binary_rev_type_o:Nnw / #2 ; } #1 ; }

```

(End definition for `_fp*_tuple_o:ww`, `_fp_tuple*_o:ww`, and `_fp_tuple/_o:ww`.)

```

19167 \cs_set_protected:Npn \__fp_tmp:w #1
19168 {
19169   \cs_new:cpn { \__fp_tuple_#1_tuple_o:ww }
19170   \s__fp_tuple \__fp_tuple_chk:w ##1 ;
19171   \s__fp_tuple \__fp_tuple_chk:w ##2 ;
19172   {
19173     \int_compare:nNnTF
19174       { \__fp_array_count:n {##1} } = { \__fp_array_count:n {##2} }
19175       { \__fp_tuple_mapthread_o:nww { \__fp_binary_type_o:Nww #1 } }
19176       { \__fp_invalid_operation_o:nww #1 }
19177       \s__fp_tuple \__fp_tuple_chk:w {##1} ;
19178       \s__fp_tuple \__fp_tuple_chk:w {##2} ;
19179   }
19180 }
19181 \__fp_tmp:w +
19182 \__fp_tmp:w -

```

(End definition for __fp_tuple_+_tuple_o:ww and __fp_tuple_-_tuple_o:ww.)

```

19183 </initex | package>

```

32 13fp-extended implementation

```

19184 <*initex | package>
19185 <@@=fp>

```

32.1 Description of fixed point numbers

This module provides a few functions to manipulate positive floating point numbers with extended precision (24 digits), but mostly provides functions for fixed-point numbers with this precision (24 digits). Those are used in the computation of Taylor series for the logarithm, exponential, and trigonometric functions. Since we eventually only care about the 16 first digits of the final result, some of the calculations are not performed with the full 24-digit precision. In other words, the last two blocks of each fixed point number may be wrong as long as the error is small enough to be rounded away when converting back to a floating point number. The fixed point numbers are expressed as

$$\{\langle a_1 \rangle\} \{\langle a_2 \rangle\} \{\langle a_3 \rangle\} \{\langle a_4 \rangle\} \{\langle a_5 \rangle\} \{\langle a_6 \rangle\} ;$$

where each $\langle a_i \rangle$ is exactly 4 digits (ranging from 0000 to 9999), except $\langle a_1 \rangle$, which may be any “not-too-large” non-negative integer, with or without leading zeros. Here, “not-too-large” depends on the specific function (see the corresponding comments for details). Checking for overflow is the responsibility of the code calling those functions. The fixed point number a corresponding to the representation above is $a = \sum_{i=1}^6 \langle a_i \rangle \cdot 10^{-4i}$.

Most functions we define here have the form

```
\__fp_fixed_<calculation>:wnn <operand1> ; <operand2> ; {<continuation>}
```

They perform the $\langle \text{calculation} \rangle$ on the two $\langle \text{operands} \rangle$, then feed the result (6 brace groups followed by a semicolon) to the $\langle \text{continuation} \rangle$, responsible for the next step of the calculation. Some functions only accept an N-type $\langle \text{continuation} \rangle$. This allows constructions such as

```

    \__fp_fixed_add:wnn  $\langle X_1 \rangle$  ;  $\langle X_2 \rangle$  ;
    \__fp_fixed_mul:wnn  $\langle X_3 \rangle$  ;
    \__fp_fixed_add:wnn  $\langle X_4 \rangle$  ;

```

to compute $(X_1 + X_2) \cdot X_3 + X_4$. This turns out to be very appropriate for computing continued fractions and Taylor series.

At the end of the calculation, the result is turned back to a floating point number using `__fp_fixed_to_float_o:wn`. This function has to change the exponent of the floating point number: it must be used after starting an integer expression for the overall exponent of the result.

32.2 Helpers for numbers with extended precision

`\c__fp_one_fixed_tl` The fixed-point number 1, used in `l3fp-expo`.

```

19186 \tl_const:Nn \c__fp_one_fixed_tl
19187 { {10000} {0000} {0000} {0000} {0000} {0000} ; }

```

(End definition for `\c__fp_one_fixed_tl`.)

`__fp_fixed_continue:wn` This function simply calls the next function.

```

19188 \cs_new:Npn \__fp_fixed_continue:wn #1; #2 { #2 #1; }

```

(End definition for `__fp_fixed_continue:wn`.)

`__fp_fixed_add_one:wn` `__fp_fixed_add_one:wn $\langle a \rangle$; $\langle continuation \rangle$`

This function adds 1 to the fixed point $\langle a \rangle$, by changing a_1 to $10000 + a_1$, then calls the $\langle continuation \rangle$. This requires $a_1 + 10000 < 2^{31}$.

```

19189 \cs_new:Npn \__fp_fixed_add_one:wn #1#2; #3
19190 {
19191   \exp_after:wn #3 \exp_after:wn
19192   { \int_value:w \__fp_int_eval:w \c__fp_myriad_int + #1 } #2 ;
19193 }

```

(End definition for `__fp_fixed_add_one:wn`.)

`__fp_fixed_div_myriad:wn` Divide a fixed point number by 10000. This is a little bit more subtle than just removing the last group and adding a leading group of zeros: the first group `#1` may have any number of digits, and we must split `#1` into the new first group and a second group of exactly 4 digits. The choice of shifts allows `#1` to be in the range $[0, 5 \cdot 10^8 - 1]$.

```

19194 \cs_new:Npn \__fp_fixed_div_myriad:wn #1#2#3#4#5#6;
19195 {
19196   \exp_after:wn \__fp_fixed_mul_after:wnn
19197   \int_value:w \__fp_int_eval:w \c__fp_leading_shift_int
19198   \exp_after:wn \__fp_pack:NNNNnw
19199   \int_value:w \__fp_int_eval:w \c__fp_trailing_shift_int
19200   + #1 ; {#2}{#3}{#4}{#5};
19201 }

```

(End definition for `__fp_fixed_div_myriad:wn`.)

`__fp_fixed_mul_after:wnn` The fixed point operations which involve multiplication end by calling this auxiliary. It braces the last block of digits, and places the $\langle continuation \rangle$ `#3` in front.

```

19202 \cs_new:Npn \__fp_fixed_mul_after:wnn #1; #2; #3 { #3 {#1} #2; }

```

(End definition for `__fp_fixed_mul_after:wnn`.)

32.3 Multiplying a fixed point number by a short one

`_fp_fixed_mul_short:wnn`

`_fp_fixed_mul_short:wnn`
 $\{\langle a_1 \rangle\} \{\langle a_2 \rangle\} \{\langle a_3 \rangle\} \{\langle a_4 \rangle\} \{\langle a_5 \rangle\} \{\langle a_6 \rangle\}$;
 $\{\langle b_0 \rangle\} \{\langle b_1 \rangle\} \{\langle b_2 \rangle\}$; $\{\langle continuation \rangle\}$

Computes the product $c = ab$ of $a = \sum_i \langle a_i \rangle 10^{-4i}$ and $b = \sum_i \langle b_i \rangle 10^{-4i}$, rounds it to the closest multiple of 10^{-24} , and leaves $\langle continuation \rangle \{\langle c_1 \rangle\} \dots \{\langle c_6 \rangle\}$; in the input stream, where each of the $\langle c_i \rangle$ are blocks of 4 digits, except $\langle c_1 \rangle$, which is any $\text{T}_{\text{E}}\text{X}$ integer. Note that indices for $\langle b \rangle$ start at 0: for instance a second operand of $\{0001\}\{0000\}\{0000\}$ leaves the first operand unchanged (rather than dividing it by 10^4 , as `_fp_fixed_mul:wnn` would).

```

19203 \cs_new:Npn \_fp_fixed_mul_short:wnn #1#2#3#4#5#6; #7#8#9;
19204 {
19205   \exp_after:wN \_fp_fixed_mul_after:wnn
19206   \int_value:w \_fp_int_eval:w \c__fp_leading_shift_int
19207     + #1*#7
19208   \exp_after:wN \_fp_pack:NNNNNw
19209   \int_value:w \_fp_int_eval:w \c__fp_middle_shift_int
19210     + #1*#8 + #2*#7
19211   \exp_after:wN \_fp_pack:NNNNNw
19212   \int_value:w \_fp_int_eval:w \c__fp_middle_shift_int
19213     + #1*#9 + #2*#8 + #3*#7
19214   \exp_after:wN \_fp_pack:NNNNNw
19215   \int_value:w \_fp_int_eval:w \c__fp_middle_shift_int
19216     + #2*#9 + #3*#8 + #4*#7
19217   \exp_after:wN \_fp_pack:NNNNNw
19218   \int_value:w \_fp_int_eval:w \c__fp_middle_shift_int
19219     + #3*#9 + #4*#8 + #5*#7
19220   \exp_after:wN \_fp_pack:NNNNNw
19221   \int_value:w \_fp_int_eval:w \c__fp_trailing_shift_int
19222     + #4*#9 + #5*#8 + #6*#7
19223     + ( #5*#9 + #6*#8 + #6*#9 / \c__fp_myriad_int )
19224     / \c__fp_myriad_int ; ;
19225 }
```

(End definition for `_fp_fixed_mul_short:wnn`.)

32.4 Dividing a fixed point number by a small integer

`_fp_fixed_div_int:wnN`

`_fp_fixed_div_int:wnN`

`_fp_fixed_div_int_auxi:wnn`

`_fp_fixed_div_int_auxii:wnn`

`_fp_fixed_div_int_pack:Nw`

`_fp_fixed_div_int_after:Nw`

`_fp_fixed_div_int:wnN` $\langle a \rangle$; $\langle n \rangle$; $\langle continuation \rangle$

Divides the fixed point number $\langle a \rangle$ by the (small) integer $0 < \langle n \rangle < 10^4$ and feeds the result to the $\langle continuation \rangle$. There is no bound on a_1 .

The arguments of the `i` auxiliary are 1: one of the a_i , 2: n , 3: the `ii` or the `iii` auxiliary. It computes a (somewhat tight) lower bound Q_i for the ratio a_i/n .

The `ii` auxiliary receives Q_i , n , and a_i as arguments. It adds Q_i to a surrounding integer expression, and starts a new one with the initial value 9999, which ensures that the result of this expression has 5 digits. The auxiliary also computes $a_i - n \cdot Q_i$, placing the result in front of the 4 digits of a_{i+1} . The resulting $a'_{i+1} = 10^4(a_i - n \cdot Q_i) + a_{i+1}$ serves as the first argument for a new call to the `i` auxiliary.

When the `iii` auxiliary is called, the situation looks like this:


```

\__fp_fixed_div_int_after:Nw <continuation>
-1 + Q1
\__fp_fixed_div_int_pack:Nw 9999 + Q2
\__fp_fixed_div_int_pack:Nw 9999 + Q3
\__fp_fixed_div_int_pack:Nw 9999 + Q4
\__fp_fixed_div_int_pack:Nw 9999 + Q5
\__fp_fixed_div_int_pack:Nw 9999
\__fp_fixed_div_int_auxii:wnn Q6 ; {<n>} {<a6>}

```

where expansion is happening from the last line up. The `iii` auxiliary adds $Q_6 + 2 \simeq a_6/n + 1$ to the last 9999, giving the integer closest to $10000 + a_6/n$.

Each `pack` auxiliary receives 5 digits followed by a semicolon. The first digit is added as a carry to the integer expression above, and the 4 other digits are braced. Each call to the `pack` auxiliary thus produces one brace group. The last brace group is produced by the `after` auxiliary, which places the `<continuation>` as appropriate.

```

19226 \cs_new:Npn \__fp_fixed_div_int:wwN #1#2#3#4#5#6 ; #7 ; #8
19227 {
19228   \exp_after:wN \__fp_fixed_div_int_after:Nw
19229   \exp_after:wN #8
19230   \int_value:w \__fp_int_eval:w - 1
19231   \__fp_fixed_div_int:wnN
19232   #1; {#7} \__fp_fixed_div_int_auxi:wnn
19233   #2; {#7} \__fp_fixed_div_int_auxi:wnn
19234   #3; {#7} \__fp_fixed_div_int_auxi:wnn
19235   #4; {#7} \__fp_fixed_div_int_auxi:wnn
19236   #5; {#7} \__fp_fixed_div_int_auxi:wnn
19237   #6; {#7} \__fp_fixed_div_int_auxii:wnn ;
19238 }
19239 \cs_new:Npn \__fp_fixed_div_int:wnN #1; #2 #3
19240 {
19241   \exp_after:wN #3
19242   \int_value:w \__fp_int_eval:w #1 / #2 - 1 ;
19243   {#2}
19244   {#1}
19245 }
19246 \cs_new:Npn \__fp_fixed_div_int_auxi:wnn #1; #2 #3
19247 {
19248   + #1
19249   \exp_after:wN \__fp_fixed_div_int_pack:Nw
19250   \int_value:w \__fp_int_eval:w 9999
19251   \exp_after:wN \__fp_fixed_div_int:wnN
19252   \int_value:w \__fp_int_eval:w #3 - #1*#2 \__fp_int_eval_end:
19253 }
19254 \cs_new:Npn \__fp_fixed_div_int_auxii:wnn #1; #2 #3 { + #1 + 2 ; }
19255 \cs_new:Npn \__fp_fixed_div_int_pack:Nw #1 #2; { + #1; {#2} }
19256 \cs_new:Npn \__fp_fixed_div_int_after:Nw #1 #2; { #1 {#2} }

```

(End definition for `__fp_fixed_div_int:wwN` and others.)

32.5 Adding and subtracting fixed points

```

\__fp_fixed_add:wnn          \__fp_fixed_add:wnn <a> ; <b> ; {<continuation>}
\__fp_fixed_sub:wnn
\__fp_fixed_add:Nnnnnwnn
\__fp_fixed_add:nnNnnnwn
\__fp_fixed_add_pack:NNNNNwn
\__fp_fixed_add_after:NNNNNwn

```

Computes $a+b$ (resp. $a-b$) and feeds the result to the $\langle continuation \rangle$. This function requires $0 \leq a_1, b_1 \leq 114748$, its result must be positive (this happens automatically for addition) and its first group must have at most 5 digits: $(a \pm b)_1 < 100000$. The two functions only differ by a sign, hence use a common auxiliary. It would be nice to grab the 12 brace groups in one go; only 9 parameters are allowed. Start by grabbing the sign, a_1, \dots, a_4 , the rest of a , and b_1 and b_2 . The second auxiliary receives the rest of a , the sign multiplying b , the rest of b , and the $\langle continuation \rangle$ as arguments. After going down through the various level, we go back up, packing digits and bringing the $\langle continuation \rangle$ (#8, then #7) from the end of the argument list to its start.

```

19257 \cs_new:Npn \__fp_fixed_add:wnn { \__fp_fixed_add:Nnnnnwnn + }
19258 \cs_new:Npn \__fp_fixed_sub:wnn { \__fp_fixed_add:Nnnnnwnn - }
19259 \cs_new:Npn \__fp_fixed_add:Nnnnnwnn #1 #2#3#4#5 #6; #7#8
19260 {
19261   \exp_after:wN \__fp_fixed_add_after:NNNNNwn
19262   \int_value:w \__fp_int_eval:w 9 9999 9998 + #2#3 #1 #7#8
19263   \exp_after:wN \__fp_fixed_add_pack:NNNNNwn
19264   \int_value:w \__fp_int_eval:w 1 9999 9998 + #4#5
19265   \__fp_fixed_add:nnNnnwn #6 #1
19266 }
19267 \cs_new:Npn \__fp_fixed_add:nnNnnwn #1#2 #3 #4#5 #6#7 ; #8
19268 {
19269   #3 #4#5
19270   \exp_after:wN \__fp_fixed_add_pack:NNNNNwn
19271   \int_value:w \__fp_int_eval:w 2 0000 0000 #3 #6#7 + #1#2 ; {#8} ;
19272 }
19273 \cs_new:Npn \__fp_fixed_add_pack:NNNNNwn #1 #2#3#4#5 #6; #7
19274 { + #1 ; {#7} {#2#3#4#5} {#6} }
19275 \cs_new:Npn \__fp_fixed_add_after:NNNNNwn 1 #1 #2#3#4#5 #6; #7
19276 { #7 {#1#2#3#4#5} {#6} }

```

(End definition for $\backslash_fp_fixed_add:wnn$ and others.)

32.6 Multiplying fixed points

```

\__fp_fixed_mul:wnn
\__fp_fixed_mul:nnnnnnnw

```

Computes $a \times b$ and feeds the result to $\langle continuation \rangle$. This function requires $0 \leq a_1, b_1 < 10000$. Once more, we need to play around the limit of 9 arguments for \TeX macros. Note that we don't need to obtain an exact rounding, contrarily to the $*$ operator, so things could be harder. We wish to perform carries in

$$\begin{aligned}
a \times b = & a_1 \cdot b_1 \cdot 10^{-8} \\
& + (a_1 \cdot b_2 + a_2 \cdot b_1) \cdot 10^{-12} \\
& + (a_1 \cdot b_3 + a_2 \cdot b_2 + a_3 \cdot b_1) \cdot 10^{-16} \\
& + (a_1 \cdot b_4 + a_2 \cdot b_3 + a_3 \cdot b_2 + a_4 \cdot b_1) \cdot 10^{-20} \\
& + \left(a_2 \cdot b_4 + a_3 \cdot b_3 + a_4 \cdot b_2 \right. \\
& \quad \left. + \frac{a_3 \cdot b_4 + a_4 \cdot b_3 + a_1 \cdot b_6 + a_2 \cdot b_5 + a_5 \cdot b_2 + a_6 \cdot b_1}{10^4} \right. \\
& \quad \left. + a_1 \cdot b_5 + a_5 \cdot b_1 \right) \cdot 10^{-24} + O(10^{-24}),
\end{aligned}$$

where the $O(10^{-24})$ stands for terms which are at most $5 \cdot 10^{-24}$; ignoring those leads to an error of at most 5 ulp. Note how the first 15 terms only depend on a_1, \dots, a_4 and b_1, \dots, b_4 , while the last 6 terms only depend on a_1, a_2, a_5, a_6 , and the corresponding parts of b . Hence, the first function grabs a_1, \dots, a_4 , the rest of a , and b_1, \dots, b_4 , and writes the 15 first terms of the expression, including a left parenthesis for the fraction. The `i` auxiliary receives $a_5, a_6, b_1, b_2, a_1, a_2, b_5, b_6$ and finally the $\langle continuation \rangle$ as arguments. It writes the end of the expression, including the right parenthesis and the denominator of the fraction. The $\langle continuation \rangle$ is finally placed in front of the 6 brace groups by `_fp_fixed_mul_after:wwn`.

```

19277 \cs_new:Npn \_fp\_fixed\_mul:wwn #1#2#3#4 #5; #6#7#8#9
19278 {
19279   \exp\_after:wN \_fp\_fixed\_mul\_after:wwn
19280   \int\_value:w \_fp\_int\_eval:w \c\_fp\_leading\_shift\_int
19281   \exp\_after:wN \_fp\_pack:NNNNNw
19282   \int\_value:w \_fp\_int\_eval:w \c\_fp\_middle\_shift\_int
19283   + #1*#6
19284   \exp\_after:wN \_fp\_pack:NNNNNw
19285   \int\_value:w \_fp\_int\_eval:w \c\_fp\_middle\_shift\_int
19286   + #1*#7 + #2*#6
19287   \exp\_after:wN \_fp\_pack:NNNNNw
19288   \int\_value:w \_fp\_int\_eval:w \c\_fp\_middle\_shift\_int
19289   + #1*#8 + #2*#7 + #3*#6
19290   \exp\_after:wN \_fp\_pack:NNNNNw
19291   \int\_value:w \_fp\_int\_eval:w \c\_fp\_middle\_shift\_int
19292   + #1*#9 + #2*#8 + #3*#7 + #4*#6
19293   \exp\_after:wN \_fp\_pack:NNNNNw
19294   \int\_value:w \_fp\_int\_eval:w \c\_fp\_trailing\_shift\_int
19295   + #2*#9 + #3*#8 + #4*#7
19296   + ( #3*#9 + #4*#8
19297     + \_fp\_fixed\_mul:nnnnnnnw #5 {#6}{#7} {#1}{#2}
19298   )
19299 \cs_new:Npn \_fp\_fixed\_mul:nnnnnnnw #1#2 #3#4 #5#6 #7#8 ;
19300 {
19301   #1*#4 + #2*#3 + #5*#8 + #6*#7 ) / \c\_fp\_myriad\_int
19302   + #1*#3 + #5*#7 ; ;
19303 }
```

(End definition for `_fp_fixed_mul:wwn` and `_fp_fixed_mul:nnnnnnnw`.)

32.7 Combining product and sum of fixed points

```

\_fp\_fixed\_mul\_add:wwwn <a> ; <b> ; <c> ; {<continuation>}
\_fp\_fixed\_mul\_sub\_back:wwwn <a> ; <b> ; <c> ; {<continuation>}
\_fp\_fixed\_one\_minus\_mul:wwn <a> ; <b> ; {<continuation>}
\_fp\_fixed\_mul\_one\_minus\_mul:wwn
```

Sometimes called FMA (fused multiply-add), these functions compute $a \times b + c$, $c - a \times b$, and $1 - a \times b$ and feed the result to the $\langle continuation \rangle$. Those functions require $0 \leq a_1, b_1, c_1 \leq 10000$. Since those functions are at the heart of the computation of Taylor expansions, we over-optimize them a bit, and in particular we do not factor out the common parts of the three functions.

For definiteness, consider the task of computing $a \times b + c$. We perform carries in

$$\begin{aligned}
a \times b + c = & (a_1 \cdot b_1 + c_1 c_2) \cdot 10^{-8} \\
& + (a_1 \cdot b_2 + a_2 \cdot b_1) \cdot 10^{-12} \\
& + (a_1 \cdot b_3 + a_2 \cdot b_2 + a_3 \cdot b_1 + c_3 c_4) \cdot 10^{-16} \\
& + (a_1 \cdot b_4 + a_2 \cdot b_3 + a_3 \cdot b_2 + a_4 \cdot b_1) \cdot 10^{-20} \\
& + \left(a_2 \cdot b_4 + a_3 \cdot b_3 + a_4 \cdot b_2 \right. \\
& \quad \left. + \frac{a_3 \cdot b_4 + a_4 \cdot b_3 + a_1 \cdot b_6 + a_2 \cdot b_5 + a_5 \cdot b_2 + a_6 \cdot b_1}{10^4} \right. \\
& \quad \left. + a_1 \cdot b_5 + a_5 \cdot b_1 + c_5 c_6 \right) \cdot 10^{-24} + O(10^{-24}),
\end{aligned}$$

where $c_1 c_2$, $c_3 c_4$, $c_5 c_6$ denote the 8-digit number obtained by juxtaposing the two blocks of digits of c , and \cdot denotes multiplication. The task is obviously tough because we have 18 brace groups in front of us.

Each of the three function starts the first two levels (the first, corresponding to 10^{-4} , is empty), with $c_1 c_2$ in the first level, calls the `i` auxiliary with arguments described later, and adds a trailing $+ c_5 c_6$; $\{\langle continuation \rangle\}$; . The $+ c_5 c_6$ piece, which is omitted for `_fp_fixed_one_minus_mul:wwn`, is taken in the integer expression for the 10^{-24} level.

```

19304 \cs_new:Npn \_fp\_fixed\_mul\_add:wwn #1; #2; #3#4#5#6#7#8;
19305 {
19306   \exp\_after:wN \_fp\_fixed\_mul\_after:wwn
19307   \int\_value:w \_fp\_int\_eval:w \c\_fp\_big\_leading\_shift\_int
19308   \exp\_after:wN \_fp\_pack\_big:NNNNNNw
19309   \int\_value:w \_fp\_int\_eval:w \c\_fp\_big\_middle\_shift\_int + #3 #4
19310   \_fp\_fixed\_mul\_add:Nwnnnwnnn +
19311   + #5 #6 ; #2 ; #1 ; #2 ; +
19312   + #7 #8 ; ;
19313 }
19314 \cs_new:Npn \_fp\_fixed\_mul\_sub\_back:wwn #1; #2; #3#4#5#6#7#8;
19315 {
19316   \exp\_after:wN \_fp\_fixed\_mul\_after:wwn
19317   \int\_value:w \_fp\_int\_eval:w \c\_fp\_big\_leading\_shift\_int
19318   \exp\_after:wN \_fp\_pack\_big:NNNNNNw
19319   \int\_value:w \_fp\_int\_eval:w \c\_fp\_big\_middle\_shift\_int + #3 #4
19320   \_fp\_fixed\_mul\_add:Nwnnnwnnn -
19321   + #5 #6 ; #2 ; #1 ; #2 ; -
19322   + #7 #8 ; ;
19323 }
19324 \cs_new:Npn \_fp\_fixed\_one\_minus\_mul:wwn #1; #2;
19325 {
19326   \exp\_after:wN \_fp\_fixed\_mul\_after:wwn
19327   \int\_value:w \_fp\_int\_eval:w \c\_fp\_big\_leading\_shift\_int
19328   \exp\_after:wN \_fp\_pack\_big:NNNNNNw
19329   \int\_value:w \_fp\_int\_eval:w \c\_fp\_big\_middle\_shift\_int +
19330   1 0000 0000
19331   \_fp\_fixed\_mul\_add:Nwnnnwnnn -
19332   ; #2 ; #1 ; #2 ; -
19333   ; ;
19334 }

```

(End definition for `_fp_fixed_mul_add:www`, `_fp_fixed_mul_sub_back:www`, and `_fp_fixed_mul_one_minus_mul:wn`.)

`_fp_fixed_mul_add:Nwnnnwnnn` $\langle op \rangle + \langle c_3 \rangle \langle c_4 \rangle ;$
 $\langle b \rangle ; \langle a \rangle ; \langle b \rangle ; \langle op \rangle$
 $+ \langle c_5 \rangle \langle c_6 \rangle ;$

Here, $\langle op \rangle$ is either $+$ or $-$. Arguments #3, #4, #5 are $\langle b_1 \rangle, \langle b_2 \rangle, \langle b_3 \rangle$; arguments #7, #8, #9 are $\langle a_1 \rangle, \langle a_2 \rangle, \langle a_3 \rangle$. We can build three levels: $a_1 \cdot b_1$ for 10^{-8} , $(a_1 \cdot b_2 + a_2 \cdot b_1)$ for 10^{-12} , and $(a_1 \cdot b_3 + a_2 \cdot b_2 + a_3 \cdot b_1 + c_3 c_4)$ for 10^{-16} . The $a-b$ products use the sign #1. Note that #2 is empty for `_fp_fixed_one_minus_mul:wn`. We call the *ii* auxiliary for levels 10^{-20} and 10^{-24} , keeping the pieces of $\langle a \rangle$ we've read, but not $\langle b \rangle$, since there is another copy later in the input stream.

```
19335 \cs_new:Npn \_fp\_fixed\_mul\_add:Nwnnnwnnn #1 #2; #3#4#5#6; #7#8#9
19336 {
19337   #1 #7*#3
19338   \exp_after:wN \_fp\_pack\_big:NNNNNNw
19339   \int_value:w \_fp\_int\_eval:w \c\_fp\_big\_middle\_shift\_int
19340   #1 #7*#4 #1 #8*#3
19341   \exp_after:wN \_fp\_pack\_big:NNNNNNw
19342   \int_value:w \_fp\_int\_eval:w \c\_fp\_big\_middle\_shift\_int
19343   #1 #7*#5 #1 #8*#4 #1 #9*#3 #2
19344   \exp_after:wN \_fp\_pack\_big:NNNNNNw
19345   \int_value:w \_fp\_int\_eval:w \c\_fp\_big\_middle\_shift\_int
19346   #1 \_fp\_fixed\_mul\_add:nnnnwnnn {#7}{#8}{#9}
19347 }
```

(End definition for `_fp_fixed_mul_add:Nwnnnwnnn`.)

`_fp_fixed_mul_add:nnnnwnnn` $\langle a \rangle ; \langle b \rangle ; \langle op \rangle$
 $+ \langle c_5 \rangle \langle c_6 \rangle ;$

Level 10^{-20} is $(a_1 \cdot b_4 + a_2 \cdot b_3 + a_3 \cdot b_2 + a_4 \cdot b_1)$, multiplied by the sign, which was inserted by the *i* auxiliary. Then we prepare level 10^{-24} . We don't have access to all parts of $\langle a \rangle$ and $\langle b \rangle$ needed to make all products. Instead, we prepare the partial expressions

$$b_1 + a_4 \cdot b_2 + a_3 \cdot b_3 + a_2 \cdot b_4 + a_1$$

$$b_2 + a_4 \cdot b_3 + a_3 \cdot b_4 + a_2.$$

Obviously, those expressions make no mathematical sense: we complete them with $a_5 \cdot$ and $\cdot b_5$, and with $a_6 \cdot b_1 + a_5 \cdot$ and $\cdot b_5 + a_1 \cdot b_6$, and of course with the trailing $+ c_5 c_6$. To do all this, we keep a_1, a_5, a_6 , and the corresponding pieces of $\langle b \rangle$.

```
19348 \cs_new:Npn \_fp\_fixed\_mul\_add:nnnnwnnn #1#2#3#4#5; #6#7#8#9
19349 {
19350   ( #1*#9 + #2*#8 + #3*#7 + #4*#6 )
19351   \exp_after:wN \_fp\_pack\_big:NNNNNNw
19352   \int_value:w \_fp\_int\_eval:w \c\_fp\_big\_trailing\_shift\_int
19353   \_fp\_fixed\_mul\_add:nnnnwnnnwN
19354   { #6 + #4*#7 + #3*#8 + #2*#9 + #1 }
19355   { #7 + #4*#8 + #3*#9 + #2 }
19356   {#1} #5;
19357   {#6}
19358 }
```

(End definition for `_fp_fixed_mul_add:nnnnwnnnn`.)

```

\_fp_fixed_mul_add:nnnnwnnnN
    \_fp_fixed_mul_add:nnnnwnnnN {<partial1>} {<partial2>}
    {<a1>} {<a5>} {<a6>} ; {<b1>} {<b5>} {<b6>} ;
    <op> + <c5> <c6> ;

```

Complete the $\langle partial_1 \rangle$ and $\langle partial_2 \rangle$ expressions as explained for the `ii` auxiliary. The second one is divided by 10000: this is the carry from level 10^{-28} . The trailing $+c_5c_6$ is taken into the expression for level 10^{-24} . Note that the total of level 10^{-24} is in the interval $[-5 \cdot 10^8, 6 \cdot 10^8]$ (give or take a couple of 10000), hence adding it to the shift gives a 10-digit number, as expected by the packing auxiliaries. See `l3fp-aux` for the definition of the shifts and packing auxiliaries.

```

19359 \cs_new:Npn \_fp_fixed_mul_add:nnnnwnnnN #1#2 #3#4#5; #6#7#8; #9
19360 {
19361     #9 (#4* #1 *#7)
19362     #9 (#5*#6+#4* #2 *#7+#3*#8) / \c__fp_myriad_int
19363 }

```

(End definition for `_fp_fixed_mul_add:nnnnwnnnN`.)

32.8 Extended-precision floating point numbers

In this section we manipulate floating point numbers with roughly 24 significant figures (“extended-precision” numbers, in short, “ep”), which take the form of an integer exponent, followed by a comma, then six groups of digits, ending with a semicolon. The first group of digit may be any non-negative integer, while other groups of digits have 4 digits. In other words, an extended-precision number is an exponent ending in a comma, then a fixed point number. The corresponding value is $0.\langle digits \rangle \cdot 10^{\langle exponent \rangle}$. This convention differs from floating points.

```

\_fp_ep_to_fixed:wnn
\_fp_ep_to_fixed_auxi:www
\_fp_ep_to_fixed_auxii:nnnnnnwnn

```

Converts an extended-precision number with an exponent at most 4 and a first block less than 10^8 to a fixed point number whose first block has 12 digits, hopefully starting with many zeros.

```

19364 \cs_new:Npn \_fp_ep_to_fixed:wnn #1,#2
19365 {
19366     \exp_after:wN \_fp_ep_to_fixed_auxi:www
19367     \int_value:w \_fp_int_eval:w 1 0000 0000 + #2 \exp_after:wN ;
19368     \exp:w \exp_end_continue_f:w
19369     \prg_replicate:nn { 4 - \int_max:nn {#1} { -32 } } { 0 } ;
19370 }
19371 \cs_new:Npn \_fp_ep_to_fixed_auxi:www 1#1; #2; #3#4#5#6#7;
19372 {
19373     \_fp_pack_eight:wNNNNNNNN
19374     \_fp_pack_twice_four:wNNNNNNNN
19375     \_fp_pack_twice_four:wNNNNNNNN
19376     \_fp_pack_twice_four:wNNNNNNNN
19377     \_fp_ep_to_fixed_auxii:nnnnnnwnn ;
19378     #2 #1#3#4#5#6#7 0000 !
19379 }
19380 \cs_new:Npn \_fp_ep_to_fixed_auxii:nnnnnnwnn #1#2#3#4#5#6#7; #8! #9
19381 { #9 {#1#2}{#3}{#4}{#5}{#6}{#7}; }

```

(End definition for `_fp_ep_to_fixed:wnn`, `_fp_ep_to_fixed_auxi:www`, and `_fp_ep_to_fixed_auxii:nnnnnnwnn`.)

```

\__fp_ep_to_ep:wwN
\__fp_ep_to_ep_loop:N
\__fp_ep_to_ep_end:www
\__fp_ep_to_ep_zero:ww

```

Normalize an extended-precision number. More precisely, leading zeros are removed from the mantissa of the argument, decreasing its exponent as appropriate. Then the digits are packed into 6 groups of 4 (discarding any remaining digit, not rounding). Finally, the continuation #8 is placed before the resulting exponent-mantissa pair. The input exponent may in fact be given as an integer expression. The `loop` auxiliary grabs a digit: if it is 0, decrement the exponent and continue looping, and otherwise call the `end` auxiliary, which places all digits in the right order (the digit that was not 0, and any remaining digits), followed by some 0, then packs them up neatly in $3 \times 2 = 6$ blocks of four. At the end of the day, remove with `__fp_use_i:ww` any digit that did not make it in the final mantissa (typically only zeros, unless the original first block has more than 4 digits).

```

19382 \cs_new:Npn \__fp_ep_to_ep:wwN #1,#2#3#4#5#6#7; #8
19383 {
19384   \exp_after:wN #8
19385   \int_value:w \__fp_int_eval:w #1 + 4
19386   \exp_after:wN \use_i:nn
19387   \exp_after:wN \__fp_ep_to_ep_loop:N
19388   \int_value:w \__fp_int_eval:w 1 0000 0000 + #2 \__fp_int_eval_end:
19389   #3#4#5#6#7 ; ; !
19390 }
19391 \cs_new:Npn \__fp_ep_to_ep_loop:N #1
19392 {
19393   \if_meaning:w 0 #1
19394   - 1
19395   \else:
19396     \__fp_ep_to_ep_end:www #1
19397   \fi:
19398   \__fp_ep_to_ep_loop:N
19399 }
19400 \cs_new:Npn \__fp_ep_to_ep_end:www
19401   #1 \fi: \__fp_ep_to_ep_loop:N #2; #3!
19402 {
19403   \fi:
19404   \if_meaning:w ; #1
19405   - 2 * \c__fp_max_exponent_int
19406   \__fp_ep_to_ep_zero:ww
19407   \fi:
19408   \__fp_pack_twice_four:wNNNNNNNN
19409   \__fp_pack_twice_four:wNNNNNNNN
19410   \__fp_pack_twice_four:wNNNNNNNN
19411   \__fp_use_i:ww , ;
19412   #1 #2 0000 0000 0000 0000 0000 0000 ;
19413 }
19414 \cs_new:Npn \__fp_ep_to_ep_zero:ww \fi: #1; #2; #3;
19415 { \fi: , {1000}{0000}{0000}{0000}{0000}{0000} ; }

```

(End definition for `__fp_ep_to_ep:wwN` and others.)

```

\__fp_ep_compare:www
\__fp_ep_compare_aux:www

```

In `l3fp-trig` we need to compare two extended-precision numbers. This is based on the same function for positive floating point numbers, with an extra test if comparing only 16 decimals is not enough to distinguish the numbers. Note that this function only works if the numbers are normalized so that their first block is in `[1000,9999]`.

```

19416 \cs_new:Npn \__fp_ep_compare:www #1,#2#3#4#5#6#7;

```

```

19417 { \_fp_ep_compare_aux:www {#1}{#2}{#3}{#4}{#5}; #6#7; }
19418 \cs_new:Npn \_fp_ep_compare_aux:www #1;#2;#3,#4#5#6#7#8#9;
19419 {
19420   \if_case:w
19421     \_fp_compare_npos:nwnw #1; {#3}{#4}{#5}{#6}{#7}; \exp_stop_f:
19422     \if_int_compare:w #2 = #8#9 \exp_stop_f:
19423       0
19424     \else:
19425       \if_int_compare:w #2 < #8#9 - \fi: 1
19426     \fi:
19427   \or: 1
19428   \else: -1
19429   \fi:
19430 }

```

(End definition for _fp_ep_compare:www and _fp_ep_compare_aux:www.)

_fp_ep_mul:wwwN
_fp_ep_mul_raw:wwwN

Multiply two extended-precision numbers: first normalize them to avoid losing too much precision, then multiply the mantissas #2 and #4 as fixed point numbers, and sum the exponents #1 and #3. The result's first block is in [100,9999].

```

19431 \cs_new:Npn \_fp_ep_mul:wwwN #1,#2; #3,#4;
19432 {
19433   \_fp_ep_to_ep:wwN #3,#4;
19434   \_fp_fixed_continue:wn
19435   {
19436     \_fp_ep_to_ep:wwN #1,#2;
19437     \_fp_ep_mul_raw:wwwN
19438   }
19439   \_fp_fixed_continue:wn
19440 }
19441 \cs_new:Npn \_fp_ep_mul_raw:wwwN #1,#2; #3,#4; #5
19442 {
19443   \_fp_fixed_mul:wn #2; #4;
19444   { \exp_after:wN #5 \int_value:w \_fp_int_eval:w #1 + #3 , }
19445 }

```

(End definition for _fp_ep_mul:wwwN and _fp_ep_mul_raw:wwwN.)

32.9 Dividing extended-precision numbers

Divisions of extended-precision numbers are difficult to perform with exact rounding: the technique used in `l3fp-basics` for 16-digit floating point numbers does not generalize easily to 24-digit numbers. Thankfully, there is no need for exact rounding.

Let us call $\langle n \rangle$ the numerator and $\langle d \rangle$ the denominator. After a simple normalization step, we can assume that $\langle n \rangle \in [0.1, 1)$ and $\langle d \rangle \in [0.1, 1)$, and compute $\langle n \rangle / (10 \langle d \rangle) \in (0.01, 1)$. In terms of the 6 blocks of digits $\langle n_1 \rangle \cdots \langle n_6 \rangle$ and the 6 blocks $\langle d_1 \rangle \cdots \langle d_6 \rangle$, the condition translates to $\langle n_1 \rangle, \langle d_1 \rangle \in [1000, 9999]$.

We first find an integer estimate $a \simeq 10^8/\langle d \rangle$ by computing

$$\begin{aligned}\alpha &= \left\lceil \frac{10^9}{\langle d_1 \rangle + 1} \right\rceil \\ \beta &= \left\lfloor \frac{10^9}{\langle d_1 \rangle} \right\rfloor \\ a &= 10^3\alpha + (\beta - \alpha) \cdot \left(10^3 - \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor \right) - 1250,\end{aligned}$$

where $\left\lceil \cdot \right\rceil$ denotes ε -TEX's rounding division, which rounds ties away from zero. The idea is to interpolate between $10^3\alpha$ and $10^3\beta$ with a parameter $\langle d_2 \rangle/10^4$, so that when $\langle d_2 \rangle = 0$ one gets $a = 10^3\beta - 1250 \simeq 10^{12}/\langle d_1 \rangle \simeq 10^8/\langle d \rangle$, while when $\langle d_2 \rangle = 9999$ one gets $a = 10^3\alpha - 1250 \simeq 10^{12}/(\langle d_1 \rangle + 1) \simeq 10^8/\langle d \rangle$. The shift by 1250 helps to ensure that a is an underestimate of the correct value. We shall prove that

$$1 - 1.755 \cdot 10^{-5} < \frac{\langle d \rangle a}{10^8} < 1.$$

We can then compute the inverse of $\langle d \rangle a/10^8 = 1 - \epsilon$ using the relation $1/(1 - \epsilon) \simeq (1 + \epsilon)(1 + \epsilon^2) + \epsilon^4$, which is correct up to a relative error of $\epsilon^5 < 1.6 \cdot 10^{-24}$. This allows us to find the desired ratio as

$$\frac{\langle n \rangle}{\langle d \rangle} = \frac{\langle n \rangle a}{10^8} ((1 + \epsilon)(1 + \epsilon^2) + \epsilon^4).$$

Let us prove the upper bound first (multiplied by 10^{15}). Note that $10^7\langle d \rangle < 10^3\langle d_1 \rangle + 10^{-1}(\langle d_2 \rangle + 1)$, and that ε -TEX's division $\left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor$ underestimates $10^{-1}(\langle d_2 \rangle + 1)$ by 0.5 at most, as can be checked for each possible last digit of $\langle d_2 \rangle$. Then,

$$10^7\langle d \rangle a < \left(10^3\langle d_1 \rangle + \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor + \frac{1}{2} \right) \left(\left(10^3 - \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor \right) \beta + \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor \alpha - 1250 \right) \quad (1)$$

$$< \left(10^3\langle d_1 \rangle + \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor + \frac{1}{2} \right) \quad (2)$$

$$\left(\left(10^3 - \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor \right) \left(\frac{10^9}{\langle d_1 \rangle} + \frac{1}{2} \right) + \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor \left(\frac{10^9}{\langle d_1 \rangle + 1} + \frac{1}{2} \right) - 1250 \right) \quad (3)$$

$$< \left(10^3\langle d_1 \rangle + \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor + \frac{1}{2} \right) \left(\frac{10^{12}}{\langle d_1 \rangle} - \left\lfloor \frac{\langle d_2 \rangle}{10} \right\rfloor \frac{10^9}{\langle d_1 \rangle(\langle d_1 \rangle + 1)} - 750 \right) \quad (4)$$

We recognize a quadratic polynomial in $[\langle d_2 \rangle/10]$ with a negative leading coefficient: this polynomial is bounded above, according to $([\langle d_2 \rangle/10] + a)(b - c[\langle d_2 \rangle/10]) \leq (b + ca)^2/(4c)$. Hence,

$$10^7\langle d \rangle a < \frac{10^{15}}{\langle d_1 \rangle(\langle d_1 \rangle + 1)} \left(\langle d_1 \rangle + \frac{1}{2} + \frac{1}{4}10^{-3} - \frac{3}{8} \cdot 10^{-9}\langle d_1 \rangle(\langle d_1 \rangle + 1) \right)^2$$

Since $\langle d_1 \rangle$ takes integer values within $[1000, 9999]$, it is a simple programming exercise to check that the squared expression is always less than $\langle d_1 \rangle(\langle d_1 \rangle + 1)$, hence $10^7\langle d \rangle a < 10^{15}$. The upper bound is proven. We also find that $\frac{3}{8}$ can be replaced by slightly smaller numbers, but nothing less than $0.374563\dots$, and going back through the derivation of

the upper bound, we find that 1250 is as small a shift as we can obtain without breaking the bound.

Now, the lower bound. The same computation as for the upper bound implies

$$10^7 \langle d \rangle a > \left(10^3 \langle d_1 \rangle + \left\lceil \frac{\langle d_2 \rangle}{10} \right\rceil - \frac{1}{2} \right) \left(\frac{10^{12}}{\langle d_1 \rangle} - \left\lceil \frac{\langle d_2 \rangle}{10} \right\rceil \frac{10^9}{\langle d_1 \rangle (\langle d_1 \rangle + 1)} - 1750 \right)$$

This time, we want to find the minimum of this quadratic polynomial. Since the leading coefficient is still negative, the minimum is reached for one of the extreme values $[y/10] = 0$ or $[y/10] = 100$, and we easily check the bound for those values.

We have proven that the algorithm gives us a precise enough answer. Incidentally, the upper bound that we derived tells us that $a < 10^8 / \langle d \rangle \leq 10^9$, hence we can compute a safely as a $\text{T}_{\text{E}}\text{X}$ integer, and even add 10^9 to it to ease grabbing of all the digits. The lower bound implies $10^8 - 1755 < a$, which we do not care about.

`__fp_ep_div:wwwn` Compute the ratio of two extended-precision numbers. The result is an extended-precision number whose first block lies in the range $[100, 9999]$, and is placed after the $\langle continuation \rangle$ once we are done. First normalize the inputs so that both first block lie in $[1000, 9999]$, then call `__fp_ep_div_esti:wwwn` $\langle denominator \rangle$ $\langle numerator \rangle$, responsible for estimating the inverse of the denominator.

```

19446 \cs_new:Npn \__fp_ep_div:wwwn #1,#2; #3,#4;
19447 {
19448   \__fp_ep_to_ep:wwN #1,#2;
19449   \__fp_fixed_continue:wn
19450   {
19451     \__fp_ep_to_ep:wwN #3,#4;
19452     \__fp_ep_div_esti:wwwn
19453   }
19454 }
```

(End definition for `__fp_ep_div:wwwn`.)

`__fp_ep_div_esti:wwwn` The `esti` function evaluates $\alpha = 10^9 / (\langle d_1 \rangle + 1)$, which is used twice in the expression for a , and combines the exponents `#1` and `#4` (with a shift by 1 because we later compute $\langle n \rangle / (10 \langle d \rangle)$). Then the `estii` function evaluates $10^9 + a$, and puts the exponent `#2` after the continuation `#7`: from there on we can forget exponents and focus on the mantissa. The `estiii` function multiplies the denominator `#7` by $10^{-8}a$ (obtained as a split into the single digit `#1` and two blocks of 4 digits, `#2#3#4#5` and `#6`). The result $10^{-8}a \langle d \rangle = (1 - \epsilon)$, and a partially packed $10^{-9}a$ (as a block of four digits, and five individual digits, not packed by lack of available macro parameters here) are passed to `__fp_ep_div_epsilon:wnNNNNn`, which computes $10^{-9}a / (1 - \epsilon)$, that is, $1 / (10 \langle d \rangle)$ and we finally multiply this by the numerator `#8`.

```

19455 \cs_new:Npn \__fp_ep_div_esti:wwwn #1,#2#3; #4,
19456 {
19457   \exp_after:wN \__fp_ep_div_estii:wwnnwwn
19458   \int_value:w \__fp_int_eval:w 10 0000 0000 / ( #2 + 1 )
19459   \exp_after:wN ;
19460   \int_value:w \__fp_int_eval:w #4 - #1 + 1 ,
19461   {#2} #3;
19462 }
19463 \cs_new:Npn \__fp_ep_div_estii:wwnnwwn #1; #2,#3#4#5; #6; #7
19464 {
```

```

19465 \exp_after:wN \_fp_ep_div_estiii:NNNNNwwwn
19466 \int_value:w \_fp_int_eval:w 10 0000 0000 - 1750
19467 + #1 000 + (10 0000 0000 / #3 - #1) * (1000 - #4 / 10) ;
19468 {#3}{#4}#5; #6; { #7 #2, }
19469 }
19470 \cs_new:Npn \_fp_ep_div_estiii:NNNNNwwwn 1#1#2#3#4#5#6; #7;
19471 {
19472 \_fp_fixed_mul_short:wwn #7; {#1}{#2#3#4#5}{#6};
19473 \_fp_ep_div_epsilon:wnNNNNNn {#1#2#3#4}#5#6
19474 \_fp_fixed_mul:wwn
19475 }

```

(End definition for `_fp_ep_div_esti:wwwwn`, `_fp_ep_div_estii:wwnnwwn`, and `_fp_ep_div_estiii:NNNNNwwwn`.)

`_fp_ep_div_epsilon:wnNNNNNn`
`_fp_ep_div_eps_pack:NNNNNw`
`_fp_ep_div_epsilonii:wwnnNNNNNn`

The bounds shown above imply that the `epsi` function's first operand is $(1 - \epsilon)$ with $\epsilon \in [0, 1.755 \cdot 10^{-5}]$. The `epsi` function computes ϵ as $1 - (1 - \epsilon)$. Since $\epsilon < 10^{-4}$, its first block vanishes and there is no need to explicitly use `#1` (which is 9999). Then `epsii` evaluates $10^{-9}a/(1 - \epsilon)$ as $(1 + \epsilon^2)(1 + \epsilon)(10^{-9}a\epsilon) + 10^{-9}a$. Importantly, we compute $10^{-9}a\epsilon$ before multiplying it with the rest, rather than multiplying by ϵ and then $10^{-9}a$, as this second option loses more precision. Also, the combination of `short_mul` and `div_myriad` is both faster and more precise than a simple `mul`.

```

19476 \cs_new:Npn \_fp_ep_div_epsilon:wnNNNNNn 1#1#2#3#4#5#6;
19477 {
19478 \exp_after:wN \_fp_ep_div_epsilonii:wwnnNNNNNn
19479 \int_value:w \_fp_int_eval:w 1 9998 - #2
19480 \exp_after:wN \_fp_ep_div_eps_pack:NNNNNw
19481 \int_value:w \_fp_int_eval:w 1 9999 9998 - #3#4
19482 \exp_after:wN \_fp_ep_div_eps_pack:NNNNNw
19483 \int_value:w \_fp_int_eval:w 2 0000 0000 - #5#6 ; ;
19484 }
19485 \cs_new:Npn \_fp_ep_div_eps_pack:NNNNNw 1#1#2#3#4#5#6;
19486 { + #1 ; {#2#3#4#5} {#6} }
19487 \cs_new:Npn \_fp_ep_div_epsilonii:wwnnNNNNNn 1#1; #2; #3#4#5#6#7#8
19488 {
19489 \_fp_fixed_mul:wwn {0000}{#1}#2; {0000}{#1}#2;
19490 \_fp_fixed_add_one:wN
19491 \_fp_fixed_mul:wwn {10000} {#1} #2 ;
19492 {
19493 \_fp_fixed_mul_short:wwn {0000}{#1}#2; {#3}{#4#5#6#7}{#8000};
19494 \_fp_fixed_div_myriad:wn
19495 \_fp_fixed_mul:wwn
19496 }
19497 \_fp_fixed_add:wwn {#3}{#4#5#6#7}{#8000}{0000}{0000}{0000};
19498 }

```

(End definition for `_fp_ep_div_epsilon:wnNNNNNn`, `_fp_ep_div_eps_pack:NNNNNw`, and `_fp_ep_div_epsilonii:wwnnNNNNNn`.)

32.10 Inverse square root of extended precision numbers

The idea here is similar to division. Normalize the input, multiplying by powers of 100 until we have $x \in [0.01, 1)$. Then find an integer approximation $r \in [101, 1003]$ of $10^2/\sqrt{x}$, as the fixed point of iterations of the Newton method: essentially $r \mapsto (r + 10^8/(x_1r))/2$,

starting from a guess that optimizes the number of steps before convergence. In fact, just as there is a slight shift when computing divisions to ensure that some inequalities hold, we replace 10^8 by a slightly larger number which ensures that $r^2x \geq 10^4$. This also causes $r \in [101, 1003]$. Another correction to the above is that the input is actually normalized to $[0.1, 1)$, and we use either 10^8 or 10^9 in the Newton method, depending on the parity of the exponent. Skipping those technical hurdles, once we have the approximation r , we set $y = 10^{-4}r^2x$ (or rather, the correct power of 10 to get $y \simeq 1$) and compute $y^{-1/2}$ through another application of Newton's method. This time, the starting value is $z = 1$, each step maps $z \mapsto z(1.5 - 0.5yz^2)$, and we perform a fixed number of steps. Our final result combines r with $y^{-1/2}$ as $x^{-1/2} = 10^{-2}ry^{-1/2}$.

First normalize the input, then check the parity of the exponent #1. If it is even, the result's exponent will be $-#1/2$, otherwise it will be $(#1 - 1)/2$ (except in the case where the input was an exact power of 100). The `auxii` function receives as #1 the result's exponent just computed, as #2 the starting value for the iteration giving r (the values 168 and 535 lead to the least number of iterations before convergence, on average), as #3 and #4 one empty argument and one 0, depending on the parity of the original exponent, as #5 and #6 the normalized mantissa (#5 $\in [1000, 9999]$), and as #7 the continuation. It sets up the iteration giving r : the `esti` function thus receives the initial two guesses #2 and 0, an approximation #5 of 10^4x (its first block of digits), and the empty/zero arguments #3 and #4, followed by the mantissa and an altered continuation where we have stored the result's exponent.

```

19499 \cs_new:Npn \__fp_ep_isqrt:wwn #1,#2;
19500 {
19501   \__fp_ep_to_ep:wwN #1,#2;
19502   \__fp_ep_isqrt_auxi:wwn
19503 }
19504 \cs_new:Npn \__fp_ep_isqrt_auxi:wwn #1,
19505 {
19506   \exp_after:wN \__fp_ep_isqrt_auxii:wwnnwn
19507   \int_value:w \__fp_int_eval:w
19508   \int_if_odd:nTF {#1}
19509     { (1 - #1) / 2 , 535 , { 0 } { } }
19510     { 1 - #1 / 2 , 168 , { } { 0 } }
19511 }
19512 \cs_new:Npn \__fp_ep_isqrt_auxii:wwnnwn #1, #2, #3#4 #5#6; #7
19513 {
19514   \__fp_ep_isqrt_esti:wwnnwn #2, 0, #5, {#3} {#4}
19515   {#5} #6 ; { #7 #1 , }
19516 }

```

(End definition for `__fp_ep_isqrt:wwn`, `__fp_ep_isqrt_aux:wwn`, and `__fp_ep_isqrt_auxii:wwnnwn`.)

If the last two approximations gave the same result, we are done: call the `estii` function to clean up. Otherwise, evaluate $(\langle prev \rangle + 1.005 \cdot 10^8 \text{ or } 9 / (\langle prev \rangle \cdot x)) / 2$, as the next approximation: omitting the 1.005 factor, this would be Newton's method. We can check by brute force that if #4 is empty (the original exponent was even), the process computes an integer slightly larger than $100/\sqrt{x}$, while if #4 is 0 (the original exponent was odd), the result is an integer slightly larger than $100/\sqrt{x/10}$. Once we are done, we evaluate $100r^2/2$ or $10r^2/2$ (when the exponent is even or odd, respectively) and feed that to `estiii`. This third auxiliary finds $y_{\text{even}}/2 = 10^{-4}r^2x/2$ or $y_{\text{odd}}/2 = 10^{-5}r^2x/2$ (again, depending on earlier parity). A simple program shows that $y \in [1, 1.0201]$. The

number $y/2$ is fed to `__fp_ep_isqrt_epsilon:wN`, which computes $1/\sqrt{y}$, and we finally multiply the result by r .

```

19517 \cs_new:Npn \__fp_ep_isqrt_esti:wwnnwn #1, #2, #3, #4
19518 {
19519   \if_int_compare:w #1 = #2 \exp_stop_f:
19520     \exp_after:wN \__fp_ep_isqrt_estii:wwnnwn
19521   \fi:
19522   \exp_after:wN \__fp_ep_isqrt_esti:wwnnwn
19523   \int_value:w \__fp_int_eval:w
19524     (#1 + 1 0050 0000 #4 / (#1 * #3)) / 2 ,
19525   #1, #3, {#4}
19526 }
19527 \cs_new:Npn \__fp_ep_isqrt_estii:wwnnwn #1, #2, #3, #4#5
19528 {
19529   \exp_after:wN \__fp_ep_isqrt_estiii:NNNNNwwnn
19530   \int_value:w \__fp_int_eval:w 1000 0000 + #2 * #2 #5 * 5
19531   \exp_after:wN , \int_value:w \__fp_int_eval:w 10000 + #2 ;
19532 }
19533 \cs_new:Npn \__fp_ep_isqrt_estiii:NNNNNwwnn 1#1#2#3#4#5#6, 1#7#8; #9;
19534 {
19535   \__fp_fixed_mul_short:wwn #9; {#1} {#2#3#4#5} {#600} ;
19536   \__fp_ep_isqrt_epsilon:wN
19537   \__fp_fixed_mul_short:wwn {#7} {#80} {0000} ;
19538 }

```

(End definition for `__fp_ep_isqrt_esti:wwnnwn`, `__fp_ep_isqrt_estii:wwnnwn`, and `__fp_ep_isqrt_estiii:NNNNNwwnn`.)

`__fp_ep_isqrt_epsilon:wN`
`__fp_ep_isqrt_epsilonii:wwN`

Here, we receive a fixed point number $y/2$ with $y \in [1, 1.0201]$. Starting from $z = 1$ we iterate $z \mapsto z(3/2 - z^2 y/2)$. In fact, we start from the first iteration $z = 3/2 - y/2$ to avoid useless multiplications. The `epsilonii` auxiliary receives z as `#1` and y as `#2`.

```

19539 \cs_new:Npn \__fp_ep_isqrt_epsilon:wN #1;
19540 {
19541   \__fp_fixed_sub:wwn {15000}{0000}{0000}{0000}{0000}{0000}; #1;
19542   \__fp_ep_isqrt_epsilonii:wwN #1;
19543   \__fp_ep_isqrt_epsilonii:wwN #1;
19544   \__fp_ep_isqrt_epsilonii:wwN #1;
19545 }
19546 \cs_new:Npn \__fp_ep_isqrt_epsilonii:wwN #1; #2;
19547 {
19548   \__fp_fixed_mul:wwn #1; #1;
19549   \__fp_fixed_mul_sub_back:wwnn #2;
19550   {15000}{0000}{0000}{0000}{0000}{0000};
19551   \__fp_fixed_mul:wwn #1;
19552 }

```

(End definition for `__fp_ep_isqrt_epsilon:wN` and `__fp_ep_isqrt_epsilonii:wwN`.)

32.11 Converting from fixed point to floating point

After computing Taylor series, we wish to convert the result from extended precision (with or without an exponent) to the public floating point format. The functions here should be called within an integer expression for the overall exponent of the floating point.

`__fp_ep_to_float_o:wwN`
`__fp_ep_inv_to_float_o:wwN`

An extended-precision number is simply a comma-delimited exponent followed by a fixed point number. Leave the exponent in the current integer expression then convert the fixed point number.

```

19553 \cs_new:Npn \__fp_ep_to_float_o:wwN #1,
19554 { + \__fp_int_eval:w #1 \__fp_fixed_to_float_o:wN }
19555 \cs_new:Npn \__fp_ep_inv_to_float_o:wwN #1,#2;
19556 {
19557   \__fp_ep_div:wwwN 1,{1000}{0000}{0000}{0000}{0000}{0000}; #1,#2;
19558   \__fp_ep_to_float_o:wwN
19559 }

```

(End definition for `__fp_ep_to_float_o:wwN` and `__fp_ep_inv_to_float_o:wwN`.)

`__fp_fixed_inv_to_float_o:wN`

Another function which reduces to converting an extended precision number to a float.

```

19560 \cs_new:Npn \__fp_fixed_inv_to_float_o:wN
19561 { \__fp_ep_inv_to_float_o:wwN 0, }

```

(End definition for `__fp_fixed_inv_to_float_o:wN`.)

`__fp_fixed_to_float_rad_o:wN`

Converts the fixed point number #1 from degrees to radians then to a floating point number. This could perhaps remain in `l3fp-trig`.

```

19562 \cs_new:Npn \__fp_fixed_to_float_rad_o:wN #1;
19563 {
19564   \__fp_fixed_mul:wwN #1; {5729}{5779}{5130}{8232}{0876}{7981};
19565   { \__fp_ep_to_float_o:wwN 2, }
19566 }

```

(End definition for `__fp_fixed_to_float_rad_o:wN`.)

`__fp_fixed_to_float_o:wN`
`__fp_fixed_to_float_o:Nw`

```

... \__fp_int_eval:w <exponent> \__fp_fixed_to_float_o:wN {<a1>} {<a2>} {<a3>}
{<a4>} {<a5>} {<a6>} ; <sign>
yields

```

```

<exponent'> ; {<a1'>} {<a2'>} {<a3'>} {<a4'>} ;

```

And the `to_fixed` version gives six brace groups instead of 4, ensuring that $1000 \leq \langle a_1' \rangle \leq 9999$. At this stage, we know that $\langle a_1 \rangle$ is positive (otherwise, it is sign of an error before), and we assume that it is less than 10^8 .¹¹

```

19567 \cs_new:Npn \__fp_fixed_to_float_o:Nw #1#2;
19568 { \__fp_fixed_to_float_o:wN #2; #1 }
19569 \cs_new:Npn \__fp_fixed_to_float_o:wN #1#2#3#4#5#6; #7
19570 { % for the 8-digit-at-the-start thing
19571   + \__fp_int_eval:w \c__fp_block_int
19572   \exp_after:wN \exp_after:wN
19573   \exp_after:wN \__fp_fixed_to_loop:N
19574   \exp_after:wN \use_none:n
19575   \int_value:w \__fp_int_eval:w
19576   1 0000 0000 + #1 \exp_after:wN \__fp_use_none_stop_f:n
19577   \int_value:w 1#2 \exp_after:wN \__fp_use_none_stop_f:n
19578   \int_value:w 1#3#4 \exp_after:wN \__fp_use_none_stop_f:n
19579   \int_value:w 1#5#6
19580   \exp_after:wN ;
19581   \exp_after:wN ;

```

¹¹Bruno: I must double check this assumption.

```

19582 }
19583 \cs_new:Npn \__fp_fixed_to_loop:N #1
19584 {
19585   \if_meaning:w 0 #1
19586   - 1
19587   \exp_after:wN \__fp_fixed_to_loop:N
19588   \else:
19589     \exp_after:wN \__fp_fixed_to_loop_end:w
19590     \exp_after:wN #1
19591   \fi:
19592 }
19593 \cs_new:Npn \__fp_fixed_to_loop_end:w #1 #2 ;
19594 {
19595   \if_meaning:w ; #1
19596     \exp_after:wN \__fp_fixed_to_float_zero:w
19597   \else:
19598     \exp_after:wN \__fp_pack_twice_four:wNNNNNNNN
19599     \exp_after:wN \__fp_pack_twice_four:wNNNNNNNN
19600     \exp_after:wN \__fp_fixed_to_float_pack:ww
19601     \exp_after:wN ;
19602   \fi:
19603   #1 #2 0000 0000 0000 0000 ;
19604 }
19605 \cs_new:Npn \__fp_fixed_to_float_zero:w ; 0000 0000 0000 0000 ;
19606 {
19607   - 2 * \c__fp_max_exponent_int ;
19608   {0000} {0000} {0000} {0000} ;
19609 }
19610 \cs_new:Npn \__fp_fixed_to_float_pack:ww #1 ; #2#3 ; ;
19611 {
19612   \if_int_compare:w #2 > 4 \exp_stop_f:
19613     \exp_after:wN \__fp_fixed_to_float_round_up:wnnnnw
19614   \fi:
19615   ; #1 ;
19616 }
19617 \cs_new:Npn \__fp_fixed_to_float_round_up:wnnnnw ; #1#2#3#4 ;
19618 {
19619   \exp_after:wN \__fp_basics_pack_high:NNNNNw
19620   \int_value:w \__fp_int_eval:w 1 #1#2
19621   \exp_after:wN \__fp_basics_pack_low:NNNNNw
19622   \int_value:w \__fp_int_eval:w 1 #3#4 + 1 ;
19623 }

```

(End definition for __fp_fixed_to_float_o:wN and __fp_fixed_to_float_o:Nw.)

```

19624 </initex | package>

```

33 l3fp-expo implementation

```

19625 (*initex | package)
19626 <@@=fp>

```

Unary functions.

```

19627 \cs_new:Npn \__fp_parse_word_exp:N
\__fp_parse_word_ln:N
\__fp_parse_word_fact:N

```

```

19628 { \__fp_parse_unary_function:NNN \__fp_exp_o:w ? }
19629 \cs_new:Npn \__fp_parse_word_ln:N
19630 { \__fp_parse_unary_function:NNN \__fp_ln_o:w ? }
19631 \cs_new:Npn \__fp_parse_word_fact:N
19632 { \__fp_parse_unary_function:NNN \__fp_fact_o:w ? }

```

(End definition for __fp_parse_word_exp:N, __fp_parse_word_ln:N, and __fp_parse_word_fact:N.)

33.1 Logarithm

33.1.1 Work plan

As for many other functions, we filter out special cases in __fp_ln_o:w. Then __fp_ln_npos_o:w receives a positive normal number, which we write in the form $a \cdot 10^b$ with $a \in [0.1, 1)$.

The rest of this section is actually not in sync with the code. Or is the code not in sync with the section? In the current code, $c \in [1, 10]$ is such that $0.7 \leq ac < 1.4$.

We are given a positive normal number, of the form $a \cdot 10^b$ with $a \in [0.1, 1)$. To compute its logarithm, we find a small integer $5 \leq c < 50$ such that $0.91 \leq ac/5 < 1.1$, and use the relation

$$\ln(a \cdot 10^b) = b \cdot \ln(10) - \ln(c/5) + \ln(ac/5).$$

The logarithms $\ln(10)$ and $\ln(c/5)$ are looked up in a table. The last term is computed using the following Taylor series of \ln near 1:

$$\ln\left(\frac{ac}{5}\right) = \ln\left(\frac{1+t}{1-t}\right) = 2t \left(1 + t^2 \left(\frac{1}{3} + t^2 \left(\frac{1}{5} + t^2 \left(\frac{1}{7} + t^2 \left(\frac{1}{9} + \dots\right)\right)\right)\right)\right)$$

where $t = 1 - 10/(ac + 5)$. We can now see one reason for the choice of $ac \sim 5$: then $ac + 5 = 10(1 - \epsilon)$ with $-0.05 < \epsilon \leq 0.045$, hence

$$t = \frac{\epsilon}{1 - \epsilon} = \epsilon(1 + \epsilon)(1 + \epsilon^2)(1 + \epsilon^4) \dots,$$

is not too difficult to compute.

33.1.2 Some constants

A few values of the logarithm as extended fixed point numbers. Those are needed in the implementation. It turns out that we don't need the value of $\ln(5)$.

```

\c__fp_ln_i_fixed_tl
\c__fp_ln_ii_fixed_tl
\c__fp_ln_iii_fixed_tl
\c__fp_ln_iv_fixed_tl
\c__fp_ln_vi_fixed_tl
\c__fp_ln_vii_fixed_tl
\c__fp_ln_viii_fixed_tl
\c__fp_ln_ix_fixed_tl
\c__fp_ln_x_fixed_tl
19633 \tl_const:Nn \c__fp_ln_i_fixed_tl { {0000}{0000}{0000}{0000}{0000}{0000};}
19634 \tl_const:Nn \c__fp_ln_ii_fixed_tl { {6931}{4718}{0559}{9453}{0941}{7232};}
19635 \tl_const:Nn \c__fp_ln_iii_fixed_tl { {10986}{1228}{8668}{1096}{9139}{5245};}
19636 \tl_const:Nn \c__fp_ln_iv_fixed_tl { {13862}{9436}{1119}{8906}{1883}{4464};}
19637 \tl_const:Nn \c__fp_ln_vi_fixed_tl { {17917}{5946}{9228}{0550}{0081}{2477};}
19638 \tl_const:Nn \c__fp_ln_vii_fixed_tl { {19459}{1014}{9055}{3133}{0510}{5353};}
19639 \tl_const:Nn \c__fp_ln_viii_fixed_tl { {20794}{4154}{1679}{8359}{2825}{1696};}
19640 \tl_const:Nn \c__fp_ln_ix_fixed_tl { {21972}{2457}{7336}{2193}{8279}{0490};}
19641 \tl_const:Nn \c__fp_ln_x_fixed_tl { {23025}{8509}{2994}{0456}{8401}{7991};}

```

(End definition for \c__fp_ln_i_fixed_tl and others.)

33.1.3 Sign, exponent, and special numbers

`__fp_ln_o:w` The logarithm of negative numbers (including $-\infty$ and -0) raises the “invalid” exception. The logarithm of $+0$ is $-\infty$, raising a division by zero exception. The logarithm of $+\infty$ or a `nan` is itself. Positive normal numbers call `__fp_ln_npos_o:w`.

```

19642 \cs_new:Npn \__fp_ln_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
19643 {
19644   \if_meaning:w 2 #3
19645     \__fp_case_use:nw { \__fp_invalid_operation_o:nw { ln } }
19646   \fi:
19647   \if_case:w #2 \exp_stop_f:
19648     \__fp_case_use:nw
19649     { \__fp_division_by_zero_o:Nnw \c_minus_inf_fp { ln } }
19650   \or:
19651   \else:
19652     \__fp_case_return_same_o:w
19653   \fi:
19654   \__fp_ln_npos_o:w \s__fp \__fp_chk:w #2#3#4;
19655 }

```

(End definition for `__fp_ln_o:w`.)

33.1.4 Absolute ln

`__fp_ln_npos_o:w` We catch the case of a significand very close to 0.1 or to 1. In all other cases, the final result is at least 10^{-4} , and then an error of $0.5 \cdot 10^{-20}$ is acceptable.

```

19656 \cs_new:Npn \__fp_ln_npos_o:w \s__fp \__fp_chk:w 10#1#2#3;
19657 { %^^A todo: ln(1) should be "exact zero", not "underflow"
19658   \exp_after:wN \__fp_sanitizew
19659   \int_value:w % for the overall sign
19660   \if_int_compare:w #1 < 1 \exp_stop_f:
19661     2
19662   \else:
19663     0
19664   \fi:
19665   \exp_after:wN \exp_stop_f:
19666   \int_value:w \__fp_int_eval:w % for the exponent
19667   \__fp_ln_significand:NNNNnnnnN #2#3
19668   \__fp_ln_exponent:wn {#1}
19669 }

```

(End definition for `__fp_ln_npos_o:w`.)

`__fp_ln_significand:NNNNnnnnN` `__fp_ln_significand:NNNNnnnnN` $\langle X_1 \rangle$ $\{\langle X_2 \rangle\}$ $\{\langle X_3 \rangle\}$ $\{\langle X_4 \rangle\}$ $\langle continuation \rangle$
This function expands to

$\langle continuation \rangle$ $\{\langle Y_1 \rangle\}$ $\{\langle Y_2 \rangle\}$ $\{\langle Y_3 \rangle\}$ $\{\langle Y_4 \rangle\}$ $\{\langle Y_5 \rangle\}$ $\{\langle Y_6 \rangle\}$;

where $Y = -\ln(X)$ as an extended fixed point.

```

19670 \cs_new:Npn \__fp_ln_significand:NNNNnnnnN #1#2#3#4
19671 {
19672   \exp_after:wN \__fp_ln_x_ii:wnnnn
19673   \int_value:w
19674   \if_case:w #1 \exp_stop_f:

```

```

19675     \or:
19676     \if_int_compare:w #2 < 4 \exp_stop_f:
19677     \__fp_int_eval:w 10 - #2
19678     \else:
19679     6
19680     \fi:
19681     \or: 4
19682     \or: 3
19683     \or: 2
19684     \or: 2
19685     \or: 2
19686     \else: 1
19687     \fi:
19688     ; { #1 #2 #3 #4 }
19689     }

```

(End definition for `__fp_ln_significand:NNNNnnnN`.)

`__fp_ln_x_ii:wnnnn` We have thus found $c \in [1, 10]$ such that $0.7 \leq ac < 1.4$ in all cases. Compute $1 + x = 1 + ac \in [1.7, 2.4)$.

```

19690 \cs_new:Npn \__fp_ln_x_ii:wnnnn #1; #2#3#4#5
19691 {
19692     \exp_after:wN \__fp_ln_div_after:Nw
19693     \cs:w c__fp_ln_ \__fp_int_to_roman:w #1 _fixed_tl \exp_after:wN \cs_end:
19694     \int_value:w
19695     \exp_after:wN \__fp_ln_x_iv:wnnnnnnnn
19696     \int_value:w \__fp_int_eval:w
19697     \exp_after:wN \__fp_ln_x_iii_var:NNNNNw
19698     \int_value:w \__fp_int_eval:w 9999 9990 + #1*#2#3 +
19699     \exp_after:wN \__fp_ln_x_iii:NNNNNw
19700     \int_value:w \__fp_int_eval:w 10 0000 0000 + #1*#4#5 ;
19701     {20000} {0000} {0000} {0000}
19702 } %^A todo: reoptimize (a generalization attempt failed).
19703 \cs_new:Npn \__fp_ln_x_iii:NNNNNw #1#2 #3#4#5#6 #7;
19704 { #1#2; {#3#4#5#6} {#7} }
19705 \cs_new:Npn \__fp_ln_x_iii_var:NNNNNw #1 #2#3#4#5 #6;
19706 {
19707     #1#2#3#4#5 + 1 ;
19708     {#1#2#3#4#5} {#6}
19709 }

```

The Taylor series to be used is expressed in terms of $t = (x - 1)/(x + 1) = 1 - 2/(x + 1)$. We now compute the quotient with extended precision, reusing some code from `__fp_-/_o:ww`. Note that $1 + x$ is known exactly.

To reuse notations from `l3fp-basics`, we want to compute A/Z with $A = 2$ and $Z = x + 1$. In `l3fp-basics`, we considered the case where both A and Z are arbitrary, in the range $[0.1, 1)$, and we had to monitor the growth of the sequence of remainders A , B , C , etc. to ensure that no overflow occurred during the computation of the next quotient. The main source of risk was our choice to define the quotient as roughly $10^9 \cdot A/10^5 \cdot Z$: then A was bound to be below $2.147 \dots$, and this limit was never far.

In our case, we can simply work with $10^8 \cdot A$ and $10^4 \cdot Z$, because our reason to work with higher powers has gone: we needed the integer $y \simeq 10^5 \cdot Z$ to be at least 10^4 , and now, the definition $y \simeq 10^4 \cdot Z$ suffices.

Let us thus define $y = \lfloor 10^4 \cdot Z \rfloor + 1 \in (1.7 \cdot 10^4, 2.4 \cdot 10^4]$, and

$$Q_1 = \left\lfloor \frac{\lfloor 10^8 \cdot A \rfloor}{y} - \frac{1}{2} \right\rfloor.$$

(The $1/2$ comes from how ε -TeX rounds.) As for division, it is easy to see that $Q_1 \leq 10^4 A/Z$, *i.e.*, Q_1 is an underestimate.

Exactly as we did for division, we set $B = 10^4 A - Q_1 Z$. Then

$$\begin{aligned} 10^4 B &\leq A_1 A_2 \cdot A_3 A_4 - \left(\frac{A_1 A_2}{y} - \frac{3}{2} \right) 10^4 Z \\ &\leq A_1 A_2 \left(1 - \frac{10^4 Z}{y} \right) + 1 + \frac{3}{2} y \\ &\leq 10^8 \frac{A}{y} + 1 + \frac{3}{2} y \end{aligned}$$

In the same way, and using $1.7 \cdot 10^4 \leq y \leq 2.4 \cdot 10^4$, and convexity, we get

$$\begin{aligned} 10^4 A &= 2 \cdot 10^4 \\ 10^4 B &\leq 10^8 \frac{A}{y} + 1.6y \leq 4.7 \cdot 10^4 \\ 10^4 C &\leq 10^8 \frac{B}{y} + 1.6y \leq 5.8 \cdot 10^4 \\ 10^4 D &\leq 10^8 \frac{C}{y} + 1.6y \leq 6.3 \cdot 10^4 \\ 10^4 E &\leq 10^8 \frac{D}{y} + 1.6y \leq 6.5 \cdot 10^4 \\ 10^4 F &\leq 10^8 \frac{E}{y} + 1.6y \leq 6.6 \cdot 10^4 \end{aligned}$$

Note that we compute more steps than for division: since t is not the end result, we need to know it with more accuracy (on the other hand, the ending is much simpler, as we don't need an exact rounding for transcendental functions, but just a faithful rounding).

`_fp_ln_x_iv:wnnnnnnnn <1 or 2> <8d> ; {\<4d>} {\<4d>} <fixed-tl>`

The number is x . Compute y by adding 1 to the five first digits.

```

19710 \cs_new:Npn \_fp\_ln\_x\_iv:wnnnnnnnn #1; #2#3#4#5 #6#7#8#9
19711 {
19712   \exp_after:wN \_fp\_div\_significand\_pack:NNN
19713   \int_value:w \_fp\_int\_eval:w
19714   \_fp\_ln\_div\_i:w #1 ;
19715   #6 #7 ; {\#8} {\#9}
19716   {\#2} {\#3} {\#4} {\#5}
19717   { \exp_after:wN \_fp\_ln\_div\_ii:wnn \int_value:w #1 }
19718   { \exp_after:wN \_fp\_ln\_div\_ii:wnn \int_value:w #1 }
19719   { \exp_after:wN \_fp\_ln\_div\_ii:wnn \int_value:w #1 }
19720   { \exp_after:wN \_fp\_ln\_div\_ii:wnn \int_value:w #1 }
19721   { \exp_after:wN \_fp\_ln\_div\_vi:wnn \int_value:w #1 }

```

```

19722 }
19723 \cs_new:Npn \__fp_ln_div_i:w #1;
19724 {
19725   \exp_after:wN \__fp_div_significand_calc:wwnnnnnnnn
19726   \int_value:w \__fp_int_eval:w 999999 + 2 0000 0000 / #1 ; % Q1
19727 }
19728 \cs_new:Npn \__fp_ln_div_ii:wwn #1; #2;#3 % y; B1;B2 <- for k=1
19729 {
19730   \exp_after:wN \__fp_div_significand_pack:NNN
19731   \int_value:w \__fp_int_eval:w
19732   \exp_after:wN \__fp_div_significand_calc:wwnnnnnnnn
19733   \int_value:w \__fp_int_eval:w 999999 + #2 #3 / #1 ; % Q2
19734   #2 #3 ;
19735 }
19736 \cs_new:Npn \__fp_ln_div_vi:wwn #1; #2;#3#4#5 #6#7#8#9 %y;F1;F2F3F4x1x2x3x4
19737 {
19738   \exp_after:wN \__fp_div_significand_pack:NNN
19739   \int_value:w \__fp_int_eval:w 1000000 + #2 #3 / #1 ; % Q6
19740 }

```

We now have essentially

```

\__fp_ln_div_after:Nw <fixed t1>
\__fp_div_significand_pack:NNN 106 + Q1
\__fp_div_significand_pack:NNN 106 + Q2
\__fp_div_significand_pack:NNN 106 + Q3
\__fp_div_significand_pack:NNN 106 + Q4
\__fp_div_significand_pack:NNN 106 + Q5
\__fp_div_significand_pack:NNN 106 + Q6 ;
<exponent> ; <continuation>

```

where $\langle \text{fixed } t1 \rangle$ holds the logarithm of a number in $[1, 10]$, and $\langle \text{exponent} \rangle$ is the exponent. Also, the expansion is done backwards. Then `__fp_div_significand_pack:NNN` puts things in the correct order to add the Q_i together and put semicolons between each piece. Once those have been expanded, we get

```

\__fp_ln_div_after:Nw <fixed-t1> <1d> ; <4d> ; <4d> ;
<4d> ; <4d> ; <4d> ; <4d> ; <exponent> ;

```

Just as with division, we know that the first two digits are 1 and 0 because of bounds on the final result of the division $2/(x+1)$, which is between roughly 0.8 and 1.2. We then compute $1 - 2/(x+1)$, after testing whether $2/(x+1)$ is greater than or smaller than 1.

```

19741 \cs_new:Npn \__fp_ln_div_after:Nw #1#2;
19742 {
19743   \if_meaning:w 0 #2
19744     \exp_after:wN \__fp_ln_t_small:Nw
19745   \else:
19746     \exp_after:wN \__fp_ln_t_large:NNw
19747     \exp_after:wN -
19748   \fi:
19749   #1
19750 }
19751 \cs_new:Npn \__fp_ln_t_small:Nw #1 #2; #3; #4; #5; #6; #7;
19752 {
19753   \exp_after:wN \__fp_ln_t_large:NNw

```

```

19754 \exp_after:wN + % <sign>
19755 \exp_after:wN #1
19756 \int_value:w \_fp_int_eval:w 9999 - #2 \exp_after:wN ;
19757 \int_value:w \_fp_int_eval:w 9999 - #3 \exp_after:wN ;
19758 \int_value:w \_fp_int_eval:w 9999 - #4 \exp_after:wN ;
19759 \int_value:w \_fp_int_eval:w 9999 - #5 \exp_after:wN ;
19760 \int_value:w \_fp_int_eval:w 9999 - #6 \exp_after:wN ;
19761 \int_value:w \_fp_int_eval:w 1 0000 - #7 ;
19762 }

```

```

\_fp_ln_t_large:NNw <sign> <fixed t1>
<t1>; <t2>; <t3>; <t4>; <t5>; <t6>;
<exponent>; <continuation>

```

Compute the square t^2 , and keep t at the end with its sign. We know that $t < 0.1765$, so every piece has at most 4 digits. However, since we were not careful in `_fp_ln_t_small:w`, they can have less than 4 digits.

```

19763 \cs_new:Npn \_fp_ln_t_large:NNw #1 #2 #3; #4; #5; #6; #7; #8;
19764 {
19765   \exp_after:wN \_fp_ln_square_t_after:w
19766   \int_value:w \_fp_int_eval:w 9999 0000 + #3*#3
19767   \exp_after:wN \_fp_ln_square_t_pack:NNNNNw
19768   \int_value:w \_fp_int_eval:w 9999 0000 + 2*#3*#4
19769   \exp_after:wN \_fp_ln_square_t_pack:NNNNNw
19770   \int_value:w \_fp_int_eval:w 9999 0000 + 2*#3*#5 + #4*#4
19771   \exp_after:wN \_fp_ln_square_t_pack:NNNNNw
19772   \int_value:w \_fp_int_eval:w 9999 0000 + 2*#3*#6 + 2*#4*#5
19773   \exp_after:wN \_fp_ln_square_t_pack:NNNNNw
19774   \int_value:w \_fp_int_eval:w
19775     1 0000 0000 + 2*#3*#7 + 2*#4*#6 + #5*#5
19776     + (2*#3*#8 + 2*#4*#7 + 2*#5*#6) / 1 0000
19777   % ; ; ;
19778   \exp_after:wN \_fp_ln_twice_t_after:w
19779   \int_value:w \_fp_int_eval:w -1 + 2*#3
19780   \exp_after:wN \_fp_ln_twice_t_pack:Nw
19781   \int_value:w \_fp_int_eval:w 9999 + 2*#4
19782   \exp_after:wN \_fp_ln_twice_t_pack:Nw
19783   \int_value:w \_fp_int_eval:w 9999 + 2*#5
19784   \exp_after:wN \_fp_ln_twice_t_pack:Nw
19785   \int_value:w \_fp_int_eval:w 9999 + 2*#6
19786   \exp_after:wN \_fp_ln_twice_t_pack:Nw
19787   \int_value:w \_fp_int_eval:w 9999 + 2*#7
19788   \exp_after:wN \_fp_ln_twice_t_pack:Nw
19789   \int_value:w \_fp_int_eval:w 10000 + 2*#8 ; ;
19790   { \_fp_ln_c:NwNw #1 }
19791   #2
19792 }
19793 \cs_new:Npn \_fp_ln_twice_t_pack:Nw #1 #2; { + #1 ; {#2} }
19794 \cs_new:Npn \_fp_ln_twice_t_after:w #1; { ; ; ; {#1} }
19795 \cs_new:Npn \_fp_ln_square_t_pack:NNNNNw #1 #2#3#4#5 #6;
19796   { + #1#2#3#4#5 ; {#6} }
19797 \cs_new:Npn \_fp_ln_square_t_after:w 1 0 #1#2#3 #4;
19798   { \_fp_ln_Taylor:wwNw {0#1#2#3} {#4} }

```

(End definition for `_fp_ln_x_ii:wnnnn`.)

_fp_ln_Taylor:wwNw Denoting $T = t^2$, we get

```
\_fp_ln_Taylor:wwNw
{⟨T1⟩} {⟨T2⟩} {⟨T3⟩} {⟨T4⟩} {⟨T5⟩} {⟨T6⟩} ; ;
{⟨(2t)1⟩} {⟨(2t)2⟩} {⟨(2t)3⟩} {⟨(2t)4⟩} {⟨(2t)5⟩} {⟨(2t)6⟩} ;
{ \_fp_ln_c:NwNw ⟨sign⟩ }
⟨fixed t1⟩ ⟨exponent⟩ ; ⟨continuation⟩
```

And we want to compute

$$\ln\left(\frac{1+t}{1-t}\right) = 2t \left(1 + T \left(\frac{1}{3} + T \left(\frac{1}{5} + T \left(\frac{1}{7} + T \left(\frac{1}{9} + \cdots\right)\right)\right)\right)\right)$$

The process looks as follows

```
\loop 5; A;
\div_int 5; 1.0; \add A; \mul T; {\loop \eval 5-2;}
\add 0.2; A; \mul T; {\loop \eval 5-2;}
\mul B; T; {\loop 3;}
\loop 3; C;
```

This uses the routine for dividing a number by a small integer ($< 10^4$).

```
19799 \cs_new:Npn \_fp_ln_Taylor:wwNw
19800 { \_fp_ln_Taylor_loop:www 21 ; {0000}{0000}{0000}{0000}{0000} ; }
19801 \cs_new:Npn \_fp_ln_Taylor_loop:www #1; #2; #3;
19802 {
19803   \if_int_compare:w #1 = 1 \exp_stop_f:
19804     \_fp_ln_Taylor_break:w
19805     \fi:
19806     \exp_after:wN \_fp_fixed_div_int:wwN \c\_fp_one_fixed_t1 #1;
19807     \_fp_fixed_add:wwn #2;
19808     \_fp_fixed_mul:wwn #3;
19809     {
19810       \exp_after:wN \_fp_ln_Taylor_loop:www
19811       \int_value:w \_fp_int_eval:w #1 - 2 ;
19812     }
19813     #3;
19814   }
19815 \cs_new:Npn \_fp_ln_Taylor_break:w \fi: #1 \_fp_fixed_add:wwn #2#3; #4 ;;
19816 {
19817   \fi:
19818   \exp_after:wN \_fp_fixed_mul:wwn
19819   \exp_after:wN { \int_value:w \_fp_int_eval:w 10000 + #2 } #3;
19820 }
```

(End definition for _fp_ln_Taylor:wwNw.)

```
\_fp_ln_c:NwNw ⟨sign⟩
{⟨r1⟩} {⟨r2⟩} {⟨r3⟩} {⟨r4⟩} {⟨r5⟩} {⟨r6⟩} ;
⟨fixed t1⟩ ⟨exponent⟩ ; ⟨continuation⟩
```

We are now reduced to finding $\ln(c)$ and $\langle exponent \rangle \ln(10)$ in a table, and adding it to the mixture. The first step is to get $\ln(c) - \ln(x) = -\ln(a)$, then we get $\mathbf{b} \ln(10)$ and add or subtract.

For now, $\ln(x)$ is given as $\cdot 10^0$. Unless both the exponent is 1 and $c = 1$, we shift to working in units of $\cdot 10^4$, since the final result is at least $\ln(10/7) \simeq 0.35$.

```

19821 \cs_new:Npn \__fp_ln_c:NwNw #1 #2; #3
19822 {
19823   \if_meaning:w + #1
19824     \exp_after:wN \exp_after:wN \exp_after:wN \__fp_fixed_sub:wwn
19825   \else:
19826     \exp_after:wN \exp_after:wN \exp_after:wN \__fp_fixed_add:wwn
19827   \fi:
19828   #3 #2 ;
19829 }

```

(End definition for $\backslash_fp_ln_c:NwNw$.)

```

\__fp_ln_exponent:wn
\__fp_ln_exponent:wn
  {\langle s_1 \rangle} {\langle s_2 \rangle} {\langle s_3 \rangle} {\langle s_4 \rangle} {\langle s_5 \rangle} {\langle s_6 \rangle} ;
  {\langle exponent \rangle}

```

Compute $\langle exponent \rangle$ times $\ln(10)$. Apart from the cases where $\langle exponent \rangle$ is 0 or 1, the result is necessarily at least $\ln(10) \simeq 2.3$ in magnitude. We can thus drop the least significant 4 digits. In the case of a very large (positive or negative) exponent, we can (and we need to) drop 4 additional digits, since the result is of order 10^4 . Naively, one would think that in both cases we can drop 4 more digits than we do, but that would be slightly too tight for rounding to happen correctly. Besides, we already have addition and subtraction for 24 digits fixed point numbers.

```

19830 \cs_new:Npn \__fp_ln_exponent:wn #1; #2
19831 {
19832   \if_case:w #2 \exp_stop_f:
19833     0 \__fp_case_return:nw { \__fp_fixed_to_float_o:Nw 2 }
19834   \or:
19835     \exp_after:wN \__fp_ln_exponent_one:ww \int_value:w
19836   \else:
19837     \if_int_compare:w #2 > 0 \exp_stop_f:
19838       \exp_after:wN \__fp_ln_exponent_small:NNww
19839       \exp_after:wN 0
19840       \exp_after:wN \__fp_fixed_sub:wwn \int_value:w
19841     \else:
19842       \exp_after:wN \__fp_ln_exponent_small:NNww
19843       \exp_after:wN 2
19844       \exp_after:wN \__fp_fixed_add:wwn \int_value:w -
19845     \fi:
19846   \fi:
19847   #2; #1;
19848 }

```

Now we painfully write all the cases.¹² No overflow nor underflow can happen, except when computing $\ln(1)$.

```

19849 \cs_new:Npn \__fp_ln_exponent_one:ww 1; #1;
19850 {
19851   0
19852   \exp_after:wN \__fp_fixed_sub:wwn \c__fp_ln_x_fixed_tl #1;
19853   \__fp_fixed_to_float_o:wN 0
19854 }

```

¹²Bruno: do rounding.

For small exponents, we just drop one block of digits, and set the exponent of the log to 4 (minus any shift coming from leading zeros in the conversion from fixed point to floating point). Note that here the exponent has been made positive.

```

19855 \cs_new:Npn \__fp_ln_exponent_small:NNww #1#2#3; #4#5#6#7#8#9;
19856 {
19857     4
19858     \exp_after:wN \__fp_fixed_mul:wwn
19859     \c__fp_ln_x_fixed_tl
19860     {#3}{0000}{0000}{0000}{0000}{0000} ;
19861     #2
19862     {0000}{#4}{#5}{#6}{#7}{#8};
19863     \__fp_fixed_to_float_o:wN #1
19864 }

```

(End definition for __fp_ln_exponent:wn.)

33.2 Exponential

33.2.1 Sign, exponent, and special numbers

__fp_exp_o:w

```

19865 \cs_new:Npn \__fp_exp_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
19866 {
19867     \if_case:w #2 \exp_stop_f:
19868     \__fp_case_return_o:Nw \c_one_fp
19869     \or:
19870     \exp_after:wN \__fp_exp_normal_o:w
19871     \or:
19872     \if_meaning:w 0 #3
19873     \exp_after:wN \__fp_case_return_o:Nw
19874     \exp_after:wN \c_inf_fp
19875     \else:
19876     \exp_after:wN \__fp_case_return_o:Nw
19877     \exp_after:wN \c_zero_fp
19878     \fi:
19879     \or:
19880     \__fp_case_return_same_o:w
19881     \fi:
19882     \s__fp \__fp_chk:w #2#3#4;
19883 }

```

(End definition for __fp_exp_o:w.)

__fp_exp_normal_o:w

__fp_exp_pos_o:NNwnw

__fp_exp_overflow:NN

```

19884 \cs_new:Npn \__fp_exp_normal_o:w \s__fp \__fp_chk:w 1#1
19885 {
19886     \if_meaning:w 0 #1
19887     \__fp_exp_pos_o:NNwnw + \__fp_fixed_to_float_o:wN
19888     \else:
19889     \__fp_exp_pos_o:NNwnw - \__fp_fixed_inv_to_float_o:wN
19890     \fi:
19891 }
19892 \cs_new:Npn \__fp_exp_pos_o:NNwnw #1#2#3 \fi: #4#5;
19893 {

```



```

19894 \fi:
19895 \if_int_compare:w #4 > \c__fp_max_exp_exponent_int
19896 \token_if_eq_charcode:NNTF + #1
19897 { \__fp_exp_overflow:NN \__fp_overflow:w \c_inf_fp }
19898 { \__fp_exp_overflow:NN \__fp_underflow:w \c_zero_fp }
19899 \exp:w
19900 \else:
19901 \exp_after:wN \__fp_sanitize:Nw
19902 \exp_after:wN 0
19903 \int_value:w #1 \__fp_int_eval:w
19904 \if_int_compare:w #4 < 0 \exp_stop_f:
19905 \exp_after:wN \use_i:nn
19906 \else:
19907 \exp_after:wN \use_ii:nn
19908 \fi:
19909 {
19910 0
19911 \__fp_decimate:nNnnnn { - #4 }
19912 \__fp_exp_Taylor:Nnnwn
19913 }
19914 {
19915 \__fp_decimate:nNnnnn { \c__fp_prec_int - #4 }
19916 \__fp_exp_pos_large:NnnNwn
19917 }
19918 #5
19919 {#4}
19920 #1 #2 0
19921 \exp:w
19922 \fi:
19923 \exp_after:wN \exp_end:
19924 }
19925 \cs_new:Npn \__fp_exp_overflow:NN #1#2
19926 {
19927 \exp_after:wN \exp_after:wN
19928 \exp_after:wN #1
19929 \exp_after:wN #2
19930 }

```

(End definition for __fp_exp_normal_o:w, __fp_exp_pos_o:Nnnwn, and __fp_exp_overflow:NN.)

```

\__fp_exp_Taylor:Nnnwn
\__fp_exp_Taylor_loop:www
\__fp_exp_Taylor_break:Nww

```

This function is called for numbers in the range $[10^{-9}, 10^{-1}]$. We compute 10 terms of the Taylor series. The first argument is irrelevant (rounding digit used by some other functions). The next three arguments, at least 16 digits, delimited by a semicolon, form a fixed point number, so we pack it in blocks of 4 digits.

```

19931 \cs_new:Npn \__fp_exp_Taylor:Nnnwn #1#2#3 #4; #5 #6
19932 {
19933 #6
19934 \__fp_pack_twice_four:wNNNNNNNN
19935 \__fp_pack_twice_four:wNNNNNNNN
19936 \__fp_pack_twice_four:wNNNNNNNN
19937 \__fp_exp_Taylor_ii:ww
19938 ; #2#3#4 0000 0000 ;
19939 }
19940 \cs_new:Npn \__fp_exp_Taylor_ii:ww #1; #2;

```

```

19941 { \_fp_exp_Taylor_loop:www 10 ; #1 ; #1 ; \s_stop }
19942 \cs_new:Npn \_fp_exp_Taylor_loop:www #1; #2; #3;
19943 {
19944   \if_int_compare:w #1 = 1 \exp_stop_f:
19945   \exp_after:wN \_fp_exp_Taylor_break:Nww
19946   \fi:
19947   \_fp_fixed_div_int:wwN #3 ; #1 ;
19948   \_fp_fixed_add_one:wN
19949   \_fp_fixed_mul:wwN #2 ;
19950   {
19951     \exp_after:wN \_fp_exp_Taylor_loop:www
19952     \int_value:w \_fp_int_eval:w #1 - 1 ;
19953     #2 ;
19954   }
19955 }
19956 \cs_new:Npn \_fp_exp_Taylor_break:Nww #1 #2; #3 \s_stop
19957 { \_fp_fixed_add_one:wN #2 ; }

```

(End definition for `_fp_exp_Taylor:Nnnwn`, `_fp_exp_Taylor_loop:www`, and `_fp_exp_Taylor_break:Nww`.)

`\c_fp_exp_intarray` The integer array has $6 \times 9 \times 4 = 216$ items encoding the values of $\exp(j \times 10^i)$ for $j = 1, \dots, 9$ and $i = -1, \dots, 4$. Each value is expressed as $\simeq 10^p \times 0.m_1m_2m_3$ with three 8-digit blocks m_1, m_2, m_3 and an integer exponent p (one more than the scientific exponent), and these are stored in the integer array as four items: $p, 10^8 + m_1, 10^8 + m_2, 10^8 + m_3$. The various exponentials are stored in increasing order of $j \times 10^i$.

Storing this data in an integer array makes it slightly harder to access (slower, too), but uses 16 bytes of memory per exponential stored, while storing as tokens used around 40 tokens; tokens have an especially large footprint in Unicode-aware engines.

```

19958 \intarray_const_from_clist:Nn \c_fp_exp_intarray
19959 {
19960   1 , 1 1105 1709 , 1 1807 5647 , 1 6248 1171 ,
19961   1 , 1 1221 4027 , 1 5816 0169 , 1 8339 2107 ,
19962   1 , 1 1349 8588 , 1 0757 6003 , 1 1039 8374 ,
19963   1 , 1 1491 8246 , 1 9764 1270 , 1 3178 2485 ,
19964   1 , 1 1648 7212 , 1 7070 0128 , 1 1468 4865 ,
19965   1 , 1 1822 1188 , 1 0039 0508 , 1 9748 7537 ,
19966   1 , 1 2013 7527 , 1 0747 0476 , 1 5216 2455 ,
19967   1 , 1 2225 5409 , 1 2849 2467 , 1 6045 7954 ,
19968   1 , 1 2459 6031 , 1 1115 6949 , 1 6638 0013 ,
19969   1 , 1 2718 2818 , 1 2845 9045 , 1 2353 6029 ,
19970   1 , 1 7389 0560 , 1 9893 0650 , 1 2272 3043 ,
19971   2 , 1 2008 5536 , 1 9231 8766 , 1 7740 9285 ,
19972   2 , 1 5459 8150 , 1 0331 4423 , 1 9078 1103 ,
19973   3 , 1 1484 1315 , 1 9102 5766 , 1 0342 1116 ,
19974   3 , 1 4034 2879 , 1 3492 7351 , 1 2260 8387 ,
19975   4 , 1 1096 6331 , 1 5842 8458 , 1 5992 6372 ,
19976   4 , 1 2980 9579 , 1 8704 1728 , 1 2747 4359 ,
19977   4 , 1 8103 0839 , 1 2757 5384 , 1 0077 1000 ,
19978   5 , 1 2202 6465 , 1 7948 0671 , 1 6516 9579 ,
19979   9 , 1 4851 6519 , 1 5409 7902 , 1 7796 9107 ,
19980   14 , 1 1068 6474 , 1 5815 2446 , 1 2146 9905 ,
19981   18 , 1 2353 8526 , 1 6837 0199 , 1 8540 7900 ,
19982   22 , 1 5184 7055 , 1 2858 7072 , 1 4640 8745 ,

```

```

19983      27 , 1 1142 0073 , 1 8981 5684 , 1 2836 6296 ,
19984      31 , 1 2515 4386 , 1 7091 9167 , 1 0062 6578 ,
19985      35 , 1 5540 6223 , 1 8439 3510 , 1 0525 7117 ,
19986      40 , 1 1220 4032 , 1 9431 7840 , 1 8020 0271 ,
19987      44 , 1 2688 1171 , 1 4181 6135 , 1 4484 1263 ,
19988      87 , 1 7225 9737 , 1 6812 5749 , 1 2581 7748 ,
19989     131 , 1 1942 4263 , 1 9524 1255 , 1 9365 8421 ,
19990     174 , 1 5221 4696 , 1 8976 4143 , 1 9505 8876 ,
19991     218 , 1 1403 5922 , 1 1785 2837 , 1 4107 3977 ,
19992     261 , 1 3773 0203 , 1 0092 9939 , 1 8234 0143 ,
19993     305 , 1 1014 2320 , 1 5473 5004 , 1 5094 5533 ,
19994     348 , 1 2726 3745 , 1 7211 2566 , 1 5673 6478 ,
19995     391 , 1 7328 8142 , 1 2230 7421 , 1 7051 8866 ,
19996     435 , 1 1970 0711 , 1 1401 7046 , 1 9938 8888 ,
19997     869 , 1 3881 1801 , 1 9428 4368 , 1 5764 8232 ,
19998    1303 , 1 7646 2009 , 1 8905 4704 , 1 8893 1073 ,
19999    1738 , 1 1506 3559 , 1 7005 0524 , 1 9009 7592 ,
20000    2172 , 1 2967 6283 , 1 8402 3667 , 1 0689 6630 ,
20001    2606 , 1 5846 4389 , 1 5650 2114 , 1 7278 5046 ,
20002    3041 , 1 1151 7900 , 1 5080 6878 , 1 2914 4154 ,
20003    3475 , 1 2269 1083 , 1 0850 6857 , 1 8724 4002 ,
20004    3909 , 1 4470 3047 , 1 3316 5442 , 1 6408 6591 ,
20005    4343 , 1 8806 8182 , 1 2566 2921 , 1 5872 6150 ,
20006    8686 , 1 7756 0047 , 1 2598 6861 , 1 0458 3204 ,
20007   13029 , 1 6830 5723 , 1 7791 4884 , 1 1932 7351 ,
20008   17372 , 1 6015 5609 , 1 3095 3052 , 1 3494 7574 ,
20009   21715 , 1 5297 7951 , 1 6443 0315 , 1 3251 3576 ,
20010   26058 , 1 4665 6719 , 1 0099 3379 , 1 5527 2929 ,
20011   30401 , 1 4108 9724 , 1 3326 3186 , 1 5271 5665 ,
20012   34744 , 1 3618 6973 , 1 3140 0875 , 1 3856 4102 ,
20013   39087 , 1 3186 9209 , 1 6113 3900 , 1 6705 9685 ,
20014   }

```

(End definition for `c__fp_exp_intarray`.)

`__fp_exp_pos_large:NnnNwn` The first two arguments are irrelevant (a rounding digit, and a brace group with 8 zeros).
`__fp_exp_large_after:wnn` The third argument is the integer part of our number, then we have the decimal part
`__fp_exp_large:NwN` delimited by a semicolon, and finally the exponent, in the range $[0, 5]$. Remove leading
`__fp_exp_intarray:w` zeros from the integer part: putting `#4` in there too ensures that an integer part of 0 is
`__fp_exp_intarray_aux:w` also removed. Then read digits one by one, looking up $\exp(\langle digit \rangle \cdot 10^{\langle exponent \rangle})$ in a table,
and multiplying that to the current total. The loop is done by `__fp_exp_large:NwN`,
whose `#1` is the $\langle exponent \rangle$, `#2` is the current mantissa, and `#3` is the $\langle digit \rangle$. At the end,
`__fp_exp_large_after:wnn` moves on to the Taylor series, eventually multiplied with
the mantissa that we have just computed.

```

20015 \cs_new:Npn \__fp_exp_pos_large:NnnNwn #1#2#3 #4#5; #6
20016 {
20017   \exp_after:wN \exp_after:wN \exp_after:wN \__fp_exp_large:NwN
20018   \exp_after:wN \exp_after:wN \exp_after:wN #6
20019   \exp_after:wN \c__fp_one_fixed_tl
20020   \int_value:w #3 #4 \exp_stop_f:
20021   #5 00000 ;
20022 }
20023 \cs_new:Npn \__fp_exp_large:NwN #1#2; #3
20024 {

```

```

20025 \if_case:w #3 ~
20026 \exp_after:wN \__fp_fixed_continue:wn
20027 \else:
20028 \exp_after:wN \__fp_exp_intarray:w
20029 \int_value:w \__fp_int_eval:w 36 * #1 + 4 * #3 \exp_after:wN ;
20030 \fi:
20031 #2;
20032 {
20033 \if_meaning:w 0 #1
20034 \exp_after:wN \__fp_exp_large_after:wnn
20035 \else:
20036 \exp_after:wN \__fp_exp_large:NwN
20037 \int_value:w \__fp_int_eval:w #1 - 1 \exp_after:wN \scan_stop:
20038 \fi:
20039 }
20040 }
20041 \cs_new:Npn \__fp_exp_intarray:w #1 ;
20042 {
20043 +
20044 \__kernel_intarray_item:Nn \c__fp_exp_intarray
20045 { \__fp_int_eval:w #1 - 3 \scan_stop: }
20046 \exp_after:wN \use_i:nnn
20047 \exp_after:wN \__fp_fixed_mul:wnn
20048 \int_value:w 0
20049 \exp_after:wN \__fp_exp_intarray_aux:w
20050 \int_value:w \__kernel_intarray_item:Nn
20051 \c__fp_exp_intarray { \__fp_int_eval:w #1 - 2 }
20052 \exp_after:wN \__fp_exp_intarray_aux:w
20053 \int_value:w \__kernel_intarray_item:Nn
20054 \c__fp_exp_intarray { \__fp_int_eval:w #1 - 1 }
20055 \exp_after:wN \__fp_exp_intarray_aux:w
20056 \int_value:w \__kernel_intarray_item:Nn \c__fp_exp_intarray {#1} ; ;
20057 }
20058 \cs_new:Npn \__fp_exp_intarray_aux:w 1 #1#2#3#4#5 ; { ; {#1#2#3#4} {#5} }
20059 \cs_new:Npn \__fp_exp_large_after:wnn #1; #2; #3
20060 {
20061 \__fp_exp_Taylor:Nnnwn ? { } { } 0 #2; {} #3
20062 \__fp_fixed_mul:wnn #1;
20063 }

```

(End definition for `__fp_exp_pos_large:NnnNwn` and others.)

33.3 Power

Raising a number a to a power b leads to many distinct situations.

a^b	$-\infty$	$(-\infty, -0)$	$-\text{integer}$	± 0	$+\text{integer}$	$(0, \infty)$	$+\infty$	NaN
$+\infty$	$+0$		$+0$	$+1$	$+\infty$	$+\infty$	$+\infty$	NaN
$(1, \infty)$	$+0$		$+ a ^b$	$+1$	$+ a ^b$	$+\infty$	$+\infty$	NaN
$+1$	$+1$		$+1$	$+1$	$+1$	$+1$	$+1$	$+1$
$(0, 1)$	$+\infty$		$+ a ^b$	$+1$	$+ a ^b$	$+0$	$+\infty$	NaN
$+0$	$+\infty$		$+\infty$	$+1$	$+0$	$+0$	$+\infty$	NaN
-0	$+\infty$	NaN	$(-1)^b \infty$	$+1$	$(-1)^b 0$	$+0$	$+0$	NaN
$(-1, 0)$	$+\infty$	NaN	$(-1)^b a ^b$	$+1$	$(-1)^b a ^b$	NaN	$+0$	NaN
-1	$+1$	NaN	$(-1)^b$	$+1$	$(-1)^b$	NaN	$+1$	NaN
$(-\infty, -1)$	$+0$	NaN	$(-1)^b a ^b$	$+1$	$(-1)^b a ^b$	NaN	$+\infty$	NaN
$-\infty$	$+0$	$+0$	$(-1)^b 0$	$+1$	$(-1)^b \infty$	NaN	$+\infty$	NaN
NaN	NaN	NaN	NaN	$+1$	NaN	NaN	NaN	NaN

We distinguished in this table the cases of finite (positive or negative) integer exponents, as $(-1)^b$ is defined in that case. One peculiarity of this operation is that $\text{NaN}^0 = 1^{\text{NaN}} = 1$, because this relation is obeyed for any number, even $\pm\infty$.

`_fp_o:ww` We cram most of the tests into a single function to save csnames. First treat the case $b = 0$: $a^0 = 1$ for any a , even nan . Then test the sign of a .

- If it is positive, and a is a normal number, call `_fp_pow_normal_o:ww` followed by the two `fp` a and b . For $a = +0$ or $+\text{inf}$, call `_fp_pow_zero_or_inf:ww` instead, to return either $+0$ or $+\infty$ as appropriate.
- If a is a `nan`, then skip to the next semicolon (which happens to be conveniently the end of b) and return `nan`.
- Finally, if a is negative, compute a^b (`_fp_pow_normal_o:ww` which ignores the sign of its first operand), and keep an extra copy of a and b (the second brace group, containing $\{ b a \}$, is inserted between a and b). Then do some tests to find the final sign of the result if it exists.

```

20064 \cs_new:cpn { \_fp\_ \iow_char:N \^ \_o:ww }
20065   \s\_fp \_fp\_chk:w #1#2#3; \s\_fp \_fp\_chk:w #4#5#6;
20066   {
20067     \if_meaning:w 0 #4
20068       \_fp\_case\_return_o:Nw \c_one\_fp
20069     \fi:
20070     \if_case:w #2 \exp\_stop\_f:
20071       \exp\_after:wN \use\_i:nn
20072     \or:
20073       \_fp\_case\_return_o:Nw \c_nan\_fp
20074     \else:
20075       \exp\_after:wN \_fp\_pow\_neg:www
20076       \exp:w \exp\_end\_continue\_f:w \exp\_after:wN \use:nn
20077     \fi:
20078     {
20079       \if_meaning:w 1 #1
20080         \exp\_after:wN \_fp\_pow\_normal_o:ww
20081       \else:
20082         \exp\_after:wN \_fp\_pow\_zero\_or\_inf:ww
20083       \fi:
20084       \s\_fp \_fp\_chk:w #1#2#3;
20085     }

```

```

20086     { \s__fp \__fp_chk:w #4#5#6; \s__fp \__fp_chk:w #1#2#3; }
20087     \s__fp \__fp_chk:w #4#5#6;
20088 }

```

(End definition for __fp_~o:ww.)

__fp_pow_zero_or_inf:ww Raising -0 or $-\infty$ to `nan` yields `nan`. For other powers, the result is $+0$ if 0 is raised to a positive power or ∞ to a negative power, and $+\infty$ otherwise. Thus, if the type of a and the sign of b coincide, the result is 0 , since those conveniently take the same possible values, 0 and 2 . Otherwise, either $a = \pm\infty$ and $b > 0$ and the result is $+\infty$, or $a = \pm 0$ with $b < 0$ and we have a division by zero unless $b = -\infty$.

```

20089 \cs_new:Npn \__fp_pow_zero_or_inf:ww
20090   \s__fp \__fp_chk:w #1#2; \s__fp \__fp_chk:w #3#4
20091   {
20092     \if_meaning:w 1 #4
20093       \__fp_case_return_same_o:w
20094     \fi:
20095     \if_meaning:w #1 #4
20096       \__fp_case_return_o:Nw \c_zero_fp
20097     \fi:
20098     \if_meaning:w 2 #1
20099       \__fp_case_return_o:Nw \c_inf_fp
20100     \fi:
20101     \if_meaning:w 2 #3
20102       \__fp_case_return_o:Nw \c_inf_fp
20103     \else:
20104       \__fp_case_use:nw
20105       {
20106         \__fp_division_by_zero_o:NNww \c_inf_fp ^
20107         \s__fp \__fp_chk:w #1 #2 ;
20108       }
20109     \fi:
20110     \s__fp \__fp_chk:w #3#4
20111   }

```

(End definition for __fp_pow_zero_or_inf:ww.)

__fp_pow_normal_o:ww We have in front of us a , and $b \neq 0$, we know that a is a normal number, and we wish to compute $|a|^b$. If $|a| = 1$, we return 1 , unless $a = -1$ and b is `nan`. Indeed, returning 1 at this point would wrongly raise “invalid” when the sign is considered. If $|a| \neq 1$, test the type of b :

- 0 Impossible, we already filtered $b = \pm 0$.
- 1 Call `__fp_pow_npos_o:Nww`.
- 2 Return $+\infty$ or $+0$ depending on the sign of b and whether the exponent of a is positive or not.
- 3 Return b .

```

20112 \cs_new:Npn \__fp_pow_normal_o:ww
20113   \s__fp \__fp_chk:w 1 #1#2#3; \s__fp \__fp_chk:w #4#5
20114   {
20115     \if_int_compare:w \__fp_str_if_eq:nn { #2 #3 }

```

```

20116         { 1 {1000} {0000} {0000} {0000} } = 0 \exp_stop_f:
20117     \if_int_compare:w #4 #1 = 32 \exp_stop_f:
20118         \exp_after:wN \__fp_case_return_ii_o:ww
20119     \fi:
20120     \__fp_case_return_o:Nww \c_one_fp
20121 \fi:
20122 \if_case:w #4 \exp_stop_f:
20123 \or:
20124     \exp_after:wN \__fp_pow_npos_o:Nww
20125     \exp_after:wN #5
20126 \or:
20127     \if_meaning:w 2 #5 \exp_after:wN \reverse_if:N \fi:
20128     \if_int_compare:w #2 > 0 \exp_stop_f:
20129         \exp_after:wN \__fp_case_return_o:Nww
20130         \exp_after:wN \c_inf_fp
20131     \else:
20132         \exp_after:wN \__fp_case_return_o:Nww
20133         \exp_after:wN \c_zero_fp
20134     \fi:
20135 \or:
20136     \__fp_case_return_ii_o:ww
20137 \fi:
20138 \s__fp \__fp_chk:w 1 #1 {#2} #3 ;
20139 \s__fp \__fp_chk:w #4 #5
20140 }

```

(End definition for __fp_pow_normal_o:ww.)

__fp_pow_npos_o:Nww We now know that $a \neq \pm 1$ is a normal number, and b is a normal number too. We want to compute $|a|^b = (|x| \cdot 10^n)^y \cdot 10^p = \exp((\ln|x| + n \ln(10)) \cdot y \cdot 10^p) = \exp(z)$. To compute the exponential accurately, we need to know the digits of z up to the 16-th position. Since the exponential of 10^5 is infinite, we only need at most 21 digits, hence the fixed point result of __fp_ln_o:w is precise enough for our needs. Start an integer expression for the decimal exponent of $e^{|z|}$. If z is negative, negate that decimal exponent, and prepare to take the inverse when converting from the fixed point to the floating point result.

```

20141 \cs_new:Npn \__fp_pow_npos_o:Nww #1 \s__fp \__fp_chk:w 1#2#3
20142 {
20143     \exp_after:wN \__fp_sanitize:Nw
20144     \exp_after:wN 0
20145     \int_value:w
20146     \if:w #1 \if_int_compare:w #3 > 0 \exp_stop_f: 0 \else: 2 \fi:
20147         \exp_after:wN \__fp_pow_npos_aux:NNnw
20148         \exp_after:wN +
20149         \exp_after:wN \__fp_fixed_to_float_o:wN
20150     \else:
20151         \exp_after:wN \__fp_pow_npos_aux:NNnw
20152         \exp_after:wN -
20153         \exp_after:wN \__fp_fixed_inv_to_float_o:wN
20154     \fi:
20155     {#3}
20156 }

```

(End definition for __fp_pow_npos_o:Nww.)

__fp_pow_npos_aux:NNnw The first argument is the conversion function from fixed point to float. Then comes an exponent and the 4 brace groups of x , followed by b . Compute $-\ln(x)$.

```

20157 \cs_new:Npn \__fp_pow_npos_aux:NNnw #1#2#3#4#5; \s_fp \__fp_chk:w 1#6#7#8;
20158 {
20159   #1
20160   \__fp_int_eval:w
20161   \__fp_ln_significand:NNNNnnnN #4#5
20162   \__fp_pow_exponent:wnN {#3}
20163   \__fp_fixed_mul:wwN #8 {0000}{0000} ;
20164   \__fp_pow_B:wwN #7;
20165   #1 #2 0 % fixed_to_float_o:wN
20166 }
20167 \cs_new:Npn \__fp_pow_exponent:wnN #1; #2
20168 {
20169   \if_int_compare:w #2 > 0 \exp_stop_f:
20170   \exp_after:wN \__fp_pow_exponent:Nwnnnnnw % n\ln(10) - (-\ln(x))
20171   \exp_after:wN +
20172   \else:
20173   \exp_after:wN \__fp_pow_exponent:Nwnnnnnw % -(\ln|\ln(10) + (-\ln(x)))
20174   \exp_after:wN -
20175   \fi:
20176   #2; #1;
20177 }
20178 \cs_new:Npn \__fp_pow_exponent:Nwnnnnnw #1#2; #3#4#5#6#7#8;
20179 { %^A todo: use that in ln.
20180   \exp_after:wN \__fp_fixed_mul_after:wwN
20181   \int_value:w \__fp_int_eval:w \c__fp_leading_shift_int
20182   \exp_after:wN \__fp_pack:NNNNNw
20183   \int_value:w \__fp_int_eval:w \c__fp_middle_shift_int
20184   #1#2*23025 - #1 #3
20185   \exp_after:wN \__fp_pack:NNNNNw
20186   \int_value:w \__fp_int_eval:w \c__fp_middle_shift_int
20187   #1 #2*8509 - #1 #4
20188   \exp_after:wN \__fp_pack:NNNNNw
20189   \int_value:w \__fp_int_eval:w \c__fp_middle_shift_int
20190   #1 #2*2994 - #1 #5
20191   \exp_after:wN \__fp_pack:NNNNNw
20192   \int_value:w \__fp_int_eval:w \c__fp_middle_shift_int
20193   #1 #2*0456 - #1 #6
20194   \exp_after:wN \__fp_pack:NNNNNw
20195   \int_value:w \__fp_int_eval:w \c__fp_trailing_shift_int
20196   #1 #2*8401 - #1 #7
20197   #1 ( #2*7991 - #8 ) / 1 0000 ; ;
20198 }
20199 \cs_new:Npn \__fp_pow_B:wwN #1#2#3#4#5#6; #7;
20200 {
20201   \if_int_compare:w #7 < 0 \exp_stop_f:
20202   \exp_after:wN \__fp_pow_C_neg:w \int_value:w -
20203   \else:
20204   \if_int_compare:w #7 < 22 \exp_stop_f:
20205   \exp_after:wN \__fp_pow_C_pos:w \int_value:w
20206   \else:
20207   \exp_after:wN \__fp_pow_C_overflow:w \int_value:w
20208   \fi:

```



```

20209 \fi:
20210 #7 \exp_after:wN ;
20211 \int_value:w \__fp_int_eval:w 10 0000 + #1 \__fp_int_eval_end:
20212 #2#3#4#5#6 0000 0000 0000 0000 0000 0000 ; %^A todo: how many 0?
20213 }
20214 \cs_new:Npn \__fp_pow_C_overflow:w #1; #2; #3
20215 {
20216 + 2 * \c__fp_max_exponent_int
20217 \exp_after:wN \__fp_fixed_continue:wn \c__fp_one_fixed_tl
20218 }
20219 \cs_new:Npn \__fp_pow_C_neg:w #1 ; 1
20220 {
20221 \exp_after:wN \exp_after:wN \exp_after:wN \__fp_pow_C_pack:w
20222 \prg_replicate:nn {#1} {0}
20223 }
20224 \cs_new:Npn \__fp_pow_C_pos:w #1; 1
20225 { \__fp_pow_C_pos_loop:wN #1; }
20226 \cs_new:Npn \__fp_pow_C_pos_loop:wN #1; #2
20227 {
20228 \if_meaning:w 0 #1
20229 \exp_after:wN \__fp_pow_C_pack:w
20230 \exp_after:wN #2
20231 \else:
20232 \if_meaning:w 0 #2
20233 \exp_after:wN \__fp_pow_C_pos_loop:wN \int_value:w
20234 \else:
20235 \exp_after:wN \__fp_pow_C_overflow:w \int_value:w
20236 \fi:
20237 \__fp_int_eval:w #1 - 1 \exp_after:wN ;
20238 \fi:
20239 }
20240 \cs_new:Npn \__fp_pow_C_pack:w
20241 {
20242 \exp_after:wN \__fp_exp_large:NwN
20243 \exp_after:wN 5
20244 \c__fp_one_fixed_tl
20245 }

```

(End definition for __fp_pow_npos_aux:NNnw.)

__fp_pow_neg:www
__fp_pow_neg_aux:wNN

This function is followed by three floating point numbers: a^b , $a \in [-\infty, -0]$, and b . If b is an even integer (case -1), $a^b = a^b$. If b is an odd integer (case 0), $a^b = -a^b$, obtained by a call to __fp_pow_neg_aux:wNN. Otherwise, the sign is undefined. This is invalid, unless a^b turns out to be $+0$ or nan , in which case we return that as a^b . In particular, since the underflow detection occurs before __fp_pow_neg:www is called, $(-0.1)**(12345.67)$ gives $+0$ rather than complaining that the sign is not defined.

```

20246 \cs_new:Npn \__fp_pow_neg:www \s__fp \__fp_chk:w #1#2; #3; #4;
20247 {
20248 \if_case:w \__fp_pow_neg_case:w #4 ;
20249 \exp_after:wN \__fp_pow_neg_aux:wNN
20250 \or:
20251 \if_int_compare:w \__fp_int_eval:w #1 / 2 = 1 \exp_stop_f:
20252 \__fp_invalid_operation_o:Nww ^ #3; #4;
20253 \exp:w \exp_end_continue_f:w

```

```

20254         \exp_after:wN \exp_after:wN
20255         \exp_after:wN \__fp_use_none_until_s:w
20256         \fi:
20257     \fi:
20258     \__fp_exp_after_o:w
20259     \s__fp \__fp_chk:w #1#2;
20260 }
20261 \cs_new:Npn \__fp_pow_neg_aux:wNN #1 \s__fp \__fp_chk:w #2#3
20262 {
20263     \exp_after:wN \__fp_exp_after_o:w
20264     \exp_after:wN \s__fp
20265     \exp_after:wN \__fp_chk:w
20266     \exp_after:wN #2
20267     \int_value:w \__fp_int_eval:w 2 - #3 \__fp_int_eval_end:
20268 }

```

(End definition for __fp_pow_neg:www and __fp_pow_neg_aux:wNN.)

__fp_pow_neg_case:w This function expects a floating point number, and determines its “parity”. It should be used after \if_case:w or in an integer expression. It gives -1 if the number is an even integer, 0 if the number is an odd integer, and 1 otherwise. Zeros and $\pm\infty$ are even (because very large finite floating points are even), while `nan` is a non-integer. The sign of normal numbers is irrelevant to parity. After __fp_decimate:nNnnnn the argument `#1` of __fp_pow_neg_case_aux:Nnnw is a rounding digit, 0 if and only if the number was an integer, and `#3` is the 8 least significant digits of that integer.

```

20269 \cs_new:Npn \__fp_pow_neg_case:w \s__fp \__fp_chk:w #1#2#3;
20270 {
20271     \if_case:w #1 \exp_stop_f:
20272         -1
20273     \or: \__fp_pow_neg_case_aux:nnnnn #3
20274     \or: -1
20275     \else: 1
20276     \fi:
20277     \exp_stop_f:
20278 }
20279 \cs_new:Npn \__fp_pow_neg_case_aux:nnnnn #1#2#3#4#5
20280 {
20281     \if_int_compare:w #1 > \c__fp_prec_int
20282         -1
20283     \else:
20284         \__fp_decimate:nNnnnn { \c__fp_prec_int - #1 }
20285         \__fp_pow_neg_case_aux:Nnnw
20286         {#2} {#3} {#4} {#5}
20287     \fi:
20288 }
20289 \cs_new:Npn \__fp_pow_neg_case_aux:Nnnw #1#2#3#4 ;
20290 {
20291     \if_meaning:w 0 #1
20292         \if_int_odd:w #3 \exp_stop_f:
20293         0
20294     \else:
20295         -1
20296     \fi:
20297     \else:

```

```

20298         1
20299     \fi:
20300 }

```

(End definition for _fp_pow_neg_case:w, _fp_pow_neg_case_aux:nnnnn, and _fp_pow_neg_case_aux:Nnnw.)

33.4 Factorial

\c_fp_fact_max_arg_int The maximum integer whose factorial fits in the exponent range is 3248, as $3249! \sim 10^{10000.8}$

```

20301 \int_const:Nn \c\_fp_fact_max_arg_int { 3248 }

```

(End definition for \c_fp_fact_max_arg_int.)

_fp_fact_o:w First detect ± 0 and $+\infty$ and `nan`. Then note that factorial of anything with a negative sign (except -0) is undefined. Then call _fp_small_int:wTF to get an integer as the argument, and start a loop. This is not the most efficient way of computing the factorial, but it works all right. Of course we work with 24 digits instead of 16. It is easy to check that computing factorials with this precision is enough.

```

20302 \cs_new:Npn \_fp_fact_o:w #1 \s__fp \_fp_chk:w #2#3#4; @
20303 {
20304     \if_case:w #2 \exp_stop_f:
20305         \_fp_case_return_o:Nw \c_one_fp
20306     \or:
20307     \or:
20308         \if_meaning:w 0 #3
20309             \exp_after:wN \_fp_case_return_same_o:w
20310         \fi:
20311     \or:
20312         \_fp_case_return_same_o:w
20313     \fi:
20314     \if_meaning:w 2 #3
20315         \_fp_case_use:nw { \_fp_invalid_operation_o:fw { fact } }
20316     \fi:
20317     \_fp_fact_pos_o:w
20318     \s__fp \_fp_chk:w #2 #3 #4 ;
20319 }

```

(End definition for _fp_fact_o:w.)

_fp_fact_pos_o:w Then check the input is an integer, and call _fp_factorial_int_o:n with that int as an argument. If it's too big the factorial overflows. Otherwise call _fp_sanitize:Nw with a positive sign marker 0 and an integer expression that will mop up any exponent in the calculation.

_fp_fact_int_o:w

```

20320 \cs_new:Npn \_fp_fact_pos_o:w #1;
20321 {
20322     \_fp_small_int:wTF #1;
20323     { \_fp_fact_int_o:n }
20324     { \_fp_invalid_operation_o:fw { fact } #1; }
20325 }
20326 \cs_new:Npn \_fp_fact_int_o:n #1
20327 {
20328     \if_int_compare:w #1 > \c\_fp_fact_max_arg_int

```

```

20329     \__fp_case_return:nw
20330     {
20331         \exp_after:wN \exp_after:wN \exp_after:wN \__fp_overflow:w
20332         \exp_after:wN \c_inf_fp
20333     }
20334     \fi:
20335     \exp_after:wN \__fp_sanitizew
20336     \exp_after:wN 0
20337     \int_value:w \__fp_int_eval:w
20338     \__fp_fact_loop_o:w #1 . 4 , { 1 } { } { } { } { } { } ;
20339 }

```

(End definition for __fp_fact_pos_o:w and __fp_fact_int_o:w.)

__fp_fact_loop_o:w The loop receives an integer #1 whose factorial we want to compute, which we progressively decrement, and the result so far as an extended-precision number #2 in the form $\langle \text{exponent} \rangle, \langle \text{mantissa} \rangle$. The loop goes in steps of two because we compute $\#1 * \#1 - 1$ as an integer expression (it must fit since #1 is at most 3248), then multiply with the result so far. We don't need to fill in most of the mantissa with zeros because __fp_ep_mul:wwwN first normalizes the extended precision number to avoid loss of precision. When reaching a small enough number simply use a table of factorials less than 10^8 . This limit is chosen because the normalization step cannot deal with larger integers.

```

20340 \cs_new:Npn \__fp_fact_loop_o:w #1 . #2 ;
20341 {
20342     \if_int_compare:w #1 < 12 \exp_stop_f:
20343     \__fp_fact_small_o:w #1
20344     \fi:
20345     \exp_after:wN \__fp_ep_mul:wwwN
20346     \exp_after:wN 4 \exp_after:wN ,
20347     \exp_after:wN { \int_value:w \__fp_int_eval:w #1 * (#1 - 1) }
20348     { } { } { } { } { } { } ;
20349     #2 ;
20350     {
20351         \exp_after:wN \__fp_fact_loop_o:w
20352         \int_value:w \__fp_int_eval:w #1 - 2 .
20353     }
20354 }
20355 \cs_new:Npn \__fp_fact_small_o:w #1 \fi: #2 ; #3 ; #4
20356 {
20357     \fi:
20358     \exp_after:wN \__fp_ep_mul:wwwN
20359     \exp_after:wN 4 \exp_after:wN ,
20360     \exp_after:wN
20361     {
20362         \int_value:w
20363         \if_case:w #1 \exp_stop_f:
20364         1 \or: 1 \or: 2 \or: 6 \or: 24 \or: 120 \or: 720 \or: 5040
20365         \or: 40320 \or: 362880 \or: 3628800 \or: 39916800
20366         \fi:
20367     } { } { } { } { } { } { } ;
20368     #3 ;
20369     \__fp_ep_to_float_o:wwN 0
20370 }

```

(End definition for _fp_fact_loop_o:w.)

20371 </initex | package>

34 l3fp-trig Implementation

20372 <*initex | package>

20373 <@@=fp>

Unary functions.

```

\_fp_parse_word_acos:N
\_fp_parse_word_acosd:N
\_fp_parse_word_acsc:N
\_fp_parse_word_acscd:N
\_fp_parse_word_asec:N
\_fp_parse_word_asecd:N
\_fp_parse_word_asin:N
\_fp_parse_word_asind:N
\_fp_parse_word_cos:N
\_fp_parse_word_cosd:N
\_fp_parse_word_cot:N
\_fp_parse_word_cotd:N
\_fp_parse_word_csc:N
\_fp_parse_word_cscd:N
\_fp_parse_word_sec:N
\_fp_parse_word_secd:N
\_fp_parse_word_sin:N
\_fp_parse_word_sind:N
\_fp_parse_word_tan:N
\_fp_parse_word_tand:N

```

```

20374 \tl_map_inline:nn
20375 {
20376   {acos} {acsc} {asec} {asin}
20377   {cos} {cot} {csc} {sec} {sin} {tan}
20378 }
20379 {
20380   \cs_new:cpx { __fp_parse_word_#1:N }
20381   {
20382     \exp_not:N \__fp_parse_unary_function:NNN
20383     \exp_not:c { __fp_#1_o:w }
20384     \exp_not:N \use_i:nn
20385   }
20386   \cs_new:cpx { __fp_parse_word_#1d:N }
20387   {
20388     \exp_not:N \__fp_parse_unary_function:NNN
20389     \exp_not:c { __fp_#1_o:w }
20390     \exp_not:N \use_ii:nn
20391   }
20392 }

```

(End definition for _fp_parse_word_acos:N and others.)

Those functions may receive a variable number of arguments.

```

\_fp_parse_word_acot:N
\_fp_parse_word_acotd:N
\_fp_parse_word_atan:N
\_fp_parse_word_atand:N

```

```

20393 \cs_new:Npn \__fp_parse_word_acot:N
20394 { \__fp_parse_function:NNN \__fp_acot_o:Nw \use_i:nn }
20395 \cs_new:Npn \__fp_parse_word_acotd:N
20396 { \__fp_parse_function:NNN \__fp_acot_o:Nw \use_ii:nn }
20397 \cs_new:Npn \__fp_parse_word_atan:N
20398 { \__fp_parse_function:NNN \__fp_atan_o:Nw \use_i:nn }
20399 \cs_new:Npn \__fp_parse_word_atand:N
20400 { \__fp_parse_function:NNN \__fp_atan_o:Nw \use_ii:nn }

```

(End definition for _fp_parse_word_acot:N and others.)

34.1 Direct trigonometric functions

The approach for all trigonometric functions (sine, cosine, tangent, cotangent, cosecant, and secant), with arguments given in radians or in degrees, is the same.

- Filter out special cases (± 0 , $\pm \inf$ and NaN).
- Keep the sign for later, and work with the absolute value $|x|$ of the argument.
- Small numbers ($|x| < 1$ in radians, $|x| < 10$ in degrees) are converted to fixed point numbers (and to radians if $|x|$ is in degrees).

- For larger numbers, we need argument reduction. Subtract a multiple of $\pi/2$ (in degrees, 90) to bring the number to the range to $[0, \pi/2)$ (in degrees, $[0, 90)$).
- Reduce further to $[0, \pi/4]$ (in degrees, $[0, 45]$) using $\sin x = \cos(\pi/2 - x)$, and when working in degrees, convert to radians.
- Use the appropriate power series depending on the octant $\lfloor \frac{x}{\pi/4} \rfloor \bmod 8$ (in degrees, the same formula with $\pi/4 \rightarrow 45$), the sign, and the function to compute.

34.1.1 Filtering special cases

`__fp_sin_o:w` This function, and its analogs for `cos`, `csc`, `sec`, `tan`, and `cot` instead of `sin`, are followed either by `\use_i:nn` and a float in radians or by `\use_ii:nn` and a float in degrees. The sine of ± 0 or NaN is the same float. The sine of $\pm\infty$ raises an invalid operation exception with the appropriate function name. Otherwise, call the `trig` function to perform argument reduction and if necessary convert the reduced argument to radians. Then, `__fp_sin_series_o:NNwww` is called to compute the Taylor series: this function receives a sign `#3`, an initial octant of 0, and the function `__fp_ep_to_float_o:wwN` which converts the result of the series to a floating point directly rather than taking its inverse, since $\sin(x) = \#3 \sin|x|$.

```

20401 \cs_new:Npn \__fp_sin_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
20402 {
20403   \if_case:w #2 \exp_stop_f:
20404     \__fp_case_return_same_o:w
20405   \or: \__fp_case_use:nw
20406     {
20407       \__fp_trig:NNNNwn #1 \__fp_sin_series_o:NNwww
20408       \__fp_ep_to_float_o:wwN #3 0
20409     }
20410   \or: \__fp_case_use:nw
20411     { \__fp_invalid_operation_o:fw { #1 { sin } { sind } } }
20412   \else: \__fp_case_return_same_o:w
20413   \fi:
20414   \s__fp \__fp_chk:w #2 #3 #4;
20415 }

```

(End definition for `__fp_sin_o:w`.)

`__fp_cos_o:w` The cosine of ± 0 is 1. The cosine of $\pm\infty$ raises an invalid operation exception. The cosine of NaN is itself. Otherwise, the `trig` function reduces the argument to at most half a right-angle and converts if necessary to radians. We then call the same series as for sine, but using a positive sign 0 regardless of the sign of x , and with an initial octant of 2, because $\cos(x) = +\sin(\pi/2 + |x|)$.

```

20416 \cs_new:Npn \__fp_cos_o:w #1 \s__fp \__fp_chk:w #2#3; @
20417 {
20418   \if_case:w #2 \exp_stop_f:
20419     \__fp_case_return_o:Nw \c_one_fp
20420   \or: \__fp_case_use:nw
20421     {
20422       \__fp_trig:NNNNwn #1 \__fp_sin_series_o:NNwww
20423       \__fp_ep_to_float_o:wwN 0 2
20424     }
20425   \or: \__fp_case_use:nw

```

```

20426         { \__fp_invalid_operation_o:fw { #1 { cos } { cosd } } }
20427     \else: \__fp_case_return_same_o:w
20428     \fi:
20429     \s__fp \__fp_chk:w #2 #3;
20430 }

```

(End definition for __fp_cos_o:w.)

__fp_csc_o:w The cosecant of ± 0 is $\pm\infty$ with the same sign, with a division by zero exception (see __fp_cot_zero_o:Nfw defined below), which requires the function name. The cosecant of $\pm\infty$ raises an invalid operation exception. The cosecant of NaN is itself. Otherwise, the `trig` function performs the argument reduction, and converts if necessary to radians before calling the same series as for sine, using the sign #3, a starting octant of 0, and inverting during the conversion from the fixed point sine to the floating point result, because $\csc(x) = \#3(\sin|x|)^{-1}$.

```

20431 \cs_new:Npn \__fp_csc_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
20432 {
20433     \if_case:w #2 \exp_stop_f:
20434         \__fp_cot_zero_o:Nfw #3 { #1 { csc } { cscd } }
20435     \or: \__fp_case_use:nw
20436         {
20437             \__fp_trig:NNNNNwn #1 \__fp_sin_series_o:NNwww
20438             \__fp_ep_inv_to_float_o:wwN #3 0
20439         }
20440     \or: \__fp_case_use:nw
20441         { \__fp_invalid_operation_o:fw { #1 { csc } { cscd } } }
20442     \else: \__fp_case_return_same_o:w
20443     \fi:
20444     \s__fp \__fp_chk:w #2 #3 #4;
20445 }

```

(End definition for __fp_csc_o:w.)

__fp_sec_o:w The secant of ± 0 is 1. The secant of $\pm\infty$ raises an invalid operation exception. The secant of NaN is itself. Otherwise, the `trig` function reduces the argument and turns it to radians before calling the same series as for sine, using a positive sign 0, a starting octant of 2, and inverting upon conversion, because $\sec(x) = +1/\sin(\pi/2 + |x|)$.

```

20446 \cs_new:Npn \__fp_sec_o:w #1 \s__fp \__fp_chk:w #2#3; @
20447 {
20448     \if_case:w #2 \exp_stop_f:
20449         \__fp_case_return_o:Nw \c_one_fp
20450     \or: \__fp_case_use:nw
20451         {
20452             \__fp_trig:NNNNNwn #1 \__fp_sin_series_o:NNwww
20453             \__fp_ep_inv_to_float_o:wwN 0 2
20454         }
20455     \or: \__fp_case_use:nw
20456         { \__fp_invalid_operation_o:fw { #1 { sec } { secd } } }
20457     \else: \__fp_case_return_same_o:w
20458     \fi:
20459     \s__fp \__fp_chk:w #2 #3;
20460 }

```

(End definition for __fp_sec_o:w.)

`__fp_tan_o:w` The tangent of ± 0 or NaN is the same floating point number. The tangent of $\pm\infty$ raises an invalid operation exception. Once more, the `trig` function does the argument reduction step and conversion to radians before calling `__fp_tan_series_o:NNwww`, with a sign #3 and an initial octant of 1 (this shift is somewhat arbitrary). See `__fp_cot_o:w` for an explanation of the 0 argument.

```

20461 \cs_new:Npn \__fp_tan_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
20462 {
20463   \if_case:w #2 \exp_stop_f:
20464     \__fp_case_return_same_o:w
20465   \or: \__fp_case_use:nw
20466     {
20467       \__fp_trig:NNNNwn #1
20468       \__fp_tan_series_o:NNwww 0 #3 1
20469     }
20470   \or: \__fp_case_use:nw
20471     { \__fp_invalid_operation_o:fw { #1 { tan } { tand } } }
20472   \else: \__fp_case_return_same_o:w
20473   \fi:
20474   \s__fp \__fp_chk:w #2 #3 #4;
20475 }

```

(End definition for `__fp_tan_o:w`.)

`__fp_cot_o:w` The cotangent of ± 0 is $\pm\infty$ with the same sign, with a division by zero exception (see `__fp_cot_zero_o:Nfw`). The cotangent of $\pm\infty$ raises an invalid operation exception. The cotangent of NaN is itself. We use $\cot x = -\tan(\pi/2 + x)$, and the initial octant for the tangent was chosen to be 1, so the octant here starts at 3. The change in sign is obtained by feeding `__fp_tan_series_o:NNwww` two signs rather than just the sign of the argument: the first of those indicates whether we compute tangent or cotangent. Those signs are eventually combined.

```

20476 \cs_new:Npn \__fp_cot_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
20477 {
20478   \if_case:w #2 \exp_stop_f:
20479     \__fp_cot_zero_o:Nfw #3 { #1 { cot } { cotd } }
20480   \or: \__fp_case_use:nw
20481     {
20482       \__fp_trig:NNNNwn #1
20483       \__fp_tan_series_o:NNwww 2 #3 3
20484     }
20485   \or: \__fp_case_use:nw
20486     { \__fp_invalid_operation_o:fw { #1 { cot } { cotd } } }
20487   \else: \__fp_case_return_same_o:w
20488   \fi:
20489   \s__fp \__fp_chk:w #2 #3 #4;
20490 }
20491 \cs_new:Npn \__fp_cot_zero_o:Nfw #1#2#3 \fi:
20492 {
20493   \fi:
20494   \token_if_eq_meaning:NNTF 0 #1
20495     { \exp_args:NNf \__fp_division_by_zero_o:Nnw \c_inf_fp }
20496     { \exp_args:NNf \__fp_division_by_zero_o:Nnw \c_minus_inf_fp }
20497   {#2}
20498 }

```


(End definition for `_fp_cot_o:w` and `_fp_cot_zero_o:Nfw`.)

34.1.2 Distinguishing small and large arguments

`_fp_trig:NNNNwn` The first argument is `\use_i:nn` if the operand is in radians and `\use_ii:nn` if it is in degrees. Arguments #2 to #5 control what trigonometric function we compute, and #6 to #8 are pieces of a normal floating point number. Call the `_series` function #2, with arguments #3, either a conversion function (`_fp_ep_to_float_o:wN` or `_fp_ep_inv_to_float_o:wN`) or a sign 0 or 2 when computing tangent or cotangent; #4, a sign 0 or 2; the octant, computed in an integer expression starting with #5 and stopped by a period; and a fixed point number obtained from the floating point number by argument reduction (if necessary) and conversion to radians (if necessary). Any argument reduction adjusts the octant accordingly by leaving a (positive) shift into its integer expression. Let us explain the integer comparison. Two of the four `\exp_after:wN` are expanded, the expansion hits the test, which is true if the float is at least 1 when working in radians, and at least 10 when working in degrees. Then one of the remaining `\exp_after:wN` hits #1, which picks the `trig` or `trigd` function in whichever branch of the conditional was taken. The final `\exp_after:wN` closes the conditional. At the end of the day, a number is `large` if it is ≥ 1 in radians or ≥ 10 in degrees, and `small` otherwise. All four `trig/trigd` auxiliaries receive the operand as an extended-precision number.

```

20499 \cs_new:Npn \_fp_trig:NNNNwn #1#2#3#4#5 \s_fp \_fp_chk:w 1#6#7#8;
20500 {
20501   \exp_after:wN #2
20502   \exp_after:wN #3
20503   \exp_after:wN #4
20504   \int_value:w \_fp_int_eval:w #5
20505   \exp_after:wN \exp_after:wN \exp_after:wN \exp_after:wN
20506   \if_int_compare:w #7 > #1 0 1 \exp_stop_f:
20507     #1 \_fp_trig_large:ww \_fp_trigd_large:ww
20508   \else:
20509     #1 \_fp_trig_small:ww \_fp_trigd_small:ww
20510   \fi:
20511   #7,#8{0000}{0000};
20512 }
```

(End definition for `_fp_trig:NNNNwn`.)

34.1.3 Small arguments

`_fp_trig_small:ww` This receives a small extended-precision number in radians and converts it to a fixed point number. Some trailing digits may be lost in the conversion, so we keep the original floating point number around: when computing sine or tangent (or their inverses), the last step is to multiply by the floating point number (as an extended-precision number) rather than the fixed point number. The period serves to end the integer expression for the octant.

```

20513 \cs_new:Npn \_fp_trig_small:ww #1,#2;
20514 { \_fp_ep_to_fixed:wwn #1,#2; . #1,#2; }
```

(End definition for `_fp_trig_small:ww`.)

`_fp_trigd_small:ww` Convert the extended-precision number to radians, then call `_fp_trig_small:ww` to massage it in the form appropriate for the `_series` auxiliary.

```

20515 \cs_new:Npn \__fp_trigd_small:ww #1,#2;
20516 {
20517   \__fp_ep_mul_raw:wwwN
20518   -1,{1745}{3292}{5199}{4329}{5769}{2369}; #1,#2;
20519   \__fp_trig_small:ww
20520 }

```

(End definition for __fp_trigd_small:ww.)

34.1.4 Argument reduction in degrees

__fp_trigd_large:ww Note that $25 \times 360 = 9000$, so $10^{k+1} \equiv 10^k \pmod{360}$ for $k \geq 3$. When the exponent #1 is very large, we can thus safely replace it by 22 (or even 19). We turn the floating point number into a fixed point number with two blocks of 8 digits followed by five blocks of 4 digits. The original float is $100 \times \langle block_1 \rangle \cdots \langle block_3 \rangle . \langle block_4 \rangle \cdots \langle block_7 \rangle$, or is equal to it modulo 360 if the exponent #1 is very large. The first auxiliary finds $\langle block_1 \rangle + \langle block_2 \rangle \pmod{9}$, a single digit, and prepends it to the 4 digits of $\langle block_3 \rangle$. It also unpacks $\langle block_4 \rangle$ and grabs the 4 digits of $\langle block_7 \rangle$. The second auxiliary grabs the $\langle block_3 \rangle$ plus any contribution from the first two blocks as #1, the first digit of $\langle block_4 \rangle$ (just after the decimal point in hundreds of degrees) as #2, and the three other digits as #3. It finds the quotient and remainder of #1#2 modulo 9, adds twice the quotient to the integer expression for the octant, and places the remainder (between 0 and 8) before #3 to form a new $\langle block_4 \rangle$. The resulting fixed point number is $x \in [0, 0.9]$. If $x \geq 0.45$, we add 1 to the octant and feed $0.9 - x$ with an exponent of 2 (to compensate the fact that we are working in units of hundreds of degrees rather than degrees) to __fp_trigd_small:ww. Otherwise, we feed it x with an exponent of 2. The third auxiliary also discards digits which were not packed into the various $\langle blocks \rangle$. Since the original exponent #1 is at least 2, those are all 0 and no precision is lost (#6 and #7 are four 0 each).

```

20521 \cs_new:Npn \__fp_trigd_large:ww #1, #2#3#4#5#6#7;
20522 {
20523   \exp_after:wN \__fp_pack_eight:wNNNNNNNN
20524   \exp_after:wN \__fp_pack_eight:wNNNNNNNN
20525   \exp_after:wN \__fp_pack_twice_four:wNNNNNNNN
20526   \exp_after:wN \__fp_pack_twice_four:wNNNNNNNN
20527   \exp_after:wN \__fp_trigd_large_auxi:nnnnwNNNN
20528   \exp_after:wN ;
20529   \exp:w \exp_end_continue_f:w
20530   \prg_replicate:nn { \int_max:nn { 22 - #1 } { 0 } } { 0 }
20531   #2#3#4#5#6#7 0000 0000 0000 !
20532 }
20533 \cs_new:Npn \__fp_trigd_large_auxi:nnnnwNNNN #1#2#3#4#5; #6#7#8#9
20534 {
20535   \exp_after:wN \__fp_trigd_large_auxii:wNw
20536   \int_value:w \__fp_int_eval:w #1 + #2
20537   - (#1 + #2 - 4) / 9 * 9 \__fp_int_eval_end:
20538   #3;
20539   #4; #5{#6#7#8#9};
20540 }
20541 \cs_new:Npn \__fp_trigd_large_auxii:wNw #1; #2#3;
20542 {
20543   + (#1#2 - 4) / 9 * 2
20544   \exp_after:wN \__fp_trigd_large_auxiii:www
20545   \int_value:w \__fp_int_eval:w #1#2

```

```

20546         - (#1#2 - 4) / 9 * 9 \_fp_int_eval_end: #3 ;
20547     }
20548 \cs_new:Npn \_fp_trigd_large_auxiii:www #1; #2; #3!
20549 {
20550     \if_int_compare:w #1 < 4500 \exp_stop_f:
20551         \exp_after:wN \_fp_use_i_until_s:nw
20552         \exp_after:wN \_fp_fixed_continue:wn
20553     \else:
20554         + 1
20555     \fi:
20556     \_fp_fixed_sub:wnn {9000}{0000}{0000}{0000}{0000}{0000};
20557     {#1}#2{0000}{0000};
20558     { \_fp_trigd_small:ww 2, }
20559 }

```

(End definition for `_fp_trigd_large:ww` and others.)

34.1.5 Argument reduction in radians

Arguments greater or equal to 1 need to be reduced to a range where we only need a few terms of the Taylor series. We reduce to the range $[0, 2\pi]$ by subtracting multiples of 2π , then to the smaller range $[0, \pi/2]$ by subtracting multiples of $\pi/2$ (keeping track of how many times $\pi/2$ is subtracted), then to $[0, \pi/4]$ by mapping $x \rightarrow \pi/2 - x$ if appropriate. When the argument is very large, say, 10^{100} , an equally large multiple of 2π must be subtracted, hence we must work with a very good approximation of 2π in order to get a sensible remainder modulo 2π .

Specifically, we multiply the argument by an approximation of $1/(2\pi)$ with 10048 digits, then discard the integer part of the result, keeping 52 digits of the fractional part. From the fractional part of $x/(2\pi)$ we deduce the octant (quotient of the first three digits by 125). We then multiply by 8 or -8 (the latter when the octant is odd), ignore any integer part (related to the octant), and convert the fractional part to an extended precision number, before multiplying by $\pi/4$ to convert back to a value in radians in $[0, \pi/4]$.

It is possible to prove that given the precision of floating points and their range of exponents, the 52 digits may start at most with 24 zeros. The 5 last digits are affected by carries from computations which are not done, hence we are left with at least $52 - 24 - 5 = 23$ significant digits, enough to round correctly up to $0.6 \cdot \text{ulp}$ in all cases.

`\c_fp_trig_intarray` This integer array stores blocks of 8 decimals of $10^{-16}/(2\pi)$. Each entry is 10^8 plus an 8 digit number storing 8 decimals. In total we store 10112 decimals of $10^{-16}/(2\pi)$. The number of decimals we really need is the maximum exponent plus the number of digits we later need, 52, plus 12 ($4 - 1$ groups of 4 digits). The memory footprint (1/2 byte per digit) is the same as an earlier method of storing the data as a control sequence name, but the major advantage is that we can unpack specific subsets of the digits without unpacking the 10112 decimals.

```

20560 \intarray_const_from_clist:Nn \c_fp_trig_intarray
20561 {
20562     100000000, 100000000, 115915494, 130918953, 135768883, 176337251,
20563     143620344, 159645740, 145644874, 176673440, 158896797, 163422653,
20564     150901138, 102766253, 108595607, 128427267, 157958036, 189291184,
20565     161145786, 152877967, 141073169, 198392292, 139966937, 140907757,
20566     130777463, 196925307, 168871739, 128962173, 197661693, 136239024,

```

20567	117236290, 111832380, 111422269, 197557159, 140461890, 108690267,
20568	139561204, 189410936, 193784408, 155287230, 199946443, 140024867,
20569	123477394, 159610898, 132309678, 130749061, 166986462, 180469944,
20570	186521878, 181574786, 156696424, 110389958, 174139348, 160998386,
20571	180991999, 162442875, 158517117, 188584311, 117518767, 116054654,
20572	175369880, 109739460, 136475933, 137680593, 102494496, 163530532,
20573	171567755, 103220324, 177781639, 171660229, 146748119, 159816584,
20574	106060168, 103035998, 113391198, 174988327, 186654435, 127975507,
20575	100162406, 177564388, 184957131, 108801221, 199376147, 168137776,
20576	147378906, 133068046, 145797848, 117613124, 127314069, 196077502,
20577	145002977, 159857089, 105690279, 167851315, 125210016, 131774602,
20578	109248116, 106240561, 145620314, 164840892, 148459191, 143521157,
20579	154075562, 100871526, 160680221, 171591407, 157474582, 172259774,
20580	162853998, 175155329, 139081398, 117724093, 158254797, 107332871,
20581	190406999, 175907657, 170784934, 170393589, 182808717, 134256403,
20582	166895116, 162545705, 194332763, 112686500, 126122717, 197115321,
20583	112599504, 138667945, 103762556, 108363171, 116952597, 158128224,
20584	194162333, 143145106, 112353687, 185631136, 136692167, 114206974,
20585	169601292, 150578336, 105311960, 185945098, 139556718, 170995474,
20586	165104316, 123815517, 158083944, 129799709, 199505254, 138756612,
20587	194458833, 106846050, 178529151, 151410404, 189298850, 163881607,
20588	176196993, 107341038, 199957869, 118905980, 193737772, 106187543,
20589	122271893, 101366255, 126123878, 103875388, 181106814, 106765434,
20590	108282785, 126933426, 179955607, 107903860, 160352738, 199624512,
20591	159957492, 176297023, 159409558, 143011648, 129641185, 157771240,
20592	157544494, 175021789, 176979240, 194903272, 194770216, 164960356,
20593	153181535, 144003840, 168987471, 176915887, 163190966, 150696440,
20594	147769706, 187683656, 177810477, 197954503, 153395758, 130188183,
20595	186879377, 166124814, 195305996, 155802190, 183598751, 103512712,
20596	190432315, 180498719, 168687775, 194656634, 162210342, 104440855,
20597	149785037, 192738694, 129353661, 193778292, 187359378, 143470323,
20598	102371458, 137923557, 111863634, 119294601, 183182291, 196416500,
20599	187830793, 131353497, 179099745, 186492902, 167450609, 189368909,
20600	145883050, 133703053, 180547312, 132158094, 131976760, 132283131,
20601	141898097, 149822438, 133517435, 169898475, 101039500, 168388003,
20602	197867235, 199608024, 100273901, 108749548, 154787923, 156826113,
20603	199489032, 168997427, 108349611, 149208289, 103776784, 174303550,
20604	145684560, 183671479, 130845672, 133270354, 185392556, 120208683,
20605	193240995, 162211753, 131839402, 109707935, 170774965, 149880868,
20606	160663609, 168661967, 103747454, 121028312, 119251846, 122483499,
20607	111611495, 166556037, 196967613, 199312829, 196077608, 127799010,
20608	107830360, 102338272, 198790854, 102387615, 157445430, 192601191,
20609	100543379, 198389046, 154921248, 129516070, 172853005, 122721023,
20610	160175233, 113173179, 175931105, 103281551, 109373913, 163964530,
20611	157926071, 180083617, 195487672, 146459804, 173977292, 144810920,
20612	109371257, 186918332, 189588628, 139904358, 168666639, 175673445,
20613	114095036, 137327191, 174311388, 106638307, 125923027, 159734506,
20614	105482127, 178037065, 133778303, 121709877, 134966568, 149080032,
20615	169885067, 141791464, 168350828, 116168533, 114336160, 173099514,
20616	198531198, 119733758, 144420984, 116559541, 152250643, 139431286,
20617	144403838, 183561508, 179771645, 101706470, 167518774, 156059160,
20618	187168578, 157939226, 123475633, 117111329, 198655941, 159689071,
20619	198506887, 144230057, 151919770, 156900382, 118392562, 120338742,
20620	135362568, 108354156, 151729710, 188117217, 195936832, 156488518,

20621 174997487, 108553116, 159830610, 113921445, 144601614, 188452770,
20622 125114110, 170248521, 173974510, 138667364, 103872860, 109967489,
20623 131735618, 112071174, 104788993, 168886556, 192307848, 150230570,
20624 157144063, 163863202, 136852010, 174100574, 185922811, 115721968,
20625 100397824, 175953001, 166958522, 112303464, 118773650, 143546764,
20626 164565659, 171901123, 108476709, 193097085, 191283646, 166919177,
20627 169387914, 133315566, 150669813, 121641521, 100895711, 172862384,
20628 126070678, 145176011, 113450800, 169947684, 122356989, 162488051,
20629 157759809, 153397080, 185475059, 175362656, 149034394, 145420581,
20630 178864356, 183042000, 131509559, 147434392, 152544850, 167491429,
20631 108647514, 142303321, 133245695, 111634945, 167753939, 142403609,
20632 105438335, 152829243, 142203494, 184366151, 146632286, 102477666,
20633 166049531, 140657343, 157553014, 109082798, 180914786, 169343492,
20634 127376026, 134997829, 195701816, 119643212, 133140475, 176289748,
20635 140828911, 174097478, 126378991, 181699939, 148749771, 151989818,
20636 172666294, 160183053, 195832752, 109236350, 168538892, 128468247,
20637 125997252, 183007668, 156937583, 165972291, 198244297, 147406163,
20638 181831139, 158306744, 134851692, 185973832, 137392662, 140243450,
20639 119978099, 140402189, 161348342, 173613676, 144991382, 171541660,
20640 163424829, 136374185, 106122610, 186132119, 198633462, 184709941,
20641 183994274, 129559156, 128333990, 148038211, 175011612, 111667205,
20642 119125793, 103552929, 124113440, 131161341, 112495318, 138592695,
20643 184904438, 146807849, 109739828, 108855297, 104515305, 139914009,
20644 188698840, 188365483, 166522246, 168624087, 125401404, 100911787,
20645 142122045, 123075334, 173972538, 114940388, 141905868, 142311594,
20646 163227443, 139066125, 116239310, 162831953, 123883392, 113153455,
20647 163815117, 152035108, 174595582, 101123754, 135976815, 153401874,
20648 107394340, 136339780, 138817210, 104531691, 182951948, 179591767,
20649 139541778, 179243527, 161740724, 160593916, 102732282, 187946819,
20650 136491289, 149714953, 143255272, 135916592, 198072479, 198580612,
20651 169007332, 118844526, 179433504, 155801952, 149256630, 162048766,
20652 116134365, 133992028, 175452085, 155344144, 109905129, 182727454,
20653 165911813, 122232840, 151166615, 165070983, 175574337, 129548631,
20654 120411217, 116380915, 160616116, 157320000, 183306114, 160618128,
20655 103262586, 195951602, 146321661, 138576614, 180471993, 127077713,
20656 116441201, 159496011, 106328305, 120759583, 148503050, 179095584,
20657 198298218, 167402898, 138551383, 123957020, 180763975, 150429225,
20658 198476470, 171016426, 197438450, 143091658, 164528360, 132493360,
20659 143546572, 137557916, 113663241, 120457809, 196971566, 134022158,
20660 180545794, 131328278, 100552461, 132088901, 187421210, 192448910,
20661 141005215, 149680971, 113720754, 100571096, 134066431, 135745439,
20662 191597694, 135788920, 179342561, 177830222, 137011486, 142492523,
20663 192487287, 113132021, 176673607, 156645598, 127260957, 141566023,
20664 143787436, 129132109, 174858971, 150713073, 191040726, 143541417,
20665 197057222, 165479803, 181512759, 157912400, 125344680, 148220261,
20666 173422990, 101020483, 106246303, 137964746, 178190501, 181183037,
20667 151538028, 179523433, 141955021, 135689770, 191290561, 143178787,
20668 192086205, 174499925, 178975690, 118492103, 124206471, 138519113,
20669 188147564, 102097605, 154895793, 178514140, 141453051, 151583964,
20670 128232654, 106020603, 131189158, 165702720, 186250269, 191639375,
20671 115278873, 160608114, 155694842, 110322407, 177272742, 116513642,
20672 134366992, 171634030, 194053074, 180652685, 109301658, 192136921,
20673 141431293, 171341061, 157153714, 106203978, 147618426, 150297807,
20674 186062669, 169960809, 118422347, 163350477, 146719017, 145045144,

20675	161663828,	146208240,	186735951,	102371302,	190444377,	194085350,
20676	134454426,	133413062,	163074595,	113830310,	122931469,	134466832,
20677	185176632,	182415152,	110179422,	164439571,	181217170,	121756492,
20678	119644493,	196532222,	118765848,	182445119,	109401340,	150443213,
20679	198586286,	121083179,	139396084,	143898019,	114787389,	177233102,
20680	186310131,	148695521,	126205182,	178063494,	157118662,	177825659,
20681	188310053,	151552316,	165984394,	109022180,	163144545,	121212978,
20682	197344714,	188741258,	126822386,	102360271,	109981191,	152056882,
20683	134723983,	158013366,	106837863,	128867928,	161973236,	172536066,
20684	185216856,	132011948,	197807339,	158419190,	166595838,	167852941,
20685	124187182,	117279875,	106103946,	106481958,	157456200,	160892122,
20686	184163943,	173846549,	158993202,	184812364,	133466119,	170732430,
20687	195458590,	173361878,	162906318,	150165106,	126757685,	112163575,
20688	188696307,	145199922,	100107766,	176830946,	198149756,	122682434,
20689	179367131,	108412102,	119520899,	148191244,	140487511,	171059184,
20690	141399078,	189455775,	118462161,	190415309,	134543802,	180893862,
20691	180732375,	178615267,	179711433,	123241969,	185780563,	176301808,
20692	184386640,	160717536,	183213626,	129671224,	126094285,	140110963,
20693	121826276,	151201170,	122552929,	128965559,	146082049,	138409069,
20694	107606920,	103954646,	119164002,	115673360,	117909631,	187289199,
20695	186343410,	186903200,	157966371,	103128612,	135698881,	176403642,
20696	152540837,	109810814,	183519031,	121318624,	172281810,	150845123,
20697	169019064,	166322359,	138872454,	163073727,	128087898,	130041018,
20698	194859136,	173742589,	141812405,	167291912,	138003306,	134499821,
20699	196315803,	186381054,	124578934,	150084553,	128031351,	118843410,
20700	107373060,	159565443,	173624887,	171292628,	198074235,	139074061,
20701	178690578,	144431052,	174262641,	176783005,	182214864,	162289361,
20702	192966929,	192033046,	169332843,	181580535,	164864073,	118444059,
20703	195496893,	153773183,	167266131,	130108623,	158802128,	180432893,
20704	144562140,	147978945,	142337360,	158506327,	104399819,	132635916,
20705	168734194,	136567839,	101281912,	120281622,	195003330,	112236091,
20706	185875592,	101959081,	122415367,	194990954,	148881099,	175891989,
20707	108115811,	163538891,	163394029,	123722049,	184837522,	142362091,
20708	100834097,	156679171,	100841679,	157022331,	178971071,	102928884,
20709	189701309,	195339954,	124415335,	106062584,	139214524,	133864640,
20710	134324406,	157317477,	155340540,	144810061,	177612569,	108474646,
20711	114329765,	143900008,	138265211,	145210162,	136643111,	197987319,
20712	102751191,	144121361,	169620456,	193602633,	161023559,	162140467,
20713	102901215,	167964187,	135746835,	187317233,	110047459,	163339773,
20714	124770449,	118885134,	141536376,	100915375,	164267438,	145016622,
20715	113937193,	106748706,	128815954,	164819775,	119220771,	102367432,
20716	189062690,	170911791,	194127762,	112245117,	123546771,	115640433,
20717	135772061,	166615646,	174474627,	130562291,	133320309,	153340551,
20718	138417181,	194605321,	150142632,	180008795,	151813296,	175497284,
20719	167018836,	157425342,	150169942,	131069156,	134310662,	160434122,
20720	105213831,	158797111,	150754540,	163290657,	102484886,	148697402,
20721	187203725,	198692811,	149360627,	140384233,	128749423,	132178578,
20722	177507355,	171857043,	178737969,	134023369,	102911446,	196144864,
20723	197697194,	134527467,	144296030,	189437192,	154052665,	188907106,
20724	162062575,	150993037,	199766583,	167936112,	181374511,	104971506,
20725	115378374,	135795558,	167972129,	135876446,	130937572,	103221320,
20726	124605656,	161129971,	131027586,	191128460,	143251843,	143269155,
20727	129284585,	173495971,	150425653,	199302112,	118494723,	121323805,
20728	116549802,	190991967,	168151180,	122483192,	151273721,	199792134,

```

20729 133106764, 121874844, 126215985, 112167639, 167793529, 182985195,
20730 185453921, 106957880, 158685312, 132775454, 133229161, 198905318,
20731 190537253, 191582222, 192325972, 178133427, 181825606, 148823337,
20732 160719681, 101448145, 131983362, 137910767, 112550175, 128826351,
20733 183649210, 135725874, 110356573, 189469487, 154446940, 118175923,
20734 106093708, 128146501, 185742532, 149692127, 164624247, 183221076,
20735 154737505, 168198834, 156410354, 158027261, 125228550, 131543250,
20736 139591848, 191898263, 104987591, 115406321, 103542638, 190012837,
20737 142615518, 178773183, 175862355, 117537850, 169565995, 170028011,
20738 158412588, 170150030, 117025916, 174630208, 142412449, 112839238,
20739 105257725, 114737141, 123102301, 172563968, 130555358, 132628403,
20740 183638157, 168682846, 143304568, 105994018, 170010719, 152092970,
20741 117799058, 132164175, 179868116, 158654714, 177489647, 116547948,
20742 183121404, 131836079, 184431405, 157311793, 149677763, 173989893,
20743 102277656, 107058530, 140837477, 152640947, 143507039, 152145247,
20744 101683884, 107090870, 161471944, 137225650, 128231458, 172995869,
20745 173831689, 171268519, 139042297, 111072135, 107569780, 137262545,
20746 181410950, 138270388, 198736451, 162848201, 180468288, 120582913,
20747 153390138, 135649144, 130040157, 106509887, 192671541, 174507066,
20748 186888783, 143805558, 135011967, 145862340, 180595327, 124727843,
20749 182925939, 157715840, 136885940, 198993925, 152416883, 178793572,
20750 179679516, 154076673, 192703125, 164187609, 162190243, 104699348,
20751 159891990, 160012977, 174692145, 132970421, 167781726, 115178506,
20752 153008552, 155999794, 102099694, 155431545, 127458567, 104403686,
20753 168042864, 184045128, 181182309, 179349696, 127218364, 192935516,
20754 120298724, 169583299, 148193297, 183358034, 159023227, 105261254,
20755 121144370, 184359584, 194433836, 138388317, 175184116, 108817112,
20756 151279233, 137457721, 193398208, 119005406, 132929377, 175306906,
20757 160741530, 149976826, 147124407, 176881724, 186734216, 185881509,
20758 191334220, 175930947, 117385515, 193408089, 157124410, 163472089,
20759 131949128, 180783576, 131158294, 100549708, 191802336, 165960770,
20760 170927599, 101052702, 181508688, 197828549, 143403726, 142729262,
20761 110348701, 139928688, 153550062, 106151434, 130786653, 196085995,
20762 100587149, 139141652, 106530207, 100852656, 124074703, 166073660,
20763 153338052, 163766757, 120188394, 197277047, 122215363, 138511354,
20764 183463624, 161985542, 159938719, 133367482, 104220974, 149956672,
20765 170250544, 164232439, 157506869, 159133019, 137469191, 142980999,
20766 134242305, 150172665, 121209241, 145596259, 160554427, 159095199,
20767 168243130, 184279693, 171132070, 121049823, 123819574, 171759855,
20768 119501864, 163094029, 175943631, 194450091, 191506160, 149228764,
20769 132319212, 197034460, 193584259, 126727638, 168143633, 109856853,
20770 127860243, 132141052, 133076065, 188414958, 158718197, 107124299,
20771 159592267, 181172796, 144388537, 196763139, 127431422, 179531145,
20772 100064922, 112650013, 132686230, 121550837,
20773 }

```

(End definition for \c__fp_trig_intarray.)

```

\__fp_trig_large:ww The exponent #1 is between 1 and 10000. We wish to look up decimals  $10^{\#1-16}/(2\pi)$ 
\__fp_trig_large_auxi:w starting from the digit #1 + 1. Since they are stored in batches of 8, compute  $\lceil \#1/8 \rceil$ 
\__fp_trig_large_auxii:w and fetch blocks of 8 digits starting there. The numbering of items in \c__fp_trig_
\__fp_trig_large_auxiii:w intarray starts at 1, so the block  $\lceil \#1/8 \rceil + 1$  contains the digit we want, at one of the
eight positions. Each call to \int_value:w \__kernel_intarray_item:Nn expands the
next, until being stopped by \__fp_trig_large_auxiii:w using \exp_stop_f:. Once

```

all these blocks are unpacked, the \exp_stop_f: and 0 to 7 digits are removed by \use_none:n...n. Finally, __fp_trig_large_auxii:w packs 64 digits (there are between 65 and 72 at this point) into groups of 4 and the auxv auxiliary is called.

```

20774 \cs_new:Npn \__fp_trig_large:ww #1, #2#3#4#5#6;
20775 {
20776   \exp_after:wN \__fp_trig_large_auxi:w
20777   \int_value:w \__fp_int_eval:w (#1 - 4) / 8 \exp_after:wN ,
20778   \int_value:w #1 , ;
20779   {#2}{#3}{#4}{#5} ;
20780 }
20781 \cs_new:Npn \__fp_trig_large_auxi:w #1, #2,
20782 {
20783   \exp_after:wN \exp_after:wN
20784   \exp_after:wN \__fp_trig_large_auxiii:w
20785   \cs:w
20786     use_none:n \prg_replicate:nn { #2 - #1 * 8 } { n }
20787   \exp_after:wN
20788   \cs_end:
20789   \int_value:w
20790   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20791     { \__fp_int_eval:w #1 + 1 \scan_stop: }
20792   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20793   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20794     { \__fp_int_eval:w #1 + 2 \scan_stop: }
20795   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20796   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20797     { \__fp_int_eval:w #1 + 3 \scan_stop: }
20798   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20799   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20800     { \__fp_int_eval:w #1 + 4 \scan_stop: }
20801   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20802   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20803     { \__fp_int_eval:w #1 + 5 \scan_stop: }
20804   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20805   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20806     { \__fp_int_eval:w #1 + 6 \scan_stop: }
20807   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20808   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20809     { \__fp_int_eval:w #1 + 7 \scan_stop: }
20810   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20811   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20812     { \__fp_int_eval:w #1 + 8 \scan_stop: }
20813   \exp_after:wN \__fp_trig_large_auxiii:w \int_value:w
20814   \__kernel_intarray_item:Nn \c__fp_trig_intarray
20815     { \__fp_int_eval:w #1 + 9 \scan_stop: }
20816   \exp_stop_f:
20817 }
20818 \cs_new:Npn \__fp_trig_large_auxii:w
20819 {
20820   \__fp_pack_twice_four:wNNNNNNNN \__fp_pack_twice_four:wNNNNNNNN
20821   \__fp_pack_twice_four:wNNNNNNNN \__fp_pack_twice_four:wNNNNNNNN
20822   \__fp_pack_twice_four:wNNNNNNNN \__fp_pack_twice_four:wNNNNNNNN
20823   \__fp_pack_twice_four:wNNNNNNNN \__fp_pack_twice_four:wNNNNNNNN
20824   \__fp_trig_large_auxv:www ;

```



```

20825     }
20826 \cs_new:Npn \__fp_trig_large_auxiii:w 1 { \exp_stop_f: }

```

(End definition for __fp_trig_large:ww and others.)

```

\__fp_trig_large_auxv:www
\__fp_trig_large_auxvi:wnnnnnnnn
\__fp_trig_large_pack:NNNNNw

```

First come the first 64 digits of the fractional part of $10^{1-16}/(2\pi)$, arranged in 16 blocks of 4, and ending with a semicolon. Then a few more digits of the same fractional part, ending with a semicolon, then 4 blocks of 4 digits holding the significand of the original argument. Multiply the 16-digit significand with the 64-digit fractional part: the `auxvi` auxiliary receives the significand as `#2#3#4#5` and 16 digits of the fractional part as `#6#7#8#9`, and computes one step of the usual ladder of `pack` functions we use for multiplication (see *e.g.*, `__fp_fixed_mul:wwn`), then discards one block of the fractional part to set things up for the next step of the ladder. We perform 13 such steps, replacing the last `middle` shift by the appropriate `trailing` shift, then discard the significand and remaining 3 blocks from the fractional part, as there are not enough digits to compute any more step in the ladder. The last semicolon closes the ladder, and we return control to the `auxvii` auxiliary.

```

20827 \cs_new:Npn \__fp_trig_large_auxv:www #1; #2; #3;
20828 {
20829     \exp_after:wN \__fp_use_i_until_s:nw
20830     \exp_after:wN \__fp_trig_large_auxvii:w
20831     \int_value:w \__fp_int_eval:w \c__fp_leading_shift_int
20832     \prg_replicate:nn { 13 }
20833     { \__fp_trig_large_auxvi:wnnnnnnnn }
20834     + \c__fp_trailing_shift_int - \c__fp_middle_shift_int
20835     \__fp_use_i_until_s:nw
20836     ; #3 #1 ; ;
20837 }
20838 \cs_new:Npn \__fp_trig_large_auxvi:wnnnnnnnn #1; #2#3#4#5#6#7#8#9
20839 {
20840     \exp_after:wN \__fp_trig_large_pack:NNNNNw
20841     \int_value:w \__fp_int_eval:w \c__fp_middle_shift_int
20842     + #2*#9 + #3*#8 + #4*#7 + #5*#6
20843     #1; {#2}{#3}{#4}{#5} {#7}{#8}{#9}
20844 }
20845 \cs_new:Npn \__fp_trig_large_pack:NNNNNw #1#2#3#4#5#6;
20846 { + #1#2#3#4#5 ; #6 }

```

(End definition for __fp_trig_large_auxv:www, __fp_trig_large_auxvi:wnnnnnnnn, and __fp_trig_large_pack:NNNNNw.)

```

\__fp_trig_large_auxvii:w
\__fp_trig_large_auxviii:w
\__fp_trig_large_auxix:Nw
\__fp_trig_large_auxx:wNNNNN
\__fp_trig_large_auxxi:w

```

The `auxvii` auxiliary is followed by 52 digits and a semicolon. We find the octant as the integer part of 8 times what follows, or equivalently as the integer part of `#1#2#3/125`, and add it to the surrounding integer expression for the octant. We then compute 8 times the 52-digit number, with a minus sign if the octant is odd. Again, the last `middle` shift is converted to a `trailing` shift. Any integer part (including negative values which come up when the octant is odd) is discarded by `__fp_use_i_until_s:nw`. The resulting fractional part should then be converted to radians by multiplying by $2\pi/8$, but first, build an extended precision number by abusing `__fp_ep_to_ep_loop:N` with the appropriate trailing markers. Finally, `__fp_trig_small:ww` sets up the argument for the functions which compute the Taylor series.

```

20847 \cs_new:Npn \__fp_trig_large_auxvii:w #1#2#3
20848 {

```

```

20849 \exp_after:wN \__fp_trig_large_auxviii:ww
20850 \int_value:w \__fp_int_eval:w (#1#2#3 - 62) / 125 ;
20851 #1#2#3
20852 }
20853 \cs_new:Npn \__fp_trig_large_auxviii:ww #1;
20854 {
20855 + #1
20856 \if_int_odd:w #1 \exp_stop_f:
20857 \exp_after:wN \__fp_trig_large_auxix:Nw
20858 \exp_after:wN -
20859 \else:
20860 \exp_after:wN \__fp_trig_large_auxix:Nw
20861 \exp_after:wN +
20862 \fi:
20863 }
20864 \cs_new:Npn \__fp_trig_large_auxix:Nw
20865 {
20866 \exp_after:wN \__fp_use_i_until:s:nw
20867 \exp_after:wN \__fp_trig_large_auxxi:w
20868 \int_value:w \__fp_int_eval:w \c__fp_leading_shift_int
20869 \prg_replicate:nn { 13 }
20870 { \__fp_trig_large_auxx:wNNNNN }
20871 + \c__fp_trailing_shift_int - \c__fp_middle_shift_int
20872 ;
20873 }
20874 \cs_new:Npn \__fp_trig_large_auxx:wNNNNN #1; #2 #3#4#5#6
20875 {
20876 \exp_after:wN \__fp_trig_large_pack:NNNNNw
20877 \int_value:w \__fp_int_eval:w \c__fp_middle_shift_int
20878 #2 8 * #3#4#5#6
20879 #1; #2
20880 }
20881 \cs_new:Npn \__fp_trig_large_auxxi:w #1;
20882 {
20883 \exp_after:wN \__fp_ep_mul_raw:wwwN
20884 \int_value:w \__fp_int_eval:w 0 \__fp_ep_to_ep_loop:N #1 ; ; !
20885 0,{7853}{9816}{3397}{4483}{0961}{5661};
20886 \__fp_trig_small:ww
20887 }

```

(End definition for __fp_trig_large_auxvii:w and others.)

34.1.6 Computing the power series

__fp_sin_series_o:NNwwww Here we receive a conversion function __fp_ep_to_float_o:wwN or __fp_ep_inv_to_float_o:wwN, a *sign* (0 or 2), a (non-negative) *octant* delimited by a dot, a *fixed point* number delimited by a semicolon, and an extended-precision number. The auxiliary receives:

- the conversion function #1;
- the final sign, which depends on the octant #3 and the sign #2;
- the octant #3, which controls the series we use;

- the square #4 * #4 of the argument as a fixed point number, computed with `__fp_fixed_mul:wnn`;
- the number itself as an extended-precision number.

If the octant is in $\{1, 2, 5, 6, \dots\}$, we are near an extremum of the function and we use the series

$$\cos(x) = 1 - x^2 \left(\frac{1}{2!} - x^2 \left(\frac{1}{4!} - x^2 \left(\dots \right) \right) \right).$$

Otherwise, the series

$$\sin(x) = x \left(1 - x^2 \left(\frac{1}{3!} - x^2 \left(\frac{1}{5!} - x^2 \left(\dots \right) \right) \right) \right)$$

is used. Finally, the extended-precision number is converted to a floating point number with the given sign, and `__fp_sanitizew` checks for overflow and underflow.

```

20888 \cs_new:Npn \__fp_sin_series_o:NNwww #1#2#3. #4;
20889 {
20890   \__fp_fixed_mul:wnn #4; #4;
20891   {
20892     \exp_after:wN \__fp_sin_series_aux_o:NNwww
20893     \exp_after:wN #1
20894     \int_value:w
20895     \if_int_odd:w \__fp_int_eval:w (#3 + 2) / 4 \__fp_int_eval_end:
20896       #2
20897     \else:
20898       \if_meaning:w #2 0 2 \else: 0 \fi:
20899     \fi:
20900     {#3}
20901   }
20902 }
20903 \cs_new:Npn \__fp_sin_series_aux_o:NNwww #1#2#3 #4; #5,#6;
20904 {
20905   \if_int_odd:w \__fp_int_eval:w #3 / 2 \__fp_int_eval_end:
20906     \exp_after:wN \use_i:nn
20907   \else:
20908     \exp_after:wN \use_ii:nn
20909   \fi:
20910   { % 1/18!
20911     \__fp_fixed_mul_sub_back:wwwn {0000}{0000}{0000}{0001}{5619}{2070};
20912     #4;{0000}{0000}{0000}{0477}{9477}{3324};
20913     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{0000}{0011}{4707}{4559}{7730};
20914     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{0000}{2087}{6756}{9878}{6810};
20915     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{0027}{5573}{1922}{3985}{8907};
20916     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{2480}{1587}{3015}{8730}{1587};
20917     \__fp_fixed_mul_sub_back:wwwn #4;{0013}{8888}{8888}{8888}{8888}{8889};
20918     \__fp_fixed_mul_sub_back:wwwn #4;{0416}{6666}{6666}{6666}{6666}{6667};
20919     \__fp_fixed_mul_sub_back:wwwn #4;{5000}{0000}{0000}{0000}{0000}{0000};
20920     \__fp_fixed_mul_sub_back:wwwn #4;{10000}{0000}{0000}{0000}{0000}{0000};
20921     { \__fp_fixed_continue:wn 0, }
20922   }
20923   { % 1/17!
20924     \__fp_fixed_mul_sub_back:wwwn {0000}{0000}{0000}{0028}{1145}{7254};
20925     #4;{0000}{0000}{0000}{7647}{1637}{3182};

```

```

20926     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{0000}{0160}{5904}{3836}{8216};
20927     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{0002}{5052}{1083}{8544}{1719};
20928     \__fp_fixed_mul_sub_back:wwwn #4;{0000}{0275}{5731}{9223}{9858}{9065};
20929     \__fp_fixed_mul_sub_back:wwwn #4;{0001}{9841}{2698}{4126}{9841}{2698};
20930     \__fp_fixed_mul_sub_back:wwwn #4;{0083}{3333}{3333}{3333}{3333}{3333};
20931     \__fp_fixed_mul_sub_back:wwwn #4;{1666}{6666}{6666}{6666}{6666}{6667};
20932     \__fp_fixed_mul_sub_back:wwwn#4;{10000}{0000}{0000}{0000}{0000}{0000};
20933     { \__fp_ep_mul:wwwn 0, } #5,#6;
20934 }
20935 {
20936     \exp_after:wN \__fp_sanitize:Nw
20937     \exp_after:wN #2
20938     \int_value:w \__fp_int_eval:w #1
20939 }
20940 #2
20941 }

```

(End definition for __fp_sin_series_o:NNwww and __fp_sin_series_aux_o:NNwww.)

__fp_tan_series_o:NNwww
__fp_tan_series_aux_o:Nnwww

Contrarily to __fp_sin_series_o:NNwww which received a conversion auxiliary as #1, here, #1 is 0 for tangent and 2 for cotangent. Consider first the case of the tangent. The octant #3 starts at 1, which means that it is 1 or 2 for $|x| \in [0, \pi/2]$, it is 3 or 4 for $|x| \in [\pi/2, \pi]$, and so on: the intervals on which $\tan|x| \geq 0$ coincide with those for which $\lfloor (\#3 + 1)/2 \rfloor$ is odd. We also have to take into account the original sign of x to get the sign of the final result; it is straightforward to check that the first \int_value:w expansion produces 0 for a positive final result, and 2 otherwise. A similar story holds for $\cot(x)$.

The auxiliary receives the sign, the octant, the square of the (reduced) input, and the (reduced) input (an extended-precision number) as arguments. It then computes the numerator and denominator of

$$\tan(x) \simeq \frac{x(1 - x^2(a_1 - x^2(a_2 - x^2(a_3 - x^2(a_4 - x^2 a_5))))))}{1 - x^2(b_1 - x^2(b_2 - x^2(b_3 - x^2(b_4 - x^2 b_5)))}.$$

The ratio is computed by __fp_ep_div:wwwn, then converted to a floating point number. For octants #3 (really, quadrants) next to a pole of the functions, the fixed point numerator and denominator are exchanged before computing the ratio. Note that this \if_int_odd:w test relies on the fact that the octant is at least 1.

```

20942 \cs_new:Npn \__fp_tan_series_o:NNwww #1#2#3. #4;
20943 {
20944     \__fp_fixed_mul:wwn #4; #4;
20945     {
20946         \exp_after:wN \__fp_tan_series_aux_o:Nnwww
20947         \int_value:w
20948         \if_int_odd:w \__fp_int_eval:w #3 / 2 \__fp_int_eval_end:
20949         \exp_after:wN \reverse_if:N
20950         \fi:
20951         \if_meaning:w #1#2 2 \else: 0 \fi:
20952     }#3}
20953 }
20954 }
20955 \cs_new:Npn \__fp_tan_series_aux_o:Nnwww #1 #2 #3; #4,#5;
20956 {

```

```

20957 \__fp_fixed_mul_sub_back:wwwn {0000}{0000}{1527}{3493}{0856}{7059};
20958 #3; {0000}{0159}{6080}{0274}{5257}{6472};
20959 \__fp_fixed_mul_sub_back:wwwn #3; {0002}{4571}{2320}{0157}{2558}{8481};
20960 \__fp_fixed_mul_sub_back:wwwn #3; {0115}{5830}{7533}{5397}{3168}{2147};
20961 \__fp_fixed_mul_sub_back:wwwn #3; {1929}{8245}{6140}{3508}{7719}{2982};
20962 \__fp_fixed_mul_sub_back:wwwn #3; {10000}{0000}{0000}{0000}{0000}{0000};
20963 { \__fp_ep_mul:wwwn 0, } #4,#5;
20964 {
20965 \__fp_fixed_mul_sub_back:wwwn {0000}{0007}{0258}{0681}{9408}{4706};
20966 #3; {0000}{2343}{7175}{1399}{6151}{7670};
20967 \__fp_fixed_mul_sub_back:wwwn #3; {0019}{2638}{4588}{9232}{8861}{3691};
20968 \__fp_fixed_mul_sub_back:wwwn #3; {0536}{6357}{0691}{4344}{6852}{4252};
20969 \__fp_fixed_mul_sub_back:wwwn #3; {5263}{1578}{9473}{6842}{1052}{6315};
20970 \__fp_fixed_mul_sub_back:wwwn #3; {10000}{0000}{0000}{0000}{0000}{0000};
20971 {
20972 \reverse_if:N \if_int_odd:w
20973 \__fp_int_eval:w (#2 - 1) / 2 \__fp_int_eval_end:
20974 \exp_after:wN \__fp_reverse_args:Nww
20975 \fi:
20976 \__fp_ep_div:wwwn 0,
20977 }
20978 }
20979 {
20980 \exp_after:wN \__fp_sanitizew
20981 \exp_after:wN #1
20982 \int_value:w \__fp_int_eval:w \__fp_ep_to_float_o:wwN
20983 }
20984 #1
20985 }

```

(End definition for `__fp_tan_series_o:NNwww` and `__fp_tan_series_aux_o:Nnwww`.)

34.2 Inverse trigonometric functions

All inverse trigonometric functions (arcsine, arccosine, arctangent, arccotangent, arcsecant, and arcsecant) are based on a function often denoted `atan2`. This function is accessed directly by feeding two arguments to arctangent, and is defined by $\text{atan}(y, x) = \text{atan}(y/x)$ for generic y and x . Its advantages over the conventional arctangent is that it takes values in $[-\pi, \pi]$ rather than $[-\pi/2, \pi/2]$, and that it is better behaved in boundary cases. Other inverse trigonometric functions are expressed in terms of `atan` as

$$\arccos x = \text{atan}(\sqrt{1 - x^2}, x) \quad (5)$$

$$\arcsin x = \text{atan}(x, \sqrt{1 - x^2}) \quad (6)$$

$$\text{asec } x = \text{atan}(\sqrt{x^2 - 1}, 1) \quad (7)$$

$$\text{acsc } x = \text{atan}(1, \sqrt{x^2 - 1}) \quad (8)$$

$$\text{atan } x = \text{atan}(x, 1) \quad (9)$$

$$\text{acot } x = \text{atan}(1, x). \quad (10)$$

Rather than introducing a new function, `atan2`, the arctangent function `atan` is overloaded: it can take one or two arguments. In the comments below, following many texts,

we call the first argument y and the second x , because $\text{atan}(y, x) = \text{atan}(y/x)$ is the angular coordinate of the point (x, y) .

As for direct trigonometric functions, the first step in computing $\text{atan}(y, x)$ is argument reduction. The sign of y gives that of the result. We distinguish eight regions where the point $(x, |y|)$ can lie, of angular size roughly $\pi/8$, characterized by their “octant”, between 0 and 7 included. In each region, we compute an arctangent as a Taylor series, then shift this arctangent by the appropriate multiple of $\pi/4$ and sign to get the result. Here is a list of octants, and how we compute the arctangent (we assume $y > 0$; otherwise replace y by $-y$ below):

0 $0 < |y| < 0.41421x$, then $\text{atan} \frac{|y|}{x}$ is given by a nicely convergent Taylor series;

1 $0 < 0.41421x < |y| < x$, then $\text{atan} \frac{|y|}{x} = \frac{\pi}{4} - \text{atan} \frac{x-|y|}{x+|y|}$;

2 $0 < 0.41421|y| < x < |y|$, then $\text{atan} \frac{|y|}{x} = \frac{\pi}{4} + \text{atan} \frac{-x+|y|}{x+|y|}$;

3 $0 < x < 0.41421|y|$, then $\text{atan} \frac{|y|}{x} = \frac{\pi}{2} - \text{atan} \frac{x}{|y|}$;

4 $0 < -x < 0.41421|y|$, then $\text{atan} \frac{|y|}{x} = \frac{\pi}{2} + \text{atan} \frac{-x}{|y|}$;

5 $0 < 0.41421|y| < -x < |y|$, then $\text{atan} \frac{|y|}{x} = \frac{3\pi}{4} - \text{atan} \frac{x+|y|}{-x+|y|}$;

6 $0 < -0.41421x < |y| < -x$, then $\text{atan} \frac{|y|}{x} = \frac{3\pi}{4} + \text{atan} \frac{-x-|y|}{-x+|y|}$;

7 $0 < |y| < -0.41421x$, then $\text{atan} \frac{|y|}{x} = \pi - \text{atan} \frac{|y|}{-x}$.

In the following, we denote by z the ratio among $|\frac{y}{x}|$, $|\frac{x}{y}|$, $|\frac{x+y}{x-y}|$, $|\frac{x-y}{x+y}|$ which appears in the right-hand side above.

34.2.1 Arctangent and arccotangent

`__fp_atan_o:Nw` The parsing step manipulates `atan` and `acot` like `min` and `max`, reading in an array of operands, but also leaves `\use_i:nn` or `\use_ii:nn` depending on whether the result should be given in radians or in degrees. The helper `__fp_parse_function_one_two:nnw` checks that the operand is one or two floating point numbers (not tuples) and leaves its second argument or its tail accordingly (its first argument is used for error messages). More precisely if we are given a single floating point number `__fp_atan_default:w` places `\c_one_fp` (expanded) after it; otherwise `__fp_atan_default:w` is omitted by `__fp_parse_function_one_two:nnw`.

```

20986 \cs_new:Npn __fp_atan_o:Nw #1
20987 {
20988   __fp_parse_function_one_two:nnw
20989   { #1 { atan } { atand } }
20990   { __fp_atan_default:w __fp_atanii_o:Nww #1 }
20991 }
20992 \cs_new:Npn __fp_acot_o:Nw #1
20993 {
20994   __fp_parse_function_one_two:nnw
20995   { #1 { acot } { acotd } }
20996   { __fp_atan_default:w __fp_acotii_o:Nww #1 }
20997 }
20998 \cs_new:Npx __fp_atan_default:w #1#2#3 @ { #1 #2 #3 \c_one_fp @ }
```

(End definition for `_fp_atan_o:Nw`, `_fp_acot_o:Nw`, and `_fp_atan_default:w`.)

`_fp_atanii_o:Nww` If either operand is `nan`, we return it. If both are normal, we call `_fp_atan_normal_o:NNnwNnw`. If both are zero or both infinity, we call `_fp_atan_inf_o:NNNw` with argument 2, leading to a result among $\{\pm\pi/4, \pm3\pi/4\}$ (in degrees, $\{\pm45, \pm135\}$). Otherwise, one is much bigger than the other, and we call `_fp_atan_inf_o:NNNw` with either an argument of 4, leading to the values $\pm\pi/2$ (in degrees, ±90), or 0, leading to $\{\pm0, \pm\pi\}$ (in degrees, $\{\pm0, \pm180\}$). Since $\text{acot}(x, y) = \text{atan}(y, x)$, `_fp_acotii_o:ww` simply reverses its two arguments.

```

20999 \cs_new:Npn \_fp_atanii_o:Nww
21000   #1 \s_fp \_fp_chk:w #2#3#4; \s_fp \_fp_chk:w #5 #6 @
21001   {
21002     \if_meaning:w 3 #2 \_fp_case_return_i_o:ww \fi:
21003     \if_meaning:w 3 #5 \_fp_case_return_ii_o:ww \fi:
21004     \if_case:w
21005       \if_meaning:w #2 #5
21006         \if_meaning:w 1 #2 10 \else: 0 \fi:
21007       \else:
21008         \if_int_compare:w #2 > #5 \exp_stop_f: 1 \else: 2 \fi:
21009       \fi:
21010       \exp_stop_f:
21011       \_fp_case_return:nw { \_fp_atan_inf_o:NNNw #1 #3 2 }
21012     \or: \_fp_case_return:nw { \_fp_atan_inf_o:NNNw #1 #3 4 }
21013     \or: \_fp_case_return:nw { \_fp_atan_inf_o:NNNw #1 #3 0 }
21014     \fi:
21015     \_fp_atan_normal_o:NNnwNnw #1
21016     \s_fp \_fp_chk:w #2#3#4;
21017     \s_fp \_fp_chk:w #5 #6
21018   }
21019 \cs_new:Npn \_fp_acotii_o:Nww #1#2; #3;
21020   { \_fp_atanii_o:Nww #1#3; #2; }

```

(End definition for `_fp_atanii_o:Nww` and `_fp_acotii_o:Nww`.)

`_fp_atan_inf_o:NNNw` This auxiliary is called whenever one number is ± 0 or $\pm\infty$ (and neither is `NaN`). Then the result only depends on the signs, and its value is a multiple of $\pi/4$. We use the same auxiliary as for normal numbers, `_fp_atan_combine_o:NwwwwwN`, with arguments the final sign #2; the octant #3; $\text{atan } z/z = 1$ as a fixed point number; $z = 0$ as a fixed point number; and $z = 0$ as an extended-precision number. Given the values we provide, $\text{atan } z$ is computed to be 0, and the result is $[\#3/2] \cdot \pi/4$ if the sign #5 of x is positive, and $[(7 - \#3)/2] \cdot \pi/4$ for negative x , where the divisions are rounded up.

```

21021 \cs_new:Npn \_fp_atan_inf_o:NNNw #1#2#3 \s_fp \_fp_chk:w #4#5#6;
21022   {
21023     \exp_after:wN \_fp_atan_combine_o:NwwwwwN
21024     \exp_after:wN #2
21025     \int_value:w \_fp_int_eval:w
21026     \if_meaning:w 2 #5 7 - \fi: #3 \exp_after:wN ;
21027     \c_fp_one_fixed_tl
21028     {0000}{0000}{0000}{0000}{0000}{0000};
21029     0,{0000}{0000}{0000}{0000}{0000}{0000}; #1
21030   }

```

(End definition for `_fp_atan_inf_o:NNNw`.)

_fp_atan_normal_o:NNnwNnw

Here we simply reorder the floating point data into a pair of signed extended-precision numbers, that is, a sign, an exponent ending with a comma, and a six-block mantissa ending with a semi-colon. This extended precision is required by other inverse trigonometric functions, to compute things like $\text{atan}(x, \sqrt{1-x^2})$ without intermediate rounding errors.

```

21031 \cs_new_protected:Npn \_fp_atan_normal_o:NNnwNnw
21032   #1 \s__fp \_fp_chk:w 1#2#3#4; \s__fp \_fp_chk:w 1#5#6#7;
21033   {
21034     \_fp_atan_test_o:NwwNwwN
21035     #2 #3, #4{0000}{0000};
21036     #5 #6, #7{0000}{0000}; #1
21037   }

```

(End definition for _fp_atan_normal_o:NNnwNnw.)

_fp_atan_test_o:NwwNwwN

This receives: the sign #1 of y , its exponent #2, its 24 digits #3 in groups of 4, and similarly for x . We prepare to call _fp_atan_combine_o:NwwwwwN which expects the sign #1, the octant, the ratio $(\text{atan } z)/z = 1 - \dots$, and the value of z , both as a fixed point number and as an extended-precision floating point number with a mantissa in $[0.01, 1)$. For now, we place #1 as a first argument, and start an integer expression for the octant. The sign of x does not affect z , so we simply leave a contribution to the octant: $\langle \text{octant} \rangle \rightarrow 7 - \langle \text{octant} \rangle$ for negative x . Then we order $|y|$ and $|x|$ in a non-decreasing order: if $|y| > |x|$, insert 3- in the expression for the octant, and swap the two numbers. The finer test with 0.41421 is done by _fp_atan_div:wnwwnw after the operands have been ordered.

```

21038 \cs_new:Npn \_fp_atan_test_o:NwwNwwN #1#2,#3; #4#5,#6;
21039   {
21040     \exp_after:wN \_fp_atan_combine_o:NwwwwwN
21041     \exp_after:wN #1
21042     \int_value:w \_fp_int_eval:w
21043     \if_meaning:w 2 #4
21044       7 - \_fp_int_eval:w
21045     \fi:
21046     \if_int_compare:w
21047       \_fp_ep_compare:www #2,#3; #5,#6; > 0 \exp_stop_f:
21048       3 -
21049     \exp_after:wN \_fp_reverse_args:Nww
21050     \fi:
21051     \_fp_atan_div:wnwwnw #2,#3; #5,#6;
21052   }

```

(End definition for _fp_atan_test_o:NwwNwwN.)

_fp_atan_div:wnwwnw
_fp_atan_near:www
_fp_atan_near_aux:wnw

This receives two positive numbers a and b (equal to $|x|$ and $|y|$ in some order), each as an exponent and 6 blocks of 4 digits, such that $0 < a < b$. If $0.41421b < a$, the two numbers are “near”, hence the point (y, x) that we started with is closer to the diagonals $\{|y| = |x|\}$ than to the axes $\{xy = 0\}$. In that case, the octant is 1 (possibly combined with the 7- and 3- inserted earlier) and we wish to compute $\text{atan } \frac{b-a}{a+b}$. Otherwise, the octant is 0 (again, combined with earlier terms) and we wish to compute $\text{atan } \frac{a}{b}$. In any case, call _fp_atan_auxi:ww followed by z , as a comma-delimited exponent and a fixed point number.

```

21053 \cs_new:Npn \_fp_atan_div:wnwwnw #1,#2#3; #4,#5#6;

```



```

21054 {
21055   \if_int_compare:w
21056     \__fp_int_eval:w 41421 * #5 < #2 000
21057     \if_case:w \__fp_int_eval:w #4 - #1 \__fp_int_eval_end:
21058       00 \or: 0 \fi:
21059     \exp_stop_f:
21060     \exp_after:wN \__fp_atan_near:wwwn
21061   \fi:
21062   0
21063   \__fp_ep_div:wwwn #1,{#2}#3; #4,{#5}#6;
21064   \__fp_atan_auxi:ww
21065 }
21066 \cs_new:Npn \__fp_atan_near:wwwn
21067   0 \__fp_ep_div:wwwn #1,#2; #3,
21068   {
21069     1
21070     \__fp_ep_to_fixed:wn #1 - #3, #2;
21071     \__fp_atan_near_aux:wn
21072   }
21073 \cs_new:Npn \__fp_atan_near_aux:wn #1; #2;
21074   {
21075     \__fp_fixed_add:wn #1; #2;
21076     { \__fp_fixed_sub:wn #2; #1; { \__fp_ep_div:wwwn 0, } 0, }
21077   }

```

(End definition for __fp_atan_div:wnwnw, __fp_atan_near:wwwn, and __fp_atan_near_aux:wn.)

__fp_atan_auxi:ww Convert z from a representation as an exponent and a fixed point number in $[0.01, 1)$ to a
 __fp_atan_auxii:w fixed point number only, then set up the call to __fp_atan_Taylor_loop:www, followed
 by the fixed point representation of z and the old representation.

```

21078 \cs_new:Npn \__fp_atan_auxi:ww #1,#2;
21079   { \__fp_ep_to_fixed:wn #1,#2; \__fp_atan_auxii:w #1,#2; }
21080 \cs_new:Npn \__fp_atan_auxii:w #1;
21081   {
21082     \__fp_fixed_mul:wn #1; #1;
21083     {
21084       \__fp_atan_Taylor_loop:www 39 ;
21085       {0000}{0000}{0000}{0000}{0000}{0000} ;
21086     }
21087     ! #1;
21088   }

```

(End definition for __fp_atan_auxi:ww and __fp_atan_auxii:w.)

__fp_atan_Taylor_loop:www We compute the series of $(\operatorname{atan} z)/z$. A typical intermediate stage has $\#1 = 2k - 1$,
 __fp_atan_Taylor_break:w $\#2 = \frac{1}{2k+1} - z^2(\frac{1}{2k+3} - z^2(\dots - z^2\frac{1}{39}))$, and $\#3 = z^2$. To go to the next step $k \rightarrow k - 1$,
 we compute $\frac{1}{2k-1}$, then subtract from it z^2 times $\#2$. The loop stops when $k = 0$: then
 $\#2$ is $(\operatorname{atan} z)/z$, and there is a need to clean up all the unnecessary data, end the integer
 expression computing the octant with a semicolon, and leave the result $\#2$ afterwards.

```

21089 \cs_new:Npn \__fp_atan_Taylor_loop:www #1; #2; #3;
21090   {
21091     \if_int_compare:w #1 = -1 \exp_stop_f:
21092     \__fp_atan_Taylor_break:w
21093   \fi:

```

```

21094 \exp_after:wN \_fp_fixed_div_int:wwN \c\_fp_one_fixed_tl #1;
21095 \_fp_rrot:www \_fp_fixed_mul_sub_back:wwwn #2; #3;
21096 {
21097   \exp_after:wN \_fp_atan_Taylor_loop:www
21098   \int_value:w \_fp_int_eval:w #1 - 2 ;
21099 }
21100 #3;
21101 }
21102 \cs_new:Npn \_fp_atan_Taylor_break:w
21103   \fi: #1 \_fp_fixed_mul_sub_back:wwwn #2; #3 !
21104   { \fi: ; #2 ; }

```

(End definition for _fp_atan_Taylor_loop:www and _fp_atan_Taylor_break:w.)

_fp_atan_combine_o:NwwwwwN This receives a $\langle sign \rangle$, an $\langle octant \rangle$, a fixed point value of $(\operatorname{atan} z)/z$, a fixed point number z , and another representation of z , as an $\langle exponent \rangle$ and the fixed point number $10^{-\langle exponent \rangle} z$, followed by either `\use_i:nn` (when working in radians) or `\use_ii:nn` (when working in degrees). The function computes the floating point result

$$\langle sign \rangle \left(\left\lceil \frac{\langle octant \rangle}{2} \right\rceil \frac{\pi}{4} + (-1)^{\langle octant \rangle} \frac{\operatorname{atan} z}{z} \cdot z \right), \quad (11)$$

multiplied by $180/\pi$ if working in degrees, and using in any case the most appropriate representation of z . The floating point result is passed to `_fp_sanitize:Nw`, which checks for overflow or underflow. If the octant is 0, leave the exponent #5 for `_fp_sanitize:Nw`, and multiply #3 = $\frac{\operatorname{atan} z}{z}$ with #6, the adjusted z . Otherwise, multiply #3 = $\frac{\operatorname{atan} z}{z}$ with #4 = z , then compute the appropriate multiple of $\frac{\pi}{4}$ and add or subtract the product #3 · #4. In both cases, convert to a floating point with `_fp_fixed_to_float_o:wN`.

```

21105 \cs_new:Npn \_fp_atan_combine_o:NwwwwwN #1 #2; #3; #4; #5,#6; #7
21106   {
21107     \exp_after:wN \_fp_sanitize:Nw
21108     \exp_after:wN #1
21109     \int_value:w \_fp_int_eval:w
21110     \if_meaning:w 0 #2
21111       \exp_after:wN \use_i:nn
21112     \else:
21113       \exp_after:wN \use_ii:nn
21114     \fi:
21115     { #5 \_fp_fixed_mul:wwn #3; #6; }
21116     {
21117       \_fp_fixed_mul:wwn #3; #4;
21118       {
21119         \exp_after:wN \_fp_atan_combine_aux:ww
21120         \int_value:w \_fp_int_eval:w #2 / 2 ; #2;
21121       }
21122     }
21123     { #7 \_fp_fixed_to_float_o:wN \_fp_fixed_to_float_rad_o:wN }
21124     #1
21125   }
21126 \cs_new:Npn \_fp_atan_combine_aux:ww #1; #2;
21127   {
21128     \_fp_fixed_mul_short:wwn
21129     {7853}{9816}{3397}{4483}{0961}{5661};

```

```

21130     {#1}{0000}{0000};
21131     {
21132     \if_int_odd:w #2 \exp_stop_f:
21133     \exp_after:wN \__fp_fixed_sub:wwn
21134     \else:
21135     \exp_after:wN \__fp_fixed_add:wwn
21136     \fi:
21137     }
21138 }

```

(End definition for __fp_atan_combine_o:NwwwwwN and __fp_atan_combine_aux:ww.)

34.2.2 Arcsine and arccosine

__fp_asin_o:w Again, the first argument provided by l3fp-parse is \use_i:nn if we are to work in radians and \use_ii:nn for degrees. Then comes a floating point number. The arcsine of ± 0 or NaN is the same floating point number. The arcsine of $\pm\infty$ raises an invalid operation exception. Otherwise, call an auxiliary common with __fp_acos_o:w, feeding it information about what function is being performed (for “invalid operation” exceptions).

```

21139 \cs_new:Npn \__fp_asin_o:w #1 \s__fp \__fp_chk:w #2#3; @
21140 {
21141     \if_case:w #2 \exp_stop_f:
21142     \__fp_case_return_same_o:w
21143     \or:
21144     \__fp_case_use:nw
21145     { \__fp_asin_normal_o:NfwNnnnnw #1 { #1 { asin } { asind } } }
21146     \or:
21147     \__fp_case_use:nw
21148     { \__fp_invalid_operation_o:fw { #1 { asin } { asind } } }
21149     \else:
21150     \__fp_case_return_same_o:w
21151     \fi:
21152     \s__fp \__fp_chk:w #2 #3;
21153 }

```

(End definition for __fp_asin_o:w.)

__fp_acos_o:w The arccosine of ± 0 is $\pi/2$ (in degrees, 90). The arccosine of $\pm\infty$ raises an invalid operation exception. The arccosine of NaN is itself. Otherwise, call an auxiliary common with __fp_sin_o:w, informing it that it was called by acos or acosd, and preparing to swap some arguments down the line.

```

21154 \cs_new:Npn \__fp_acos_o:w #1 \s__fp \__fp_chk:w #2#3; @
21155 {
21156     \if_case:w #2 \exp_stop_f:
21157     \__fp_case_use:nw { \__fp_atan_inf_o:NNNw #1 0 4 }
21158     \or:
21159     \__fp_case_use:nw
21160     {
21161         \__fp_asin_normal_o:NfwNnnnnw #1 { #1 { acos } { acosd } }
21162         \__fp_reverse_args:Nww
21163     }
21164     \or:
21165     \__fp_case_use:nw
21166     { \__fp_invalid_operation_o:fw { #1 { acos } { acosd } } }

```

```

21167     \else:
21168         \__fp_case_return_same_o:w
21169     \fi:
21170     \s__fp \__fp_chk:w #2 #3;
21171 }

```

(End definition for __fp_acos_o:w.)

__fp_asin_normal_o:NfwNnnnnw

If the exponent #5 is at most 0, the operand lies within $(-1, 1)$ and the operation is permitted: call __fp_asin_auxi_o:NnNww with the appropriate arguments. If the number is exactly ± 1 (the test works because we know that $\#5 \geq 1$, $\#6\#7 \geq 10000000$, $\#8\#9 \geq 0$, with equality only for ± 1), we also call __fp_asin_auxi_o:NnNww. Otherwise, __fp_use_i:ww gets rid of the asin auxiliary, and raises instead an invalid operation, because the operand is outside the domain of arcsine or arccosine.

```

21172 \cs_new:Npn \__fp_asin_normal_o:NfwNnnnnw
21173     #1#2#3 \s__fp \__fp_chk:w 1#4#5#6#7#8#9;
21174 {
21175     \if_int_compare:w #5 < 1 \exp_stop_f:
21176         \exp_after:wN \__fp_use_none_until_s:w
21177     \fi:
21178     \if_int_compare:w \__fp_int_eval:w #5 + #6#7 + #8#9 = 1000 0001 ~
21179         \exp_after:wN \__fp_use_none_until_s:w
21180     \fi:
21181     \__fp_use_i:ww
21182     \__fp_invalid_operation_o:fw {#2}
21183     \s__fp \__fp_chk:w 1#4{#5}{#6}{#7}{#8}{#9};
21184     \__fp_asin_auxi_o:NnNww
21185     #1 {#3} #4 #5,{#6}{#7}{#8}{#9}{0000}{0000};
21186 }

```

(End definition for __fp_asin_normal_o:NfwNnnnnw.)

__fp_asin_auxi_o:NnNww
__fp_asin_isqrt:wn

We compute $x/\sqrt{1-x^2}$. This function is used by asin and acos, but also by acsc and asec after inverting the operand, thus it must manipulate extended-precision numbers. First evaluate $1-x^2$ as $(1+x)(1-x)$: this behaves better near $x = 1$. We do the addition/subtraction with fixed point numbers (they are not implemented for extended-precision floats), but go back to extended-precision floats to multiply and compute the inverse square root $1/\sqrt{1-x^2}$. Finally, multiply by the (positive) extended-precision float $|x|$, and feed the (signed) result, and the number +1, as arguments to the arctangent function. When computing the arccosine, the arguments $x/\sqrt{1-x^2}$ and +1 are swapped by #2 (__fp_reverse_args:Nww in that case) before __fp_atan_test_o:NwwNwwN is evaluated. Note that the arctangent function requires normalized arguments, hence the need for ep_to_ep and continue after ep_mul.

```

21187 \cs_new:Npn \__fp_asin_auxi_o:NnNww #1#2#3#4,#5;
21188 {
21189     \__fp_ep_to_fixed:wwn #4,#5;
21190     \__fp_asin_isqrt:wn
21191     \__fp_ep_mul:wwwn #4,#5;
21192     \__fp_ep_to_ep:wwN
21193     \__fp_fixed_continue:wn
21194     { #2 \__fp_atan_test_o:NwwNwwN #3 }
21195     0 1,{1000}{0000}{0000}{0000}{0000}{0000}; #1
21196 }

```

```

21197 \cs_new:Npn \__fp_asin_isqrt:wn #1;
21198 {
21199     \exp_after:wN \__fp_fixed_sub:wwn \c__fp_one_fixed_tl #1;
21200     {
21201         \__fp_fixed_add_one:wn #1;
21202         \__fp_fixed_continue:wn { \__fp_ep_mul:wwwwn 0, } 0,
21203     }
21204     \__fp_ep_isqrt:wwn
21205 }

```

(End definition for __fp_asin_auxi_o:NnNww and __fp_asin_isqrt:wn.)

34.2.3 Arccosecant and arcsecant

__fp_acsc_o:w Cases are mostly labelled by #2, except when #2 is 2: then we use #3#2, which is 02 = 2 when the number is $+\infty$ and 22 when the number is $-\infty$. The arccosecant of ± 0 raises an invalid operation exception. The arccosecant of $\pm\infty$ is ± 0 with the same sign. The arcosecant of NaN is itself. Otherwise, __fp_acsc_normal_o:NfwNnw does some more tests, keeping the function name (acsc or acscd) as an argument for invalid operation exceptions.

```

21206 \cs_new:Npn \__fp_acsc_o:w #1 \s__fp \__fp_chk:w #2#3#4; @
21207 {
21208     \if_case:w \if_meaning:w 2 #2 #3 \fi: #2 \exp_stop_f:
21209         \__fp_case_use:nw
21210         { \__fp_invalid_operation_o:fw { #1 { acsc } { acscd } } }
21211     \or: \__fp_case_use:nw
21212         { \__fp_acsc_normal_o:NfwNnw #1 { #1 { acsc } { acscd } } }
21213     \or: \__fp_case_return_o:Nw \c_zero_fp
21214     \or: \__fp_case_return_same_o:w
21215     \else: \__fp_case_return_o:Nw \c_minus_zero_fp
21216     \fi:
21217     \s__fp \__fp_chk:w #2 #3 #4;
21218 }

```

(End definition for __fp_acsc_o:w.)

__fp_asec_o:w The arcsecant of ± 0 raises an invalid operation exception. The arcsecant of $\pm\infty$ is $\pi/2$ (in degrees, 90). The arcosecant of NaN is itself. Otherwise, do some more tests, keeping the function name asec (or asecd) as an argument for invalid operation exceptions, and a __fp_reverse_args:Nww following precisely that appearing in __fp_acos_o:w.

```

21219 \cs_new:Npn \__fp_asec_o:w #1 \s__fp \__fp_chk:w #2#3; @
21220 {
21221     \if_case:w #2 \exp_stop_f:
21222         \__fp_case_use:nw
21223         { \__fp_invalid_operation_o:fw { #1 { asec } { asecd } } }
21224     \or:
21225         \__fp_case_use:nw
21226         {
21227             \__fp_acsc_normal_o:NfwNnw #1 { #1 { asec } { asecd } }
21228             \__fp_reverse_args:Nww
21229         }
21230     \or: \__fp_case_use:nw { \__fp_atan_inf_o:NNNw #1 0 4 }
21231     \else: \__fp_case_return_same_o:w
21232     \fi:

```

```

21233     \s__fp \__fp_chk:w #2 #3;
21234 }

```

(End definition for __fp_asec_o:w.)

__fp_acsc_normal_o:NfwNnw If the exponent is non-positive, the operand is less than 1 in absolute value, which is always an invalid operation: complain. Otherwise, compute the inverse of the operand, and feed it to __fp_asin_auxi_o:NnNww (with all the appropriate arguments). This computes what we want thanks to $\operatorname{acsc}(x) = \operatorname{asin}(1/x)$ and $\operatorname{asec}(x) = \operatorname{acos}(1/x)$.

```

21235 \cs_new:Npn \__fp_acsc_normal_o:NfwNnw #1#2#3 \s__fp \__fp_chk:w 1#4#5#6;
21236 {
21237     \int_compare:nNnTF {#5} < 1
21238     {
21239         \__fp_invalid_operation_o:fw {#2}
21240         \s__fp \__fp_chk:w 1#4{#5}#6;
21241     }
21242     {
21243         \__fp_ep_div:wwwwn
21244         1,{1000}{0000}{0000}{0000}{0000}{0000};
21245         #5,#6{0000}{0000};
21246         { \__fp_asin_auxi_o:NnNww #1 {#3} #4 }
21247     }
21248 }

```

(End definition for __fp_acsc_normal_o:NfwNnw.)

```

21249 </initex | package>

```

35 13fp-convert implementation

```

21250 <*initex | package>

```

```

21251 <@@=fp>

```

35.1 Dealing with tuples

__fp_tuple_convert:Nw The first argument is for instance __fp_to_tl_dispatch:w, which converts any floating point object to the appropriate representation. We loop through all items, putting ,~ between all of them and making sure to remove the leading ,~.

```

21252 \cs_new:Npn \__fp_tuple_convert:Nw #1 \s__fp_tuple \__fp_tuple_chk:w #2 ;
21253 {
21254     \int_case:nnF { \__fp_array_count:n {#2} }
21255     {
21256         { 0 } { ( ) }
21257         { 1 } { \__fp_tuple_convert_end:w @ { #1 #2 , } }
21258     }
21259     {
21260         \__fp_tuple_convert_loop:nNw { } #1
21261         #2 { ? \__fp_tuple_convert_end:w } ;
21262         @ { \use_none:nn }
21263     }
21264 }
21265 \cs_new:Npn \__fp_tuple_convert_loop:nNw #1#2#3#4; #5 @ #6
21266 {
21267     \use_none:n #3

```

```

21268 \exp_args:Nf \__fp_tuple_convert_loop:nNw { #2 #3#4 ; } #2 #5
21269 @ { #6 , ~ #1 }
21270 }
21271 \cs_new:Npn \__fp_tuple_convert_end:w #1 @ #2
21272 { \exp_after:wN ( \exp:w \exp_end_continue_f:w #2 ) }

```

(End definition for __fp_tuple_convert:Nw, __fp_tuple_convert_loop:nNw, and __fp_tuple_convert_end:w.)

35.2 Trimming trailing zeros

__fp_trim_zeros:w If #1 ends with a 0, the loop auxiliary takes that zero as an end-delimiter for its first argument, and the second argument is the same loop auxiliary. Once the last trailing zero is reached, the second argument is the dot auxiliary, which removes a trailing dot if any. We then clean-up with the end auxiliary, keeping only the number.

```

21273 \cs_new:Npn \__fp_trim_zeros:w #1 ;
21274 {
21275   \__fp_trim_zeros_loop:w #1
21276   ; \__fp_trim_zeros_loop:w 0; \__fp_trim_zeros_dot:w .; \s_stop
21277 }
21278 \cs_new:Npn \__fp_trim_zeros_loop:w #1 0; #2 { #2 #1 ; #2 }
21279 \cs_new:Npn \__fp_trim_zeros_dot:w #1 .; { \__fp_trim_zeros_end:w #1 ; }
21280 \cs_new:Npn \__fp_trim_zeros_end:w #1 ; #2 \s_stop { #1 }

```

(End definition for __fp_trim_zeros:w and others.)

35.3 Scientific notation

\fp_to_scientific:N The three public functions evaluate their argument, then pass it to __fp_to_scientific_dispatch:w.

```

\fp_to_scientific:c
\fp_to_scientific:n
21281 \cs_new:Npn \fp_to_scientific:N #1
21282 { \exp_after:wN \__fp_to_scientific_dispatch:w #1 }
21283 \cs_generate_variant:Nn \fp_to_scientific:N { c }
21284 \cs_new:Npn \fp_to_scientific:n
21285 {
21286   \exp_after:wN \__fp_to_scientific_dispatch:w
21287   \exp:w \exp_end_continue_f:w \__fp_parse:n
21288 }

```

(End definition for \fp_to_scientific:N and \fp_to_scientific:n. These functions are documented on page 194.)

__fp_to_scientific_dispatch:w We allow tuples.

```

\__fp_to_scientific_recover:w
\__fp_tuple_to_scientific:w
21289 \cs_new:Npn \__fp_to_scientific_dispatch:w #1
21290 {
21291   \__fp_change_func_type:NNN
21292   #1 \__fp_to_scientific:w \__fp_to_scientific_recover:w
21293   #1
21294 }
21295 \cs_new:Npn \__fp_to_scientific_recover:w #1 #2 ;
21296 {
21297   \__fp_error:nffn { fp-unknown-type } { \tl_to_str:n { #2 ; } } { } { }
21298   nan
21299 }

```

```

21300 \cs_new:Npn \__fp_tuple_to_scientific:w
21301 { \__fp_tuple_convert:Nw \__fp_to_scientific_dispatch:w }

```

(End definition for __fp_to_scientific_dispatch:w, __fp_to_scientific_recover:w, and __fp_tuple_to_scientific:w.)

```

\__fp_to_scientific:w
\__fp_to_scientific_normal:wnnnnn
\__fp_to_scientific_normal:wNw

```

Expressing an internal floating point number in scientific notation is quite easy: no rounding, and the format is very well defined. First cater for the sign: negative numbers (#2 = 2) start with -; we then only need to care about positive numbers and `nan`. Then filter the special cases: ± 0 are represented as 0; infinities are converted to a number slightly larger than the largest after an “invalid_operation” exception; `nan` is represented as 0 after an “invalid_operation” exception. In the normal case, decrement the exponent and unbrace the 4 brace groups, then in a second step grab the first digit (previously hidden in braces) to order the various parts correctly.

```

21302 \cs_new:Npn \__fp_to_scientific:w \s__fp \__fp_chk:w #1#2
21303 {
21304   \if_meaning:w 2 #2 \exp_after:wN - \exp:w \exp_end_continue_f:w \fi:
21305   \if_case:w #1 \exp_stop_f:
21306     \__fp_case_return:nw { 0.000000000000000e0 }
21307   \or: \exp_after:wN \__fp_to_scientific_normal:wnnnnn
21308   \or:
21309     \__fp_case_use:nw
21310     {
21311       \__fp_invalid_operation:nnw
21312       { \fp_to_scientific:N \c__fp_overflowing_fp }
21313       { fp_to_scientific }
21314     }
21315   \or:
21316     \__fp_case_use:nw
21317     {
21318       \__fp_invalid_operation:nnw
21319       { \fp_to_scientific:N \c_zero_fp }
21320       { fp_to_scientific }
21321     }
21322   \fi:
21323   \s__fp \__fp_chk:w #1 #2
21324 }
21325 \cs_new:Npn \__fp_to_scientific_normal:wnnnnn
21326 \s__fp \__fp_chk:w 1 #1 #2 #3#4#5#6 ;
21327 {
21328   \exp_after:wN \__fp_to_scientific_normal:wNw
21329   \exp_after:wN e
21330   \int_value:w \__fp_int_eval:w #2 - 1
21331   ; #3 #4 #5 #6 ;
21332 }
21333 \cs_new:Npn \__fp_to_scientific_normal:wNw #1 ; #2#3;
21334 { #2.#3 #1 }

```

(End definition for __fp_to_scientific:w, __fp_to_scientific_normal:wnnnnn, and __fp_to_scientific_normal:wNw.)

35.4 Decimal representation

`\fp_to_decimal:N` All three public variants are based on the same `__fp_to_decimal_dispatch:w` after evaluating their argument to an internal floating point.

`\fp_to_decimal:c`

```

21335 \cs_new:Npn \fp_to_decimal:N #1
21336 { \exp_after:wN \__fp_to_decimal_dispatch:w #1 }
21337 \cs_generate_variant:Nn \fp_to_decimal:N { c }
21338 \cs_new:Npn \fp_to_decimal:n
21339 {
21340     \exp_after:wN \__fp_to_decimal_dispatch:w
21341     \exp:w \exp_end_continue_f:w \__fp_parse:n
21342 }
```

(End definition for `\fp_to_decimal:N` and `\fp_to_decimal:n`. These functions are documented on page 194.)

`__fp_to_decimal_dispatch:w`
`__fp_to_decimal_recover:w`
`__fp_tuple_to_decimal:w`

We allow tuples.

```

21343 \cs_new:Npn \__fp_to_decimal_dispatch:w #1
21344 {
21345     \__fp_change_func_type:NNN
21346     #1 \__fp_to_decimal:w \__fp_to_decimal_recover:w
21347     #1
21348 }
21349 \cs_new:Npn \__fp_to_decimal_recover:w #1 #2 ;
21350 {
21351     \__fp_error:nffn { fp-unknown-type } { \tl_to_str:n { #2 ; } } { } { }
21352     nan
21353 }
21354 \cs_new:Npn \__fp_tuple_to_decimal:w
21355 { \__fp_tuple_convert:Nw \__fp_to_decimal_dispatch:w }
```

(End definition for `__fp_to_decimal_dispatch:w`, `__fp_to_decimal_recover:w`, and `__fp_tuple_to_decimal:w`.)

`__fp_to_decimal:w`
`__fp_to_decimal_normal:wnnnnn`
`__fp_to_decimal_large:Nnnw`
`__fp_to_decimal_huge:wnnnn`

The structure is similar to `__fp_to_scientific:w`. Insert `-` for negative numbers. Zero gives 0, $\pm\infty$ and NaN yield an “invalid operation” exception; note that $\pm\infty$ produces a very large output, which we don’t expand now since it most likely won’t be needed. Normal numbers with an exponent in the range [1, 15] have that number of digits before the decimal separator: “decimate” them, and remove leading zeros with `\int_value:w`, then trim trailing zeros and dot. Normal numbers with an exponent 16 or larger have no decimal separator, we only need to add trailing zeros. When the exponent is non-positive, the result should be 0.<zeros><digits>, trimmed.

```

21356 \cs_new:Npn \__fp_to_decimal:w \s__fp \__fp_chk:w #1#2
21357 {
21358     \if_meaning:w 2 #2 \exp_after:wN - \exp:w \exp_end_continue_f:w \fi:
21359     \if_case:w #1 \exp_stop_f:
21360         \__fp_case_return:nw { 0 }
21361     \or: \exp_after:wN \__fp_to_decimal_normal:wnnnnn
21362     \or:
21363         \__fp_case_use:nw
21364         {
21365             \__fp_invalid_operation:nnw
21366             { \fp_to_decimal:N \c__fp_overflowing_fp }
21367             { fp_to_decimal }

```

```

21368     }
21369     \or:
21370     \__fp_case_use:nw
21371     {
21372         \__fp_invalid_operation:nnw
21373         { 0 }
21374         { fp_to_decimal }
21375     }
21376     \fi:
21377     \s__fp \__fp_chk:w #1 #2
21378 }
21379 \cs_new:Npn \__fp_to_decimal_normal:wnnnnn
21380 \s__fp \__fp_chk:w 1 #1 #2 #3#4#5#6 ;
21381 {
21382     \int_compare:nNnTF {#2} > 0
21383     {
21384         \int_compare:nNnTF {#2} < \c__fp_prec_int
21385         {
21386             \__fp_decimate:nNnnnn { \c__fp_prec_int - #2 }
21387             \__fp_to_decimal_large:Nnnw
21388         }
21389         {
21390             \exp_after:wN \exp_after:wN
21391             \exp_after:wN \__fp_to_decimal_huge:wnnnn
21392             \prg_replicate:nn { #2 - \c__fp_prec_int } { 0 } ;
21393         }
21394         {#3} {#4} {#5} {#6}
21395     }
21396     {
21397         \exp_after:wN \__fp_trim_zeros:w
21398         \exp_after:wN 0
21399         \exp_after:wN .
21400         \exp:w \exp_end_continue_f:w \prg_replicate:nn { - #2 } { 0 }
21401         #3#4#5#6 ;
21402     }
21403 }
21404 \cs_new:Npn \__fp_to_decimal_large:Nnnw #1#2#3#4;
21405 {
21406     \exp_after:wN \__fp_trim_zeros:w \int_value:w
21407     \if_int_compare:w #2 > 0 \exp_stop_f:
21408     #2
21409     \fi:
21410     \exp_stop_f:
21411     #3.#4 ;
21412 }
21413 \cs_new:Npn \__fp_to_decimal_huge:wnnnn #1; #2#3#4#5 { #2#3#4#5 #1 }

```

(End definition for __fp_to_decimal:w and others.)

35.5 Token list representation

\fp_to_tl:N These three public functions evaluate their argument, then pass it to __fp_to_tl_dispatch:w.
\fp_to_tl:c
\fp_to_tl:n

```

21414 \cs_new:Npn \fp_to_tl:N #1 { \exp_after:wN \__fp_to_tl_dispatch:w #1 }

```

```

21415 \cs_generate_variant:Nn \fp_to_tl:N { c }
21416 \cs_new:Npn \fp_to_tl:n
21417 {
21418   \exp_after:wN \__fp_to_tl_dispatch:w
21419   \exp:w \exp_end_continue_f:w \__fp_parse:n
21420 }

```

(End definition for `\fp_to_tl:N` and `\fp_to_tl:n`. These functions are documented on page 194.)

```

\__fp_to_tl_dispatch:w We allow tuples.
\__fp_to_tl_recover:w 21421 \cs_new:Npn \__fp_to_tl_dispatch:w #1
\__fp_tuple_to_tl:w 21422 { \__fp_change_func_type:NNN #1 \__fp_to_tl:w \__fp_to_tl_recover:w #1 }
21423 \cs_new:Npn \__fp_to_tl_recover:w #1 #2 ;
21424 {
21425   \__fp_error:nffn { fp-unknown-type } { \tl_to_str:n { #2 ; } } { } { }
21426   nan
21427 }
21428 \cs_new:Npn \__fp_tuple_to_tl:w
21429 { \__fp_tuple_convert:Nw \__fp_to_tl_dispatch:w }

```

(End definition for `__fp_to_tl_dispatch:w`, `__fp_to_tl_recover:w`, and `__fp_tuple_to_tl:w`.)

```

\__fp_to_tl:w A structure similar to \__fp_to_scientific_dispatch:w and \__fp_to_decimal_
\__fp_to_tl_normal:nnnnn dispatch:w, but without the “invalid operation” exception. First filter special cases.
\__fp_to_tl_scientific:wnnnnn We express normal numbers in decimal notation if the exponent is in the range  $[-2, 16]$ ,
\__fp_to_tl_scientific:wNw and otherwise use scientific notation.

```

```

21430 \cs_new:Npn \__fp_to_tl:w \s__fp \__fp_chk:w #1#2
21431 {
21432   \if_meaning:w 2 #2 \exp_after:wN - \exp:w \exp_end_continue_f:w \fi:
21433   \if_case:w #1 \exp_stop_f:
21434     \__fp_case_return:nw { 0 }
21435   \or: \exp_after:wN \__fp_to_tl_normal:nnnnn
21436   \or: \__fp_case_return:nw { inf }
21437   \else: \__fp_case_return:nw { nan }
21438   \fi:
21439 }
21440 \cs_new:Npn \__fp_to_tl_normal:nnnnn #1
21441 {
21442   \int_compare:nTF
21443     { -2 <= #1 <= \c__fp_prec_int }
21444     { \__fp_to_decimal_normal:wnnnnn }
21445     { \__fp_to_tl_scientific:wnnnnn }
21446   \s__fp \__fp_chk:w 1 0 {#1}
21447 }
21448 \cs_new:Npn \__fp_to_tl_scientific:wnnnnn
21449   \s__fp \__fp_chk:w 1 #1 #2 #3#4#5#6 ;
21450 {
21451   \exp_after:wN \__fp_to_tl_scientific:wNw
21452   \exp_after:wN e
21453   \int_value:w \__fp_int_eval:w #2 - 1
21454   ; #3 #4 #5 #6 ;
21455 }
21456 \cs_new:Npn \__fp_to_tl_scientific:wNw #1 ; #2#3;
21457 { \__fp_trim_zeros:w #2.#3 ; #1 }

```

(End definition for `__fp_to_tl:w` and others.)

35.6 Formatting

This is not implemented yet, as it is not yet clear what a correct interface would be, for this kind of structured conversion from a floating point (or other types of variables) to a string. Ideas welcome.

35.7 Convert to dimension or integer

\fp_to_dim:N All three public variants are based on the same `__fp_to_dim_dispatch:w` after evaluating their argument to an internal floating point. We only allow floating point numbers, not tuples.

\fp_to_dim:c

\fp_to_dim:n

```

\__fp_to_dim_dispatch:w 21458 \cs_new:Npn \fp_to_dim:N #1
\__fp_to_dim_recover:w 21459 { \exp_after:wN \__fp_to_dim_dispatch:w #1 }
\__fp_to_dim:w 21460 \cs_generate_variant:Nn \fp_to_dim:N { c }
21461 \cs_new:Npn \fp_to_dim:n
21462 {
21463   \exp_after:wN \__fp_to_dim_dispatch:w
21464   \exp:w \exp_end_continue_f:w \__fp_parse:n
21465 }
21466 \cs_new:Npn \__fp_to_dim_dispatch:w #1#2 ;
21467 {
21468   \__fp_change_func_type:NNN #1 \__fp_to_dim:w \__fp_to_dim_recover:w
21469   #1 #2 ;
21470 }
21471 \cs_new:Npn \__fp_to_dim_recover:w #1
21472 { \__fp_invalid_operation:nnw { 0pt } { fp_to_dim } }
21473 \cs_new:Npn \__fp_to_dim:w #1 ; { \__fp_to_decimal:w #1 ; pt }

```

(End definition for `\fp_to_dim:N` and others. These functions are documented on page 194.)

\fp_to_int:N For the most part identical to `\fp_to_dim:N` but without `pt`, and where `__fp_to_int:w` does more work. To convert to an integer, first round to 0 places (to the nearest integer), then express the result as a decimal number: the definition of `__fp_to_decimal_dispatch:w` is such that there are no trailing dot nor zero.

\fp_to_int:c

\fp_to_int:n

```

\__fp_to_int_dispatch:w 21474 \cs_new:Npn \fp_to_int:N #1 { \exp_after:wN \__fp_to_int_dispatch:w #1 }
\__fp_to_int_recover:w 21475 \cs_generate_variant:Nn \fp_to_int:N { c }
21476 \cs_new:Npn \fp_to_int:n
21477 {
21478   \exp_after:wN \__fp_to_int_dispatch:w
21479   \exp:w \exp_end_continue_f:w \__fp_parse:n
21480 }
21481 \cs_new:Npn \__fp_to_int_dispatch:w #1#2 ;
21482 {
21483   \__fp_change_func_type:NNN #1 \__fp_to_int:w \__fp_to_int_recover:w
21484   #1 #2 ;
21485 }
21486 \cs_new:Npn \__fp_to_int_recover:w #1
21487 { \__fp_invalid_operation:nnw { 0 } { fp_to_int } }
21488 \cs_new:Npn \__fp_to_int:w #1;
21489 {
21490   \exp_after:wN \__fp_to_decimal:w \exp:w \exp_end_continue_f:w
21491   \__fp_round:Nwn \__fp_round_to_nearest:NNN #1; { 0 }
21492 }

```

(End definition for `\fp_to_int:N` and others. These functions are documented on page 194.)

35.8 Convert from a dimension

`\dim_to_fp:n` The dimension expression (which can in fact be a glue expression) is evaluated, converted to a number (*i.e.*, expressed in scaled points), then multiplied by $2^{-16} = 0.0000152587890625$ to give a value expressed in points. The auxiliary `__fp_mul_npos_o:Nww` expects the desired *final sign* and two floating point operands (of the form `\s__fp ...`;) as arguments. This set of functions is also used to convert dimension registers to floating points while parsing expressions: in this context there is an additional exponent, which is the first argument of `__fp_from_dim_test:ww`, and is combined with the exponent -4 of 2^{-16} . There is also a need to expand afterwards: this is performed by `__fp_mul_npos_o:Nww`, and cancelled by `\prg_do_nothing:` here.

```

21493 \__kernel_patch_args:nNnpn { { (#1) } }
21494 \cs_new:Npn \dim_to_fp:n #1
21495 {
21496   \exp_after:wN \__fp_from_dim_test:ww
21497   \exp_after:wN 0
21498   \exp_after:wN ,
21499   \int_value:w \tex_glueexpr:D #1 ;
21500 }
21501 \cs_new:Npn \__fp_from_dim_test:ww #1, #2
21502 {
21503   \if_meaning:w 0 #2
21504     \__fp_case_return:nw { \exp_after:wN \c_zero_fp }
21505   \else:
21506     \exp_after:wN \__fp_from_dim:wNw
21507     \int_value:w \__fp_int_eval:w #1 - 4
21508     \if_meaning:w - #2
21509       \exp_after:wN , \exp_after:wN 2 \int_value:w
21510     \else:
21511       \exp_after:wN , \exp_after:wN 0 \int_value:w #2
21512     \fi:
21513   \fi:
21514 }
21515 \cs_new:Npn \__fp_from_dim:wNw #1,#2#3;
21516 {
21517   \__fp_pack_twice_four:wNNNNNNNN \__fp_from_dim:wNNnnnnnn ;
21518   #3 000 0000 00 {10}987654321; #2 {#1}
21519 }
21520 \cs_new:Npn \__fp_from_dim:wNNnnnnnn #1; #2#3#4#5#6#7#8#9
21521 { \__fp_from_dim:wnnnnwNn #1 {#2#300} {0000} ; }
21522 \cs_new:Npn \__fp_from_dim:wnnnnwNn #1; #2#3#4#5#6; #7#8
21523 {
21524   \__fp_mul_npos_o:Nww #7
21525   \s__fp \__fp_chk:w 1 #7 {#5} #1 ;
21526   \s__fp \__fp_chk:w 1 0 {#8} {1525} {8789} {0625} {0000} ;
21527   \prg_do_nothing:
21528 }

```

(End definition for `\dim_to_fp:n` and others. This function is documented on page 168.)

35.9 Use and eval

`\fp_use:N` Those public functions are simple copies of the decimal conversions.
`\fp_use:c`
`\fp_eval:n`

```

21529 \cs_new_eq:NN \fp_use:N \fp_to_decimal:N
21530 \cs_generate_variant:Nn \fp_use:N { c }
21531 \cs_new_eq:NN \fp_eval:n \fp_to_decimal:n

```

(End definition for `\fp_use:N` and `\fp_eval:n`. These functions are documented on page 195.)

\fp_abs:n Trivial but useful. See the implementation of `\fp_add:Nn` for an explanation of why to use `__fp_parse:n`, namely, for better error reporting.

```

21532 \cs_new:Npn \fp_abs:n #1
21533 { \fp_to_decimal:n { abs \__fp_parse:n {#1} } }

```

(End definition for `\fp_abs:n`. This function is documented on page 209.)

\fp_max:nn Similar to `\fp_abs:n`, for consistency with `\int_max:nn`, etc.

```

\fp_min:nn 21534 \cs_new:Npn \fp_max:nn #1#2
21535 { \fp_to_decimal:n { max ( \__fp_parse:n {#1} , \__fp_parse:n {#2} ) } }
21536 \cs_new:Npn \fp_min:nn #1#2
21537 { \fp_to_decimal:n { min ( \__fp_parse:n {#1} , \__fp_parse:n {#2} ) } }

```

(End definition for `\fp_max:nn` and `\fp_min:nn`. These functions are documented on page 209.)

35.10 Convert an array of floating points to a comma list

`__fp_array_to_clist:n` Converts an array of floating point numbers to a comma-list. If speed here ends up irrelevant, we can simplify the code for the auxiliary to become

```

\cs_new:Npn \__fp_array_to_clist_loop:Nw #1#2;
{
  \use_none:n #1
  { , ~ } \fp_to_tl:n { #1 #2 ; }
  \__fp_array_to_clist_loop:Nw
}

```

The `\use_ii:nn` function is expanded after `__fp_expand:n` is done, and it removes `,~` from the start of the representation.

```

21538 \cs_new:Npn \__fp_array_to_clist:n #1
21539 {
21540   \tl_if_empty:nF {#1}
21541   {
21542     \exp_last_unbraced:Ne \use_ii:nn
21543     {
21544       \__fp_array_to_clist_loop:Nw #1 { ? \prg_break: } ;
21545       \prg_break_point:
21546     }
21547   }
21548 }
21549 \cs_new:Npn \__fp_array_to_clist_loop:Nw #1#2;
21550 {
21551   \use_none:n #1
21552   , ~
21553   \exp_not:f { \__fp_to_tl_dispatch:w #1 #2 ; }
21554   \__fp_array_to_clist_loop:Nw
21555 }

```

(End definition for `__fp_array_to_clist:n` and `__fp_array_to_clist_loop:Nw`.)

```

21556 </initex | package>

```

36 l3fp-random Implementation

```

21557 \*initex | package)
21558 <@@=fp>

  \_fp_parse_word_rand:N
\_fp_parse_word_randint:N
Those functions may receive a variable number of arguments. We won't use the argument ?.

21559 \cs_new:Npn \_fp_parse_word_rand:N
21560 { \_fp_parse_function:NNN \_fp_rand_o:Nw ? }
21561 \cs_new:Npn \_fp_parse_word_randint:N
21562 { \_fp_parse_function:NNN \_fp_randint_o:Nw ? }

(End definition for \_fp_parse_word_rand:N and \_fp_parse_word_randint:N.)

```

36.1 Engine support

Most engines provide random numbers, but not all. We write the test twice simply in order to write the `false` branch first.

```

21563 \sys_if_rand_exist:F
21564 {
21565   \_kernel_msg_new:nnn { kernel } { fp-no-random }
21566   { Random-numbers-unavailable-for~#1 }
21567   \cs_new:Npn \_fp_rand_o:Nw ? #1 @
21568   {
21569     \_kernel_msg_expandable_error:nnn { kernel } { fp-no-random }
21570     { fp-rand }
21571     \exp_after:wN \c_nan_fp
21572   }
21573   \cs_new_eq:NN \_fp_randint_o:Nw \_fp_rand_o:Nw
21574   \cs_new:Npn \int_rand:nn #1#2
21575   {
21576     \_kernel_msg_expandable_error:nnn { kernel } { fp-no-random }
21577     { \int_rand:nn {#1} {#2} }
21578     \int_eval:n {#1}
21579   }
21580   \cs_new:Npn \int_rand:n #1
21581   {
21582     \_kernel_msg_expandable_error:nnn { kernel } { fp-no-random }
21583     { \int_rand:n {#1} }
21584     1
21585   }
21586 }
21587 \sys_if_rand_exist:T
21588 {

```

Obviously, every word “random” below means “pseudo-random”, as we have no access to entropy (except a very unreliable source of entropy: the time it takes to run some code).

The primitive random number generator (RNG) is provided as `\tex_uniformdeviate:D`. Under the hood, it maintains an array of 55 28-bit numbers, updated with a linear recursion relation (similar to Fibonacci numbers) modulo 2^{28} . When `\tex_uniformdeviate:D` $\langle integer \rangle$ is called (for brevity denote by N the $\langle integer \rangle$), the next 28-bit number is read from the array, scaled by $N/2^{28}$, and rounded. To prevent 0 and N from appearing half as often as other numbers, they are both mapped to the result 0.

This process means that `\tex_uniformdeviate:D` only gives a uniform distribution from 0 to $N-1$ if N is a divisor of 2^{28} , so we will mostly call the RNG with such power of 2 arguments. If N does not divide 2^{28} , then the relative non-uniformity (difference between probabilities of getting different numbers) is about $N/2^{28}$. This implies that detecting deviation from $1/N$ of the probability of a fixed value X requires about $2^{56}/N$ random trials. But collective patterns can reduce this to about $2^{56}/N^2$. For instance with $N = 3 \times 2^k$, the modulo 3 repartition of such random numbers is biased with a non-uniformity about $2^k/2^{28}$ (which is much worse than the circa $3/2^{28}$ non-uniformity from taking directly $N = 3$). This is detectable after about $2^{56}/2^{2k} = 9 \cdot 2^{56}/N^2$ random numbers. For $k = 15$, $N = 98304$, this means roughly 2^{26} calls to the RNG (experimentally this takes at the very least 16 seconds on a 2 giga-hertz processor). While this bias is not quite problematic, it is uncomfortably close to being so, and it becomes worse as N is increased. In our code, we shall thus combine several results from the RNG.

The RNG has three types of unexpected correlations. First, everything is linear modulo 2^{28} , hence the lowest k bits of the random numbers only depend on the lowest k bits of the seed (and of course the number of times the RNG was called since setting the seed). The recommended way to get a number from 0 to $N-1$ is thus to scale the raw 28-bit integer, as the engine's RNG does. We will go further and in fact typically we discard some of the lowest bits.

Second, suppose that we call the RNG with the same argument N to get a set of K integers in $[0, N-1]$ (throwing away repeats), and suppose that $N > K^3$ and $K > 55$. The recursion used to construct more 28-bit numbers from previous ones is linear: $x_n = x_{n-55} - x_{n-24}$ or $x_n = x_{n-55} - x_{n-24} + 2^{28}$. After rescaling and rounding we find that the result $N_n \in [0, N-1]$ is among $N_{n-55} - N_{n-24} + \{-1, 0, 1\}$ modulo N (a more detailed analysis shows that 0 appears with frequency close to $3/4$). The resulting set thus has more triplets (a, b, c) than expected obeying $a = b + c$ modulo N . Namely it will have of order $(K-55) \times 3/4$ such triplets, when one would expect $K^3/(6N)$. This starts to be detectable around $N = 2^{18} > 55^3$ (earlier if one keeps track of positions too, but this is more subtle than it looks because the array of 28-bit integers is read backwards by the engine). Hopefully the correlation is subtle enough to not affect realistic documents so we do not specifically mitigate against this. Since we typically use two calls to the RNG per `\int_rand:nn` we would need to investigate linear relations between the x_{2n} on the one hand and between the x_{2n+1} on the other hand. Such relations will have more complicated coefficients than ± 1 , which alleviates the issue.

Third, consider successive batches of 165 calls to the RNG (with argument 2^{28} or with argument 2 for instance), then most batches have more odd than even numbers. Note that this does not mean that there are more odd than even numbers overall. Similar issues are discussed in Knuth's TAOCP volume 2 near exercise 3.3.2-31. We do not have any mitigation strategy for this.

Ideally, our algorithm should be:

- Uniform. The result should be as uniform as possible assuming that the RNG's underlying 28-bit integers are uniform.
- Uncorrelated. The result should not have detectable correlations between different seeds, similar to the lowest-bit ones mentioned earlier.
- Quick. The algorithm should be fast in \TeX , so no “bit twiddling”, but “digit twiddling” is ok.
- Simple. The behaviour must be documentable precisely.

- Predictable. The number of calls to the RNG should be the same for any `\int_rand:nn`, because then the algorithm can be modified later without changing the result of other uses of the RNG.
- Robust. It should work even for `\int_rand:nn { - \c_max_int } { \c_max_int }` where the range is not representable as an integer. In fact, we also provide later a floating-point `randint` whose range can go all the way up to $2 \times 10^{16} - 1$ possible values.

Some of these requirements conflict. For instance, uniformity cannot be achieved with a fixed number of calls to the RNG.

Denote by `random(N)` one call to `\tex_uniformdeviate:D` with argument N , and by `ediv(p,q)` the ε -TeX rounding division giving $\lfloor p/q + 1/2 \rfloor$. Denote by $\langle min \rangle$, $\langle max \rangle$ and $R = \langle max \rangle - \langle min \rangle + 1$ the arguments of `\int_min:nn` and the number of possible outcomes. Note that $R \in [1, 2^{32} - 1]$ cannot necessarily be represented as an integer (however, $R - 2^{31}$ can). Our strategy is to get two 28-bit integers X and Y from the RNG, split each into 14-bit integers, as $X = X_1 \times 2^{14} + X_0$ and $Y = Y_1 \times 2^{14} + Y_0$ then return essentially $\langle min \rangle + \lfloor R(X_1 \times 2^{-14} + Y_1 \times 2^{-28} + Y_0 \times 2^{-42} + X_0 \times 2^{-56}) \rfloor$. For small R the X_0 term has a tiny effect so we ignore it and we can compute $R \times Y/2^{28}$ much more directly by `random(R)`.

- If $R \leq 2^{17} - 1$ then return `ediv(R random(214) + random(R) + 213, 214) - 1 + \langle min \rangle`. The shifts by 2^{13} and -1 convert ε -TeX division to truncated division. The bound on R ensures that the number obtained after the shift is less than `\c_max_int`. The non-uniformity is at most of order $2^{17}/2^{42} = 2^{-25}$.
- Split $R = R_2 \times 2^{28} + R_1 \times 2^{14} + R_0$, where $R_2 \in [0, 15]$. Compute $\langle min \rangle + R_2 X_1 2^{14} + (R_2 Y_1 + R_1 X_1) + \text{ediv}(R_2 Y_0 + R_1 Y_1 + R_0 X_1 + \text{ediv}(R_2 X_0 + R_0 Y_1 + \text{ediv}((2^{14} R_1 + R_0)(2^{14} Y_0 + X_0), 2^{28}), 2^{14}), 2^{14})$ then map a result of $\langle max \rangle + 1$ to $\langle min \rangle$. Writing each `ediv` in terms of truncated division with a shift, and using $\lfloor (p + \lfloor r/s \rfloor)/q \rfloor = \lfloor (ps + r)/(sq) \rfloor$, what we compute is equal to $\lfloor \langle exact \rangle + 2^{-29} + 2^{-15} + 2^{-1} \rfloor$ with $\langle exact \rangle = \langle min \rangle + R \times 0.X_1 Y_1 Y_0 X_0$. Given we map $\langle max \rangle + 1$ to $\langle min \rangle$, the shift has no effect on uniformity. The non-uniformity is bounded by $R/2^{56} < 2^{-24}$. It may be possible to speed up the code by dropping tiny terms such as $R_0 X_0$, but the analysis of non-uniformity proves too difficult.

To avoid the overflow when the computation yields $\langle max \rangle + 1$ with $\langle max \rangle = 2^{31} - 1$ (note that R is then arbitrary), we compute the result in two pieces. Compute $\langle first \rangle = \langle min \rangle + R_2 X_1 2^{14}$ if $R_2 < 8$ or $\langle min \rangle + 8 X_1 2^{14} + (R_2 - 8) X_1 2^{14}$ if $R_2 \geq 8$, the expressions being chosen to avoid overflow. Compute $\langle second \rangle = R_2 Y_1 + R_1 X_1 + \text{ediv}(\dots)$, at most $R_2 2^{14} + R_1 2^{14} + R_0 \leq 2^{28} + 15 \times 2^{14} - 1$, not at risk of overflowing. We have $\langle first \rangle + \langle second \rangle = \langle max \rangle + 1 = \langle min \rangle + R$ if and only if $\langle second \rangle = R 2^{14} + R_0 + R_2 2^{14}$ and $2^{14} R_2 X_1 = 2^{28} R_2 - 2^{14} R_2$ (namely $R_2 = 0$ or $X_1 = 2^{14} - 1$). In that case, return $\langle min \rangle$, otherwise return $\langle first \rangle + \langle second \rangle$, which is safe because it is at most $\langle max \rangle$. Note that the decision of what to return does not need $\langle first \rangle$ explicitly so we don't actually compute it, just put it in an integer expression in which $\langle second \rangle$ is eventually added (or not).

- To get a floating point number in $[0, 1)$ just call the $R = 10000 \leq 2^{17} - 1$ procedure above to produce four blocks of four digits.
- To get an integer floating point number in a range (whose size can be up to $2 \times 10^{16} - 1$), work with fixed-point numbers: get six times four digits to build a fixed

point number, multiply by R and add $\langle min \rangle$. This requires some care because l3fp-extended only supports non-negative numbers.

`\c__kernel_randint_max_int` Constant equal to $2^{17} - 1$, the maximal size of a range that `\int_range:nn` can do with its “simple” algorithm.

```
21589 \int_const:Nn \c__kernel_randint_max_int { 131071 }
```

(End definition for `\c__kernel_randint_max_int`.)

`__kernel_randint:n` Used in an integer expression, `__kernel_randint:n {R}` gives a random number $1 + \lfloor (R \text{ random}(2^{14}) + \text{random}(R)) / 2^{14} \rfloor$ that is in $[1, R]$. Previous code was computing $\lfloor p / 2^{14} \rfloor$ as `ediv(p - 2^{13}, 2^{14})` but that wrongly gives -1 for $p = 0$.

```
21590 \cs_new:Npn \__kernel_randint:n #1
21591 {
21592   (#1 * \tex_uniformdeviate:D 16384
21593   + \tex_uniformdeviate:D #1 + 8192 ) / 16384
21594 }
```

(End definition for `__kernel_randint:n`.)

`__fp_rand_myriads:n` Used as `__fp_rand_myriads:n {XXX}` with one letter X (specifically) per block of four digit we want; it expands to `;` followed by the requested number of brace groups, each containing four (pseudo-random) digits. Digits are produced as a random number in $[10000, 19999]$ for the usual reason of preserving leading zeros.

```
21595 \cs_new:Npn \__fp_rand_myriads:n #1
21596 { \__fp_rand_myriads_loop:w #1 \prg_break: X \prg_break_point: ; }
21597 \cs_new:Npn \__fp_rand_myriads_loop:w #1 X
21598 {
21599   #1
21600   \exp_after:wN \__fp_rand_myriads_get:w
21601   \int_value:w \__fp_int_eval:w 9999 +
21602   \__kernel_randint:n { 10000 }
21603   \__fp_rand_myriads_loop:w
21604 }
21605 \cs_new:Npn \__fp_rand_myriads_get:w 1 #1 ; { ; {#1} }
```

(End definition for `__fp_rand_myriads:n`, `__fp_rand_myriads_loop:w`, and `__fp_rand_myriads_get:w`.)

36.2 Random floating point

`__fp_rand_o:Nw` First we check that `random` was called without argument. Then get four blocks of four digits and convert that fixed point number to a floating point number (this correctly sets the exponent). This has a minor bug: if all of the random numbers are zero then the result is correctly 0 but it raises the underflow flag; it should not do that.

`__fp_rand_o:w`

```
21606 \cs_new:Npn \__fp_rand_o:Nw ? #1 @
21607 {
21608   \tl_if_empty:nTF {#1}
21609   {
21610     \exp_after:wN \__fp_rand_o:w
21611     \exp:w \exp_end_continue_f:w
21612     \__fp_rand_myriads:n { XXXX } { 0000 } { 0000 } ; 0
21613   }
```

```

21614         {
21615             \__kernel_msg_expandable_error:nnnnn
21616             { kernel } { fp-num-args } { rand() } { 0 } { 0 }
21617             \exp_after:wN \c_nan_fp
21618         }
21619     }
21620 \cs_new:Npn \__fp_rand_o:w ;
21621 {
21622     \exp_after:wN \__fp_sanitize:Nw
21623     \exp_after:wN 0
21624     \int_value:w \__fp_int_eval:w \c_zero_int
21625     \__fp_fixed_to_float_o:wN
21626 }

```

(End definition for __fp_rand_o:Nw and __fp_rand_o:w.)

36.3 Random integer

__fp_randint_o:Nw Enforce that there is one argument (then add first argument 1) or two arguments. Call __fp_randint_default:w __fp_randint_badarg:w on each; this function inserts 1 \exp_stop_f: to end the \if_case:w statement if either the argument is not an integer or if its absolute value is $\geq 10^{16}$. Also bail out if __fp_compare_back:ww yields 1, meaning that the bounds are not in the right order. Otherwise an auxiliary converts each argument times 10^{-16} (hence the shift in exponent) to a 24-digit fixed point number (see l3fp-extended). Then compute the number of choices, $\langle max \rangle + 1 - \langle min \rangle$. Create a random 24-digit fixed-point number with __fp_rand_myriads:n, then use a fused multiply-add instruction to multiply the number of choices to that random number and add it to $\langle min \rangle$. Then truncate to 16 digits (namely select the integer part of 10^{16} times the result) before converting back to a floating point number (__fp_sanitize:Nw takes care of zero). To avoid issues with negative numbers, add 1 to all fixed point numbers (namely 10^{16} to the integers they represent), except of course when it is time to convert back to a float.

```

21627 \cs_new:Npn \__fp_randint_o:Nw ?
21628 {
21629     \__fp_parse_function_one_two:nnw
21630     { randint }
21631     { \__fp_randint_default:w \__fp_randint_o:w }
21632 }
21633 \cs_new:Npn \__fp_randint_default:w #1 { \exp_after:wN #1 \c_one_fp }
21634 \cs_new:Npn \__fp_randint_badarg:w \s__fp \__fp_chk:w #1#2#3;
21635 {
21636     \__fp_int:wTF \s__fp \__fp_chk:w #1#2#3;
21637     {
21638         \if_meaning:w 1 #1
21639         \if_int_compare:w
21640             \__fp_use_i_until_s:nw #3 ; > \c__fp_prec_int
21641             1 \exp_stop_f:
21642         \fi:
21643         \fi:
21644     }
21645     { 1 \exp_stop_f: }
21646 }
21647 \cs_new:Npn \__fp_randint_o:w #1; #2; @
21648 {

```

```

21649         \if_case:w
21650             \__fp_randint_badarg:w #1;
21651             \__fp_randint_badarg:w #2;
21652             \if:w 1 \__fp_compare_back:ww #2; #1; 1 \exp_stop_f: \fi:
21653             0 \exp_stop_f:
21654             \__fp_randint_auxi_o:ww #1; #2;
21655         \or:
21656             \__fp_invalid_operation_tl_o:ff
21657             { randint } { \__fp_array_to_clist:n { #1; #2; } }
21658         \exp:w
21659         \fi:
21660         \exp_after:wN \exp_end:
21661     }
21662     \cs_new:Npn \__fp_randint_auxi_o:ww #1 ; #2 ; #3 \exp_end:
21663     {
21664         \fi:
21665         \__fp_randint_auxii:wn #2 ;
21666         { \__fp_randint_auxii:wn #1 ; \__fp_randint_auxiii_o:ww }
21667     }
21668     \cs_new:Npn \__fp_randint_auxii:wn \s__fp \__fp_chk:w #1#2#3#4 ;
21669     {
21670         \if_meaning:w 0 #1
21671         \exp_after:wN \use_i:nn
21672         \else:
21673         \exp_after:wN \use_ii:nn
21674         \fi:
21675         { \exp_after:wN \__fp_fixed_continue:wn \c__fp_one_fixed_tl }
21676         {
21677             \exp_after:wN \__fp_ep_to_fixed:wwn
21678             \int_value:w \__fp_int_eval:w
21679             #3 - \c__fp_prec_int , #4 {0000} {0000} ;
21680             {
21681                 \if_meaning:w 0 #2
21682                 \exp_after:wN \use_i:nnnn
21683                 \exp_after:wN \__fp_fixed_add_one:wN
21684                 \fi:
21685                 \exp_after:wN \__fp_fixed_sub:wwn \c__fp_one_fixed_tl
21686             }
21687             \__fp_fixed_continue:wn
21688         }
21689     }
21690     \cs_new:Npn \__fp_randint_auxiii_o:ww #1 ; #2 ;
21691     {
21692         \__fp_fixed_add:wwn #2 ;
21693         {0000} {0000} {0000} {0001} {0000} {0000} ;
21694         \__fp_fixed_sub:wwn #1 ;
21695         {
21696             \exp_after:wN \use_i:nn
21697             \exp_after:wN \__fp_fixed_mul_add:wwwn
21698             \exp:w \exp_end_continue_f:w \__fp_rand_myriads:n { XXXXXX } ;
21699         }
21700         #1 ;
21701         \__fp_randint_auxiv_o:ww
21702         #2 ;

```

```

21703     \_fp_randint_auxv_o:w #1 ; @
21704 }
21705 \cs_new:Npn \_fp_randint_auxiv_o:ww #1#2#3#4#5 ; #6#7#8#9
21706 {
21707     \if_int_compare:w
21708         \if_int_compare:w #1#2 > #6#7 \exp_stop_f: 1 \else:
21709         \if_int_compare:w #1#2 < #6#7 \exp_stop_f: - \fi: \fi:
21710         #3#4 > #8#9 \exp_stop_f:
21711         \_fp_use_i_until_s:nw
21712     \fi:
21713     \_fp_randint_auxv_o:w {#1}{#2}{#3}{#4}#5
21714 }
21715 \cs_new:Npn \_fp_randint_auxv_o:w #1#2#3#4#5 ; #6 @
21716 {
21717     \exp_after:wN \_fp_sanitize:Nw
21718     \int_value:w
21719     \if_int_compare:w #1 < 10000 \exp_stop_f:
21720         2
21721     \else:
21722         0
21723     \exp_after:wN \exp_after:wN
21724     \exp_after:wN \_fp_reverse_args:Nww
21725     \fi:
21726     \exp_after:wN \_fp_fixed_sub:wwn \c__fp_one_fixed_tl
21727     {#1} {#2} {#3} {#4} {0000} {0000} ;
21728     {
21729         \exp_after:wN \exp_stop_f:
21730         \int_value:w \_fp_int_eval:w \c__fp_prec_int
21731         \_fp_fixed_to_float_o:wN
21732     }
21733     0
21734     \exp:w \exp_after:wN \exp_end:
21735 }

```

(End definition for _fp_randint_o:Nw and others.)

\int_rand:nn Evaluate the argument and filter out the case where the lower bound #1 is more than the upper bound #2. Then determine whether the range is narrower than \c__kernel_randint_max_int; #2-#1 may overflow for very large positive #2 and negative #1. If the range is narrow, call _kernel_randint:n {<choices>} where <choices> is the number of possible outcomes. If the range is wide, use somewhat slower code.

```

21736 \cs_new:Npn \int_rand:nn #1#2
21737 {
21738     \int_eval:n
21739     {
21740         \exp_after:wN \_fp_randint:ww
21741         \int_value:w \int_eval:n {#1} \exp_after:wN ;
21742         \int_value:w \int_eval:n {#2} ;
21743     }
21744 }
21745 \cs_new:Npn \_fp_randint:ww #1; #2;
21746 {
21747     \if_int_compare:w #1 > #2 \exp_stop_f:
21748     \_kernel_msg_expandable_error:nnnn

```

```

21749         { kernel } { randint-backward-range } {#1} {#2}
21750     \__fp_randint:ww #2; #1;
21751 \else:
21752     \if_int_compare:w \__fp_int_eval:w #2
21753         \if_int_compare:w #1 > \c_zero_int
21754             - #1 < \__fp_int_eval:w
21755         \else:
21756             < \__fp_int_eval:w #1 +
21757         \fi:
21758         \c_kernel_randint_max_int
21759         \__fp_int_eval_end:
21760         \__kernel_randint:n
21761         { \__fp_int_eval:w #2 - #1 + 1 \__fp_int_eval_end: }
21762         - 1 + #1
21763     \else:
21764         \__kernel_randint:nn {#1} {#2}
21765     \fi:
21766 \fi:
21767 }

```

(End definition for `\int_rand:nn` and `__fp_randint:ww`. This function is documented on page 95.)

Any $n \in [-2^{31} + 1, 2^{31} - 1]$ is uniquely written as $2^{14}n_1 + n_2$ with $n_1 \in [-2^{17}, 2^{17} - 1]$ and $n_2 \in [0, 2^{14} - 1]$. Calling `__fp_randint_split_o:Nw n` ; gives n_1 ; n_2 ; and expands the next token once. We do this for two random numbers and apply `__fp_randint_split_o:Nw` twice to fully decompose the range R . One subtlety is that we compute $R - 2^{31} = \langle \max \rangle - \langle \min \rangle - (2^{31} - 1) \in [-2^{31} + 1, 2^{31} - 1]$ rather than R to avoid overflow. Then we have `__fp_randint_wide_aux:w` $\langle X_1 \rangle; \langle X_0 \rangle; \langle Y_1 \rangle; \langle Y_0 \rangle; \langle R_2 \rangle; \langle R_1 \rangle; \langle R_0 \rangle; .$ and we apply the algorithm described earlier.

```

21768 \cs_new:Npn \__kernel_randint:nn #1#2
21769 {
21770     #1
21771     \exp_after:wN \__fp_randint_wide_aux:w
21772     \int_value:w
21773     \exp_after:wN \__fp_randint_split_o:Nw
21774     \tex_uniformdeviate:D 268435456 ;
21775     \int_value:w
21776     \exp_after:wN \__fp_randint_split_o:Nw
21777     \tex_uniformdeviate:D 268435456 ;
21778     \int_value:w
21779     \exp_after:wN \__fp_randint_split_o:Nw
21780     \int_value:w \__fp_int_eval:w 131072 +
21781     \exp_after:wN \__fp_randint_split_o:Nw
21782     \int_value:w
21783     \__kernel_int_add:nnn {#2} { -#1 } { -\c_max_int } ;
21784     .
21785 }
21786 \cs_new:Npn \__fp_randint_split_o:Nw #1#2 ;
21787 {
21788     \if_meaning:w 0 #1
21789         0 \exp_after:wN ; \int_value:w 0
21790     \else:
21791         \exp_after:wN \__fp_randint_split_aux:w
21792         \int_value:w \__fp_int_eval:w (#1#2 - 8192) / 16384 ;

```

```

21793         + #1#2
21794         \fi:
21795         \exp_after:wN ;
21796     }
21797 \cs_new:Npn \__fp_randint_split_aux:w #1 ;
21798 {
21799     #1 \exp_after:wN ;
21800     \int_value:w \__fp_int_eval:w - #1 * 16384
21801 }
21802 \cs_new:Npn \__fp_randint_wide_aux:w #1;#2; #3;#4; #5;#6;#7; .
21803 {
21804     \exp_after:wN \__fp_randint_wide_auxii:w
21805     \int_value:w \__fp_int_eval:w #5 * #3 + #6 * #1 +
21806     (#5 * #4 + #6 * #3 + #7 * #1 +
21807     (#5 * #2 + #7 * #3 +
21808     (16384 * #6 + #7) * (16384 * #4 + #2) / 268435456) / 16384
21809     ) / 16384 \exp_after:wN ;
21810     \int_value:w \__fp_int_eval:w (#5 + #6) * 16384 + #7 ;
21811     #1 ; #5 ;
21812 }
21813 \cs_new:Npn \__fp_randint_wide_auxii:w #1; #2; #3; #4;
21814 {
21815     \if_int_odd:w 0
21816         \if_int_compare:w #1 = #2 \else: \exp_stop_f: \fi:
21817         \if_int_compare:w #4 = \c_zero_int 1 \fi:
21818         \if_int_compare:w #3 = 16383 ~ 1 \fi:
21819         \exp_stop_f:
21820         \exp_after:wN \prg_break:
21821     \fi:
21822     \if_int_compare:w #4 < 8 \exp_stop_f:
21823         + #4 * #3 * 16384
21824     \else:
21825         + 8 * #3 * 16384 + (#4 - 8) * #3 * 16384
21826     \fi:
21827     + #1
21828     \prg_break_point:
21829 }

```

(End definition for __kernel_randint:nn and others.)

\int_rand:n Similar to \int_rand:nn, but needs fewer checks.

```

\__fp_randint:n 21830 \cs_new:Npn \int_rand:n #1
21831 {
21832     \int_eval:n
21833     { \exp_args:Nf \__fp_randint:n { \int_eval:n {#1} } }
21834 }
21835 \cs_new:Npn \__fp_randint:n #1
21836 {
21837     \if_int_compare:w #1 < 1 \exp_stop_f:
21838     \__kernel_msg_expandable_error:nnnn
21839     { kernel } { randint-backward-range } { 1 } {#1}
21840     \__fp_randint:ww #1; 1;
21841     \else:
21842     \if_int_compare:w #1 > \c__kernel_randint_max_int

```

```

21843         \__kernel_randint:nn { 1 } {#1}
21844     \else:
21845         \__kernel_randint:n {#1}
21846     \fi:
21847 \fi:
21848 }

```

(End definition for `\int_rand:n` and `__fp_randint:n`. This function is documented on page 95.)

End the initial conditional that ensures these commands are only defined in engines that support random numbers.

```

21849 }
21850 </initex | package>

```

37 l3fparray implementation

```

21851 <*initex | package>
21852 <@@=fp>

```

In analogy to `l3intarray` it would make sense to have `<@@=fparray>`, but we need direct access to `__fp_parse:n` from `l3fp-parse`, and a few other (less crucial) internals of the `l3fp` family.

37.1 Allocating arrays

There are somewhat more than $(2^{31} - 1)^2$ floating point numbers so we store each floating point number as three entries in integer arrays. To avoid having to multiply indices by three or to add 1 etc, a floating point array is just a token list consisting of three tokens: integer arrays of the same size.

`\g__fp_array_int` Used to generate unique names for the three integer arrays.

```

21853 \int_new:N \g__fp_array_int

```

(End definition for `\g__fp_array_int`.)

`\l__fp_array_loop_int` Used to loop in `__fp_array_gzero:N`.

```

21854 \int_new:N \l__fp_array_loop_int

```

(End definition for `\l__fp_array_loop_int`.)

`\fparray_new:Nn` Build a three token token list, then define all three tokens to be integer arrays of the same size. No need to initialize the data: the integer arrays start with zeros, and three zeros denote precisely `\c_zero_fp`, as we want.

`__fp_array_new:nNNN`

```

21855 \cs_new_protected:Npn \fparray_new:Nn #1#2
21856 {
21857     \tl_new:N #1
21858     \prg_replicate:nn { 3 }
21859     {
21860         \int_gincr:N \g__fp_array_int
21861         \exp_args:NNc \tl_gput_right:Nn #1
21862         { g__fp_array_ \__fp_int_to_roman:w \g__fp_array_int _intarray }
21863     }
21864     \exp_last_unbraced:Nfo \__fp_array_new:nNNNN
21865     { \int_eval:n {#2} } #1 #1

```



```

21866 }
21867 \cs_new_protected:Npn \__fp_array_new:nNNNN #1#2#3#4#5
21868 {
21869   \int_compare:nNnTF {#1} < 0
21870   {
21871     \__kernel_msg_error:nnn { kernel } { negative-array-size } {#1}
21872     \cs_undefine:N #1
21873     \int_gsub:Nn \g__fp_array_int { 3 }
21874   }
21875   {
21876     \intarray_new:Nn #2 {#1}
21877     \intarray_new:Nn #3 {#1}
21878     \intarray_new:Nn #4 {#1}
21879   }
21880 }

```

(End definition for `\farray_new:Nn` and `__fp_array_new:nNNNN`. This function is documented on page 252.)

`\farray_count:N` Size of any of the intarrays, here we pick the third.

```

21881 \cs_new:Npn \farray_count:N #1
21882 {
21883   \exp_after:wN \use_i:nnn
21884   \exp_after:wN \intarray_count:N #1
21885 }

```

(End definition for `\farray_count:N`. This function is documented on page 252.)

37.2 Array items

`__fp_array_bounds:NNnTF` See the `\intarray` analogue: only names change. The functions `\farray_gset:Nnn` and `__fp_array_bounds_error:NNn` share bounds checking. The T branch is used if #3 is within bounds of the array #2.

```

21886 \cs_new:Npn \__fp_array_bounds:NNnTF #1#2#3#4#5
21887 {
21888   \if_int_compare:w 1 > #3 \exp_stop_f:
21889     \__fp_array_bounds_error:NNn #1 #2 {#3}
21890     #5
21891   \else:
21892     \if_int_compare:w #3 > \farray_count:N #2 \exp_stop_f:
21893       \__fp_array_bounds_error:NNn #1 #2 {#3}
21894       #5
21895     \else:
21896       #4
21897     \fi:
21898   \fi:
21899 }
21900 \cs_new:Npn \__fp_array_bounds_error:NNn #1#2#3
21901 {
21902   #1 { kernel } { out-of-bounds }
21903   { \token_to_str:N #2 } {#3} { \farray_count:N #2 }
21904 }

```

(End definition for `__fp_array_bounds:NNnTF` and `__fp_array_bounds_error:NNn`.)

```

    \fpararray_gset:Nnn Evaluate, then store exponent in one intarray, sign and 8 digits of mantissa in the next,
    \__fp_array_gset:NNNNww and 8 trailing digits in the last.
    \__fp_array_gset:w
    \__fp_array_gset_recover:Nw
    \__fp_array_gset_special:nnNNN
    \__fp_array_gset_normal:w
21905 \cs_new_protected:Npn \fpararray_gset:Nnn #1#2#3
21906 {
21907     \exp_after:wN \exp_after:wN
21908     \exp_after:wN \__fp_array_gset:NNNNww
21909     \exp_after:wN #1
21910     \exp_after:wN #1
21911     \int_value:w \int_eval:n {#2} \exp_after:wN ;
21912     \exp:w \exp_end_continue_f:w \__fp_parse:n {#3}
21913 }
21914 \cs_new_protected:Npn \__fp_array_gset:NNNNww #1#2#3#4#5 ; #6 ;
21915 {
21916     \__fp_array_bounds:NNnTF \__kernel_msg_error:nxxxx #4 {#5}
21917     {
21918         \exp_after:wN \__fp_change_func_type:NNN
21919         \__fp_use_i_until_s:nw #6 ;
21920         \__fp_array_gset:w
21921         \__fp_array_gset_recover:Nw
21922         #6 ; {#5} #1 #2 #3
21923     }
21924     { }
21925 }
21926 \cs_new_protected:Npn \__fp_array_gset_recover:Nw #1#2 ;
21927 {
21928     \__fp_error:nffn { fp-unknown-type } { \tl_to_str:n { #2 ; } } { } { } { }
21929     \exp_after:wN #1 \c_nan_fp
21930 }
21931 \cs_new_protected:Npn \__fp_array_gset:w \s__fp \__fp_chk:w #1#2
21932 {
21933     \if_case:w #1 \exp_stop_f:
21934         \__fp_case_return:nw { \__fp_array_gset_special:nnNNN {#2} }
21935     \or: \exp_after:wN \__fp_array_gset_normal:w
21936     \or: \__fp_case_return:nw { \__fp_array_gset_special:nnNNN { #2 3 } }
21937     \or: \__fp_case_return:nw { \__fp_array_gset_special:nnNNN { 1 } }
21938     \fi:
21939     \s__fp \__fp_chk:w #1 #2
21940 }
21941 \cs_new_protected:Npn \__fp_array_gset_normal:w
21942     \s__fp \__fp_chk:w 1 #1 #2 #3#4#5 ; #6#7#8#9
21943 {
21944     \__kernel_intarray_gset:Nnn #7 {#6} {#2}
21945     \__kernel_intarray_gset:Nnn #8 {#6}
21946     { \if_meaning:w 2 #1 3 \else: 1 \fi: #3#4 }
21947     \__kernel_intarray_gset:Nnn #9 {#6} { 1 \use:nn #5 }
21948 }
21949 \cs_new_protected:Npn \__fp_array_gset_special:nnNNN #1#2#3#4#5
21950 {
21951     \__kernel_intarray_gset:Nnn #3 {#2} {#1}
21952     \__kernel_intarray_gset:Nnn #4 {#2} {0}
21953     \__kernel_intarray_gset:Nnn #5 {#2} {0}
21954 }

```

(End definition for \fpararray_gset:Nnn and others. This function is documented on page 252.)

\fpararray_gzero:N

```
21955 \cs_new_protected:Npn \fpararray_gzero:N #1
21956 {
21957   \int_zero:N \l__fp_array_loop_int
21958   \prg_replicate:nn { \fpararray_count:N #1 }
21959   {
21960     \int_incr:N \l__fp_array_loop_int
21961     \exp_after:wN \__fp_array_gset_special:nnNNN
21962     \exp_after:wN 0
21963     \exp_after:wN \l__fp_array_loop_int
21964     #1
21965   }
21966 }
```

(End definition for \fpararray_gzero:N. This function is documented on page 252.)

\fpararray_item:Nn

\fpararray_item_to_tl:Nn

__fp_array_item:NwN

__fp_array_item:NNNnN

__fp_array_item:N

__fp_array_item:w

__fp_array_item_special:w

__fp_array_item_normal:w

```
21967 \cs_new:Npn \fpararray_item:Nn #1#2
21968 {
21969   \exp_after:wN \__fp_array_item:NwN
21970   \exp_after:wN #1
21971   \int_value:w \int_eval:n {#2} ;
21972   \__fp_to_decimal:w
21973 }
21974 \cs_new:Npn \fpararray_item_to_tl:Nn #1#2
21975 {
21976   \exp_after:wN \__fp_array_item:NwN
21977   \exp_after:wN #1
21978   \int_value:w \int_eval:n {#2} ;
21979   \__fp_to_tl:w
21980 }
21981 \cs_new:Npn \__fp_array_item:NwN #1#2 ; #3
21982 {
21983   \__fp_array_bounds:NNnTF \__kernel_msg_expandable_error:nnfff #1 {#2}
21984   { \exp_after:wN \__fp_array_item:NNNnN #1 {#2} #3 }
21985   { \exp_after:wN #3 \c_nan_fp }
21986 }
21987 \cs_new:Npn \__fp_array_item:NNNnN #1#2#3#4
21988 {
21989   \exp_after:wN \__fp_array_item:N
21990   \int_value:w \__kernel_intarray_item:Nn #2 {#4} \exp_after:wN ;
21991   \int_value:w \__kernel_intarray_item:Nn #3 {#4} \exp_after:wN ;
21992   \int_value:w \__kernel_intarray_item:Nn #1 {#4} ;
21993 }
21994 \cs_new:Npn \__fp_array_item:N #1
21995 {
21996   \if_meaning:w 0 #1 \exp_after:wN \__fp_array_item_special:w \fi:
21997   \__fp_array_item:w #1
21998 }
21999 \cs_new:Npn \__fp_array_item:w #1 #2#3#4#5 #6 ; 1 #7 ;
22000 {
22001   \exp_after:wN \__fp_array_item_normal:w
22002   \int_value:w \if_meaning:w #1 1 0 \else: 2 \fi: \exp_stop_f:
22003   #7 ; {#2#3#4#5} {#6} ;
```

```

22004 }
22005 \cs_new:Npn \__fp_array_item_special:w #1 ; #2 ; #3 ; #4
22006 {
22007   \exp_after:wN #4
22008   \exp:w \exp_end_continue_f:w
22009   \if_case:w #3 \exp_stop_f:
22010     \exp_after:wN \c_zero_fp
22011   \or: \exp_after:wN \c_nan_fp
22012   \or: \exp_after:wN \c_minus_zero_fp
22013   \or: \exp_after:wN \c_inf_fp
22014   \else: \exp_after:wN \c_minus_inf_fp
22015   \fi:
22016 }
22017 \cs_new:Npn \__fp_array_item_normal:w #1 #2#3#4#5 #6 ; #7 ; #8 ; #9
22018 { #9 \s__fp \__fp_chk:w 1 #1 {#8} #7 {#2#3#4#5} {#6} ; }

```

(End definition for `\fpararray_item:Nn` and others. These functions are documented on page 252.)

```
22019 </initex | package>
```

38 l3sort implementation

```
22020 <*initex | package>
```

```
22021 <@@=sort>
```

38.1 Variables

```
\g__sort_internal_seq
\g__sort_internal_tl
```

Sorting happens in a group; the result is stored in those global variables before being copied outside the group to the proper places. For `seq` and `tl` this is more efficient than using `\use:x` (or some `\exp_args:NNNx`) to smuggle the definition outside the group since \TeX does not need to re-read tokens. For `clist` we don't gain anything since the result is converted from `seq` to `clist` anyways.

```
22022 \seq_new:N \g__sort_internal_seq
22023 \tl_new:N \g__sort_internal_tl
```

(End definition for `\g__sort_internal_seq` and `\g__sort_internal_tl`.)

```
\l__sort_length_int
\l__sort_min_int
\l__sort_top_int
\l__sort_max_int
\l__sort_true_max_int
```

The sequence has `\l__sort_length_int` items and is stored from `\l__sort_min_int` to `\l__sort_top_int - 1`. While reading the sequence in memory, we check that `\l__sort_top_int` remains at most `\l__sort_max_int`, precomputed by `__sort_compute_range:.` That bound is such that the merge sort only uses `\toks` registers less than `\l__sort_true_max_int`, namely those that have not been allocated for use in other code: the user's comparison code could alter these.

```
22024 \int_new:N \l__sort_length_int
22025 \int_new:N \l__sort_min_int
22026 \int_new:N \l__sort_top_int
22027 \int_new:N \l__sort_max_int
22028 \int_new:N \l__sort_true_max_int
```

(End definition for `\l__sort_length_int` and others.)

```
\l__sort_block_int
```

Merge sort is done in several passes. In each pass, blocks of size `\l__sort_block_int` are merged in pairs. The block size starts at 1, and, for a length in the range $[2^k + 1, 2^{k+1}]$, reaches 2^k in the last pass.

```
22029 \int_new:N \l__sort_block_int
```

(End definition for \l__sort_block_int.)

\l__sort_begin_int When merging two blocks, \l__sort_begin_int marks the lowest index in the two
\l__sort_end_int blocks, and \l__sort_end_int marks the highest index, plus 1.

```
22030 \int_new:N \l__sort_begin_int
22031 \int_new:N \l__sort_end_int
```

(End definition for \l__sort_begin_int and \l__sort_end_int.)

\l__sort_A_int When merging two blocks (whose end-points are beg and end), *A* starts from the high end
\l__sort_B_int of the low block, and decreases until reaching beg. The index *B* starts from the top of the
\l__sort_C_int range and marks the register in which a sorted item should be put. Finally, *C* points to
the copy of the high block in the interval of registers starting at \l__sort_length_int,
upwards. *C* starts from the upper limit of that range.

```
22032 \int_new:N \l__sort_A_int
22033 \int_new:N \l__sort_B_int
22034 \int_new:N \l__sort_C_int
```

(End definition for \l__sort_A_int, \l__sort_B_int, and \l__sort_C_int.)

38.2 Finding available \toks registers

__sort_shrink_range: After __sort_compute_range: (defined below) determines that \toks registers be-
__sort_shrink_range_loop: tween \l__sort_min_int (included) and \l__sort_true_max_int (excluded) have not
yet been assigned, __sort_shrink_range: computes \l__sort_max_int to reflect the
need for a buffer when merging blocks in the merge sort. Given $2^n \leq A \leq 2^n + 2^{n-1}$
registers we can sort $\lfloor A/2 \rfloor + 2^{n-2}$ items while if we have $2^n + 2^{n-1} \leq A \leq 2^{n+1}$ registers
we can sort $A - 2^{n-1}$ items. We first find out a power 2^n such that $2^n \leq A \leq 2^{n+1}$
by repeatedly halving \l__sort_block_int, starting at 2^{15} or 2^{14} namely half the total
number of registers, then we use the formulas and set \l__sort_max_int.

```
22035 \cs_new_protected:Npn \__sort_shrink_range:
22036 {
22037   \int_set:Nn \l__sort_A_int
22038     { \l__sort_true_max_int - \l__sort_min_int + 1 }
22039   \int_set:Nn \l__sort_block_int { \c_max_register_int / 2 }
22040   \__sort_shrink_range_loop:
22041   \int_set:Nn \l__sort_max_int
22042     {
22043     \int_compare:nNnTF
22044       { \l__sort_block_int * 3 / 2 } > \l__sort_A_int
22045       {
22046         \l__sort_min_int
22047         + ( \l__sort_A_int - 1 ) / 2
22048         + \l__sort_block_int / 4
22049         - 1
22050       }
22051       { \l__sort_true_max_int - \l__sort_block_int / 2 }
22052     }
22053 }
22054 \cs_new_protected:Npn \__sort_shrink_range_loop:
22055 {
22056   \if_int_compare:w \l__sort_A_int < \l__sort_block_int
22057     \tex_divide:D \l__sort_block_int 2 \exp_stop_f:
```

```

22058     \exp_after:wN \__sort_shrink_range_loop:
22059     \fi:
22060 }

```

(End definition for __sort_shrink_range: and __sort_shrink_range_loop:.)

__sort_compute_range: First find out what \toks have not yet been assigned. There are many cases. In L^AT_EX 2_ε with no package, available \toks range from \count15 + 1 to \c_max_register_int included (this was not altered despite the 2015 changes). When \loctoks is defined, namely in plain (e)T_EX, or when the package etex is loaded in L^AT_EX 2_ε, redefine __sort_compute_range: to use the range \count265 to \count275 - 1. The elocalloc package also defines \loctoks but uses yet another number for the upper bound, namely \e@alloc@top (minus one). We must check for \loctoks every time a sorting function is called, as etex or elocalloc could be loaded.

In ConT_EXt MkIV the range is from \c_syst_last_allocated_toks+1 to \c_max_register_int, and in MkII it is from \lastallocatedtoks+1 to \c_max_register_int. In all these cases, call __sort_shrink_range:. The L^AT_EX3 format mode is easiest: no \toks are ever allocated so available \toks range from 0 to \c_max_register_int and we precompute the result of __sort_shrink_range:.

```

22061 (*package)
22062 \cs_new_protected:Npn \__sort_compute_range:
22063 {
22064     \int_set:Nn \l__sort_min_int { \tex_count:D 15 + 1 }
22065     \int_set:Nn \l__sort_true_max_int { \c_max_register_int + 1 }
22066     \__sort_shrink_range:
22067     \if_meaning:w \loctoks \tex_undefined:D \else:
22068         \if_meaning:w \loctoks \scan_stop: \else:
22069             \__sort_redefine_compute_range:
22070             \__sort_compute_range:
22071         \fi:
22072     \fi:
22073 }
22074 \cs_new_protected:Npn \__sort_redefine_compute_range:
22075 {
22076     \cs_if_exist:cTF { ver@elocalloc.sty }
22077     {
22078         \cs_gset_protected:Npn \__sort_compute_range:
22079         {
22080             \int_set:Nn \l__sort_min_int { \tex_count:D 265 }
22081             \int_set_eq:NN \l__sort_true_max_int \e@alloc@top
22082             \__sort_shrink_range:
22083         }
22084     }
22085     {
22086         \cs_gset_protected:Npn \__sort_compute_range:
22087         {
22088             \int_set:Nn \l__sort_min_int { \tex_count:D 265 }
22089             \int_set:Nn \l__sort_true_max_int { \tex_count:D 275 }
22090             \__sort_shrink_range:
22091         }
22092     }
22093 }
22094 \cs_if_exist:NT \loctoks { \__sort_redefine_compute_range: }

```

```

22095 \tl_map_inline:nn { \lastallocatedtoks \c_syst_last_allocated_toks }
22096 {
22097   \cs_if_exist:NT #1
22098   {
22099     \cs_gset_protected:Npn \__sort_compute_range:
22100     {
22101       \int_set:Nn \l__sort_min_int { #1 + 1 }
22102       \int_set:Nn \l__sort_true_max_int { \c_max_register_int + 1 }
22103       \__sort_shrink_range:
22104     }
22105   }
22106 }
22107 </package>
22108 <*initex>
22109 \int_const:Nn \c__sort_max_length_int
22110 { ( \c_max_register_int + 1 ) * 3 / 4 }
22111 \cs_new_protected:Npn \__sort_compute_range:
22112 {
22113   \int_set:Nn \l__sort_min_int { 0 }
22114   \int_set:Nn \l__sort_true_max_int { \c_max_register_int + 1 }
22115   \int_set:Nn \l__sort_max_int { \c__sort_max_length_int }
22116 }
22117 </initex>

```

(End definition for __sort_compute_range:, __sort_redefine_compute_range:, and \c__sort_max_length_int.)

38.3 Protected user commands

__sort_main:NNNn Sorting happens in three steps. First store items in \toks registers ranging from \l__sort_min_int to \l__sort_top_int - 1, while checking that the list is not too long. If we reach the maximum length, that's an error; exit the group. Secondly, sort the array of \toks registers, using the user-defined sorting function: __sort_level: calls __sort_compare:nn as needed. Finally, unpack the \toks registers (now sorted) into the target tl, or into \g__sort_internal_seq for seq and clist. This is done by __sort_seq:NNNNn and __sort_tl:NNn.

```

22118 \cs_new_protected:Npn \__sort_main:NNNn #1#2#3#4
22119 {
22120   <package> \__sort_disable_tokstokdef:
22121   \__sort_compute_range:
22122   \int_set_eq:NN \l__sort_top_int \l__sort_min_int
22123   #1 #3
22124   {
22125     \if_int_compare:w \l__sort_top_int = \l__sort_max_int
22126     \__sort_too_long_error:NNw #2 #3
22127     \fi:
22128     \tex_toks:D \l__sort_top_int {##1}
22129     \int_incr:N \l__sort_top_int
22130   }
22131   \int_set:Nn \l__sort_length_int
22132   { \l__sort_top_int - \l__sort_min_int }
22133   \cs_set:Npn \__sort_compare:nn ##1 ##2 {#4}
22134   \int_set:Nn \l__sort_block_int { 1 }
22135   \__sort_level:

```

22136 }

(End definition for _sort_main:NNNn.)

\tl_sort:Nn Call the main sorting function then unpack \toks registers outside the group into the
\tl_sort:cn target token list. The unpacking is done by _sort_tl_toks:w; registers are numbered
\tl_gsort:Nn from \l__sort_min_int to \l__sort_top_int - 1. For expansion behaviour we need
\tl_gsort:cn a couple of primitives. The \tl_gclear:N reduces memory usage. The \prg_break_
_sort_tl:NNn point: is used by _sort_main:NNNn when the list is too long.
_sort_tl_toks:w

```

22137 \cs_new_protected:Npn \tl_sort:Nn { \_sort_tl:NNn \tl_set_eq:NN }
22138 \cs_generate_variant:Nn \tl_sort:Nn { c }
22139 \cs_new_protected:Npn \tl_gsort:Nn { \_sort_tl:NNn \tl_gset_eq:NN }
22140 \cs_generate_variant:Nn \tl_gsort:Nn { c }
22141 \cs_new_protected:Npn \_sort_tl:NNn #1#2#3
22142 {
22143   \group_begin:
22144   \_sort_main:NNNn \tl_map_inline:Nn \tl_map_break:n #2 {#3}
22145   \tl_gset:Nx \g__sort_internal_tl
22146   { \_sort_tl_toks:w \l__sort_min_int ; }
22147   \group_end:
22148   #1 #2 \g__sort_internal_tl
22149   \tl_gclear:N \g__sort_internal_tl
22150   \prg_break_point:
22151 }
22152 \cs_new:Npn \_sort_tl_toks:w #1 ;
22153 {
22154   \if_int_compare:w #1 < \l__sort_top_int
22155   { \tex_the:D \tex_toks:D #1 }
22156   \exp_after:wN \_sort_tl_toks:w
22157   \int_value:w \int_eval:n { #1 + 1 } \exp_after:wN ;
22158   \fi:
22159 }
```

(End definition for \tl_sort:Nn and others. These functions are documented on page 46.)

\seq_sort:Nn Use the same general framework for seq and clist. Apply the general sorting code, then
\seq_sort:cn unpack \toks into \g__sort_internal_seq. Outside the group copy or convert (for
\seq_gsort:Nn clist) the data to the target variable. The \seq_gclear:N reduces memory usage. The
\seq_gsort:cn \prg_break_point: is used by _sort_main:NNNn when the list is too long.
\clist_sort:Nn

```

22160 \cs_new_protected:Npn \seq_sort:Nn
22161 { \_sort_seq:NNNNn \seq_map_inline:Nn \seq_map_break:n \seq_set_eq:NN }
22162 \cs_generate_variant:Nn \seq_sort:Nn { c }
22163 \cs_new_protected:Npn \seq_gsort:Nn
22164 { \_sort_seq:NNNNn \seq_map_inline:Nn \seq_map_break:n \seq_gset_eq:NN }
22165 \cs_generate_variant:Nn \seq_gsort:Nn { c }
22166 \cs_new_protected:Npn \clist_sort:Nn
22167 {
22168   \_sort_seq:NNNNn \clist_map_inline:Nn \clist_map_break:n
22169   \clist_set_from_seq:NN
22170 }
22171 \cs_generate_variant:Nn \clist_sort:Nn { c }
22172 \cs_new_protected:Npn \clist_gsort:Nn
22173 {
22174   \_sort_seq:NNNNn \clist_map_inline:Nn \clist_map_break:n
```



```

22175     \clist_gset_from_seq:NN
22176   }
22177 \cs_generate_variant:Nn \clist_gsort:Nn { c }
22178 \cs_new_protected:Npn \__sort_seq:NNNNn #1#2#3#4#5
22179 {
22180   \group_begin:
22181     \__sort_main:NNNn #1 #2 #4 {#5}
22182     \seq_gset_from_inline_x:Nnn \g__sort_internal_seq
22183     {
22184       \int_step_function:nnN
22185         { \l__sort_min_int } { \l__sort_top_int - 1 }
22186     }
22187     { \tex_the:D \tex_toks:D ##1 }
22188   \group_end:
22189   #3 #4 \g__sort_internal_seq
22190   \seq_gclear:N \g__sort_internal_seq
22191   \prg_break_point:
22192 }

```

(End definition for `\seq_sort:Nn` and others. These functions are documented on page 77.)

38.4 Merge sort

`__sort_level:` This function is called once blocks of size `\l__sort_block_int` (initially 1) are each sorted. If the whole list fits in one block, then we are done (this also takes care of the case of an empty list or a list with one item). Otherwise, go through pairs of blocks starting from 0, then double the block size, and repeat.

```

22193 \cs_new_protected:Npn \__sort_level:
22194 {
22195   \if_int_compare:w \l__sort_block_int < \l__sort_length_int
22196     \l__sort_end_int \l__sort_min_int
22197     \__sort_merge_blocks:
22198     \tex_advance:D \l__sort_block_int \l__sort_block_int
22199     \exp_after:wN \__sort_level:
22200   \fi:
22201 }

```

(End definition for `__sort_level:.`)

`__sort_merge_blocks:` This function is called to merge a pair of blocks, starting at the last value of `\l__sort_end_int` (end-point of the previous pair of blocks). If shifting by one block to the right we reach the end of the list, then this pass has ended: the end of the list is sorted already. Otherwise, store the result of that shift in *A*, which indexes the first block starting from the top end. Then locate the end-point (maximum) of the second block: shift *end* upwards by one more block, but keeping it \leq *top*. Copy this upper block of `\toks` registers in registers above *length*, indexed by *C*: this is covered by `__sort_copy_block:.` Once this is done we are ready to do the actual merger using `__sort_merge_blocks_aux:`, after shifting *A*, *B* and *C* so that they point to the largest index in their respective ranges rather than pointing just beyond those ranges. Of course, once that pair of blocks is merged, move on to the next pair.

```

22202 \cs_new_protected:Npn \__sort_merge_blocks:
22203 {
22204   \l__sort_begin_int \l__sort_end_int

```

```

22205 \tex_advance:D \l__sort_end_int \l__sort_block_int
22206 \if_int_compare:w \l__sort_end_int < \l__sort_top_int
22207   \l__sort_A_int \l__sort_end_int
22208   \tex_advance:D \l__sort_end_int \l__sort_block_int
22209   \if_int_compare:w \l__sort_end_int > \l__sort_top_int
22210     \l__sort_end_int \l__sort_top_int
22211   \fi:
22212   \l__sort_B_int \l__sort_A_int
22213   \l__sort_C_int \l__sort_top_int
22214   \__sort_copy_block:
22215   \int_decr:N \l__sort_A_int
22216   \int_decr:N \l__sort_B_int
22217   \int_decr:N \l__sort_C_int
22218   \exp_after:wN \__sort_merge_blocks_aux:
22219   \exp_after:wN \__sort_merge_blocks:
22220 \fi:
22221 }

```

(End definition for __sort_merge_blocks:.)

__sort_copy_block: We wish to store a copy of the “upper” block of \toks registers, ranging between the initial value of \l__sort_B_int (included) and \l__sort_end_int (excluded) into a new range starting at the initial value of \l__sort_C_int, namely \l__sort_top_int.

```

22222 \cs_new_protected:Npn \__sort_copy_block:
22223 {
22224   \tex_toks:D \l__sort_C_int \tex_toks:D \l__sort_B_int
22225   \int_incr:N \l__sort_C_int
22226   \int_incr:N \l__sort_B_int
22227   \if_int_compare:w \l__sort_B_int = \l__sort_end_int
22228     \use_i:nn
22229   \fi:
22230   \__sort_copy_block:
22231 }

```

(End definition for __sort_copy_block:.)

__sort_merge_blocks_aux: At this stage, the first block starts at \l__sort_begin_int, and ends at \l__sort_A_int, and the second block starts at \l__sort_top_int and ends at \l__sort_C_int. The result of the merger is stored at positions indexed by \l__sort_B_int, which starts at \l__sort_end_int − 1 and decreases down to \l__sort_begin_int, covering the full range of the two blocks. In other words, we are building the merger starting with the largest values. The comparison function is defined to return either **swapped** or **same**. Of course, this means the arguments need to be given in the order they appear originally in the list.

```

22232 \cs_new_protected:Npn \__sort_merge_blocks_aux:
22233 {
22234   \exp_after:wN \__sort_compare:nn \exp_after:wN
22235   { \tex_the:D \tex_toks:D \exp_after:wN \l__sort_A_int \exp_after:wN }
22236   \exp_after:wN { \tex_the:D \tex_toks:D \l__sort_C_int }
22237   \prg_do_nothing:
22238   \__sort_return_mark:w
22239   \__sort_return_mark:w
22240   \q_mark
22241   \__sort_return_none_error:

```

22242 }

(End definition for _sort_merge_blocks_aux:.)

\sort_return_same: Each comparison should call \sort_return_same: or \sort_return_swapped: exactly once. If neither is called, _sort_return_none_error: is called, since the return_mark removes tokens until \q_mark. If one is called, the return_mark auxiliary removes everything except _sort_return_same:w (or its swapped analogue) followed by _sort_return_none_error:. Finally if two or more are called, _sort_return_two_error: ends up before any _sort_return_mark:w, so that it produces an error.

```

22243 \cs_new_protected:Npn \sort_return_same:
22244   #1 \_sort_return_mark:w #2 \q_mark
22245   {
22246     #1
22247     #2
22248     \_sort_return_two_error:
22249     \_sort_return_mark:w
22250     \q_mark
22251     \_sort_return_same:w
22252   }
22253 \cs_new_protected:Npn \sort_return_swapped:
22254   #1 \_sort_return_mark:w #2 \q_mark
22255   {
22256     #1
22257     #2
22258     \_sort_return_two_error:
22259     \_sort_return_mark:w
22260     \q_mark
22261     \_sort_return_swapped:w
22262   }
22263 \cs_new_protected:Npn \_sort_return_mark:w #1 \q_mark { }
22264 \cs_new_protected:Npn \_sort_return_none_error:
22265   {
22266     \__kernel_msg_error:nxxx { kernel } { return-none }
22267     { \tex_the:D \tex_toks:D \l__sort_A_int }
22268     { \tex_the:D \tex_toks:D \l__sort_C_int }
22269     \_sort_return_same:w \_sort_return_none_error:
22270   }
22271 \cs_new_protected:Npn \_sort_return_two_error:
22272   {
22273     \__kernel_msg_error:nxxx { kernel } { return-two }
22274     { \tex_the:D \tex_toks:D \l__sort_A_int }
22275     { \tex_the:D \tex_toks:D \l__sort_C_int }
22276   }

```

(End definition for \sort_return_same: and others. These functions are documented on page 213.)

_sort_return_same:w If the comparison function returns **same**, then the second argument fed to _sort_compare:nn should remain to the right of the other one. Since we build the merger starting from the right, we copy that \toks register into the allotted range, then shift the pointers *B* and *C*, and go on to do one more step in the merger, unless the second block has been exhausted: then the remainder of the first block is already in the correct registers and we are done with merging those two blocks.

```

22277 \cs_new_protected:Npn \_sort_return_same:w #1 \_sort_return_none_error:

```

```

22278 {
22279   \tex_toks:D \l__sort_B_int \tex_toks:D \l__sort_C_int
22280   \int_decr:N \l__sort_B_int
22281   \int_decr:N \l__sort_C_int
22282   \if_int_compare:w \l__sort_C_int < \l__sort_top_int
22283     \use_i:nn
22284   \fi:
22285   \__sort_merge_blocks_aux:
22286 }

```

(End definition for __sort_return_same:w.)

__sort_return_swapped:w If the comparison function returns **swapped**, then the next item to add to the merger is the first argument, contents of the \toks register *A*. Then shift the pointers *A* and *B* to the left, and go for one more step for the merger, unless the left block was exhausted (*A* goes below the threshold). In that case, all remaining \toks registers in the second block, indexed by *C*, are copied to the merger by __sort_merge_blocks_end:.

```

22287 \cs_new_protected:Npn \__sort_return_swapped:w #1 \__sort_return_none_error:
22288 {
22289   \tex_toks:D \l__sort_B_int \tex_toks:D \l__sort_A_int
22290   \int_decr:N \l__sort_B_int
22291   \int_decr:N \l__sort_A_int
22292   \if_int_compare:w \l__sort_A_int < \l__sort_begin_int
22293     \__sort_merge_blocks_end: \use_i:nn
22294   \fi:
22295   \__sort_merge_blocks_aux:
22296 }

```

(End definition for __sort_return_swapped:w.)

__sort_merge_blocks_end: This function's task is to copy the \toks registers in the block indexed by *C* to the merger indexed by *B*. The end can equally be detected by checking when *B* reaches the threshold *begin*, or when *C* reaches *top*.

```

22297 \cs_new_protected:Npn \__sort_merge_blocks_end:
22298 {
22299   \tex_toks:D \l__sort_B_int \tex_toks:D \l__sort_C_int
22300   \int_decr:N \l__sort_B_int
22301   \int_decr:N \l__sort_C_int
22302   \if_int_compare:w \l__sort_B_int < \l__sort_begin_int
22303     \use_i:nn
22304   \fi:
22305   \__sort_merge_blocks_end:
22306 }

```

(End definition for __sort_merge_blocks_end:.)

38.5 Expandable sorting

Sorting expandably is very different from sorting and assigning to a variable. Since tokens cannot be stored, they must remain in the input stream, and be read through at every step. It is thus necessarily much slower (at best $O(n^2 \ln n)$) than non-expandable sorting functions ($O(n \ln n)$).

A prototypical version of expandable quicksort is as follows. If the argument has no item, return nothing, otherwise partition, using the first item as a pivot (argument #4 of

`__sort:nnNnn`). The arguments of `__sort:nnNnn` are 1. items less than #4, 2. items greater or equal to #4, 3. comparison, 4. pivot, 5. next item to test. If #5 is the tail of the list, call `\tl_sort:nN` on #1 and on #2, placing #4 in between; `\use:ff` expands the parts to make `\tl_sort:nN` f-expandable. Otherwise, compare #4 and #5 using #3. If they are ordered, place #5 amongst the “greater” items, otherwise amongst the “lesser” items, and continue partitioning.

```
\cs_new:Npn \tl_sort:nN #1#2
{
  \tl_if_blank:nF {#1}
  {
    \__sort:nnNnn { } { } #2
    #1 \q_recursion_tail \q_recursion_stop
  }
}
\cs_new:Npn \__sort:nnNnn #1#2#3#4#5
{
  \quark_if_recursion_tail_stop_do:nn {#5}
  { \use:ff { \tl_sort:nN {#1} #3 {#4} } { \tl_sort:nN {#2} #3 } }
  #3 {#4} {#5}
  { \__sort:nnNnn {#1} { #2 {#5} } #3 {#4} }
  { \__sort:nnNnn { #1 {#5} } {#2} #3 {#4} }
}
\cs_generate_variant:Nn \use:nn { ff }
```

There are quite a few optimizations available here: the code below is less legible, but more than twice as fast.

In the simple version of the code, `__sort:nnNnn` is called $O(n \ln n)$ times on average (the number of comparisons required by the quicksort algorithm). Hence most of our focus is on optimizing that function.

The first speed up is to avoid testing for the end of the list at every call to `__sort:nnNnn`. For this, the list is prepared by changing each $\langle item \rangle$ of the original token list into $\langle command \rangle \{ \langle item \rangle \}$, just like sequences are stored. We arrange things such that the $\langle command \rangle$ is the $\langle conditional \rangle$ provided by the user: the loop over the $\langle prepared tokens \rangle$ then looks like

```
\cs_new:Npn \__sort_loop:wNn ... #6#7
{
  #6 { \langle pivot \rangle } {#7} \langle loop big \rangle \langle loop small \rangle
  \langle extra arguments \rangle
}
\__sort_loop:wNn ... \langle prepared tokens \rangle
\langle end-loop \rangle {} \q_stop
```

In this example, which matches the structure of `__sort_quick_split_i:NnnnnNn` and a few other functions below, the `__sort_loop:wNn` auxiliary normally receives the user’s $\langle conditional \rangle$ as #6 and an $\langle item \rangle$ as #7. This is compared to the $\langle pivot \rangle$ (the argument #5, not shown here), and the $\langle conditional \rangle$ leaves the $\langle loop big \rangle$ or $\langle loop small \rangle$ auxiliary, which both have the same form as `__sort_loop:wNn`, receiving the next pair $\langle conditional \rangle \{ \langle item \rangle \}$ as #6 and #7. At the end, #6 is the $\langle end-loop \rangle$ function, which terminates the loop.

The second speed up is to minimize the duplicated tokens between the `true` and `false` branches of the conditional. For this, we introduce two versions of `__sort:nnNnn`, which receive the new item as `#1` and place it either into the list `#2` of items less than the pivot `#4` or into the list `#3` of items greater or equal to the pivot.

```
\cs_new:Npn \__sort_i:nnnnNn #1#2#3#4#5#6
{
  #5 {#4} {#6} \__sort_ii:nnnnNn \__sort_i:nnnnNn
  {#6} { #2 {#1} } {#3} {#4}
}
\cs_new:Npn \__sort_ii:nnnnNn #1#2#3#4#5#6
{
  #5 {#4} {#6} \__sort_ii:nnnnNn \__sort_i:nnnnNn
  {#6} {#2} { #3 {#1} } {#4}
}
```

Note that the two functions have the form of `__sort_loop:wNn` above, receiving as `#5` the conditional or a function to end the loop. In fact, the lists `#2` and `#3` must be made of pairs $\langle \text{conditional} \rangle \{ \langle \text{item} \rangle \}$, so we have to replace `{#6}` above by `{ #5 {#6} }`, and `{#1}` by `#1`. The actual functions have one more argument, so all argument numbers are shifted compared to this code.

The third speed up is to avoid `\use:ff` using a continuation-passing style: `__sort_quick_split:NnNn` expects a list followed by `\q_mark {<code>}`, and expands to $\langle \text{code} \rangle \langle \text{sorted list} \rangle$. Sorting the two parts of the list around the pivot is done with

```
\__sort_quick_split:NnNn #2 ... \q_mark
{
  \__sort_quick_split:NnNn #1 ... \q_mark {<code>}
  {<pivot>}
}
```

Items which are larger than the $\langle \text{pivot} \rangle$ are sorted, then placed after code that sorts the smaller items, and after the (braced) $\langle \text{pivot} \rangle$.

The fourth speed up is avoid the recursive call to `\tl_sort:nN` with an empty first argument. For this, we introduce functions similar to the `__sort_i:nnnnNn` of the last example, but aware of whether the list of $\langle \text{conditional} \rangle \{ \langle \text{item} \rangle \}$ read so far that are less than the pivot, and the list of those greater or equal, are empty or not: see `__sort_quick_split:NnNn` and functions defined below. Knowing whether the lists are empty or not is useless if we do not use distinct ending codes as appropriate. The splitting auxiliaries communicate to the $\langle \text{end-loop} \rangle$ function (that is initially placed after the “prepared” list) by placing a specific ending function, ignored when looping, but useful at the end. In fact, the $\langle \text{end-loop} \rangle$ function does nothing but place the appropriate ending function in front of all its arguments. The ending functions take care of sorting non-empty sublists, placing the pivot in between, and the continuation before.

The final change in fact slows down the code a little, but is required to avoid memory issues: schematically, when \TeX encounters

```
\use:n { \use:n { \use:n { ... } ... } ... }
```

the argument of the first `\use:n` is not completely read by the second `\use:n`, hence must remain in memory; then the argument of the second `\use:n` is not completely read when grabbing the argument of the third `\use:n`, hence must remain in memory, and so

on. The memory consumption grows quadratically with the number of nested `\use:n`. In practice, this means that we must read everything until a trailing `\q_stop` once in a while, otherwise sorting lists of more than a few thousand items would exhaust a typical \TeX 's memory.

`\tl_sort:nN`

`__sort_quick_prepare:Nnnn`
`__sort_quick_prepare_end:NNNnw`
`__sort_quick_cleanup:w`

The code within the `\exp_not:f` sorts the list, leaving in most cases a leading `\exp_not:f`, which stops the expansion, letting the result be return within `\exp_not:n`. We filter out the case of a list with no item, which would otherwise cause problems. Then prepare the token list `#1` by inserting the conditional `#2` before each item. The `prepare` auxiliary receives the conditional as `#1`, the prepared token list so far as `#2`, the next prepared item as `#3`, and the item after that as `#4`. The loop ends when `#4` contains `\prg_break_point:`, then the `prepare_end` auxiliary finds the prepared token list as `#4`. The scene is then set up for `__sort_quick_split:NnNn`, which sorts the prepared list and perform the post action placed after `\q_mark`, namely removing the trailing `\s_stop` and `\q_stop` and leaving `\exp_stop_f:` to stop f-expansion.

```

22307 \cs_new:Npn \tl_sort:nN #1#2
22308 {
22309   \exp_not:f
22310   {
22311     \tl_if_blank:nF {#1}
22312     {
22313       \__sort_quick_prepare:Nnnn #2 { } { }
22314       #1
22315       { \prg_break_point: \__sort_quick_prepare_end:NNNnw }
22316       \q_stop
22317     }
22318   }
22319 }
22320 \cs_new:Npn \__sort_quick_prepare:Nnnn #1#2#3#4
22321 {
22322   \prg_break: #4 \prg_break_point:
22323   \__sort_quick_prepare:Nnnn #1 { #2 #3 } { #1 {#4} }
22324 }
22325 \cs_new:Npn \__sort_quick_prepare_end:NNNnw #1#2#3#4#5 \q_stop
22326 {
22327   \__sort_quick_split:NnNn #4 \__sort_quick_end:nnTFNn { }
22328   \q_mark { \__sort_quick_cleanup:w \exp_stop_f: }
22329   \s_stop \q_stop
22330 }
22331 \cs_new:Npn \__sort_quick_cleanup:w #1 \s_stop \q_stop {#1}

```

(End definition for `\tl_sort:nN` and others. This function is documented on page 46.)

`__sort_quick_split:NnNn`

`__sort_quick_only_i:NnnnnNn`
`__sort_quick_only_ii:NnnnnNn`
`__sort_quick_split_i:NnnnnNn`
`__sort_quick_split_ii:NnnnnNn`

The `only_i`, `only_ii`, `split_i` and `split_ii` auxiliaries receive a useless first argument, the new item `#2` (that they append to either one of the next two arguments), the list `#3` of items less than the pivot, bigger items `#4`, the pivot `#5`, a `\function` `#6`, and an item `#7`. The `\function` is the user's `\conditional` except at the end of the list where it is `__sort_quick_end:nnTFNn`. The comparison is applied to the `\pivot` and the `\item`, and calls the `only_i` or `split_i` auxiliaries if the `\item` is smaller, and the `only_ii` or `split_ii` auxiliaries otherwise. In both cases, the next auxiliary goes to work right away, with no intermediate expansion that would slow down operations. Note that the argument `#2` left for the next call has the form `\conditional { \item }`, so that the lists `#3` and `#4` keep the right form to be fed to the next sorting function. The `split` auxiliary

differs from these in that it is missing three of the arguments, which would be empty, and its first argument is always the user's *conditional* rather than an ending function.

```

22332 \cs_new:Npn \__sort_quick_split:NnNn #1#2#3#4
22333 {
22334   #3 {#2} {#4} \__sort_quick_only_ii:NnnnnNn
22335   \__sort_quick_only_i:NnnnnNn
22336   \__sort_quick_single_end:nnnwnw
22337   { #3 {#4} } { } { } {#2}
22338 }
22339 \cs_new:Npn \__sort_quick_only_i:NnnnnNn #1#2#3#4#5#6#7
22340 {
22341   #6 {#5} {#7} \__sort_quick_split_ii:NnnnnNn
22342   \__sort_quick_only_i:NnnnnNn
22343   \__sort_quick_only_i_end:nnnwnw
22344   { #6 {#7} } { #3 #2 } { } {#5}
22345 }
22346 \cs_new:Npn \__sort_quick_only_ii:NnnnnNn #1#2#3#4#5#6#7
22347 {
22348   #6 {#5} {#7} \__sort_quick_only_ii:NnnnnNn
22349   \__sort_quick_split_i:NnnnnNn
22350   \__sort_quick_only_ii_end:nnnwnw
22351   { #6 {#7} } { } { #4 #2 } {#5}
22352 }
22353 \cs_new:Npn \__sort_quick_split_i:NnnnnNn #1#2#3#4#5#6#7
22354 {
22355   #6 {#5} {#7} \__sort_quick_split_ii:NnnnnNn
22356   \__sort_quick_split_i:NnnnnNn
22357   \__sort_quick_split_end:nnnwnw
22358   { #6 {#7} } { #3 #2 } {#4} {#5}
22359 }
22360 \cs_new:Npn \__sort_quick_split_ii:NnnnnNn #1#2#3#4#5#6#7
22361 {
22362   #6 {#5} {#7} \__sort_quick_split_ii:NnnnnNn
22363   \__sort_quick_split_i:NnnnnNn
22364   \__sort_quick_split_end:nnnwnw
22365   { #6 {#7} } {#3} { #4 #2 } {#5}
22366 }

```

(End definition for `__sort_quick_split:NnNn` and others.)

<pre> __sort_quick_end:nnTFNn __sort_quick_single_end:nnnwnw __sort_quick_only_i_end:nnnwnw __sort_quick_only_ii_end:nnnwnw __sort_quick_split_end:nnnwnw </pre>	<p>The <code>__sort_quick_end:nnTFNn</code> appears instead of the user's conditional, and receives as its arguments the pivot #1, a fake item #2, a <code>true</code> and a <code>false</code> branches #3 and #4, followed by an ending function #5 (one of the four auxiliaries here) and another copy #6 of the fake item. All those are discarded except the function #5. This function receives lists #1 and #2 of items less than or greater than the pivot #3, then a continuation code #5 just after <code>\q_mark</code>. To avoid a memory problem described earlier, all of the ending functions read #6 until <code>\q_stop</code> and place #6 back into the input stream. When the lists #1 and #2 are empty, the <code>single</code> auxiliary simply places the continuation #5 before the pivot {#3}. When #2 is empty, #1 is sorted and placed before the pivot {#3}, taking care to feed the continuation #5 as a continuation for the function sorting #1. When #1 is empty, #2 is sorted, and the continuation argument is used to place the continuation #5 and the pivot {#3} before the sorted result. Finally, when both lists are</p>
---	---

non-empty, items larger than the pivot are sorted, then items less than the pivot, and the continuations are done in such a way to place the pivot in between.

```

22367 \cs_new:Npn \__sort_quick_end:nnTFNn #1#2#3#4#5#6 {#5}
22368 \cs_new:Npn \__sort_quick_single_end:nnnwnw #1#2#3#4 \q_mark #5#6 \q_stop
22369 { #5 {#3} #6 \q_stop }
22370 \cs_new:Npn \__sort_quick_only_i_end:nnnwnw #1#2#3#4 \q_mark #5#6 \q_stop
22371 {
22372   \__sort_quick_split:NnNn #1
22373   \__sort_quick_end:nnTFNn { } \q_mark {#5}
22374   {#3}
22375   #6 \q_stop
22376 }
22377 \cs_new:Npn \__sort_quick_only_ii_end:nnnwnw #1#2#3#4 \q_mark #5#6 \q_stop
22378 {
22379   \__sort_quick_split:NnNn #2
22380   \__sort_quick_end:nnTFNn { } \q_mark { #5 {#3} }
22381   #6 \q_stop
22382 }
22383 \cs_new:Npn \__sort_quick_split_end:nnnwnw #1#2#3#4 \q_mark #5#6 \q_stop
22384 {
22385   \__sort_quick_split:NnNn #2 \__sort_quick_end:nnTFNn { } \q_mark
22386   {
22387     \__sort_quick_split:NnNn #1
22388     \__sort_quick_end:nnTFNn { } \q_mark {#5}
22389     {#3}
22390   }
22391   #6 \q_stop
22392 }

```

(End definition for __sort_quick_end:nnTFNn and others.)

38.6 Messages

__sort_error: Bailing out of the sorting code is a bit tricky. It may not be safe to use a delimited argument, so instead we redefine many l3sort commands to be trivial, with __sort_level: jumping to the break point. This error recovery won't work in a group.

```

22393 \cs_new_protected:Npn \__sort_error:
22394 {
22395   \cs_set_eq:NN \__sort_merge_blocks_aux: \prg_do_nothing:
22396   \cs_set_eq:NN \__sort_merge_blocks: \prg_do_nothing:
22397   \cs_set_protected:Npn \__sort_level: { \group_end: \prg_break: }
22398 }

```

(End definition for __sort_error:.)

__sort_disable_toksdef: While sorting, \toksdef is locally disabled to prevent users from using \newtoks or similar commands in their comparison code: the \toks registers that would be assigned are in use by l3sort. In format mode, none of this is needed since there is no \toks allocator.

```

22399 (*package)
22400 \cs_new_protected:Npn \__sort_disable_toksdef:
22401 { \cs_set_eq:NN \toksdef \__sort_disabled_toksdef:n }
22402 \cs_new_protected:Npn \__sort_disabled_toksdef:n #1

```

```

22403 {
22404   \__kernel_msg_error:nxx { kernel } { toksdef }
22405   { \token_to_str:N #1 }
22406   \__sort_error:
22407   \tex_toksdef:D #1
22408 }
22409 \__kernel_msg_new:nnnn { kernel } { toksdef }
22410 { Allocation~of~\iow_char:N\ toks~registers~impossible~while~sorting. }
22411 {
22412   The~comparison~code~used~for~sorting~a~list~has~attempted~to~
22413   define~#1~as~a~new~\iow_char:N\ toks~register~using~
22414   \iow_char:N\ newtoks~
22415   or~a~similar~command.~The~list~will~not~be~sorted.
22416 }
22417 </package>

```

(End definition for __sort_disable_toksdef: and __sort_disabled_toksdef:n.)

__sort_too_long_error:NNw When there are too many items in a sequence, this is an error, and we clean up properly the mapping over items in the list: break using the type-specific breaking function #1.

```

22418 \cs_new_protected:Npn \__sort_too_long_error:NNw #1#2 \fi:
22419 {
22420   \fi:
22421   \__kernel_msg_error:nnxxx { kernel } { too-large }
22422   { \token_to_str:N #2 }
22423   { \int_eval:n { \l__sort_true_max_int - \l__sort_min_int } }
22424   { \int_eval:n { \l__sort_top_int - \l__sort_min_int } }
22425   #1 \__sort_error:
22426 }
22427 \__kernel_msg_new:nnnn { kernel } { too-large }
22428 { The~list~#1~is~too~long~to~be~sorted~by~TeX. }
22429 {
22430   TeX~has~#2~toks~registers~still~available:~
22431   this~only~allows~to~sort~with~up~to~#3~
22432   items.~The~list~will~not~be~sorted.
22433 }

```

(End definition for __sort_too_long_error:NNw.)

```

22434 \__kernel_msg_new:nnnn { kernel } { return-none }
22435 { The~comparison~code~did~not~return. }
22436 {
22437   When~sorting~a~list,~the~code~to~compare~items~#1~and~#2~
22438   did~not~call~
22439   \iow_char:N\ sort_return_same: ~nor~
22440   \iow_char:N\ sort_return_swapped: .~
22441   Exactly~one~of~these~should~be~called.
22442 }
22443 \__kernel_msg_new:nnnn { kernel } { return-two }
22444 { The~comparison~code~returned~multiple~times. }
22445 {
22446   When~sorting~a~list,~the~code~to~compare~items~#1~and~#2~called~
22447   \iow_char:N\ sort_return_same: ~or~
22448   \iow_char:N\ sort_return_swapped: ~multiple~times.~
22449   Exactly~one~of~these~should~be~called.
22450 }

```

39 l3tl-analysis implementation

39.1 Internal functions

`\s__tl` The format used to store token lists internally uses the scan mark `\s__tl` as a delimiter.

(End definition for `\s__tl`.)

39.2 Internal format

The task of the `l3tl-analysis` module is to convert token lists to an internal format which allows us to extract all the relevant information about individual tokens (category code, character code), as well as reconstruct the token list quickly. This internal format is used in `l3regex` where we need to support arbitrary tokens, and it is used in conversion functions in `l3str-convert`, where we wish to support clusters of characters instead of single tokens.

We thus need a way to encode any *<token>* (even begin-group and end-group character tokens) in a way amenable to manipulating tokens individually. The best we can do is to find *<tokens>* which both *o*-expand and *x*-expand to the given *<token>*. Collecting more information about the category code and character code is also useful for regular expressions, since most regexes are catcode-agnostic. The internal format thus takes the form of a succession of items of the form

<tokens> `\s__tl` *<catcode>* *<char code>* `\s__tl`

The *<tokens>* *o*- and *x*-expand to the original token in the token list or to the cluster of tokens corresponding to one Unicode character in the given encoding (for `l3str-convert`). The *<catcode>* is given as a single hexadecimal digit, 0 for control sequences. The *<char code>* is given as a decimal number, −1 for control sequences.

Using delimited arguments lets us build the *<tokens>* progressively when doing an encoding conversion in `l3str-convert`. On the other hand, the delimiter `\s__tl` may not appear unbraced in *<tokens>*. This is not a problem because we are careful to wrap control sequences in braces (as an argument to `\exp_not:n`) when converting from a general token list to the internal format.

The current rule for converting a *<token>* to a balanced set of *<tokens>* which both *o*-expands and *x*-expands to it is the following.

- A control sequence `\cs` becomes `\exp_not:n { \cs } \s__tl 0 −1 \s__tl`.
- A begin-group character `{` becomes `\exp_after:wN { \if_false: } \fi: \s__tl 1 <char code> \s__tl`.
- An end-group character `}` becomes `\if_false: { \fi: } \s__tl 2 <char code> \s__tl`.
- A character with any other category code becomes `\exp_not:n {<character>} \s__tl <hex catcode> <char code> \s__tl`.

39.3 Variables and helper functions

`\s__tl` The scan mark `\s__tl` is used as a delimiter in the internal format. This is more practical than using a quark, because we would then need to control expansion much more carefully: compare `\int_value:w ‘#1 \s__tl` with `\int_value:w ‘#1 \exp_stop_f: \exp_not:N \q_mark` to extract a character code followed by the delimiter in an x-expansion.

```
22454 \scan_new:N \s__tl
```

(End definition for \s__tl.)

`\l__tl_analysis_token` The tokens in the token list are probed with the `\futurelet` primitive. We use `\l__tl_analysis_token` in that construction. In some cases, we convert the following token to a string before probing it: then the token variable used is `\l__tl_analysis_char_token`.

```
22455 \cs_new_eq:NN \l__tl_analysis_token ?
```

```
22456 \cs_new_eq:NN \l__tl_analysis_char_token ?
```

(End definition for \l__tl_analysis_token and \l__tl_analysis_char_token.)

`\l__tl_analysis_normal_int` The number of normal (N-type argument) tokens since the last special token.

```
22457 \int_new:N \l__tl_analysis_normal_int
```

(End definition for \l__tl_analysis_normal_int.)

`\l__tl_analysis_index_int` During the first pass, this is the index in the array being built. During the second pass, it is equal to the maximum index in the array from the first pass.

```
22458 \int_new:N \l__tl_analysis_index_int
```

(End definition for \l__tl_analysis_index_int.)

`\l__tl_analysis_nesting_int` Nesting depth of explicit begin-group and end-group characters during the first pass. This lets us detect the end of the token list without a reserved end-marker.

```
22459 \int_new:N \l__tl_analysis_nesting_int
```

(End definition for \l__tl_analysis_nesting_int.)

`\l__tl_analysis_type_int` When encountering special characters, we record their “type” in this integer.

```
22460 \int_new:N \l__tl_analysis_type_int
```

(End definition for \l__tl_analysis_type_int.)

`\g__tl_analysis_result_tl` The result of the conversion is stored in this token list, with a succession of items of the form

```
⟨tokens⟩ \s__tl ⟨catcode⟩ ⟨char code⟩ \s__tl
```

```
22461 \tl_new:N \g__tl_analysis_result_tl
```

(End definition for \g__tl_analysis_result_tl.)

`_tl_analysis_extract_charcode:` Extracting the character code from the meaning of `\l_tl_analysis_token`. This has no error checking, and should only be assumed to work for begin-group and end-group character tokens. It produces a number in the form ‘*⟨char⟩*’.

```

22462 \cs_new:Npn \_tl_analysis_extract_charcode:
22463 {
22464   \exp_after:wN \_tl_analysis_extract_charcode_aux:w
22465   \token_to_meaning:N \l\_tl_analysis_token
22466 }
22467 \cs_new:Npn \_tl_analysis_extract_charcode_aux:w #1 ~ #2 ~ { ‘ ’ }

```

(End definition for `_tl_analysis_extract_charcode:` and `_tl_analysis_extract_charcode_aux:w`.)

`_tl_analysis_cs_space_count:NN` Counts the number of spaces in the string representation of its second argument, as well as the number of characters following the last space in that representation, and feeds the two numbers as semicolon-delimited arguments to the first argument. When this function is used, the escape character is printable and non-space.

```

22468 \cs_new:Npn \_tl_analysis_cs_space_count:NN #1 #2
22469 {
22470   \exp_after:wN #1
22471   \int_value:w \int_eval:w 0
22472   \exp_after:wN \_tl_analysis_cs_space_count:w
22473   \token_to_str:N #2
22474   \fi: \_tl_analysis_cs_space_count_end:w ; ~ !
22475 }
22476 \cs_new:Npn \_tl_analysis_cs_space_count:w #1 ~
22477 {
22478   \if_false: #1 #1 \fi:
22479   + 1
22480   \_tl_analysis_cs_space_count:w
22481 }
22482 \cs_new:Npn \_tl_analysis_cs_space_count_end:w ; #1 \fi: #2 !
22483 { \exp_after:wN ; \int_value:w \str_count_ignore_spaces:n {#1} ; }

```

(End definition for `_tl_analysis_cs_space_count:NN`, `_tl_analysis_cs_space_count:w`, and `_tl_analysis_cs_space_count_end:w`.)

39.4 Plan of attack

Our goal is to produce a token list of the form roughly

$$\begin{aligned}
 &\langle token\ 1 \rangle \backslash s@_ \langle catcode\ 1 \rangle \langle char\ code\ 1 \rangle \backslash s@_ \\
 &\langle token\ 2 \rangle \backslash s_tl \langle catcode\ 2 \rangle \langle char\ code\ 2 \rangle \backslash s_tl \\
 &\dots \langle token\ N \rangle \backslash s_tl \langle catcode\ N \rangle \langle char\ code\ N \rangle \backslash s_tl
 \end{aligned}$$

Most but not all tokens can be grabbed as an undelimited (N-type) argument by \TeX . The plan is to have a two pass system. In the first pass, locate special tokens, and store them in various `\toks` registers. In the second pass, which is done within an x-expanding assignment, normal tokens are taken in as N-type arguments, and special tokens are retrieved from the `\toks` registers, and removed from the input stream by some means. The whole process takes linear time, because we avoid building the result one item at a time.

We make the escape character printable (backslash, but this later oscillates between slash and backslash): this allows us to distinguish characters from control sequences.

A token has two characteristics: its `\meaning`, and what it looks like for `TEX` when it is in scanning mode (*e.g.*, when capturing parameters for a macro). For our purposes, we distinguish the following meanings:

- begin-group token (category code 1), either space (character code 32), or non-space;
- end-group token (category code 2), either space (character code 32), or non-space;
- space token (category code 10, character code 32);
- anything else (then the token is always an N-type argument).

The token itself can “look like” one of the following

- a non-active character, in which case its meaning is automatically that associated to its character code and category code, we call it “true” character;
- an active character;
- a control sequence.

The only tokens which are not valid N-type arguments are true begin-group characters, true end-group characters, and true spaces. We detect those characters by scanning ahead with `\futurelet`, then distinguishing true characters from control sequences set equal to them using the `\string` representation.

The second pass is a simple exercise in expandable loops.

`__tl_analysis:n` Everything is done within a group, and all definitions are local. We use `\group_align_safe_begin/end:` to avoid problems in case `__tl_analysis:n` is used within an alignment and its argument contains alignment tab tokens.

```

22484 \cs_new_protected:Npn \__tl_analysis:n #1
22485 {
22486   \group_begin:
22487   \group_align_safe_begin:
22488     \__tl_analysis_a:n {#1}
22489     \__tl_analysis_b:n {#1}
22490   \group_align_safe_end:
22491   \group_end:
22492 }
```

(End definition for `__tl_analysis:n`.)

39.5 Disabling active characters

`__tl_analysis_disable:n` Active characters can cause problems later on in the processing, so we provide a way to disable them, by setting them to `undefined`. Since Unicode contains too many characters to loop over all of them, we instead do this whenever we encounter a character. For `pTEX` and `upTEX` we skip characters beyond [0, 255] because `\lccode` only allows those values.

```

22493 \group_begin:
22494   \char_set_catcode_active:N \^^@
22495   \cs_new_protected:Npn \__tl_analysis_disable:n #1
22496   {
22497     \tex_lccode:D 0 = #1 \exp_stop_f:
22498     \tex_lowercase:D { \tex_let:D \^^@ } \tex_undefined:D
22499   }
```

```

22500 \bool_lazy_or:nnT
22501 { \sys_if_engine_ptex_p: }
22502 { \sys_if_engine_uptex_p: }
22503 {
22504   \cs_gset_protected:Npn \_tl_analysis_disable:n #1
22505   {
22506     \if_int_compare:w 256 > #1 \exp_stop_f:
22507     \tex_lccode:D 0 = #1 \exp_stop_f:
22508     \tex_lowercase:D { \tex_let:D ^~@ } \tex_undefined:D
22509     \fi:
22510   }
22511 }
22512 \group_end:

```

(End definition for `_tl_analysis_disable:n`.)

39.6 First pass

The goal of this pass is to detect special (non-N-type) tokens, and count how many N-type tokens lie between special tokens. Also, we wish to store some representation of each special token in a `\toks` register.

We have 11 types of tokens:

1. a true non-space begin-group character;
2. a true space begin-group character;
3. a true non-space end-group character;
4. a true space end-group character;
5. a true space blank space character;
6. an active character;
7. any other true character;
8. a control sequence equal to a begin-group token (category code 1);
9. a control sequence equal to an end-group token (category code 2);
10. a control sequence equal to a space token (character code 32, category code 10);
11. any other control sequence.

Our first tool is `\futurelet`. This cannot distinguish case 8 from 1 or 2, nor case 9 from 3 or 4, nor case 10 from case 5. Those cases are later distinguished by applying the `\string` primitive to the following token, after possibly changing the escape character to ensure that a control sequence's string representation cannot be mistaken for the true character.

In cases 6, 7, and 11, the following token is a valid N-type argument, so we grab it and distinguish the case of a character from a control sequence: in the latter case, `\str_tail:n {\token}` is non-empty, because the escape character is printable.

`__tl_analysis_a:n` We read tokens one by one using `\futurelet`. While performing the loop, we keep track of the number of true begin-group characters minus the number of true end-group characters in `\l__tl_analysis_nesting_int`. This reaches -1 when we read the closing brace.

```

22513 \cs_new_protected:Npn \__tl_analysis_a:n #1
22514 {
22515     \__tl_analysis_disable:n { 32 }
22516     \int_set:Nn \tex_escapechar:D { 92 }
22517     \int_zero:N \l__tl_analysis_normal_int
22518     \int_zero:N \l__tl_analysis_index_int
22519     \int_zero:N \l__tl_analysis_nesting_int
22520     \if_false: { \fi: \__tl_analysis_a_loop:w #1 }
22521     \int_decr:N \l__tl_analysis_index_int
22522 }

```

(End definition for `__tl_analysis_a:n`.)

`__tl_analysis_a_loop:w` Read one character and check its type.

```

22523 \cs_new_protected:Npn \__tl_analysis_a_loop:w
22524 { \tex_futurelet:D \l__tl_analysis_token \__tl_analysis_a_type:w }

```

(End definition for `__tl_analysis_a_loop:w`.)

`__tl_analysis_a_type:w` At this point, `\l__tl_analysis_token` holds the meaning of the following token. We store in `\l__tl_analysis_type_int` information about the meaning of the token ahead:

- 0 space token;
- 1 begin-group token;
- -1 end-group token;
- 2 other.

The values 0, 1, -1 correspond to how much a true such character changes the nesting level (2 is used only here, and is irrelevant later). Then call the auxiliary for each case. Note that nesting conditionals here is safe because we only skip over `\l__tl_analysis_token` if it matches with one of the character tokens (hence is not a primitive conditional).

```

22525 \cs_new_protected:Npn \__tl_analysis_a_type:w
22526 {
22527     \l__tl_analysis_type_int =
22528     \if_meaning:w \l__tl_analysis_token \c_space_token
22529     0
22530     \else:
22531     \if_catcode:w \exp_not:N \l__tl_analysis_token \c_group_begin_token
22532     1
22533     \else:
22534     \if_catcode:w \exp_not:N \l__tl_analysis_token \c_group_end_token
22535     - 1
22536     \else:
22537     2
22538     \fi:
22539     \fi:
22540     \fi:
22541     \exp_stop_f:

```



```

22542 \if_case:w \l__tl_analysis_type_int
22543 \exp_after:wN \__tl_analysis_a_space:w
22544 \or: \exp_after:wN \__tl_analysis_a_bgroup:w
22545 \or: \exp_after:wN \__tl_analysis_a_safe:N
22546 \else: \exp_after:wN \__tl_analysis_a_egroup:w
22547 \fi:
22548 }

```

(End definition for __tl_analysis_a_type:w.)

```

\__tl_analysis_a_space:w
\__tl_analysis_a_space_test:w

```

In this branch, the following token's meaning is a blank space. Apply `\string` to that token: a true blank space gives a space, a control sequence gives a result starting with the escape character, an active character gives something else than a space since we disabled the space. We grab as `\l__tl_analysis_char_token` the first character of the string representation then test it in `__tl_analysis_a_space_test:w`. Also, since `__tl_analysis_a_store:` expects the special token to be stored in the relevant `\toks` register, we do that. The extra `\exp_not:n` is unnecessary of course, but it makes the treatment of all tokens more homogeneous. If we discover that the next token was actually a control sequence or an active character instead of a true space, then we step the counter of normal tokens. We now have in front of us the whole string representation of the control sequence, including potential spaces; those will appear to be true spaces later in this pass. Hence, all other branches of the code in this first pass need to consider the string representation, so that the second pass does not need to test the meaning of tokens, only strings.

```

22549 \cs_new_protected:Npn \__tl_analysis_a_space:w
22550 {
22551 \tex_afterassignment:D \__tl_analysis_a_space_test:w
22552 \exp_after:wN \cs_set_eq:NN
22553 \exp_after:wN \l__tl_analysis_char_token
22554 \token_to_str:N
22555 }
22556 \cs_new_protected:Npn \__tl_analysis_a_space_test:w
22557 {
22558 \if_meaning:w \l__tl_analysis_char_token \c_space_token
22559 \tex_toks:D \l__tl_analysis_index_int { \exp_not:n { ~ } }
22560 \__tl_analysis_a_store:
22561 \else:
22562 \int_incr:N \l__tl_analysis_normal_int
22563 \fi:
22564 \__tl_analysis_a_loop:w
22565 }

```

(End definition for __tl_analysis_a_space:w and __tl_analysis_a_space_test:w.)

```

\__tl_analysis_a_bgroup:w
\__tl_analysis_a_egroup:w
\__tl_analysis_a_group:nw
\__tl_analysis_a_group_aux:w
\__tl_analysis_group_auxii:w
\__tl_analysis_group_test:w

```

The token is most likely a true character token with catcode 1 or 2, but it might be a control sequence, or an active character. Optimizing for the first case, we store in a `\toks` register some code that expands to that token. Since we will turn what follows into a string, we make sure the escape character is different from the current character code (by switching between solidus and backslash). To detect the special case of an active character let to the catcode 1 or 2 character with the same character code, we disable the active character with that character code and re-test: if the following token has become undefined we can in fact safely grab it. We are finally ready to turn what follows to a

string and test it. This is one place where we need `\l__tl_analysis_char_token` to be a separate control sequence from `\l__tl_analysis_token`, to compare them.

```

22566 \group_begin:
22567   \char_set_catcode_group_begin:N \^^@ % {
22568   \cs_new_protected:Npn \__tl_analysis_a_bgroup:w
22569     { \__tl_analysis_a_group:nw { \exp_after:wN \^^@ \if_false: } \fi: } }
22570   \char_set_catcode_group_end:N \^^@
22571   \cs_new_protected:Npn \__tl_analysis_a_egroup:w
22572     { \__tl_analysis_a_group:nw { \if_false: { \fi: \^^@ } } % }
22573 \group_end:
22574 \cs_new_protected:Npn \__tl_analysis_a_group:nw #1
22575 {
22576   \tex_lccode:D 0 = \__tl_analysis_extract_charcode: \scan_stop:
22577   \tex_lowercase:D { \tex_toks:D \l__tl_analysis_index_int {#1} }
22578   \if_int_compare:w \tex_lccode:D 0 = \tex_escapechar:D
22579     \int_set:Nn \tex_escapechar:D { 139 - \tex_escapechar:D }
22580   \fi:
22581   \__tl_analysis_disable:n { \tex_lccode:D 0 }
22582   \tex_futurelet:D \l__tl_analysis_token \__tl_analysis_a_group_aux:w
22583 }
22584 \cs_new_protected:Npn \__tl_analysis_a_group_aux:w
22585 {
22586   \if_meaning:w \l__tl_analysis_token \tex_undefined:D
22587     \exp_after:wN \__tl_analysis_a_safe:N
22588   \else:
22589     \exp_after:wN \__tl_analysis_a_group_auxii:w
22590   \fi:
22591 }
22592 \cs_new_protected:Npn \__tl_analysis_a_group_auxii:w
22593 {
22594   \tex_afterassignment:D \__tl_analysis_a_group_test:w
22595   \exp_after:wN \cs_set_eq:NN
22596   \exp_after:wN \l__tl_analysis_char_token
22597   \token_to_str:N
22598 }
22599 \cs_new_protected:Npn \__tl_analysis_a_group_test:w
22600 {
22601   \if_charcode:w \l__tl_analysis_token \l__tl_analysis_char_token
22602     \__tl_analysis_a_store:
22603   \else:
22604     \int_incr:N \l__tl_analysis_normal_int
22605   \fi:
22606   \__tl_analysis_a_loop:w
22607 }

```

(End definition for `__tl_analysis_a_bgroup:w` and others.)

`__tl_analysis_a_store:` This function is called each time we meet a special token; at this point, the `\toks` register `\l__tl_analysis_index_int` holds a token list which expands to the given special token. Also, the value of `\l__tl_analysis_type_int` indicates which case we are in:

- -1 end-group character;
- 0 space character;

- 1 begin-group character.

We need to distinguish further the case of a space character (code 32) from other character codes, because those behave differently in the second pass. Namely, after testing the `\lccode` of 0 (which holds the present character code) we change the cases above to

- -2 space end-group character;
- -1 non-space end-group character;
- 0 space blank space character;
- 1 non-space begin-group character;
- 2 space begin-group character.

This has the property that non-space characters correspond to odd values of `\l__tl_analysis_type_int`. The number of normal tokens until here and the type of special token are packed into a `\skip` register. Finally, we check whether we reached the last closing brace, in which case we stop by disabling the looping function (locally).

```

22608 \cs_new_protected:Npn \__tl_analysis_a_store:
22609 {
22610   \tex_advance:D \l__tl_analysis_nesting_int \l__tl_analysis_type_int
22611   \if_int_compare:w \tex_lccode:D 0 = '\ \exp_stop_f:
22612     \tex_advance:D \l__tl_analysis_type_int \l__tl_analysis_type_int
22613   \fi:
22614   \tex_skip:D \l__tl_analysis_index_int
22615     = \l__tl_analysis_normal_int sp
22616     plus \l__tl_analysis_type_int sp \scan_stop:
22617   \int_incr:N \l__tl_analysis_index_int
22618   \int_zero:N \l__tl_analysis_normal_int
22619   \if_int_compare:w \l__tl_analysis_nesting_int = -1 \exp_stop_f:
22620     \cs_set_eq:NN \__tl_analysis_a_loop:w \scan_stop:
22621   \fi:
22622 }
```

(End definition for __tl_analysis_a_store:.)

```

\__tl_analysis_a_safe:N
\__tl_analysis_a_cs:ww
```

This should be the simplest case: since the upcoming token is safe, we can simply grab it in a second pass. If the token is a single character (including space), the `\if_charcode:w` test yields true; we disable a potentially active character (that could otherwise masquerade as the true character in the next pass) and we count one “normal” token. On the other hand, if the token is a control sequence, we should replace it by its string representation for compatibility with other code branches. Instead of slowly looping through the characters with the main code, we use the knowledge of how the second pass works: if the control sequence name contains no space, count that token as a number of normal tokens equal to its string length. If the control sequence contains spaces, they should be registered as special characters by increasing `\l__tl_analysis_index_int` (no need to carefully count character between each space), and all characters after the last space should be counted in the following sequence of “normal” tokens.

```

22623 \cs_new_protected:Npn \__tl_analysis_a_safe:N #1
22624 {
22625   \if_charcode:w
22626     \scan_stop:
```

```

22627         \exp_after:wN \use_none:n \token_to_str:N #1 \prg_do_nothing:
22628         \scan_stop:
22629         \exp_after:wN \use_i:nn
22630     \else:
22631         \exp_after:wN \use_ii:nn
22632     \fi:
22633     {
22634         \__tl_analysis_disable:n { '#1 }
22635         \int_incr:N \l__tl_analysis_normal_int
22636     }
22637     { \__tl_analysis_cs_space_count:NN \__tl_analysis_a_cs:ww #1 }
22638     \__tl_analysis_a_loop:w
22639 }
22640 \cs_new_protected:Npn \__tl_analysis_a_cs:ww #1; #2;
22641 {
22642     \if_int_compare:w #1 > 0 \exp_stop_f:
22643         \tex_skip:D \l__tl_analysis_index_int
22644         = \int_eval:n { \l__tl_analysis_normal_int + 1 } sp \exp_stop_f:
22645         \tex_advance:D \l__tl_analysis_index_int #1 \exp_stop_f:
22646     \else:
22647         \tex_advance:D
22648     \fi:
22649     \l__tl_analysis_normal_int #2 \exp_stop_f:
22650 }

```

(End definition for `__tl_analysis_a_safe:N` and `__tl_analysis_a_cs:ww`.)

39.7 Second pass

The second pass is an exercise in expandable loops. All the necessary information is stored in `\skip` and `\toks` registers.

`__tl_analysis_b:n` Start the loop with the index 0. No need for an end-marker: the loop stops by itself when the last index is read. We repeatedly oscillate between reading long stretches of normal tokens, and reading special tokens.

```

22651 \cs_new_protected:Npn \__tl_analysis_b:n #1
22652 {
22653     \tl_gset:Nx \g__tl_analysis_result_tl
22654     {
22655         \__tl_analysis_b_loop:w 0; #1
22656         \prg_break_point:
22657     }
22658 }
22659 \cs_new:Npn \__tl_analysis_b_loop:w #1;
22660 {
22661     \exp_after:wN \__tl_analysis_b_normals:ww
22662     \int_value:w \tex_skip:D #1 ; #1 ;
22663 }

```

(End definition for `__tl_analysis_b:n` and `__tl_analysis_b_loop:w`.)

`__tl_analysis_b_normals:ww` The first argument is the number of normal tokens which remain to be read, and the second argument is the index in the array produced in the first step. A character's string representation is always one character long, while a control sequence is always longer (we

have set the escape character to a printable value). In both cases, we leave `\exp_not:n` $\langle token \rangle$ `\s__tl` in the input stream (after x-expansion). Here, `\exp_not:n` is used rather than `\exp_not:N` because `#3` could be a macro parameter character or could be `\s__tl` (which must be hidden behind braces in the result).

```

22664 \cs_new:Npn \__tl_analysis_b_normals:ww #1;
22665 {
22666   \if_int_compare:w #1 = 0 \exp_stop_f:
22667     \__tl_analysis_b_special:w
22668   \fi:
22669   \__tl_analysis_b_normal:wwN #1;
22670 }
22671 \cs_new:Npn \__tl_analysis_b_normal:wwN #1; #2; #3
22672 {
22673   \exp_not:n { \exp_not:n { #3 } } \s__tl
22674   \if_charcode:w
22675     \scan_stop:
22676     \exp_after:wN \use_none:n \token_to_str:N #3 \prg_do_nothing:
22677     \scan_stop:
22678     \exp_after:wN \__tl_analysis_b_char:Nww
22679   \else:
22680     \exp_after:wN \__tl_analysis_b_cs:Nww
22681   \fi:
22682   #3 #1; #2;
22683 }

```

(End definition for `__tl_analysis_b_normals:ww` and `__tl_analysis_b_normal:wwN`.)

`__tl_analysis_b_char:Nww` If the normal token we grab is a character, leave $\langle catcode \rangle$ $\langle charcode \rangle$ followed by `\s__tl` in the input stream, and call `__tl_analysis_b_normals:ww` with its first argument decremented.

```

22684 \cs_new:Npx \__tl_analysis_b_char:Nww #1
22685 {
22686   \exp_not:N \if_meaning:w #1 \exp_not:N \tex_undefined:D
22687   \token_to_str:N D \exp_not:N \else:
22688   \exp_not:N \if_catcode:w #1 \c_catcode_other_token
22689   \token_to_str:N C \exp_not:N \else:
22690   \exp_not:N \if_catcode:w #1 \c_catcode_letter_token
22691   \token_to_str:N B \exp_not:N \else:
22692   \exp_not:N \if_catcode:w #1 \c_math_toggle_token      3
22693   \exp_not:N \else:
22694   \exp_not:N \if_catcode:w #1 \c_alignment_token      4
22695   \exp_not:N \else:
22696   \exp_not:N \if_catcode:w #1 \c_math_superscript_token 7
22697   \exp_not:N \else:
22698   \exp_not:N \if_catcode:w #1 \c_math_subscript_token  8
22699   \exp_not:N \else:
22700   \exp_not:N \if_catcode:w #1 \c_space_token
22701   \token_to_str:N A \exp_not:N \else:
22702   6
22703   \exp_not:n { \fi: \fi: \fi: \fi: \fi: \fi: \fi: \fi: }
22704   \exp_not:N \int_value:w '#1 \s__tl
22705   \exp_not:N \exp_after:wN \exp_not:N \__tl_analysis_b_normals:ww
22706   \exp_not:N \int_value:w \exp_not:N \int_eval:w - 1 +
22707 }

```

(End definition for _tl_analysis_b_char:Nww.)

_tl_analysis_b_cs:Nww If the token we grab is a control sequence, leave 0 -1 (as category code and character
_tl_analysis_b_cs_test:ww code) in the input stream, followed by \s_tl, and call _tl_analysis_b_normals:ww
with updated arguments.

```

22708 \cs_new:Npn \_tl\_analysis\_b\_cs:Nww #1
22709 {
22710   0 -1 \s\_tl
22711   \_tl\_analysis\_cs\_space\_count:NN \_tl\_analysis\_b\_cs\_test:ww #1
22712 }
22713 \cs_new:Npn \_tl\_analysis\_b\_cs\_test:ww #1 ; #2 ; #3 ; #4 ;
22714 {
22715   \exp_after:wN \_tl\_analysis\_b\_normals:ww
22716   \int_value:w \int_eval:w
22717   \if_int_compare:w #1 = 0 \exp_stop_f:
22718     #3
22719   \else:
22720     \tex_skip:D \int_eval:n { #4 + #1 } \exp_stop_f:
22721   \fi:
22722   - #2
22723   \exp_after:wN ;
22724   \int_value:w \int_eval:n { #4 + #1 } ;
22725 }

```

(End definition for _tl_analysis_b_cs:Nww and _tl_analysis_b_cs_test:ww.)

_tl_analysis_b_special:w Here, #1 is the current index in the array built in the first pass. Check now whether we
_tl_analysis_b_special_char:wN reached the end (we shouldn't keep the trailing end-group character that marked the end
_tl_analysis_b_special_space:w of the token list in the first pass). Unpack the \toks register: when x-expanding again,
we will get the special token. Then leave the category code in the input stream, followed
by the character code, and call _tl_analysis_b_loop:w with the next index.

```

22726 \group_begin:
22727   \char_set_catcode_other:N A
22728   \cs_new:Npn \_tl\_analysis\_b\_special:w
22729     \fi: \_tl\_analysis\_b\_normal:wwN 0 ; #1 ;
22730   {
22731     \fi:
22732     \if_int_compare:w #1 = \l\_tl\_analysis\_index\_int
22733       \exp_after:wN \prg_break:
22734     \fi:
22735     \tex_the:D \tex_toks:D #1 \s\_tl
22736     \if_case:w \tex_gluestretch:D \tex_skip:D #1 \exp_stop_f:
22737       \token_to_str:N A
22738     \or: 1
22739     \or: 1
22740     \else: 2
22741     \fi:
22742     \if_int_odd:w \tex_gluestretch:D \tex_skip:D #1 \exp_stop_f:
22743       \exp_after:wN \_tl\_analysis\_b\_special\_char:wN \int_value:w
22744     \else:
22745       \exp_after:wN \_tl\_analysis\_b\_special\_space:w \int_value:w
22746     \fi:
22747     \int_eval:n { 1 + #1 } \exp_after:wN ;
22748     \token_to_str:N

```

```

22749     }
22750 \group_end:
22751 \cs_new:Npn \__tl_analysis_b_special_char:wN #1 ; #2
22752 {
22753     \int_value:w '#2 \s_tl
22754     \__tl_analysis_b_loop:w #1 ;
22755 }
22756 \cs_new:Npn \__tl_analysis_b_special_space:w #1 ; ~
22757 {
22758     32 \s_tl
22759     \__tl_analysis_b_loop:w #1 ;
22760 }

```

(End definition for __tl_analysis_b_special:w, __tl_analysis_b_special_char:wN, and __tl_analysis_b_special_space:w.)

39.8 Mapping through the analysis

```

\tl_analysis_map_inline:nn
\tl_analysis_map_inline:Nn
  \__tl_analysis_map_inline_aux:Nn
  \__tl_analysis_map_inline_aux:nnn

```

First obtain the analysis of the token list into \g__tl_analysis_result_tl. To allow nested mappings, increase the nesting depth \g__kernel_prg_map_int (shared between all modules), then define the looping macro, which has a name specific to that nesting depth. That looping grabs the $\langle tokens \rangle$, $\langle catcode \rangle$ and $\langle char code \rangle$; it checks for the end of the loop with \use_none:n ##2, normally empty, but which becomes \tl_map_break: at the end; it then performs the user's code #2, and loops by calling itself. When the loop ends, remember to decrease the nesting depth.

```

22761 \cs_new_protected:Npn \tl_analysis_map_inline:nn #1
22762 {
22763     \__tl_analysis:n {#1}
22764     \int_gincr:N \g__kernel_prg_map_int
22765     \exp_args:Nc \__tl_analysis_map_inline_aux:Nn
22766     { \__tl_analysis_map_inline_ \int_use:N \g__kernel_prg_map_int :wNw }
22767 }
22768 \cs_new_protected:Npn \tl_analysis_map_inline:Nn #1
22769 { \exp_args:No \tl_analysis_map_inline:nn #1 }
22770 \cs_new_protected:Npn \__tl_analysis_map_inline_aux:Nn #1#2
22771 {
22772     \cs_gset_protected:Npn #1 ##1 \s_tl ##2 ##3 \s_tl
22773     {
22774         \use_none:n ##2
22775         \__tl_analysis_map_inline_aux:nnn {##1} {##3} {##2}
22776     }
22777     \cs_gset_protected:Npn \__tl_analysis_map_inline_aux:nnn ##1##2##3
22778     {
22779         #2
22780         #1
22781     }
22782     \exp_after:wN #1
22783     \g__tl_analysis_result_tl
22784     \s_tl { ? \tl_map_break: } \s_tl
22785     \prg_break_point:Nn \tl_map_break:
22786     { \int_gdecr:N \g__kernel_prg_map_int }
22787 }

```

(End definition for \tl_analysis_map_inline:nn and others. These functions are documented on page 214.)

39.9 Showing the results

`\tl_analysis_show:N` Add to `__tl_analysis:n` a third pass to display tokens to the terminal. If the token list variable is not defined, throw the same error as `\tl_show:N` by simply calling that function.

```

22788 \cs_new_protected:Npn \tl_analysis_show:N #1
22789 {
22790   \tl_if_exist:NTF #1
22791   {
22792     \exp_args:No \__tl_analysis:n {#1}
22793     \msg_show:nnxxxx { LaTeX / kernel } { show-tl-analysis }
22794     { \token_to_str:N #1 } { \__tl_analysis_show: } { } { }
22795   }
22796   { \tl_show:N #1 }
22797 }
22798 \cs_new_protected:Npn \tl_analysis_show:n #1
22799 {
22800   \__tl_analysis:n {#1}
22801   \msg_show:nnxxxx { LaTeX / kernel } { show-tl-analysis }
22802   { } { \__tl_analysis_show: } { } { }
22803 }

```

(End definition for `\tl_analysis_show:N` and `\tl_analysis_show:n`. These functions are documented on page 214.)

`__tl_analysis_show:` Here, `#1` o- and x-expands to the token; `#2` is the category code (one uppercase hexadecimal digit), 0 for control sequences; `#3` is the character code, which we ignore. In the cases of control sequences and active characters, the meaning may overflow one line, and we want to truncate it. Those cases are thus separated out.

```

22804 \cs_new:Npn \__tl_analysis_show:
22805 {
22806   \exp_after:wN \__tl_analysis_show_loop:wNw \g__tl_analysis_result_tl
22807   \s__tl { ? \prg_break: } \s__tl
22808   \prg_break_point:
22809 }
22810 \cs_new:Npn \__tl_analysis_show_loop:wNw #1 \s__tl #2 #3 \s__tl
22811 {
22812   \use_none:n #2
22813   \iow_newline: > \use:nn { ~ } { ~ }
22814   \if_int_compare:w "#2 = 0 \exp_stop_f:
22815     \exp_after:wN \__tl_analysis_show_cs:n
22816   \else:
22817     \if_int_compare:w "#2 = 13 \exp_stop_f:
22818     \exp_after:wN \exp_after:wN
22819     \exp_after:wN \__tl_analysis_show_active:n
22820   \else:
22821     \exp_after:wN \exp_after:wN
22822     \exp_after:wN \__tl_analysis_show_normal:n
22823   \fi:
22824   \fi:
22825   {#1}
22826   \__tl_analysis_show_loop:wNw
22827 }

```

(End definition for `__tl_analysis_show:` and `__tl_analysis_show_loop:wNw`.)

`_tl_analysis_show_normal:n` Non-active characters are a simple matter of printing the character, and its meaning. Our test suite checks that begin-group and end-group characters do not mess up \TeX 's alignment status.

```

22828 \cs_new:Npn \_tl_analysis_show_normal:n #1
22829 {
22830     \exp_after:wN \token_to_str:N #1 ~
22831     ( \exp_after:wN \token_to_meaning:N #1 )
22832 }

```

(End definition for _tl_analysis_show_normal:n.)

`_tl_analysis_show_value:N` This expands to the value of #1 if it has any.

```

22833 \cs_new:Npn \_tl_analysis_show_value:N #1
22834 {
22835     \token_if_expandable:NF #1
22836     {
22837         \token_if_chardef:NTF      #1 \prg_break: { }
22838         \token_if_mathchardef:NTF  #1 \prg_break: { }
22839         \token_if_dim_register:NTF  #1 \prg_break: { }
22840         \token_if_int_register:NTF  #1 \prg_break: { }
22841         \token_if_skip_register:NTF #1 \prg_break: { }
22842         \token_if_toks_register:NTF #1 \prg_break: { }
22843         \use_none:nnn
22844         \prg_break_point:
22845         \use:n { \exp_after:wN = \tex_the:D #1 }
22846     }
22847 }

```

(End definition for _tl_analysis_show_value:N.)

`_tl_analysis_show_cs:n` Control sequences and active characters are printed in the same way, making sure not to go beyond the `\l_iow_line_count_int`. In case of an overflow, we replace the last characters by `\c_tl_analysis_show_etc_str`.

```

\_tl_analysis_show_active:n
\_tl_analysis_show_long:nn
\_tl_analysis_show_long_aux:nnnn
22848 \cs_new:Npn \_tl_analysis_show_cs:n #1
22849 { \exp_args:No \_tl_analysis_show_long:nn {#1} { control-sequence= } }
22850 \cs_new:Npn \_tl_analysis_show_active:n #1
22851 { \exp_args:No \_tl_analysis_show_long:nn {#1} { active-character= } }
22852 \cs_new:Npn \_tl_analysis_show_long:nn #1
22853 {
22854     \_tl_analysis_show_long_aux:oofn
22855     { \token_to_str:N #1 }
22856     { \token_to_meaning:N #1 }
22857     { \_tl_analysis_show_value:N #1 }
22858 }
22859 \cs_new:Npn \_tl_analysis_show_long_aux:nnnn #1#2#3#4
22860 {
22861     \int_compare:nNnTF
22862     { \str_count:n { #1 ~ ( #4 #2 #3 ) } }
22863     > { \l_iow_line_count_int - 3 }
22864     {
22865         \str_range:nnn { #1 ~ ( #4 #2 #3 ) } { 1 }
22866         {
22867             \l_iow_line_count_int - 3
22868             - \str_count:N \c_tl_analysis_show_etc_str

```

```

22869     }
22870     \c__tl_analysis_show_etc_str
22871   }
22872   { #1 ~ ( #4 #2 #3 ) }
22873 }
22874 \cs_generate_variant:Nn \__tl_analysis_show_long_aux:nnnn { oof }

```

(End definition for `__tl_analysis_show_cs:n` and others.)

39.10 Messages

`\c__tl_analysis_show_etc_str` When a control sequence (or active character) and its meaning are too long to fit in one line of the terminal, the end is replaced by this token list.

```

22875 \tl_const:Nx \c__tl_analysis_show_etc_str % (
22876   { \token_to_str:N \ETC.) }

```

(End definition for `\c__tl_analysis_show_etc_str`.)

```

22877 \__kernel_msg_new:nnn { kernel } { show-tl-analysis }
22878 {
22879   The-token~list~ \tl_if_empty:nF {#1} { #1 ~ }
22880   \tl_if_empty:nTF {#2}
22881     { is~empty }
22882     { contains~the~tokens: #2 }
22883 }
22884 </initex | package>

```

40 l3regex implementation

```

22885 <*initex | package>
22886 <@@=regex>

```

40.1 Plan of attack

Most regex engines use backtracking. This allows to provide very powerful features (back-references come to mind first), but it is costly, and raises the problem of catastrophic backtracking. Since $\text{T}_{\text{E}}\text{X}$ is not first and foremost a programming language, complicated code tends to run slowly, and we must use faster, albeit slightly more restrictive, techniques, coming from automata theory.

Given a regular expression of n characters, we do the following:

- (Compiling.) Analyse the regex, finding invalid input, and convert it to an internal representation.
- (Building.) Convert the compiled regex to a non-deterministic finite automaton (NFA) with $O(n)$ states which accepts precisely token lists matching that regex.
- (Matching.) Loop through the query token list one token (one “position”) at a time, exploring in parallel every possible path (“active thread”) through the NFA, considering active threads in an order determined by the quantifiers’ greediness.

We use the following vocabulary in the code comments (and in variable names).

- *Group*: index of the capturing group, -1 for non-capturing groups.

- *Position*: each token in the query is labelled by an integer $\langle position \rangle$, with $\min_pos - 1 \leq \langle position \rangle \leq \max_pos$. The lowest and highest positions correspond to imaginary begin and end markers (with inaccessible category code and character code).
- *Query*: the token list to which we apply the regular expression.
- *State*: each state of the NFA is labelled by an integer $\langle state \rangle$ with $\min_state \leq \langle state \rangle < \max_state$.
- *Active thread*: state of the NFA that is reached when reading the query token list for the matching. Those threads are ordered according to the greediness of quantifiers.
- *Step*: used when matching, starts at 0, incremented every time a character is read, and is not reset when searching for repeated matches. The integer `\l__regex_step_int` is a unique id for all the steps of the matching algorithm.

We use `l3intarray` to manipulate arrays of integers (stored into some dimension registers in scaled points). We also abuse TeX's `\toks` registers, by accessing them directly by number rather than tying them to control sequence using the `\newtoks` allocation functions. Specifically, these arrays and `\toks` are used as follows. When building, `\toks\langle state \rangle` holds the tests and actions to perform in the $\langle state \rangle$ of the NFA. When matching,

- `\g__regex_state_active_intarray` holds the last $\langle step \rangle$ in which each $\langle state \rangle$ was active.
- `\g__regex_thread_state_intarray` maps each $\langle thread \rangle$ (with $\min_active \leq \langle thread \rangle < \max_active$) to the $\langle state \rangle$ in which the $\langle thread \rangle$ currently is. The $\langle threads \rangle$ are ordered starting from the best to the least preferred.
- `\toks\langle thread \rangle` holds the submatch information for the $\langle thread \rangle$, as the contents of a property list.
- `\g__regex_charcode_intarray` and `\g__regex_catcode_intarray` hold the character codes and category codes of tokens at each $\langle position \rangle$ in the query.
- `\g__regex_balance_intarray` holds the balance of begin-group and end-group character tokens which appear before that point in the token list.
- `\toks\langle position \rangle` holds $\langle tokens \rangle$ which o- and x-expand to the $\langle position \rangle$ -th token in the query.
- `\g__regex_submatch_prev_intarray`, `\g__regex_submatch_begin_intarray` and `\g__regex_submatch_end_intarray` hold, for each submatch (as would be extracted by `\regex_extract_all:nnN`), the place where the submatch started to be looked for and its two end-points. For historical reasons, the minimum index is twice \max_state , and the used registers go up to `\l__regex_submatch_int`. They are organized in blocks of `\l__regex_capturing_group_int` entries, each block corresponding to one match with all its submatches stored in consecutive entries.

The code is structured as follows. Variables are introduced in the relevant section. First we present some generic helper functions. Then comes the code for compiling a regular expression, and for showing the result of the compilation. The building phase

converts a compiled regex to NFA states, and the automaton is run by the code in the following section. The only remaining brick is parsing the replacement text and performing the replacement. We are then ready for all the user functions. Finally, messages, and a little bit of tracing code.

40.2 Helpers

`__regex_int_eval:w` Access the primitive: performance is key here, so we do not use the slower route *via* `\int_eval:n`.

```
22887 \cs_new_eq:NN \__regex_int_eval:w \tex_numexpr:D
22888 % \end{macrocode}
22889 % \end{macro}
22890 %
22891 % \begin{macro}{\__regex_standard_escapechar:}
22892 % Make the \tn{escapechar} into the standard backslash.
22893 % \begin{macrocode}
22894 \cs_new_protected:Npn \__regex_standard_escapechar:
22895 { \int_set:Nn \tex_escapechar:D { '\ } }
```

(End definition for `__regex_int_eval:w`.)

`__regex_toks_use:w` Unpack a `\toks` given its number.

```
22896 \cs_new:Npn \__regex_toks_use:w { \tex_the:D \tex_toks:D }
```

(End definition for `__regex_toks_use:w`.)

`__regex_toks_clear:N` Empty a `\toks` or set it to a value, given its number.

```
\__regex_toks_set:Nn
\__regex_toks_set:No
22897 \cs_new_protected:Npn \__regex_toks_clear:N #1
22898 { \__regex_toks_set:Nn #1 { } }
22899 \cs_new_eq:NN \__regex_toks_set:Nn \tex_toks:D
22900 \cs_new_protected:Npn \__regex_toks_set:No #1
22901 { \__regex_toks_set:Nn #1 \exp_after:wN }
```

(End definition for `__regex_toks_clear:N` and `__regex_toks_set:Nn`.)

`__regex_toks_memcpy:NNn` Copy #3 `\toks` registers from #2 onwards to #1 onwards, like C's `memcpy`.

```
22902 \cs_new_protected:Npn \__regex_toks_memcpy:NNn #1#2#3
22903 {
22904   \prg_replicate:nn {#3}
22905   {
22906     \tex_toks:D #1 = \tex_toks:D #2
22907     \int_incr:N #1
22908     \int_incr:N #2
22909   }
22910 }
```

(End definition for `__regex_toks_memcpy:NNn`.)

`__regex_toks_put_left:Nx` During the building phase we wish to add x-expanded material to `\toks`, either to the left
`__regex_toks_put_right:Nx` or to the right. The expansion is done “by hand” for optimization (these operations are
`__regex_toks_put_right:Nn` used quite a lot). The `Nn` version of `__regex_toks_put_right:Nx` is provided because
it is more efficient than x-expanding with `\exp_not:n`.

```
22911 \cs_new_protected:Npn \__regex_toks_put_left:Nx #1#2
22912 {
```

```

22913 \cs_set:Npx \__regex_tmp:w { #2 }
22914 \tex_toks:D #1 \exp_after:wN \exp_after:wN \exp_after:wN
22915 { \exp_after:wN \__regex_tmp:w \tex_the:D \tex_toks:D #1 }
22916 }
22917 \cs_new_protected:Npn \__regex_toks_put_right:Nx #1#2
22918 {
22919 \cs_set:Npx \__regex_tmp:w {#2}
22920 \tex_toks:D #1 \exp_after:wN
22921 { \tex_the:D \tex_toks:D \exp_after:wN #1 \__regex_tmp:w }
22922 }
22923 \cs_new_protected:Npn \__regex_toks_put_right:Nn #1#2
22924 { \tex_toks:D #1 \exp_after:wN { \tex_the:D \tex_toks:D #1 #2 } }

```

(End definition for __regex_toks_put_left:Nx and __regex_toks_put_right:Nx.)

`__regex_curr_cs_to_str:` Expands to the string representation of the token (known to be a control sequence) at the current position `\l__regex_curr_pos_int`. It should only be used in `x`-expansion to avoid losing a leading space.

```

22925 \cs_new:Npn \__regex_curr_cs_to_str:
22926 {
22927 \exp_after:wN \exp_after:wN \exp_after:wN \cs_to_str:N
22928 \tex_the:D \tex_toks:D \l__regex_curr_pos_int
22929 }

```

(End definition for __regex_curr_cs_to_str:.)

40.2.1 Constants and variables

`__regex_tmp:w` Temporary function used for various short-term purposes.

```

22930 \cs_new:Npn \__regex_tmp:w { }

```

(End definition for __regex_tmp:w.)

`\l__regex_internal_a_tl` Temporary variables used for various purposes.

```

\l__regex_internal_b_tl
\l__regex_internal_a_int
\l__regex_internal_b_int
\l__regex_internal_c_int
\l__regex_internal_bool
\l__regex_internal_seq
\g__regex_internal_tl
22931 \tl_new:N \l__regex_internal_a_tl
22932 \tl_new:N \l__regex_internal_b_tl
22933 \int_new:N \l__regex_internal_a_int
22934 \int_new:N \l__regex_internal_b_int
22935 \int_new:N \l__regex_internal_c_int
22936 \bool_new:N \l__regex_internal_bool
22937 \seq_new:N \l__regex_internal_seq
22938 \tl_new:N \g__regex_internal_tl

```

(End definition for \l__regex_internal_a_tl and others.)

`\l__regex_build_tl` This temporary variable is specifically for use with the `tl_build` machinery.

```

22939 \tl_new:N \l__regex_build_tl

```

(End definition for \l__regex_build_tl.)

`\c__regex_no_match_regex` This regular expression matches nothing, but is still a valid regular expression. We could use a failing assertion, but I went for an empty class. It is used as the initial value for regular expressions declared using `\regex_new:N`.

```

22940 \tl_const:Nn \c__regex_no_match_regex
22941 {
22942   \__regex_branch:n
22943   { \__regex_class:NnnnN \c_true_bool { } { 1 } { 0 } \c_true_bool }
22944 }

```

(End definition for \c__regex_no_match_regex.)

`\g__regex_charcode_intarray`
`\g__regex_catcode_intarray`
`\g__regex_balance_intarray` The first thing we do when matching is to go once through the query token list and store the information for each token into `\g__regex_charcode_intarray`, `\g__regex_catcode_intarray` and `\toks` registers. We also store the balance of begin-group/end-group characters into `\g__regex_balance_intarray`.

```

22945 \intarray_new:Nn \g__regex_charcode_intarray { 65536 }
22946 \intarray_new:Nn \g__regex_catcode_intarray { 65536 }
22947 \intarray_new:Nn \g__regex_balance_intarray { 65536 }

```

(End definition for \g__regex_charcode_intarray, \g__regex_catcode_intarray, and \g__regex_balance_intarray.)

`\l__regex_balance_int` During this phase, `\l__regex_balance_int` counts the balance of begin-group and end-group character tokens which appear before a given point in the token list. This variable is also used to keep track of the balance in the replacement text.

```

22948 \int_new:N \l__regex_balance_int

```

(End definition for \l__regex_balance_int.)

`\l__regex_cs_name_tl` This variable is used in `__regex_item_cs:n` to store the csname of the currently-tested token when the regex contains a sub-regex for testing csnames.

```

22949 \tl_new:N \l__regex_cs_name_tl

```

(End definition for \l__regex_cs_name_tl.)

40.2.2 Testing characters

```

\c__regex_ascii_min_int
\c__regex_ascii_max_control_int
\c__regex_ascii_max_int
22950 \int_const:Nn \c__regex_ascii_min_int { 0 }
22951 \int_const:Nn \c__regex_ascii_max_control_int { 31 }
22952 \int_const:Nn \c__regex_ascii_max_int { 127 }

```

(End definition for \c__regex_ascii_min_int, \c__regex_ascii_max_control_int, and \c__regex_ascii_max_int.)

```

\c__regex_ascii_lower_int
22953 \int_const:Nn \c__regex_ascii_lower_int { 'a - 'A }

```

(End definition for \c__regex_ascii_lower_int.)

`__regex_break_point:TF`
`__regex_break_true:w` When testing whether a character of the query token list matches a given character class in the regular expression, we often have to test it against several ranges of characters, checking if any one of those matches. This is done with a structure like

```

    <test1> ... <testn>
    \__regex_break_point:TF {<true code>} {<false code>}

```

If any of the tests succeeds, it calls `__regex_break_true:w`, which cleans up and leaves `<true code>` in the input stream. Otherwise, `__regex_break_point:TF` leaves the `<false code>` in the input stream.

```

22954 \cs_new_protected:Npn \__regex_break_true:w
22955     #1 \__regex_break_point:TF #2 #3 {#2}
22956 \cs_new_protected:Npn \__regex_break_point:TF #1 #2 { #2 }

```

(End definition for `__regex_break_point:TF` and `__regex_break_true:w`.)

`__regex_item_reverse:n` This function makes showing regular expressions easier, and lets us define `\D` in terms of `\d` for instance. There is a subtlety: the end of the query is marked by `-2`, and thus matches `\D` and other negated properties; this case is caught by another part of the code.

```

22957 \cs_new_protected:Npn \__regex_item_reverse:n #1
22958 {
22959     #1
22960     \__regex_break_point:TF { } \__regex_break_true:w
22961 }

```

(End definition for `__regex_item_reverse:n`.)

`__regex_item_caseful_equal:n` Simple comparisons triggering `__regex_break_true:w` when true.

```

\__regex_item_caseful_range:nn
22962 \cs_new_protected:Npn \__regex_item_caseful_equal:n #1
22963 {
22964     \if_int_compare:w #1 = \l__regex_curr_char_int
22965     \exp_after:wN \__regex_break_true:w
22966     \fi:
22967 }
22968 \cs_new_protected:Npn \__regex_item_caseful_range:nn #1 #2
22969 {
22970     \reverse_if:N \if_int_compare:w #1 > \l__regex_curr_char_int
22971     \reverse_if:N \if_int_compare:w #2 < \l__regex_curr_char_int
22972     \exp_after:wN \exp_after:wN \exp_after:wN \__regex_break_true:w
22973     \fi:
22974     \fi:
22975 }

```

(End definition for `__regex_item_caseful_equal:n` and `__regex_item_caseful_range:nn`.)

`__regex_item_caseless_equal:n` For caseless matching, we perform the test both on the `current_char` and on the `case_changed_char`. Before doing the second set of tests, we make sure that `case_changed_char` has been computed.

```

\__regex_item_caseless_range:nn
22976 \cs_new_protected:Npn \__regex_item_caseless_equal:n #1
22977 {
22978     \if_int_compare:w #1 = \l__regex_curr_char_int
22979     \exp_after:wN \__regex_break_true:w
22980     \fi:
22981     \if_int_compare:w \l__regex_case_changed_char_int = \c_max_int
22982     \__regex_compute_case_changed_char:
22983     \fi:
22984     \if_int_compare:w #1 = \l__regex_case_changed_char_int
22985     \exp_after:wN \__regex_break_true:w

```

```

22986     \fi:
22987   }
22988 \cs_new_protected:Npn \__regex_item_caseless_range:nn #1 #2
22989 {
22990   \reverse_if:N \if_int_compare:w #1 > \l__regex_curr_char_int
22991   \reverse_if:N \if_int_compare:w #2 < \l__regex_curr_char_int
22992   \exp_after:wN \exp_after:wN \exp_after:wN \__regex_break_true:w
22993   \fi:
22994   \fi:
22995   \if_int_compare:w \l__regex_case_changed_char_int = \c_max_int
22996   \__regex_compute_case_changed_char:
22997   \fi:
22998   \reverse_if:N \if_int_compare:w #1 > \l__regex_case_changed_char_int
22999   \reverse_if:N \if_int_compare:w #2 < \l__regex_case_changed_char_int
23000   \exp_after:wN \exp_after:wN \exp_after:wN \__regex_break_true:w
23001   \fi:
23002   \fi:
23003 }

```

(End definition for __regex_item_caseless_equal:n and __regex_item_caseless_range:nn.)

__regex_compute_case_changed_char: This function is called when \l__regex_case_changed_char_int has not yet been computed (or rather, when it is set to the marker value \c_max_int). If the current character code is in the range [65,90] (upper-case), then add 32, making it lowercase. If it is in the lower-case letter range [97,122], subtract 32.

```

23004 \cs_new_protected:Npn \__regex_compute_case_changed_char:
23005 {
23006   \int_set_eq:NN \l__regex_case_changed_char_int \l__regex_curr_char_int
23007   \if_int_compare:w \l__regex_curr_char_int > 'Z \exp_stop_f:
23008   \if_int_compare:w \l__regex_curr_char_int > 'z \exp_stop_f: \else:
23009   \if_int_compare:w \l__regex_curr_char_int < 'a \exp_stop_f: \else:
23010   \int_sub:Nn \l__regex_case_changed_char_int
23011   { \c__regex_ascii_lower_int }
23012   \fi:
23013   \fi:
23014   \else:
23015   \if_int_compare:w \l__regex_curr_char_int < 'A \exp_stop_f: \else:
23016   \int_add:Nn \l__regex_case_changed_char_int
23017   { \c__regex_ascii_lower_int }
23018   \fi:
23019   \fi:
23020 }

```

(End definition for __regex_compute_case_changed_char:.)

__regex_item_equal:n Those must always be defined to expand to a **caseful** (default) or **caseless** version, and not be protected: they must expand when compiling, to hard-code which tests are caseless or caseful.

```

23021 \cs_new_eq:NN \__regex_item_equal:n ?
23022 \cs_new_eq:NN \__regex_item_range:nn ?

```

(End definition for __regex_item_equal:n and __regex_item_range:nn.)

`_regex_item_catcode:nT` The argument is a sum of powers of 4 with exponents given by the allowed category codes (between 0 and 13). Dividing by a given power of 4 gives an odd result if and only if that category code is allowed. If the catcode does not match, then skip the character code tests which follow.

```

23023 \cs_new_protected:Npn \_regex_item_catcode:
23024 {
23025   "
23026   \if_case:w \l__regex_curr_catcode_int
23027     1          \or: 4          \or: 10          \or: 40
23028   \or: 100     \or:           \or: 1000         \or: 4000
23029   \or: 10000   \or:           \or: 100000        \or: 400000
23030   \or: 1000000 \or: 4000000 \else: 1*0
23031   \fi:
23032 }
23033 \cs_new_protected:Npn \_regex_item_catcode:nT #1
23034 {
23035   \if_int_odd:w \int_eval:n { #1 / \_regex_item_catcode: } \exp_stop_f:
23036   \exp_after:wN \use:n
23037   \else:
23038     \exp_after:wN \use_none:n
23039   \fi:
23040 }
23041 \cs_new_protected:Npn \_regex_item_catcode_reverse:nT #1#2
23042 { \_regex_item_catcode:nT {#1} { \_regex_item_reverse:n {#2} } }

```

(End definition for `_regex_item_catcode:nT`, `_regex_item_catcode_reverse:nT`, and `_regex_item_catcode:.`)

`_regex_item_exact:nn` This matches an exact *<category>-<character code>* pair, or an exact control sequence, more precisely one of several possible control sequences.

```

23043 \cs_new_protected:Npn \_regex_item_exact:nn #1#2
23044 {
23045   \if_int_compare:w #1 = \l__regex_curr_catcode_int
23046   \if_int_compare:w #2 = \l__regex_curr_char_int
23047   \exp_after:wN \exp_after:wN \exp_after:wN \_regex_break_true:w
23048   \fi:
23049   \fi:
23050 }
23051 \cs_new_protected:Npn \_regex_item_exact_cs:n #1
23052 {
23053   \int_compare:nNnTF \l__regex_curr_catcode_int = 0
23054   {
23055     \tl_set:Nx \l__regex_internal_a_tl
23056     { \scan_stop: \_regex_curr_cs_to_str: \scan_stop: }
23057     \tl_if_in:noTF { \scan_stop: #1 \scan_stop: }
23058     \l__regex_internal_a_tl
23059     { \_regex_break_true:w } { }
23060   }
23061   { }
23062 }

```

(End definition for `_regex_item_exact:nn` and `_regex_item_exact_cs:n`.)

`_regex_item_cs:n` Match a control sequence (the argument is a compiled regex). First test the catcode of the current token to be zero. Then perform the matching test, and break if the csname

indeed matches. The three `\exp_after:wN` expand the contents of the `\toks⟨current position⟩` (of the form `\exp_not:n {⟨control sequence⟩}`) to `⟨control sequence⟩`. We store the cs name before building states for the cs, as those states may overlap with toks registers storing the user's input.

```

23063 \cs_new_protected:Npn \__regex_item_cs:n #1
23064 {
23065   \int_compare:nNnT \l__regex_curr_catcode_int = 0
23066   {
23067     \group_begin:
23068       \tl_set:Nx \l__regex_cs_name_tl { \__regex_curr_cs_to_str: }
23069       \__regex_single_match:
23070       \__regex_disable_submatches:
23071       \__regex_build_for_cs:n {#1}
23072       \bool_set_eq:NN \l__regex_saved_success_bool
23073         \g__regex_success_bool
23074       \exp_args:NV \__regex_match_cs:n \l__regex_cs_name_tl
23075       \if_meaning:w \c_true_bool \g__regex_success_bool
23076         \group_insert_after:N \__regex_break_true:w
23077       \fi:
23078       \bool_gset_eq:NN \g__regex_success_bool
23079         \l__regex_saved_success_bool
23080     \group_end:
23081   }
23082 }

```

(End definition for `__regex_item_cs:n`.)

40.2.3 Character property tests

`__regex_prop_d:` Character property tests for `\d`, `\W`, *etc.* These character properties are not affected by the `(?i)` option. The characters recognized by each one are as follows: `\d=[0-9]`, `\w=[0-9A-Z_a-z]`, `\s=[_\^\^I\^\^J\^\^L\^\^M]`, `\h=[_\^\^I]`, `\v=[\^\^J-\^\^M]`, and the upper case counterparts match anything that the lower case does not match. The order in which the various tests appear is optimized for usual mostly lower case letter text.

```

\__regex_prop_N:
23083 \cs_new_protected:Npn \__regex_prop_d:
23084 { \__regex_item_caseful_range:nn { '0 } { '9 } }
23085 \cs_new_protected:Npn \__regex_prop_h:
23086 {
23087   \__regex_item_caseful_equal:n { '\ }
23088   \__regex_item_caseful_equal:n { '\^\^I }
23089 }
23090 \cs_new_protected:Npn \__regex_prop_s:
23091 {
23092   \__regex_item_caseful_equal:n { '\ }
23093   \__regex_item_caseful_equal:n { '\^\^I }
23094   \__regex_item_caseful_equal:n { '\^\^J }
23095   \__regex_item_caseful_equal:n { '\^\^L }
23096   \__regex_item_caseful_equal:n { '\^\^M }
23097 }
23098 \cs_new_protected:Npn \__regex_prop_v:
23099 { \__regex_item_caseful_range:nn { '\^\^J } { '\^\^M } } % lf, vtab, ff, cr
23100 \cs_new_protected:Npn \__regex_prop_w:
23101 {

```

```

23102     \_regex_item_caseful_range:nn { 'a } { 'z }
23103     \_regex_item_caseful_range:nn { 'A } { 'Z }
23104     \_regex_item_caseful_range:nn { '0 } { '9 }
23105     \_regex_item_caseful_equal:n { ' _ }
23106   }
23107 \cs_new_protected:Npn \_regex_prop_N:
23108 {
23109     \_regex_item_reverse:n
23110     { \_regex_item_caseful_equal:n { '^~J } }
23111 }

```

(End definition for _regex_prop_d: and others.)

```

\_regex_posix_alnum: POSIX properties. No surprise.
\_regex_posix_alpha: 23112 \cs_new_protected:Npn \_regex_posix_alnum:
\_regex_posix_ascii: 23113 { \_regex_posix_alpha: \_regex_posix_digit: }
\_regex_posix_blank: 23114 \cs_new_protected:Npn \_regex_posix_alpha:
\_regex_posix_cntrl: 23115 { \_regex_posix_lower: \_regex_posix_upper: }
\_regex_posix_digit: 23116 \cs_new_protected:Npn \_regex_posix_ascii:
\_regex_posix_graph: 23117 {
\_regex_posix_lower: 23118     \_regex_item_caseful_range:nn
\_regex_posix_print: 23119     \c__regex_ascii_min_int
\_regex_posix_punct: 23120     \c__regex_ascii_max_int
23121 }
\_regex_posix_space: 23122 \cs_new_eq:NN \_regex_posix_blank: \_regex_prop_h:
\_regex_posix_upper: 23123 \cs_new_protected:Npn \_regex_posix_cntrl:
  \_regex_posix_word: 23124 {
\_regex_posix_xdigit: 23125     \_regex_item_caseful_range:nn
23126     \c__regex_ascii_min_int
23127     \c__regex_ascii_max_control_int
23128     \_regex_item_caseful_equal:n \c__regex_ascii_max_int
23129 }
23130 \cs_new_eq:NN \_regex_posix_digit: \_regex_prop_d:
23131 \cs_new_protected:Npn \_regex_posix_graph:
23132 { \_regex_item_caseful_range:nn { ' ! } { '\~ } }
23133 \cs_new_protected:Npn \_regex_posix_lower:
23134 { \_regex_item_caseful_range:nn { 'a } { 'z } }
23135 \cs_new_protected:Npn \_regex_posix_print:
23136 { \_regex_item_caseful_range:nn { '\ } { '\~ } }
23137 \cs_new_protected:Npn \_regex_posix_punct:
23138 {
23139     \_regex_item_caseful_range:nn { ' ! } { '/ }
23140     \_regex_item_caseful_range:nn { ': } { '@ }
23141     \_regex_item_caseful_range:nn { '[' } { '' }
23142     \_regex_item_caseful_range:nn { '\{ } { '\~ }
23143 }
23144 \cs_new_protected:Npn \_regex_posix_space:
23145 {
23146     \_regex_item_caseful_equal:n { '\ }
23147     \_regex_item_caseful_range:nn { '\^~I } { '\^~M }
23148 }
23149 \cs_new_protected:Npn \_regex_posix_upper:
23150 { \_regex_item_caseful_range:nn { 'A } { 'Z } }
23151 \cs_new_eq:NN \_regex_posix_word: \_regex_prop_w:

```

```

23152 \cs_new_protected:Npn \__regex_posix_xdigit:
23153 {
23154   \__regex_posix_digit:
23155   \__regex_item_caseful_range:nn { 'A } { 'F }
23156   \__regex_item_caseful_range:nn { 'a } { 'f }
23157 }

```

(End definition for __regex_posix_alnum: and others.)

40.2.4 Simple character escape

Before actually parsing the regular expression or the replacement text, we go through them once, converting \n to the character 10, *etc.* In this pass, we also convert any special character (*, ?, {, etc.) or escaped alphanumeric character into a marker indicating that this was a special sequence, and replace escaped special characters and non-escaped alphanumeric characters by markers indicating that those were “raw” characters. The rest of the code can then avoid caring about escaping issues (those can become quite complex to handle in combination with ranges in character classes).

Usage: __regex_escape_use:nnnn *<inline 1>* *<inline 2>* *<inline 3>* {*<token list>*} The *<token list>* is converted to a string, then read from left to right, interpreting backslashes as escaping the next character. Unescaped characters are fed to the function *<inline 1>*, and escaped characters are fed to the function *<inline 2>* within an x-expansion context (typically those functions perform some tests on their argument to decide how to output them). The escape sequences \a, \e, \f, \n, \r, \t and \x are recognized, and those are replaced by the corresponding character, then fed to *<inline 3>*. The result is then left in the input stream. Spaces are ignored unless escaped.

The conversion is done within an x-expanding assignment.

__regex_escape_use:nnnn The result is built in \l__regex_internal_a_tl, which is then left in the input stream. Tracing code is added as appropriate inside this token list. Go through #4 once, applying #1, #2, or #3 as relevant to each character (after de-escaping it).

```

23158 \__kernel_patch:nnNNpn
23159 {
23160   \__regex_trace_push:nnN { regex } { 1 } \__regex_escape_use:nnnn
23161   \group_begin:
23162     \tl_set:Nx \l__regex_internal_a_tl
23163     { \__regex_trace_pop:nnN { regex } { 1 } \__regex_escape_use:nnnn }
23164     \use_none:nnn
23165   }
23166   { }
23167 \cs_new_protected:Npn \__regex_escape_use:nnnn #1#2#3#4
23168 {
23169   \group_begin:
23170     \tl_clear:N \l__regex_internal_a_tl
23171     \cs_set:Npn \__regex_escape_unescaped:N ##1 { #1 }
23172     \cs_set:Npn \__regex_escape_escaped:N ##1 { #2 }
23173     \cs_set:Npn \__regex_escape_raw:N ##1 { #3 }
23174     \__regex_standard_escapechar:
23175     \tl_gset:Nx \g__regex_internal_tl
23176     { \__kernel_str_to_other_fast:n {#4} }
23177     \tl_put_right:Nx \l__regex_internal_a_tl
23178     {
23179       \exp_after:wN \__regex_escape_loop:N \g__regex_internal_tl

```

```

23180         { break } \prg_break_point:
23181     }
23182     \exp_after:wN
23183     \group_end:
23184     \l__regex_internal_a_tl
23185 }

```

(End definition for __regex_escape_use:nnnn.)

__regex_escape_loop:N __regex_escape_loop:N reads one character: if it is special (space, backslash, or end-marker), perform the associated action, otherwise it is simply an unescaped character. After a backslash, the same is done, but unknown characters are “escaped”.

```

23186 \cs_new:Npn \__regex_escape_loop:N #1
23187 {
23188     \cs_if_exist_use:cF { __regex_escape\_token_to_str:N #1:w }
23189     { \__regex_escape_unescaped:N #1 }
23190     \__regex_escape_loop:N
23191 }
23192 \cs_new:cpn { __regex_escape\_c_backslash_str :w }
23193     \__regex_escape_loop:N #1
23194 {
23195     \cs_if_exist_use:cF { __regex_escape\_token_to_str:N #1:w }
23196     { \__regex_escape_escaped:N #1 }
23197     \__regex_escape_loop:N
23198 }

```

(End definition for __regex_escape_loop:N and __regex_escape_w.)

__regex_escape_unescaped:N Those functions are never called before being given a new meaning, so their definitions here don’t matter.

```

\__regex_escape_escaped:N
\__regex_escape_raw:N
23199 \cs_new_eq:NN \__regex_escape_unescaped:N ?
23200 \cs_new_eq:NN \__regex_escape_escaped:N ?
23201 \cs_new_eq:NN \__regex_escape_raw:N ?

```

(End definition for __regex_escape_unescaped:N, __regex_escape_escaped:N, and __regex_escape_raw:N.)

__regex_escape_break:w The loop is ended upon seeing the end-marker “break”, with an error if the string ended in a backslash. Spaces are ignored, and \a, \e, \f, \n, \r, \t take their meaning here.

```

\__regex_escape_/break:w
\__regex_escape_/a:w
\__regex_escape_/e:w
\__regex_escape_/f:w
\__regex_escape_/n:w
\__regex_escape_/r:w
\__regex_escape_/t:w
\__regex_escape_\_w
23202 \cs_new_eq:NN \__regex_escape_break:w \prg_break:
23203 \cs_new:cpn { __regex_escape_/break:w }
23204 {
23205     \__kernel_msg_expandable_error:nn { kernel } { trailing-backslash }
23206     \prg_break:
23207 }
23208 \cs_new:cpn { __regex_escape\_~:w } { }
23209 \cs_new:cpx { __regex_escape_/a:w }
23210     { \exp_not:N \__regex_escape_raw:N \iow_char:N \^G }
23211 \cs_new:cpx { __regex_escape_/t:w }
23212     { \exp_not:N \__regex_escape_raw:N \iow_char:N \^I }
23213 \cs_new:cpx { __regex_escape_/n:w }
23214     { \exp_not:N \__regex_escape_raw:N \iow_char:N \^J }
23215 \cs_new:cpx { __regex_escape_/f:w }
23216     { \exp_not:N \__regex_escape_raw:N \iow_char:N \^L }

```

```

23217 \cs_new:cpx { __regex_escape_/r:w }
23218 { \exp_not:N __regex_escape_raw:N \iow_char:N ^^M }
23219 \cs_new:cpx { __regex_escape_/e:w }
23220 { \exp_not:N __regex_escape_raw:N \iow_char:N ^^[ }

```

(End definition for `__regex_escape_break:w` and others.)

```

__regex_escape_/x:w
__regex_escape_x_end:w
__regex_escape_x_large:n

```

When `\x` is encountered, `__regex_escape_x_test:N` is responsible for grabbing some hexadecimal digits, and feeding the result to `__regex_escape_x_end:w`. If the number is too big interrupt the assignment and produce an error, otherwise call `__regex_escape_raw:N` on the corresponding character token.

```

23221 \cs_new:cpn { __regex_escape_/x:w } __regex_escape_loop:N
23222 {
23223   \exp_after:wN __regex_escape_x_end:w
23224   \int_value:w "0 __regex_escape_x_test:N
23225 }
23226 \cs_new:Npn __regex_escape_x_end:w #1 ;
23227 {
23228   \int_compare:nNnTF {#1} > \c_max_char_int
23229   {
23230     \kernel_msg_expandable_error:nnff { kernel } { x-overflow }
23231     {#1} { \int_to_Hex:n {#1} }
23232   }
23233   {
23234     \exp_last_unbraced:Nf __regex_escape_raw:N
23235     { \char_generate:nn {#1} { 12 } }
23236   }
23237 }

```

(End definition for `__regex_escape_/x:w`, `__regex_escape_x_end:w`, and `__regex_escape_x_large:n`.)

```

__regex_escape_x_test:N
__regex_escape_x_testii:N

```

Find out whether the first character is a left brace (allowing any number of hexadecimal digits), or not (allowing up to two hexadecimal digits). We need to check for the end-of-string marker. Eventually, call either `__regex_escape_x_loop:N` or `__regex_escape_x:N`.

```

23238 \cs_new:Npn __regex_escape_x_test:N #1
23239 {
23240   \str_if_eq:nnTF {#1} { break } { ; }
23241   {
23242     \if_charcode:w \c_space_token #1
23243     \exp_after:wN __regex_escape_x_test:N
23244     \else:
23245       \exp_after:wN __regex_escape_x_testii:N
23246       \exp_after:wN #1
23247     \fi:
23248   }
23249 }
23250 \cs_new:Npn __regex_escape_x_testii:N #1
23251 {
23252   \if_charcode:w \c_left_brace_str #1
23253   \exp_after:wN __regex_escape_x_loop:N
23254   \else:
23255     __regex_hexadecimal_use:NTF #1
23256     { \exp_after:wN __regex_escape_x:N }

```

```

23257     { ; \exp_after:wN \_regex_escape_loop:N \exp_after:wN #1 }
23258     \fi:
23259   }

```

(End definition for _regex_escape_x_test:N and _regex_escape_x_testii:N.)

_regex_escape_x:N This looks for the second digit in the unbraced case.

```

23260 \cs_new:Npn \_regex_escape_x:N #1
23261 {
23262   \str_if_eq:nnTF {#1} { break } { ; }
23263   {
23264     \_regex_hexadecimal_use:NTF #1
23265     { ; \_regex_escape_loop:N }
23266     { ; \_regex_escape_loop:N #1 }
23267   }
23268 }

```

(End definition for _regex_escape_x:N.)

_regex_escape_x_loop:N Grab hexadecimal digits, skip spaces, and at the end, check that there is a right brace, otherwise raise an error outside the assignment.

_regex_escape_x_loop_error:

```

23269 \cs_new:Npn \_regex_escape_x_loop:N #1
23270 {
23271   \str_if_eq:nnTF {#1} { break }
23272   { ; \_regex_escape_x_loop_error:n { } {#1} }
23273   {
23274     \_regex_hexadecimal_use:NTF #1
23275     { \_regex_escape_x_loop:N }
23276     {
23277       \token_if_eq_charcode:NNTF \c_space_token #1
23278       { \_regex_escape_x_loop:N }
23279       {
23280         ;
23281         \exp_after:wN
23282         \token_if_eq_charcode:NNTF \c_right_brace_str #1
23283         { \_regex_escape_loop:N }
23284         { \_regex_escape_x_loop_error:n {#1} }
23285       }
23286     }
23287   }
23288 }
23289 \cs_new:Npn \_regex_escape_x_loop_error:n #1
23290 {
23291   \__kernel_msg_expandable_error:nnn { kernel } { x-missing-rbrace } {#1}
23292   \_regex_escape_loop:N #1
23293 }

```

(End definition for _regex_escape_x_loop:N and _regex_escape_x_loop_error:.)

_regex_hexadecimal_use:NTF TEX detects uppercase hexadecimal digits for us but not the lowercase letters, which we need to detect and replace by their uppercase counterpart.

```

23294 \prg_new_conditional:Npnn \_regex_hexadecimal_use:N #1 { TF }
23295 {
23296   \if_int_compare:w 1 < "1 \token_to_str:N #1 \exp_stop_f:
23297     #1 \prg_return_true:

```

```

23298     \else:
23299         \if_case:w
23300             \int_eval:n { \exp_after:wN ‘ \token_to_str:N #1 - ‘a }
23301             A
23302         \or: B
23303         \or: C
23304         \or: D
23305         \or: E
23306         \or: F
23307     \else:
23308         \prg_return_false:
23309         \exp_after:wN \use_none:n
23310     \fi:
23311     \prg_return_true:
23312 \fi:
23313 }

```

(End definition for `__regex_hexadecimal_use:NTF`.)

`__regex_char_if_alphanumeric:NTF`

These two tests are used in the first pass when parsing a regular expression. That pass is responsible for finding escaped and non-escaped characters, and recognizing which ones have special meanings and which should be interpreted as “raw” characters. Namely,

- alphanumeric are “raw” if they are not escaped, and may have a special meaning when escaped;
- non-alphanumeric printable ascii characters are “raw” if they are escaped, and may have a special meaning when not escaped;
- characters other than printable ascii are always “raw”.

The code is ugly, and highly based on magic numbers and the ascii codes of characters. This is mostly unavoidable for performance reasons. Maybe the tests can be optimized a little bit more. Here, “alphanumeric” means 0–9, A–Z, a–z; “special” character means non-alphanumeric but printable ascii, from space (hex 20) to del (hex 7E).

```

23314 \prg_new_conditional:Npnn \__regex_char_if_special:N #1 { TF }
23315 {
23316     \if_int_compare:w ‘#1 > ‘Z \exp_stop_f:
23317     \if_int_compare:w ‘#1 > ‘z \exp_stop_f:
23318     \if_int_compare:w ‘#1 < \c__regex_ascii_max_int
23319         \prg_return_true: \else: \prg_return_false: \fi:
23320     \else:
23321         \if_int_compare:w ‘#1 < ‘a \exp_stop_f:
23322         \prg_return_true: \else: \prg_return_false: \fi:
23323     \fi:
23324 \else:
23325     \if_int_compare:w ‘#1 > ‘9 \exp_stop_f:
23326     \if_int_compare:w ‘#1 < ‘A \exp_stop_f:
23327         \prg_return_true: \else: \prg_return_false: \fi:
23328     \else:
23329         \if_int_compare:w ‘#1 < ‘0 \exp_stop_f:
23330         \if_int_compare:w ‘#1 < ‘\ \exp_stop_f:
23331         \prg_return_false: \else: \prg_return_true: \fi:
23332     \else: \prg_return_false: \fi:
23333 \fi:

```



```

23334     \fi:
23335   }
23336 \prg_new_conditional:Npnn \__regex_char_if_alphanumeric:N #1 { TF }
23337 {
23338   \if_int_compare:w '#1 > 'Z \exp_stop_f:
23339     \if_int_compare:w '#1 > 'z \exp_stop_f:
23340     \prg_return_false:
23341   \else:
23342     \if_int_compare:w '#1 < 'a \exp_stop_f:
23343     \prg_return_false: \else: \prg_return_true: \fi:
23344   \fi:
23345 \else:
23346   \if_int_compare:w '#1 > '9 \exp_stop_f:
23347   \if_int_compare:w '#1 < 'A \exp_stop_f:
23348   \prg_return_false: \else: \prg_return_true: \fi:
23349 \else:
23350   \if_int_compare:w '#1 < '0 \exp_stop_f:
23351   \prg_return_false: \else: \prg_return_true: \fi:
23352 \fi:
23353 \fi:
23354 }

```

(End definition for `__regex_char_if_alphanumeric:N` and `__regex_char_if_special:N`.)

40.3 Compiling

A regular expression starts its life as a string of characters. In this section, we convert it to internal instructions, resulting in a “compiled” regular expression. This compiled expression is then turned into states of an automaton in the building phase. Compiled regular expressions consist of the following:

- `__regex_class:NnnN` $\langle \text{boolean} \rangle$ $\{ \langle \text{tests} \rangle \}$ $\{ \langle \text{min} \rangle \}$ $\{ \langle \text{more} \rangle \}$ $\langle \text{lazyness} \rangle$
- `__regex_group:nnnN` $\{ \langle \text{branches} \rangle \}$ $\{ \langle \text{min} \rangle \}$ $\{ \langle \text{more} \rangle \}$ $\langle \text{lazyness} \rangle$, also `__regex_group_no_capture:nnnN` and `__regex_group_resetting:nnnN` with the same syntax.
- `__regex_branch:n` $\{ \langle \text{contents} \rangle \}$
- `__regex_command_K:`
- `__regex_assertion:Nn` $\langle \text{boolean} \rangle$ $\{ \langle \text{assertion test} \rangle \}$, where the $\langle \text{assertion test} \rangle$ is `__regex_b_test:` or `__regex_anchor:N` $\langle \text{integer} \rangle$

Tests can be the following:

- `__regex_item_caseful_equal:n` $\{ \langle \text{char code} \rangle \}$
- `__regex_item_caseless_equal:n` $\{ \langle \text{char code} \rangle \}$
- `__regex_item_caseful_range:nn` $\{ \langle \text{min} \rangle \}$ $\{ \langle \text{max} \rangle \}$
- `__regex_item_caseless_range:nn` $\{ \langle \text{min} \rangle \}$ $\{ \langle \text{max} \rangle \}$
- `__regex_item_catcode:nT` $\{ \langle \text{catcode bitmap} \rangle \}$ $\{ \langle \text{tests} \rangle \}$

- `__regex_item_catcode_reverse:nT` $\{\langle catcode\ bitmap\rangle\}$ $\{\langle tests\rangle\}$
- `__regex_item_reverse:n` $\{\langle tests\rangle\}$
- `__regex_item_exact:nn` $\{\langle catcode\rangle\}$ $\{\langle char\ code\rangle\}$
- `__regex_item_exact_cs:n` $\{\langle csnames\rangle\}$, more precisely given as $\langle csname\rangle$ `\scan_stop:` $\langle csname\rangle$ `\scan_stop:` $\langle csname\rangle$ and so on in a brace group.
- `__regex_item_cs:n` $\{\langle compiled\ regex\rangle\}$

40.3.1 Variables used when compiling

`\l__regex_group_level_int` We make sure to open the same number of groups as we close.

```
23355 \int_new:N \l__regex_group_level_int
```

(End definition for `\l__regex_group_level_int`.)

`\l__regex_mode_int` While compiling, ten modes are recognized, labelled -63 , -23 , -6 , -2 , 0 , 2 , 3 , 6 , 23 , 63 .
`\c__regex_cs_in_class_mode_int` See section 40.3.3. We only define some of these as constants.

```
23356 \int_new:N \l__regex_mode_int
23357 \int_const:Nn \c__regex_cs_in_class_mode_int { -6 }
23358 \int_const:Nn \c__regex_cs_mode_int { -2 }
23359 \int_const:Nn \c__regex_outer_mode_int { 0 }
23360 \int_const:Nn \c__regex_catcode_mode_int { 2 }
23361 \int_const:Nn \c__regex_class_mode_int { 3 }
23362 \int_const:Nn \c__regex_catcode_in_class_mode_int { 6 }
```

(End definition for `\l__regex_mode_int` and others.)

`\l__regex_catcodes_int` We wish to allow constructions such as `\c[~BE](. . \cL[a-z] . .)`, where the outer catcode test applies to the whole group, but is superseded by the inner catcode test. For this to work, we need to keep track of lists of allowed category codes: `\l__regex_catcodes_int` and `\l__regex_default_catcodes_int` are bitmaps, sums of 4^c , for all allowed catcodes c . The latter is local to each capturing group, and we reset `\l__regex_catcodes_int` to that value after each character or class, changing it only when encountering a `\c` escape. The boolean records whether the list of categories of a catcode test has to be inverted: compare `\c[~BE]` and `\c[BE]`.

```
23363 \int_new:N \l__regex_catcodes_int
23364 \int_new:N \l__regex_default_catcodes_int
23365 \bool_new:N \l__regex_catcodes_bool
```

(End definition for `\l__regex_catcodes_int`, `\l__regex_default_catcodes_int`, and `\l__regex_catcodes_bool`.)

`\c__regex_catcode_C_int` Constants: 4^c for each category, and the sum of all powers of 4.

```
23366 \int_const:Nn \c__regex_catcode_C_int { "1 }
23367 \int_const:Nn \c__regex_catcode_B_int { "4 }
23368 \int_const:Nn \c__regex_catcode_E_int { "10 }
23369 \int_const:Nn \c__regex_catcode_M_int { "40 }
23370 \int_const:Nn \c__regex_catcode_T_int { "100 }
23371 \int_const:Nn \c__regex_catcode_P_int { "1000 }
23372 \int_const:Nn \c__regex_catcode_U_int { "4000 }
23373 \int_const:Nn \c__regex_catcode_D_int { "10000 }
23374 \int_const:Nn \c__regex_catcode_S_int { "100000 }
```

`\c__regex_catcode_O_int`
`\c__regex_catcode_A_int`
`\c__regex_all_catcodes_int`

```

23375 \int_const:Nn \c__regex_catcode_L_int { "400000 }
23376 \int_const:Nn \c__regex_catcode_O_int { "1000000 }
23377 \int_const:Nn \c__regex_catcode_A_int { "4000000 }
23378 \int_const:Nn \c__regex_all_catcodes_int { "5515155 }

```

(End definition for \c__regex_catcode_C_int and others.)

\l__regex_internal_regex The compilation step stores its result in this variable.

```

23379 \cs_new_eq:NN \l__regex_internal_regex \c__regex_no_match_regex

```

(End definition for \l__regex_internal_regex.)

\l__regex_show_prefix_seq This sequence holds the prefix that makes up the line displayed to the user. The various items must be removed from the right, which is tricky with a token list, hence we use a sequence.

```

23380 \seq_new:N \l__regex_show_prefix_seq

```

(End definition for \l__regex_show_prefix_seq.)

\l__regex_show_lines_int A hack. To know whether a given class has a single item in it or not, we count the number of lines when showing the class.

```

23381 \int_new:N \l__regex_show_lines_int

```

(End definition for \l__regex_show_lines_int.)

40.3.2 Generic helpers used when compiling

__regex_two_if_eq:NNNNTF Used to compare pairs of things like __regex_compile_special:N ? together. It's often inconvenient to get the catcodes of the character to match so we just compare the character code. Besides, the expanding behaviour of \if:w is very useful as that means we can use \c_left_brace_str and the like.

```

23382 \prg_new_conditional:Npnn \__regex_two_if_eq:NNNN #1#2#3#4 { TF }
23383 {
23384   \if_meaning:w #1 #3
23385   \if:w #2 #4
23386     \prg_return_true:
23387   \else:
23388     \prg_return_false:
23389   \fi:
23390 \else:
23391   \prg_return_false:
23392 \fi:
23393 }

```

(End definition for __regex_two_if_eq:NNNNTF.)

__regex_get_digits:NTFw If followed by some raw digits, collect them one by one in the integer variable #1, and take the true branch. Otherwise, take the false branch.

```

23394 \cs_new_protected:Npn \__regex_get_digits:NTFw #1#2#3#4#5
23395 {
23396   \__regex_if_raw_digit:NNTF #4 #5
23397   { #1 = #5 \__regex_get_digits_loop:nw {#2} }
23398   { #3 #4 #5 }
23399 }

```

```

23400 \cs_new:Npn \__regex_get_digits_loop:nw #1#2#3
23401 {
23402   \__regex_if_raw_digit:NNTF #2 #3
23403   { #3 \__regex_get_digits_loop:nw {#1} }
23404   { \scan_stop: #1 #2 #3 }
23405 }

```

(End definition for `__regex_get_digits:NNTFw` and `__regex_get_digits_loop:w`.)

`__regex_if_raw_digit:NNTF` Test used when grabbing digits for the `{m,n}` quantifier. It only accepts non-escaped digits.

```

23406 \prg_new_conditional:Npnn \__regex_if_raw_digit:NN #1#2 { TF }
23407 {
23408   \if_meaning:w \__regex_compile_raw:N #1
23409   \if_int_compare:w 1 < 1 #2 \exp_stop_f:
23410   \prg_return_true:
23411   \else:
23412   \prg_return_false:
23413   \fi:
23414   \else:
23415   \prg_return_false:
23416   \fi:
23417 }

```

(End definition for `__regex_if_raw_digit:NNTF`.)

40.3.3 Mode

When compiling the NFA corresponding to a given regex string, we can be in ten distinct modes, which we label by some magic numbers:

- 6 `[\c{...}]` control sequence in a class,
- 2 `\c{...}` control sequence,
- 0 ... outer,
- 2 `\c...` catcode test,
- 6 `[\c...]` catcode test in a class,
- 63 `[\c{[...]}]` class inside mode -6,
- 23 `\c{[...]}` class inside mode -2,
- 3 `[...]` class inside mode 0,
- 23 `\c[...]` class inside mode 2,
- 63 `[\c[...]]` class inside mode 6.

This list is exhaustive, because `\c` escape sequences cannot be nested, and character classes cannot be nested directly. The choice of numbers is such as to optimize the most useful tests, and make transitions from one mode to another as simple as possible.

- Even modes mean that we are not directly in a character class. In this case, a left bracket appends 3 to the mode. In a character class, a right bracket changes the mode as $m \rightarrow (m - 15)/13$, truncated.
- Grouping, assertion, and anchors are allowed in non-positive even modes (0, -2, -6), and do not change the mode. Otherwise, they trigger an error.
- A left bracket is special in even modes, appending 3 to the mode; in those modes, quantifiers and the dot are recognized, and the right bracket is normal. In odd modes (within classes), the left bracket is normal, but the right bracket ends the class, changing the mode from m to $(m - 15)/13$, truncated; also, ranges are recognized.
- In non-negative modes, left and right braces are normal. In negative modes, however, left braces trigger a warning; right braces end the control sequence, going from -2 to 0 or -6 to 3, with error recovery for odd modes.
- Properties (such as the `\d` character class) can appear in any mode.

`_regex_if_in_class:TF` Test whether we are directly in a character class (at the innermost level of nesting). There, many escape sequences are not recognized, and special characters are normal. Also, for every raw character, we must look ahead for a possible raw dash.

```

23418 \cs_new:Npn \_regex_if_in_class:TF
23419 {
23420   \if_int_odd:w \l__regex_mode_int
23421     \exp_after:wN \use_i:nn
23422   \else:
23423     \exp_after:wN \use_ii:nn
23424   \fi:
23425 }
```

(End definition for `_regex_if_in_class:TF`.)

`_regex_if_in_cs:TF` Right braces are special only directly inside control sequences (at the inner-most level of nesting, not counting groups).

```

23426 \cs_new:Npn \_regex_if_in_cs:TF
23427 {
23428   \if_int_odd:w \l__regex_mode_int
23429     \exp_after:wN \use_ii:nn
23430   \else:
23431     \if_int_compare:w \l__regex_mode_int < \c__regex_outer_mode_int
23432       \exp_after:wN \exp_after:wN \exp_after:wN \use_i:nn
23433     \else:
23434       \exp_after:wN \exp_after:wN \exp_after:wN \use_ii:nn
23435     \fi:
23436   \fi:
23437 }
```

(End definition for `_regex_if_in_cs:TF`.)

`_regex_if_in_class_or_catcode:TF` Assertions are only allowed in modes 0, -2, and -6, *i.e.*, even, non-positive modes.

```

23438 \cs_new:Npn \_regex_if_in_class_or_catcode:TF
23439 {
23440   \if_int_odd:w \l__regex_mode_int
```

```

23441     \exp_after:wN \use_i:nn
23442 \else:
23443     \if_int_compare:w \l__regex_mode_int > \c__regex_outer_mode_int
23444     \exp_after:wN \exp_after:wN \exp_after:wN \use_i:nn
23445 \else:
23446     \exp_after:wN \exp_after:wN \exp_after:wN \use_ii:nn
23447 \fi:
23448 \fi:
23449 }

```

(End definition for __regex_if_in_class_or_catcode:TF.)

__regex_if_within_catcode:TF This test takes the true branch if we are in a catcode test, either immediately following it (modes 2 and 6) or in a class on which it applies (modes 23 and 63). This is used to tweak how left brackets behave in modes 2 and 6.

```

23450 \cs_new:Npn \__regex_if_within_catcode:TF
23451 {
23452     \if_int_compare:w \l__regex_mode_int > \c__regex_outer_mode_int
23453     \exp_after:wN \use_i:nn
23454 \else:
23455     \exp_after:wN \use_ii:nn
23456 \fi:
23457 }

```

(End definition for __regex_if_within_catcode:TF.)

__regex_chk_c_allowed:T The \c escape sequence is only allowed in modes 0 and 3, *i.e.*, not within any other \c escape sequence.

```

23458 \cs_new_protected:Npn \__regex_chk_c_allowed:T
23459 {
23460     \if_int_compare:w \l__regex_mode_int = \c__regex_outer_mode_int
23461     \exp_after:wN \use:n
23462 \else:
23463     \if_int_compare:w \l__regex_mode_int = \c__regex_class_mode_int
23464     \exp_after:wN \exp_after:wN \exp_after:wN \use:n
23465 \else:
23466     \__kernel_msg_error:nn { kernel } { c-bad-mode }
23467     \exp_after:wN \exp_after:wN \exp_after:wN \use_none:n
23468 \fi:
23469 \fi:
23470 }

```

(End definition for __regex_chk_c_allowed:T.)

__regex_mode_quit_c: This function changes the mode as it is needed just after a catcode test.

```

23471 \cs_new_protected:Npn \__regex_mode_quit_c:
23472 {
23473     \if_int_compare:w \l__regex_mode_int = \c__regex_catcode_mode_int
23474     \int_set_eq:NN \l__regex_mode_int \c__regex_outer_mode_int
23475 \else:
23476     \if_int_compare:w \l__regex_mode_int =
23477     \c__regex_catcode_in_class_mode_int
23478     \int_set_eq:NN \l__regex_mode_int \c__regex_class_mode_int
23479 \fi:
23480 \fi:
23481 }

```

(End definition for _regex_mode_quit_c:.)

40.3.4 Framework

_regex_compile:w Used when compiling a user regex or a regex for the \c{...} escape sequence within
_regex_compile_end: another regex. Start building a token list within a group (with x-expansion at the outset),
and set a few variables (group level, catcodes), then start the first branch. At the end,
make sure there are no dangling classes nor groups, close the last branch: we are done
building \l_regex_internal_regex.

```

23482 \cs_new_protected:Npn \_regex_compile:w
23483 {
23484   \group_begin:
23485     \tl_build_begin:N \l\_regex_build_tl
23486     \int_zero:N \l\_regex_group_level_int
23487     \int_set_eq:NN \l\_regex_default_catcodes_int
23488       \c\_regex_all_catcodes_int
23489     \int_set_eq:NN \l\_regex_catcodes_int \l\_regex_default_catcodes_int
23490     \cs_set:Npn \_regex_item_equal:n { \_regex_item_caseful_equal:n }
23491     \cs_set:Npn \_regex_item_range:nn { \_regex_item_caseful_range:nn }
23492     \tl_build_put_right:Nn \l\_regex_build_tl
23493       { \_regex_branch:n { \if_false: } \fi: }
23494   }
23495 \cs_new_protected:Npn \_regex_compile_end:
23496 {
23497   \__regex_if_in_class:TF
23498   {
23499     \__kernel_msg_error:nn { kernel } { missing-rbrack }
23500     \use:c { \_regex_compile_]: }
23501     \prg_do_nothing: \prg_do_nothing:
23502   }
23503   { }
23504   \if_int_compare:w \l\_regex_group_level_int > 0 \exp_stop_f:
23505     \__kernel_msg_error:nnx { kernel } { missing-rparen }
23506     { \int_use:N \l\_regex_group_level_int }
23507     \prg_replicate:nn
23508       { \l\_regex_group_level_int }
23509     {
23510       \tl_build_put_right:Nn \l\_regex_build_tl
23511       {
23512         \if_false: { \fi: }
23513         \if_false: { \fi: } { 1 } { 0 } \c_true_bool
23514       }
23515       \tl_build_end:N \l\_regex_build_tl
23516       \exp_args:NNNo
23517       \group_end:
23518       \tl_build_put_right:Nn \l\_regex_build_tl
23519         { \l\_regex_build_tl }
23520     }
23521     \fi:
23522     \tl_build_put_right:Nn \l\_regex_build_tl { \if_false: { \fi: } }
23523     \tl_build_end:N \l\_regex_build_tl
23524     \exp_args:NNNx
23525     \group_end:

```

```

23526 \tl_set:Nn \l__regex_internal_regex { \l__regex_build_tl }
23527 }

```

(End definition for __regex_compile:w and __regex_compile_end:.)

__regex_compile:n The compilation is done between __regex_compile:w and __regex_compile_end:, starting in mode 0. Then __regex_escape_use:nnnn distinguishes special characters, escaped alphanumerics, and raw characters, interpreting \a, \x and other sequences. The 4 trailing \prg_do_nothing: are needed because some functions defined later look up to 4 tokens ahead. Before ending, make sure that any \c{...} is properly closed. No need to check that brackets are closed properly since __regex_compile_end: does that. However, catch the case of a trailing \cL construction.

```

23528 \cs_new_protected:Npn \__regex_compile:n #1
23529 {
23530   \__regex_compile:w
23531   \__regex_standard_escapechar:
23532   \int_set_eq:NN \l__regex_mode_int \c__regex_outer_mode_int
23533   \__regex_escape_use:nnnn
23534   {
23535     \__regex_char_if_special:NTF ##1
23536     \__regex_compile_special:N \__regex_compile_raw:N ##1
23537   }
23538   {
23539     \__regex_char_if_alphanumeric:NTF ##1
23540     \__regex_compile_escaped:N \__regex_compile_raw:N ##1
23541   }
23542   { \__regex_compile_raw:N ##1 }
23543   { #1 }
23544   \prg_do_nothing: \prg_do_nothing:
23545   \prg_do_nothing: \prg_do_nothing:
23546   \int_compare:nNnT \l__regex_mode_int = \c__regex_catcode_mode_int
23547   { \__kernel_msg_error:nn { kernel } { c-trailing } }
23548   \int_compare:nNnT \l__regex_mode_int < \c__regex_outer_mode_int
23549   {
23550     \__kernel_msg_error:nn { kernel } { c-missing-rbrace }
23551     \__regex_compile_end_cs:
23552     \prg_do_nothing: \prg_do_nothing:
23553     \prg_do_nothing: \prg_do_nothing:
23554   }
23555   \__regex_compile_end:
23556 }

```

(End definition for __regex_compile:n.)

__regex_compile_escaped:N If the special character or escaped alphanumeric has a particular meaning in regexes, the corresponding function is used. Otherwise, it is interpreted as a raw character. We distinguish special characters from escaped alphanumeric characters because they behave differently when appearing as an end-point of a range.

```

23557 \cs_new_protected:Npn \__regex_compile_special:N #1
23558 {
23559   \cs_if_exist_use:cF { __regex_compile_#1: }
23560   { \__regex_compile_raw:N #1 }
23561 }
23562 \cs_new_protected:Npn \__regex_compile_escaped:N #1

```



```

23563 {
23564   \cs_if_exist_use:cF { __regex_compile_/#1: }
23565   { \__regex_compile_raw:N #1 }
23566 }

```

(End definition for __regex_compile_escaped:N and __regex_compile_special:N.)

__regex_compile_one:n This is used after finding one “test”, such as \d, or a raw character. If that followed a catcode test (e.g., \cL), then restore the mode. If we are not in a class, then the test is “standalone”, and we need to add __regex_class:NnnnN and search for quantifiers. In any case, insert the test, possibly together with a catcode test if appropriate.

```

23567 \cs_new_protected:Npn \__regex_compile_one:n #1
23568 {
23569   \__regex_mode_quit_c:
23570   \__regex_if_in_class:TF { }
23571   {
23572     \tl_build_put_right:Nn \l__regex_build_tl
23573     { \__regex_class:NnnnN \c_true_bool { \if_false: } \fi: }
23574   }
23575   \tl_build_put_right:Nx \l__regex_build_tl
23576   {
23577     \if_int_compare:w \l__regex_catcodes_int <
23578     \c__regex_all_catcodes_int
23579     \__regex_item_catcode:nT { \int_use:N \l__regex_catcodes_int }
23580     { \exp_not:N \exp_not:n {#1} }
23581     \else:
23582     \exp_not:N \exp_not:n {#1}
23583     \fi:
23584   }
23585   \int_set_eq:NN \l__regex_catcodes_int \l__regex_default_catcodes_int
23586   \__regex_if_in_class:TF { } { \__regex_compile_quantifier:w }
23587 }

```

(End definition for __regex_compile_one:n.)

__regex_compile_abort_tokens:n This function places the collected tokens back in the input stream, each as a raw character.
__regex_compile_abort_tokens:x Spaces are not preserved.

```

23588 \cs_new_protected:Npn \__regex_compile_abort_tokens:n #1
23589 {
23590   \use:x
23591   {
23592     \exp_args:No \tl_map_function:nN { \tl_to_str:n {#1} }
23593     \__regex_compile_raw:N
23594   }
23595 }
23596 \cs_generate_variant:Nn \__regex_compile_abort_tokens:n { x }

```

(End definition for __regex_compile_abort_tokens:n.)

40.3.5 Quantifiers

__regex_compile_quantifier:w This looks ahead and finds any quantifier (special character equal to either of ?+*{).

```

23597 \cs_new_protected:Npn \__regex_compile_quantifier:w #1#2
23598 {

```

```

23599 \token_if_eq_meaning:NNTF #1 \__regex_compile_special:N
23600 {
23601     \cs_if_exist_use:cF { __regex_compile_quantifier_#2:w }
23602     { \__regex_compile_quantifier_none: #1 #2 }
23603 }
23604 { \__regex_compile_quantifier_none: #1 #2 }
23605 }

```

(End definition for __regex_compile_quantifier:w.)

__regex_compile_quantifier_none: Those functions are called whenever there is no quantifier, or a braced construction is invalid (equivalent to no quantifier, and whatever characters were grabbed are left raw).

```

23606 \cs_new_protected:Npn \__regex_compile_quantifier_none:
23607 {
23608     \tl_build_put_right:Nn \l__regex_build_tl
23609     { \if_false: { \fi: } { 1 } { 0 } \c_false_bool }
23610 }
23611 \cs_new_protected:Npn \__regex_compile_quantifier_abort:xNN #1#2#3
23612 {
23613     \__regex_compile_quantifier_none:
23614     \__kernel_msg_warning:nxxx { kernel } { invalid-quantifier } {#1} {#3}
23615     \__regex_compile_abort_tokens:x {#1}
23616     #2 #3
23617 }

```

(End definition for __regex_compile_quantifier_none: and __regex_compile_quantifier_abort:xNN.)

__regex_compile_quantifier_lazyness:nnNN Once the “main” quantifier (?, *, + or a braced construction) is found, we check whether it is lazy (followed by a question mark). We then add to the compiled regex a closing brace (ending __regex_class:NnnnN and friends), the start-point of the range, its end-point, and a boolean, true for lazy and false for greedy operators.

```

23618 \cs_new_protected:Npn \__regex_compile_quantifier_lazyness:nnNN #1#2#3#4
23619 {
23620     \__regex_two_if_eq:NNNTF #3 #4 \__regex_compile_special:N ?
23621     {
23622         \tl_build_put_right:Nn \l__regex_build_tl
23623         { \if_false: { \fi: } { #1 } { #2 } \c_true_bool }
23624     }
23625     {
23626         \tl_build_put_right:Nn \l__regex_build_tl
23627         { \if_false: { \fi: } { #1 } { #2 } \c_false_bool }
23628         #3 #4
23629     }
23630 }

```

(End definition for __regex_compile_quantifier_lazyness:nnNN.)

__regex_compile_quantifier?:w For each “basic” quantifier, ?, *, +, feed the correct arguments to __regex_compile_quantifier_lazyness:nnNN, -1 means that there is no upper bound on the number of repetitions.

```

23631 \cs_new_protected:cpn { __regex_compile_quantifier?:w }
23632 { \__regex_compile_quantifier_lazyness:nnNN { 0 } { 1 } }
23633 \cs_new_protected:cpn { __regex_compile_quantifier*:w }
23634 { \__regex_compile_quantifier_lazyness:nnNN { 0 } { -1 } }

```

```

23635 \cs_new_protected:cpn { __regex_compile_quantifier_+:w }
23636 { \__regex_compile_quantifier_lazyness:nnNN { 1 } { -1 } }

```

(End definition for `__regex_compile_quantifier_?:w`, `__regex_compile_quantifier_+:w`, and `__regex_compile_quantifier_+:w`.)

```

\__regex_compile_quantifier_{:w
\__regex_compile_quantifier_braced_auxi:w
\__regex_compile_quantifier_braced_auxii:w
\__regex_compile_quantifier_braced_auxiii:w

```

Three possible syntaxes: $\{\langle int \rangle\}$, $\{\langle int \rangle, \}$, or $\{\langle int \rangle, \langle int \rangle\}$. Any other syntax causes us to abort and put whatever we collected back in the input stream, as `raw` characters, including the opening brace. Grab a number into `\l__regex_internal_a_int`. If the number is followed by a right brace, the range is $[a, a]$. If followed by a comma, grab one more number, and call the `_ii` or `_iii` auxiliary. Those auxiliaries check for a closing brace, leading to the range $[a, \infty]$ or $[a, b]$, encoded as $\{a\}\{-1\}$ and $\{a\}\{b-a\}$.

```

23637 \cs_new_protected:cpn { __regex_compile_quantifier_ \c_left_brace_str :w }
23638 {
23639   \__regex_get_digits:NTFw \l__regex_internal_a_int
23640   { \__regex_compile_quantifier_braced_auxi:w }
23641   { \__regex_compile_quantifier_abort:xNN { \c_left_brace_str } }
23642 }
23643 \cs_new_protected:Npn \__regex_compile_quantifier_braced_auxi:w #1#2
23644 {
23645   \str_case_e:nnF { #1 #2 }
23646   {
23647     { \__regex_compile_special:N \c_right_brace_str }
23648     {
23649       \exp_args:No \__regex_compile_quantifier_lazyness:nnNN
23650       { \int_use:N \l__regex_internal_a_int } { 0 }
23651     }
23652     { \__regex_compile_special:N , }
23653     {
23654       \__regex_get_digits:NTFw \l__regex_internal_b_int
23655       { \__regex_compile_quantifier_braced_auxiii:w }
23656       { \__regex_compile_quantifier_braced_auxii:w }
23657     }
23658   }
23659   {
23660     \__regex_compile_quantifier_abort:xNN
23661     { \c_left_brace_str \int_use:N \l__regex_internal_a_int }
23662     #1 #2
23663   }
23664 }
23665 \cs_new_protected:Npn \__regex_compile_quantifier_braced_auxii:w #1#2
23666 {
23667   \__regex_two_if_eq:NNNTF #1 #2 \__regex_compile_special:N \c_right_brace_str
23668   {
23669     \exp_args:No \__regex_compile_quantifier_lazyness:nnNN
23670     { \int_use:N \l__regex_internal_a_int } { -1 }
23671   }
23672   {
23673     \__regex_compile_quantifier_abort:xNN
23674     { \c_left_brace_str \int_use:N \l__regex_internal_a_int , }
23675     #1 #2
23676   }
23677 }
23678 \cs_new_protected:Npn \__regex_compile_quantifier_braced_auxiii:w #1#2

```

```

23679 {
23680   \_regex_two_if_eq:NNNTF #1 #2 \_regex_compile_special:N \c_right_brace_str
23681   {
23682     \if_int_compare:w \l__regex_internal_a_int >
23683     \l__regex_internal_b_int
23684     \_kernel_msg_error:nnxx { kernel } { backwards-quantifier }
23685     { \int_use:N \l__regex_internal_a_int }
23686     { \int_use:N \l__regex_internal_b_int }
23687     \int_zero:N \l__regex_internal_b_int
23688   \else:
23689     \int_sub:Nn \l__regex_internal_b_int \l__regex_internal_a_int
23690   \fi:
23691   \exp_args:Noo \_regex_compile_quantifier_laziness:nnNN
23692   { \int_use:N \l__regex_internal_a_int }
23693   { \int_use:N \l__regex_internal_b_int }
23694 }
23695 {
23696   \_regex_compile_quantifier_abort:xNN
23697   {
23698     \c_left_brace_str
23699     \int_use:N \l__regex_internal_a_int ,
23700     \int_use:N \l__regex_internal_b_int
23701   }
23702   #1 #2
23703 }
23704 }

```

(End definition for _regex_compile_quantifier_{:w and others.)

40.3.6 Raw characters

_regex_compile_raw_error:N Within character classes, and following catcode tests, some escaped alphanumeric sequences such as \b do not have any meaning. They are replaced by a raw character, after spitting out an error.

```

23705 \cs_new_protected:Npn \_regex_compile_raw_error:N #1
23706 {
23707   \_kernel_msg_error:nnx { kernel } { bad-escape } {#1}
23708   \_regex_compile_raw:N #1
23709 }

```

(End definition for _regex_compile_raw_error:N.)

_regex_compile_raw:N If we are in a character class and the next character is an unescaped dash, this denotes a range. Otherwise, the current character #1 matches itself.

```

23710 \cs_new_protected:Npn \_regex_compile_raw:N #1#2#3
23711 {
23712   \_regex_if_in_class:TF
23713   {
23714     \_regex_two_if_eq:NNNTF #2 #3 \_regex_compile_special:N -
23715     { \_regex_compile_range:Nw #1 }
23716     {
23717       \_regex_compile_one:n
23718       { \_regex_item_equal:n { \int_value:w '#1 } }
23719       #2 #3

```

```

23720     }
23721   }
23722   {
23723     \_regex_compile_one:n
23724     { \_regex_item_equal:n { \int_value:w '#1 } }
23725     #2 #3
23726   }
23727 }

```

(End definition for _regex_compile_raw:N.)

_regex_compile_range:Nw
_regex_if_end_range:NNTF

We have just read a raw character followed by a dash; this should be followed by an end-point for the range. Valid end-points are: any raw character; any special character, except a right bracket. In particular, escaped characters are forbidden.

```

23728 \prg_new_protected_conditional:Npnn \_regex_if_end_range:NN #1#2 { TF }
23729 {
23730   \if_meaning:w \_regex_compile_raw:N #1
23731   \prg_return_true:
23732   \else:
23733     \if_meaning:w \_regex_compile_special:N #1
23734     \if_charcode:w ] #2
23735     \prg_return_false:
23736     \else:
23737     \prg_return_true:
23738     \fi:
23739     \else:
23740     \prg_return_false:
23741     \fi:
23742   \fi:
23743 }
23744 \cs_new_protected:Npn \_regex_compile_range:Nw #1#2#3
23745 {
23746   \_regex_if_end_range:NNTF #2 #3
23747   {
23748     \if_int_compare:w '#1 > '#3 \exp_stop_f:
23749     \_kernel_msg_error:nxxx { kernel } { range-backwards } {#1} {#3}
23750     \else:
23751     \tl_build_put_right:Nx \l__regex_build_tl
23752     {
23753       \if_int_compare:w '#1 = '#3 \exp_stop_f:
23754       \_regex_item_equal:n
23755       \else:
23756       \_regex_item_range:nn { \int_value:w '#1 }
23757       \fi:
23758       { \int_value:w '#3 }
23759     }
23760     \fi:
23761   }
23762   {
23763     \_kernel_msg_warning:nxxx { kernel } { range-missing-end }
23764     {#1} { \c_backslash_str #3 }
23765     \tl_build_put_right:Nx \l__regex_build_tl
23766     {
23767       \_regex_item_equal:n { \int_value:w '#1 \exp_stop_f: }

```

```

23768         \_regex_item_equal:n { \int_value:w ‘- \exp_stop_f: }
23769     }
23770     #2#3
23771 }
23772 }

```

(End definition for _regex_compile_range:Nw and _regex_if_end_range:NNTF.)

40.3.7 Character properties

_regex_compile_.: In a class, the dot has no special meaning. Outside, insert _regex_prop_., which matches any character or control sequence, and refuses -2 (end-marker).

```

23773 \cs_new_protected:cpx { \_regex_compile_.: }
23774 {
23775     \exp_not:N \_regex_if_in_class:TF
23776     { \_regex_compile_raw:N . }
23777     { \_regex_compile_one:n \exp_not:c { \_regex_prop_.: } }
23778 }
23779 \cs_new_protected:cpn { \_regex_prop_.: }
23780 {
23781     \if_int_compare:w \l__regex_curr_char_int > - 2 \exp_stop_f:
23782     \exp_after:wN \_regex_break_true:w
23783     \fi:
23784 }

```

(End definition for _regex_compile_.: and _regex_prop_.:)

_regex_compile_/d: The constants _regex_prop_d:, etc. hold a list of tests which match the corresponding character class, and jump to the _regex_break_point:TF marker. As for a normal character, we check for quantifiers.

```

\_regex_compile_/d: 23785 \cs_set_protected:Npn \_regex_tmp:w #1#2
\_regex_compile_/D: 23786 {
\_regex_compile_/h: 23787     \cs_new_protected:cpx { \_regex_compile_/#1: }
\_regex_compile_/S: 23788     { \_regex_compile_one:n \exp_not:c { \_regex_prop_#1: } }
\_regex_compile_/v: 23789     \cs_new_protected:cpx { \_regex_compile_/#2: }
\_regex_compile_/V: 23790     {
\_regex_compile_/w: 23791         \_regex_compile_one:n
\_regex_compile_/W: 23792         { \_regex_item_reverse:n \exp_not:c { \_regex_prop_#1: } }
\_regex_compile_/N: 23793     }
23794 }
23795 \_regex_tmp:w d D
23796 \_regex_tmp:w h H
23797 \_regex_tmp:w s S
23798 \_regex_tmp:w v V
23799 \_regex_tmp:w w W
23800 \cs_new_protected:cpn { \_regex_compile_/N: }
23801 { \_regex_compile_one:n \_regex_prop_N: }

```

(End definition for _regex_compile_/d: and others.)

40.3.8 Anchoring and simple assertions

`__regex_compile_anchor:NF` In modes where assertions are allowed, anchor to the start of the query, the start of the match, or the end of the query, depending on the integer #1. In other modes, #2 treats the character as raw, with an error for escaped letters (\$ is valid in a class, but \A is definitely a mistake on the user's part).

```

__regex_compile_~:
__regex_compile_/A:
__regex_compile_/G:
__regex_compile_$:
__regex_compile_/Z:
__regex_compile_/z:
23802 \cs_new_protected:Npn __regex_compile_anchor:NF #1#2
23803 {
23804     __regex_if_in_class_or_catcode:TF {#2}
23805     {
23806         \tl_build_put_right:Nn \l__regex_build_tl
23807         { __regex_assertion:Nn \c_true_bool { __regex_anchor:N #1 } }
23808     }
23809 }
23810 \cs_set_protected:Npn __regex_tmp:w #1#2
23811 {
23812     \cs_new_protected:cpn { __regex_compile_/#1: }
23813     { __regex_compile_anchor:NF #2 { __regex_compile_raw_error:N #1 } }
23814 }
23815 __regex_tmp:w A \l__regex_min_pos_int
23816 __regex_tmp:w G \l__regex_start_pos_int
23817 __regex_tmp:w Z \l__regex_max_pos_int
23818 __regex_tmp:w z \l__regex_max_pos_int
23819 \cs_set_protected:Npn __regex_tmp:w #1#2
23820 {
23821     \cs_new_protected:cpn { __regex_compile_#1: }
23822     { __regex_compile_anchor:NF #2 { __regex_compile_raw:N #1 } }
23823 }
23824 \exp_args:Nx __regex_tmp:w { \iow_char:N ^ } \l__regex_min_pos_int
23825 \exp_args:Nx __regex_tmp:w { \iow_char:N $ } \l__regex_max_pos_int

```

(End definition for `__regex_compile_anchor:NF` and others.)

`__regex_compile_/b:` Contrarily to `~` and `$`, which could be implemented without really knowing what precedes in the token list, this requires more information, namely, the knowledge of the last character code.

`__regex_compile_/B:`

```

23826 \cs_new_protected:cpn { __regex_compile_/b: }
23827 {
23828     __regex_if_in_class_or_catcode:TF
23829     { __regex_compile_raw_error:N b }
23830     {
23831         \tl_build_put_right:Nn \l__regex_build_tl
23832         { __regex_assertion:Nn \c_true_bool { __regex_b_test: } }
23833     }
23834 }
23835 \cs_new_protected:cpn { __regex_compile_/B: }
23836 {
23837     __regex_if_in_class_or_catcode:TF
23838     { __regex_compile_raw_error:N B }
23839     {
23840         \tl_build_put_right:Nn \l__regex_build_tl
23841         { __regex_assertion:Nn \c_false_bool { __regex_b_test: } }
23842     }
23843 }

```

(End definition for `_regex_compile/b:` and `_regex_compile/B:.`)

40.3.9 Character classes

`_regex_compile_:` Outside a class, right brackets have no meaning. In a class, change the mode ($m \rightarrow (m - 15)/13$, truncated) to reflect the fact that we are leaving the class. Look for quantifiers, unless we are still in a class after leaving one (the case of `[... \cL[...] ...]`). quantifiers.

```

23844 \cs_new_protected:cpn { \_regex_compile_ }
23845 {
23846   \_regex_if_in_class:TF
23847   {
23848     \if_int_compare:w \l__regex_mode_int >
23849       \c__regex_catcode_in_class_mode_int
23850       \tl_build_put_right:Nn \l__regex_build_tl { \if_false: { \fi: } }
23851     \fi:
23852     \tex_advance:D \l__regex_mode_int - 15 \exp_stop_f:
23853     \tex_divide:D \l__regex_mode_int 13 \exp_stop_f:
23854     \if_int_odd:w \l__regex_mode_int \else:
23855       \exp_after:wN \_regex_compile_quantifier:w
23856     \fi:
23857   }
23858   { \_regex_compile_raw:N ] }
23859 }

```

(End definition for `_regex_compile_:`)

`_regex_compile_[:` In a class, left brackets might introduce a POSIX character class, or mean nothing. Immediately following `\c<category>`, we must insert the appropriate catcode test, then parse the class; we pre-expand the catcode as an optimization. Otherwise (modes 0, -2 and -6) just parse the class. The mode is updated later.

```

23860 \cs_new_protected:cpn { \_regex_compile_[: }
23861 {
23862   \_regex_if_in_class:TF
23863   { \_regex_compile_class_posix_test:w }
23864   {
23865     \_regex_if_within_catcode:TF
23866     {
23867       \exp_after:wN \_regex_compile_class_catcode:w
23868       \int_use:N \l__regex_catcodes_int ;
23869     }
23870     { \_regex_compile_class_normal:w }
23871   }
23872 }

```

(End definition for `_regex_compile_[:`)

`_regex_compile_class_normal:w` In the “normal” case, we insert `_regex_class:NnnnN` *<boolean>* in the compiled code. The *<boolean>* is true for positive classes, and false for negative classes, characterized by a leading `^`. The auxiliary `_regex_compile_class:TFNN` also checks for a leading `]` which has a special meaning.

```

23873 \cs_new_protected:Npn \_regex_compile_class_normal:w
23874 {
23875   \_regex_compile_class:TFNN

```



```

23876     { \_regex\_class:NnnnN \c\_true\_bool }
23877     { \_regex\_class:NnnnN \c\_false\_bool }
23878   }

```

(End definition for _regex_compile_class_normal:w.)

_regex_compile_class_catcode:w This function is called for a left bracket in modes 2 or 6 (catcode test, and catcode test within a class). In mode 2 the whole construction needs to be put in a class (like single character). Then determine if the class is positive or negative, inserting _regex_item_catcode:nT or the reverse variant as appropriate, each with the current catcodes bitmap #1 as an argument, and reset the catcodes.

```

23879 \cs\_new\_protected:Npn \_regex\_compile\_class\_catcode:w #1;
23880 {
23881   \if\_int\_compare:w \l\_regex\_mode\_int = \c\_regex\_catcode\_mode\_int
23882     \tl\_build\_put\_right:Nn \l\_regex\_build\_tl
23883     { \_regex\_class:NnnnN \c\_true\_bool { \if\_false: } \fi: }
23884   \fi:
23885   \int\_set\_eq:NN \l\_regex\_catcodes\_int \l\_regex\_default\_catcodes\_int
23886   \_regex\_compile\_class:TFNN
23887     { \_regex\_item\_catcode:nT {#1} }
23888     { \_regex\_item\_catcode\_reverse:nT {#1} }
23889 }

```

(End definition for _regex_compile_class_catcode:w.)

_regex_compile_class:TFNN If the first character is ^, then the class is negative (use #2), otherwise it is positive (use #1). If the next character is a right bracket, then it should be changed to a raw one.

```

23890 \cs\_new\_protected:Npn \_regex\_compile\_class:TFNN #1#2#3#4
23891 {
23892   \l\_regex\_mode\_int = \int\_value:w \l\_regex\_mode\_int 3 \exp\_stop\_f:
23893   \_regex\_two\_if\_eq:NNNNTF #3 #4 \_regex\_compile\_special:N ^
23894   {
23895     \tl\_build\_put\_right:Nn \l\_regex\_build\_tl { #2 { \if\_false: } \fi: }
23896     \_regex\_compile\_class:NN
23897   }
23898   {
23899     \tl\_build\_put\_right:Nn \l\_regex\_build\_tl { #1 { \if\_false: } \fi: }
23900     \_regex\_compile\_class:NN #3 #4
23901   }
23902 }
23903 \cs\_new\_protected:Npn \_regex\_compile\_class:NN #1#2
23904 {
23905   \token\_if\_eq\_charcode:NNTF #2 ]
23906   { \_regex\_compile\_raw:N #2 }
23907   { #1 #2 }
23908 }

```

(End definition for _regex_compile_class:TFNN and _regex_compile_class:NN.)

_regex_compile_class_posix_test:w Here we check for a syntax such as [:alpha:]. We also detect [= and [. which have a meaning in POSIX regular expressions, but are not implemented in l3regex. In case we see [:, grab raw characters until hopefully reaching :]. If that's missing, or the POSIX class is unknown, abort. If all is right, add the test to the current class, with an extra _regex_item_reverse:n for negative classes.

```

23909 \cs_new_protected:Npn \__regex_compile_class_posix_test:w #1#2
23910 {
23911   \token_if_eq_meaning:NNT \__regex_compile_special:N #1
23912   {
23913     \str_case:nn { #2 }
23914     {
23915       : { \__regex_compile_class_posix:NNNNw }
23916       = {
23917         \__kernel_msg_warning:nmx { kernel }
23918         { posix-unsupported } { = }
23919       }
23920       . {
23921         \__kernel_msg_warning:nmx { kernel }
23922         { posix-unsupported } { . }
23923       }
23924     }
23925   }
23926   \__regex_compile_raw:N [ #1 #2
23927 }
23928 \cs_new_protected:Npn \__regex_compile_class_posix:NNNNw #1#2#3#4#5#6
23929 {
23930   \__regex_two_if_eq:NNNNTF #5 #6 \__regex_compile_special:N ^
23931   {
23932     \bool_set_false:N \l__regex_internal_bool
23933     \tl_set:Nx \l__regex_internal_a_tl { \if_false: } \fi:
23934     \__regex_compile_class_posix_loop:w
23935   }
23936   {
23937     \bool_set_true:N \l__regex_internal_bool
23938     \tl_set:Nx \l__regex_internal_a_tl { \if_false: } \fi:
23939     \__regex_compile_class_posix_loop:w #5 #6
23940   }
23941 }
23942 \cs_new:Npn \__regex_compile_class_posix_loop:w #1#2
23943 {
23944   \token_if_eq_meaning:NNTF \__regex_compile_raw:N #1
23945   { #2 \__regex_compile_class_posix_loop:w }
23946   { \if_false: { \fi: } \__regex_compile_class_posix_end:w #1 #2 }
23947 }
23948 \cs_new_protected:Npn \__regex_compile_class_posix_end:w #1#2#3#4
23949 {
23950   \__regex_two_if_eq:NNNNTF #1 #2 \__regex_compile_special:N :
23951   { \__regex_two_if_eq:NNNNTF #3 #4 \__regex_compile_special:N ] }
23952   { \use_ii:nn }
23953   {
23954     \cs_if_exist:cTF { __regex_posix_ \l__regex_internal_a_tl : }
23955     {
23956       \__regex_compile_one:n
23957       {
23958         \bool_if:NF \l__regex_internal_bool \__regex_item_reverse:n
23959         \exp_not:c { __regex_posix_ \l__regex_internal_a_tl : }
23960       }
23961     }
23962   }

```

```

23963         \_kernel_msg_warning:nxx { kernel } { posix-unknown }
23964         { \l__regex_internal_a_tl }
23965         \_regex_compile_abort_tokens:x
23966         {
23967             [: \bool_if:NF \l__regex_internal_bool { ^ }
23968             \l__regex_internal_a_tl :]
23969         }
23970     }
23971 }
23972 {
23973     \_kernel_msg_error:nxxx { kernel } { posix-missing-close }
23974     { [: \l__regex_internal_a_tl ] { #2 #4 }
23975     \_regex_compile_abort_tokens:x { [: \l__regex_internal_a_tl ]
23976     #1 #2 #3 #4
23977     }
23978 }

```

(End definition for `_regex_compile_class_posix_test:w` and others.)

40.3.10 Groups and alternations

`_regex_compile_group_begin:N` The contents of a regex group are turned into compiled code in `\l__regex_build_tl`, which ends up with items of the form `_regex_branch:n {⟨concatenation⟩}`. This construction is done using `\tl_build_...` functions within a `TeX` group, which automatically makes sure that options (case-sensitivity and default catcode) are reset at the end of the group. The argument `#1` is `_regex_group:nnnN` or a variant thereof. A small subtlety to support `\cL(abc)` as a shorthand for `(\cLa\cLb\cLc)`: exit any pending catcode test, save the category code at the start of the group as the default catcode for that group, and make sure that the catcode is restored to the default outside the group.

```

23979 \cs_new_protected:Npn \_regex_compile_group_begin:N #1
23980 {
23981     \tl_build_put_right:Nn \l__regex_build_tl { #1 { \if_false: } \fi: }
23982     \_regex_mode_quit_c:
23983     \group_begin:
23984         \tl_build_begin:N \l__regex_build_tl
23985         \int_set_eq:NN \l__regex_default_catcodes_int \l__regex_catcodes_int
23986         \int_incr:N \l__regex_group_level_int
23987         \tl_build_put_right:Nn \l__regex_build_tl
23988         { \_regex_branch:n { \if_false: } \fi: }
23989     }
23990 \cs_new_protected:Npn \_regex_compile_group_end:
23991 {
23992     \if_int_compare:w \l__regex_group_level_int > 0 \exp_stop_f:
23993         \tl_build_put_right:Nn \l__regex_build_tl { \if_false: { \fi: } }
23994         \tl_build_end:N \l__regex_build_tl
23995         \exp_args:NNNx
23996         \group_end:
23997         \tl_build_put_right:Nn \l__regex_build_tl { \l__regex_build_tl }
23998         \int_set_eq:NN \l__regex_catcodes_int \l__regex_default_catcodes_int
23999         \exp_after:wN \_regex_compile_quantifier:w
24000     \else:
24001         \_kernel_msg_warning:nn { kernel } { extra-rparen }

```

```

24002     \exp_after:wN \_regex_compile_raw:N \exp_after:wN )
24003   \fi:
24004 }

(End definition for \_regex_compile_group_begin:N and \_regex_compile_group_end:.)

```

`_regex_compile_(:` In a class, parentheses are not special. In a catcode test inside a class, a left parenthesis gives an error, to catch `[a\cL(bcd)e]`. Otherwise check for a `?`, denoting special groups, and run the code for the corresponding special group.

```

24005 \cs_new_protected:cpn { \_regex_compile_(: }
24006 {
24007   \_regex_if_in_class:TF { \_regex_compile_raw:N ( }
24008   {
24009     \if_int_compare:w \l_regex_mode_int =
24010       \c_regex_catcode_in_class_mode_int
24011       \_kernel_msg_error:nn { kernel } { c-lparen-in-class }
24012       \exp_after:wN \_regex_compile_raw:N \exp_after:wN (
24013     \else:
24014       \exp_after:wN \_regex_compile_lparen:w
24015     \fi:
24016   }
24017 }
24018 \cs_new_protected:Npn \_regex_compile_lparen:w #1#2#3#4
24019 {
24020   \_regex_two_if_eq:NNNTF #1 #2 \_regex_compile_special:N ?
24021   {
24022     \cs_if_exist_use:cF
24023       { \_regex_compile_special_group\_token_to_str:N #4 :w }
24024     {
24025       \_kernel_msg_warning:nnx { kernel } { special-group-unknown }
24026       { (? #4 }
24027       \_regex_compile_group_begin:N \_regex_group:nnnN
24028       \_regex_compile_raw:N ? #3 #4
24029     }
24030   }
24031   {
24032     \_regex_compile_group_begin:N \_regex_group:nnnN
24033     #1 #2 #3 #4
24034   }
24035 }

(End definition for \_regex_compile_(:.)

```

`_regex_compile_|:` In a class, the pipe is not special. Otherwise, end the current branch and open another one.

```

24036 \cs_new_protected:cpn { \_regex_compile_|: }
24037 {
24038   \_regex_if_in_class:TF { \_regex_compile_raw:N | }
24039   {
24040     \tl_build_put_right:Nn \l_regex_build_tl
24041       { \if_false: { \fi: } \_regex_branch:n { \if_false: } \fi: }
24042   }
24043 }

(End definition for \_regex_compile_|:.)

```

`__regex_compile_)`: Within a class, parentheses are not special. Outside, close a group.

```
24044 \cs_new_protected:cpn { __regex_compile_): }
24045 {
24046   \__regex_if_in_class:TF { \__regex_compile_raw:N ) }
24047   { \__regex_compile_group_end: }
24048 }
```

(End definition for `__regex_compile_)`.)

`__regex_compile_special_group::w` Non-capturing, and resetting groups are easy to take care of during compilation; for those
`__regex_compile_special_group|:w` groups, the harder parts come when building.

```
24049 \cs_new_protected:cpn { __regex_compile_special_group::w }
24050 { \__regex_compile_group_begin:N \__regex_group_no_capture:nnnN }
24051 \cs_new_protected:cpn { __regex_compile_special_group|:w }
24052 { \__regex_compile_group_begin:N \__regex_group_resetting:nnnN }
```

(End definition for `__regex_compile_special_group::w` and `__regex_compile_special_group|:w`.)

`__regex_compile_special_group_i:w` The match can be made case-insensitive by setting the option with `(?i)`; the original
`__regex_compile_special_group-:w` behaviour is restored by `(?-i)`. This is the only supported option.

```
24053 \cs_new_protected:Npn \__regex_compile_special_group_i:w #1#2
24054 {
24055   \__regex_two_if_eq:NNNTF #1 #2 \__regex_compile_special:N )
24056   {
24057     \cs_set:Npn \__regex_item_equal:n
24058     { \__regex_item_caseless_equal:n }
24059     \cs_set:Npn \__regex_item_range:nn
24060     { \__regex_item_caseless_range:nn }
24061   }
24062   {
24063     \__kernel_msg_warning:nnx { kernel } { unknown-option } { (?i #2 }
24064     \__regex_compile_raw:N (
24065     \__regex_compile_raw:N ?
24066     \__regex_compile_raw:N i
24067     #1 #2
24068   }
24069 }
24070 \cs_new_protected:cpn { __regex_compile_special_group-:w } #1#2#3#4
24071 {
24072   \__regex_two_if_eq:NNNTF #1 #2 \__regex_compile_raw:N i
24073   { \__regex_two_if_eq:NNNTF #3 #4 \__regex_compile_special:N ) }
24074   { \use_ii:nn }
24075   {
24076     \cs_set:Npn \__regex_item_equal:n
24077     { \__regex_item_caseful_equal:n }
24078     \cs_set:Npn \__regex_item_range:nn
24079     { \__regex_item_caseful_range:nn }
24080   }
24081   {
24082     \__kernel_msg_warning:nnx { kernel } { unknown-option } { (?-#2#4 }
24083     \__regex_compile_raw:N (
24084     \__regex_compile_raw:N ?
24085     \__regex_compile_raw:N -
24086     #1 #2 #3 #4
```

```

24087     }
24088 }

```

(End definition for `_regex_compile_special_group_i:w` and `_regex_compile_special_group_~:w`.)

40.3.11 Catcodes and csnames

`_regex_compile/c:` The `\c` escape sequence can be followed by a capital letter representing a character category, by a left bracket which starts a list of categories, or by a brace group holding a regular expression for a control sequence name. Otherwise, raise an error.

```

24089 \cs_new_protected:cpn { \_regex_compile/c: }
24090 { \_regex_chk_c_allowed:T { \_regex_compile_c_test:NN } }
24091 \cs_new_protected:Npn \_regex_compile_c_test:NN #1#2
24092 {
24093   \token_if_eq_meaning:NNTF #1 \_regex_compile_raw:N
24094   {
24095     \int_if_exist:cTF { c\_regex_catcode_#2_int }
24096     {
24097       \int_set_eq:Nc \l\_regex_catcodes_int
24098       { c\_regex_catcode_#2_int }
24099       \l\_regex_mode_int
24100       = \if_case:w \l\_regex_mode_int
24101         \c\_regex_catcode_mode_int
24102         \else:
24103           \c\_regex_catcode_in_class_mode_int
24104         \fi:
24105       \token_if_eq_charcode:NNT C #2 { \_regex_compile_c_C:NN }
24106     }
24107   }
24108   { \cs_if_exist_use:cF { \_regex_compile_c_#2:w } }
24109   {
24110     \__kernel_msg_error:nnx { kernel } { c-missing-category } {#2}
24111     #1 #2
24112   }
24113 }

```

(End definition for `_regex_compile/c:` and `_regex_compile_c_test:NN`.)

`_regex_compile_c_C:NN` If `\cC` is not followed by `.` or `(...)` then complain because that construction cannot match anything, except in cases like `\cC[\c{...}]`, where it has no effect.

```

24114 \cs_new_protected:Npn \_regex_compile_c_C:NN #1#2
24115 {
24116   \token_if_eq_meaning:NNTF #1 \_regex_compile_special:N
24117   {
24118     \token_if_eq_charcode:NNTF #2 .
24119     { \use_none:n }
24120     { \token_if_eq_charcode:NNF #2 ( } % )
24121   }
24122   { \use:n }
24123   { \__kernel_msg_error:nnn { kernel } { c-C-invalid } {#2} }
24124   #1 #2
24125 }

```

(End definition for `_regex_compile_c_C:NN`.)

```

24126 \cs_new_protected:cpn { __regex_compile_c[:w] } #1#2
24127 {
24128   \l__regex_mode_int
24129   = \if_case:w \l__regex_mode_int
24130     \c__regex_catcode_mode_int
24131     \else:
24132       \c__regex_catcode_in_class_mode_int
24133     \fi:
24134   \int_zero:N \l__regex_catcodes_int
24135   \__regex_two_if_eq:NNNTF #1 #2 \__regex_compile_special:N ^
24136   {
24137     \bool_set_false:N \l__regex_catcodes_bool
24138     \__regex_compile_c_lbrack_loop:NN
24139   }
24140   {
24141     \bool_set_true:N \l__regex_catcodes_bool
24142     \__regex_compile_c_lbrack_loop:NN
24143     #1 #2
24144   }
24145 }
24146 \cs_new_protected:Npn \__regex_compile_c_lbrack_loop:NN #1#2
24147 {
24148   \token_if_eq_meaning:NNTF #1 \__regex_compile_raw:N
24149   {
24150     \int_if_exist:cTF { c__regex_catcode_#2_int }
24151     {
24152       \exp_args:Nc \__regex_compile_c_lbrack_add:N
24153       { c__regex_catcode_#2_int }
24154       \__regex_compile_c_lbrack_loop:NN
24155     }
24156   }
24157   {
24158     \token_if_eq_charcode:NNTF #2 ]
24159     { \__regex_compile_c_lbrack_end: }
24160   }
24161   {
24162     \__kernel_msg_error:nmx { kernel } { c-missing-rbrack } {#2}
24163     \__regex_compile_c_lbrack_end:
24164     #1 #2
24165   }
24166 }
24167 \cs_new_protected:Npn \__regex_compile_c_lbrack_add:N #1
24168 {
24169   \if_int_odd:w \int_eval:n { \l__regex_catcodes_int / #1 } \exp_stop_f:
24170   \else:
24171     \int_add:Nn \l__regex_catcodes_int {#1}
24172   \fi:
24173 }
24174 \cs_new_protected:Npn \__regex_compile_c_lbrack_end:
24175 {
24176   \if_meaning:w \c_false_bool \l__regex_catcodes_bool
24177   \int_set:Nn \l__regex_catcodes_int

```

When encountering \c[, the task is to collect uppercase letters representing character categories. First check for ^ which negates the list of category codes.

```

24178         { \c__regex_all_catcodes_int - \l__regex_catcodes_int }
24179     \fi:
24180 }

```

(End definition for __regex_compile_c[:w and others.)

__regex_compile_c_{: The case of a left brace is easy, based on what we have done so far: in a group, compile the regular expression, after changing the mode to forbid nesting \c. Additionally, disable submatch tracking since groups don't escape the scope of \c{...}.

```

24181 \cs_new_protected:cpn { __regex_compile_c_ \c_left_brace_str :w }
24182 {
24183     \__regex_compile:w
24184     \__regex_disable_submatches:
24185     \l__regex_mode_int
24186     = \if_case:w \l__regex_mode_int
24187       \c__regex_cs_mode_int
24188     \else:
24189       \c__regex_cs_in_class_mode_int
24190     \fi:
24191 }

```

(End definition for __regex_compile_c_{:.)

__regex_compile_{: Non-escaped right braces are only special if they appear when compiling the regular expression for a csname, but not within a class: \c{[{}]} matches the control sequences \{ and \}. So, end compiling the inner regex (this closes any dangling class or group). __regex_compile_cs_aux:Nn Then insert the corresponding test in the outer regex. As an optimization, if the control sequence test simply consists of several explicit possibilities (branches) then use __regex_item_exact_cs:n with an argument consisting of all possibilities separated by \scan_stop:.

```

24192 \flag_new:n { __regex_cs }
24193 \cs_new_protected:cpn { __regex_compile_ \c_right_brace_str : }
24194 {
24195     \__regex_if_in_cs:TF
24196     { \__regex_compile_end_cs: }
24197     { \exp_after:wN \__regex_compile_raw:N \c_right_brace_str }
24198 }
24199 \cs_new_protected:Npn \__regex_compile_end_cs:
24200 {
24201     \__regex_compile_end:
24202     \flag_clear:n { __regex_cs }
24203     \tl_set:Nx \l__regex_internal_a_tl
24204     {
24205         \exp_after:wN \__regex_compile_cs_aux:Nn \l__regex_internal_regex
24206         \q_nil \q_nil \q_recursion_stop
24207     }
24208     \exp_args:Nx \__regex_compile_one:n
24209     {
24210         \flag_if_raised:nTF { __regex_cs }
24211         { \__regex_item_cs:n { \exp_not:o \l__regex_internal_regex } }
24212         {
24213             \__regex_item_exact_cs:n
24214             { \tl_tail:N \l__regex_internal_a_tl }
24215         }
24216     }
24217 }

```



```

24216     }
24217   }
24218   \cs_new:Npn \__regex_compile_cs_aux:Nn #1#2
24219   {
24220     \cs_if_eq:NNTF #1 \__regex_branch:n
24221     {
24222       \scan_stop:
24223       \__regex_compile_cs_aux:NNnnnN #2
24224       \q_nil \q_nil \q_nil \q_nil \q_nil \q_nil \q_recursion_stop
24225       \__regex_compile_cs_aux:Nn
24226     }
24227     {
24228       \quark_if_nil:NF #1 { \flag_raise_if_clear:n { __regex_cs } }
24229       \use_none_delimit_by_q_recursion_stop:w
24230     }
24231   }
24232   \cs_new:Npn \__regex_compile_cs_aux:NNnnnN #1#2#3#4#5#6
24233   {
24234     \bool_lazy_all:nTF
24235     {
24236       { \cs_if_eq_p:NN #1 \__regex_class:NnnnN }
24237       {#2}
24238       { \tl_if_head_eq_meaning_p:nN {#3} \__regex_item_caseful_equal:n }
24239       { \int_compare_p:nNn { \tl_count:n {#3} } = { 2 } }
24240       { \int_compare_p:nNn {#5} = { 0 } }
24241     }
24242     {
24243       \prg_replicate:nn {#4}
24244       { \char_generate:nn { \use_ii:nn #3 } {12} }
24245       \__regex_compile_cs_aux:NNnnnN
24246     }
24247     {
24248       \quark_if_nil:NF #1
24249       {
24250         \flag_raise_if_clear:n { __regex_cs }
24251         \use_i_delimit_by_q_recursion_stop:nw
24252       }
24253       \use_none_delimit_by_q_recursion_stop:w
24254     }
24255   }

```

(End definition for __regex_compile_}: and others.)

40.3.12 Raw token lists with \u

__regex_compile_/u: The \u escape is invalid in classes and directly following a catcode test. Otherwise, it must be followed by a left brace. We then collect the characters for the argument of \u within an x-expanding assignment. In principle we could just wait to encounter a right brace, but this is unsafe: if the right brace was missing, then we would reach the end-markers of the regex, and continue, leading to obscure fatal errors. Instead, we only allow raw and special characters, and stop when encountering a special right brace, any escaped character, or the end-marker.

```

24256   \cs_new_protected:cpn { __regex_compile_/u: } #1#2
24257   {

```

```

24258 \_regex_if_in_class_or_catcode:TF
24259 { \_regex_compile_raw_error:N u #1 #2 }
24260 {
24261   \_regex_two_if_eq:NNNTF #1 #2 \_regex_compile_special:N \c_left_brace_str
24262   {
24263     \tl_set:Nx \l__regex_internal_a_tl { \if_false: } \fi:
24264     \_regex_compile_u_loop:NN
24265   }
24266   {
24267     \_kernel_msg_error:nn { kernel } { u-missing-lbrace }
24268     \_regex_compile_raw:N u #1 #2
24269   }
24270 }
24271 }
24272 \cs_new:Npn \_regex_compile_u_loop:NN #1#2
24273 {
24274   \token_if_eq_meaning:NNTF #1 \_regex_compile_raw:N
24275   { #2 \_regex_compile_u_loop:NN }
24276   {
24277     \token_if_eq_meaning:NNTF #1 \_regex_compile_special:N
24278     {
24279       \exp_after:wN \token_if_eq_charcode:NNTF \c_right_brace_str #2
24280       { \if_false: { \fi: } \_regex_compile_u_end: }
24281       { #2 \_regex_compile_u_loop:NN }
24282     }
24283     {
24284       \if_false: { \fi: }
24285       \_kernel_msg_error:nnx { kernel } { u-missing-rbrace } {#2}
24286       \_regex_compile_u_end:
24287       #1 #2
24288     }
24289   }
24290 }

```

(End definition for _regex_compile_/u: and _regex_compile_u_loop:NN.)

_regex_compile_u_end: Once we have extracted the variable's name, we store the contents of that variable in \l__regex_internal_a_tl. The behaviour of \u then depends on whether we are within a \c{...} escape (in this case, the variable is turned to a string), or not.

```

24291 \cs_new_protected:Npn \_regex_compile_u_end:
24292 {
24293   \tl_set:Nv \l__regex_internal_a_tl { \l__regex_internal_a_tl }
24294   \if_int_compare:w \l__regex_mode_int = \c__regex_outer_mode_int
24295   \_regex_compile_u_not_cs:
24296   \else:
24297     \_regex_compile_u_in_cs:
24298   \fi:
24299 }

```

(End definition for _regex_compile_u_end:.)

_regex_compile_u_in_cs: When \u appears within a control sequence, we convert the variable to a string with escaped spaces. Then for each character insert a class matching exactly that character, once.

```

24300 \cs_new_protected:Npn \__regex_compile_u_in_cs:
24301 {
24302   \tl_gset:Nx \g__regex_internal_tl
24303   {
24304     \exp_args:No \__kernel_str_to_other_fast:n
24305     { \l__regex_internal_a_tl }
24306   }
24307   \tl_build_put_right:Nx \l__regex_build_tl
24308   {
24309     \tl_map_function:NN \g__regex_internal_tl
24310     \__regex_compile_u_in_cs_aux:n
24311   }
24312 }
24313 \cs_new:Npn \__regex_compile_u_in_cs_aux:n #1
24314 {
24315   \__regex_class:NnnnN \c_true_bool
24316   { \__regex_item_caseful_equal:n { \int_value:w '#1 } }
24317   { 1 } { 0 } \c_false_bool
24318 }

```

(End definition for __regex_compile_u_in_cs:.)

__regex_compile_u_not_cs: In mode 0, the \u escape adds one state to the NFA for each token in \l__regex_internal_a_tl. If a given *<token>* is a control sequence, then insert a string comparison test, otherwise, __regex_item_exact:nn which compares catcode and character code.

```

24319 \cs_new_protected:Npn \__regex_compile_u_not_cs:
24320 {
24321   \tl_analysis_map_inline:Nn \l__regex_internal_a_tl
24322   {
24323     \tl_build_put_right:Nx \l__regex_build_tl
24324     {
24325       \__regex_class:NnnnN \c_true_bool
24326       {
24327         \if_int_compare:w "##3 = 0 \exp_stop_f:
24328         \__regex_item_exact_cs:n
24329         { \exp_after:wN \cs_to_str:N ##1 }
24330         \else:
24331         \__regex_item_exact:nn { \int_value:w "##3 } { ##2 }
24332         \fi:
24333       }
24334       { 1 } { 0 } \c_false_bool
24335     }
24336   }
24337 }

```

(End definition for __regex_compile_u_not_cs:.)

40.3.13 Other

__regex_compile_/K: The \K control sequence is currently the only “command”, which performs some action, rather than matching something. It is allowed in the same contexts as \b. At the compilation stage, we leave it as a single control sequence, defined later.

```

24338 \cs_new_protected:cpn { __regex_compile_/K: }
24339 {

```

```

24340 \int_compare:nNnTF \l__regex_mode_int = \c__regex_outer_mode_int
24341 { \tl_build_put_right:Nn \l__regex_build_tl { \__regex_command_K: } }
24342 { \__regex_compile_raw_error:N K }
24343 }

```

(End definition for __regex_compile_/K:.)

40.3.14 Showing regexes

__regex_show:N Within a group and within \tl_build_begin:N ... \tl_build_end:N we redefine all the function that can appear in a compiled regex, then run the regex. The result stored in \l__regex_internal_a_tl is then meant to be shown.

```

24344 \cs_new_protected:Npn \__regex_show:N #1
24345 {
24346   \group_begin:
24347   \tl_build_begin:N \l__regex_build_tl
24348   \cs_set_protected:Npn \__regex_branch:n
24349   {
24350     \seq_pop_right:NN \l__regex_show_prefix_seq
24351     \l__regex_internal_a_tl
24352     \__regex_show_one:n { +-branch }
24353     \seq_put_right:No \l__regex_show_prefix_seq
24354     \l__regex_internal_a_tl
24355     \use:n
24356   }
24357   \cs_set_protected:Npn \__regex_group:nnnN
24358   { \__regex_show_group_aux:nnnnN { } }
24359   \cs_set_protected:Npn \__regex_group_no_capture:nnnN
24360   { \__regex_show_group_aux:nnnnN { ~(no~capture) } }
24361   \cs_set_protected:Npn \__regex_group_resetting:nnnN
24362   { \__regex_show_group_aux:nnnnN { ~(resetting) } }
24363   \cs_set_eq:NN \__regex_class:NnnnN \__regex_show_class:NnnnN
24364   \cs_set_protected:Npn \__regex_command_K:
24365   { \__regex_show_one:n { reset~match~start~(\iow_char:N\K) } }
24366   \cs_set_protected:Npn \__regex_assertion:Nn ##1##2
24367   {
24368     \__regex_show_one:n
24369     { \bool_if:NF ##1 { negative~ } assertion:~##2 }
24370   }
24371   \cs_set:Npn \__regex_b_test: { word~boundary }
24372   \cs_set_eq:NN \__regex_anchor:N \__regex_show_anchor_to_str:N
24373   \cs_set_protected:Npn \__regex_item_caseful_equal:n ##1
24374   { \__regex_show_one:n { char~code~\int_eval:n{##1} } }
24375   \cs_set_protected:Npn \__regex_item_caseful_range:nn ##1##2
24376   {
24377     \__regex_show_one:n
24378     { range~[\int_eval:n{##1}, \int_eval:n{##2}] }
24379   }
24380   \cs_set_protected:Npn \__regex_item_caseless_equal:n ##1
24381   { \__regex_show_one:n { char~code~\int_eval:n{##1}~(caseless) } }
24382   \cs_set_protected:Npn \__regex_item_caseless_range:nn ##1##2
24383   {
24384     \__regex_show_one:n
24385     { Range~[\int_eval:n{##1}, \int_eval:n{##2}]~(caseless) }

```

```

24386     }
24387     \cs_set_protected:Npn \__regex_item_catcode:nT
24388       { \__regex_show_item_catcode:NnT \c_true_bool }
24389     \cs_set_protected:Npn \__regex_item_catcode_reverse:nT
24390       { \__regex_show_item_catcode:NnT \c_false_bool }
24391     \cs_set_protected:Npn \__regex_item_reverse:n
24392       { \__regex_show_scope:nn { Reversed~match } }
24393     \cs_set_protected:Npn \__regex_item_exact:nn ##1##2
24394       { \__regex_show_one:n { char~##2,~catcode~##1 } }
24395     \cs_set_eq:NN \__regex_item_exact_cs:n \__regex_show_item_exact_cs:n
24396     \cs_set_protected:Npn \__regex_item_cs:n
24397       { \__regex_show_scope:nn { control~sequence } }
24398     \cs_set:cpn { \__regex_prop.: } { \__regex_show_one:n { any~token } }
24399     \seq_clear:N \l__regex_show_prefix_seq
24400     \__regex_show_push:n { ~ }
24401     \cs_if_exist_use:N #1
24402     \tl_build_end:N \l__regex_build_tl
24403     \exp_args:NNNo
24404     \group_end:
24405     \tl_set:Nn \l__regex_internal_a_tl { \l__regex_build_tl }
24406   }

```

(End definition for __regex_show:N.)

__regex_show_one:n Every part of the final message go through this function, which adds one line to the output, with the appropriate prefix.

```

24407 \cs_new_protected:Npn \__regex_show_one:n #1
24408 {
24409   \int_incr:N \l__regex_show_lines_int
24410   \tl_build_put_right:Nx \l__regex_build_tl
24411   {
24412     \exp_not:N \iow_newline:
24413     \seq_map_function:NN \l__regex_show_prefix_seq \use:n
24414     #1
24415   }
24416 }

```

(End definition for __regex_show_one:n.)

__regex_show_push:n Enter and exit levels of nesting. The scope function prints its first argument as an “introduction”, then performs its second argument in a deeper level of nesting.

```

\__regex_show_pop:
\__regex_show_scope:nn
24417 \cs_new_protected:Npn \__regex_show_push:n #1
24418 { \seq_put_right:Nx \l__regex_show_prefix_seq { #1 ~ } }
24419 \cs_new_protected:Npn \__regex_show_pop:
24420 { \seq_pop_right:NN \l__regex_show_prefix_seq \l__regex_internal_a_tl }
24421 \cs_new_protected:Npn \__regex_show_scope:nn #1#2
24422 {
24423   \__regex_show_one:n {#1}
24424   \__regex_show_push:n { ~ }
24425   #2
24426   \__regex_show_pop:
24427 }

```

(End definition for __regex_show_push:n, __regex_show_pop:, and __regex_show_scope:nn.)

`__regex_show_group_aux:nnnnN`

We display all groups in the same way, simply adding a message, (no capture) or (resetting), to special groups. The odd `\use_ii:nn` avoids printing a spurious +-branch for the first branch.

```
24428 \cs_new_protected:Npn \__regex_show_group_aux:nnnnN #1#2#3#4#5
24429 {
24430   \__regex_show_one:n { , -group~begin #1 }
24431   \__regex_show_push:n { | }
24432   \use_ii:nn #2
24433   \__regex_show_pop:
24434   \__regex_show_one:n
24435   { ' -group~end \__regex_msg_repeated:nnN {#3} {#4} #5 }
24436 }
```

(End definition for `__regex_show_group_aux:nnnnN`.)

`__regex_show_class:NnnnN`

I'm entirely unhappy about this function: I couldn't find a way to test if a class is a single test. Instead, collect the representation of the tests in the class. If that had more than one line, write Match or Don't match on its own line, with the repeating information if any. Then the various tests on lines of their own, and finally a line. Otherwise, we need to evaluate the representation of the tests again (since the prefix is incorrect). That's clunky, but not too expensive, since it's only one test.

```
24437 \cs_set:Npn \__regex_show_class:NnnnN #1#2#3#4#5
24438 {
24439   \group_begin:
24440   \tl_build_begin:N \l__regex_build_tl
24441   \int_zero:N \l__regex_show_lines_int
24442   \__regex_show_push:n {~}
24443   #2
24444   \int_compare:nTF { \l__regex_show_lines_int = 0 }
24445   {
24446     \group_end:
24447     \__regex_show_one:n { \bool_if:NTF #1 { Fail } { Pass } }
24448   }
24449   {
24450     \bool_if:nTF
24451     { #1 && \int_compare_p:n { \l__regex_show_lines_int = 1 } }
24452     {
24453       \group_end:
24454       #2
24455       \tl_build_put_right:Nn \l__regex_build_tl
24456       { \__regex_msg_repeated:nnN {#3} {#4} #5 }
24457     }
24458     {
24459       \tl_build_end:N \l__regex_build_tl
24460       \exp_args:NNNo
24461       \group_end:
24462       \tl_set:Nn \l__regex_internal_a_tl \l__regex_build_tl
24463       \__regex_show_one:n
24464       {
24465         \bool_if:NTF #1 { Match } { Don't~match }
24466         \__regex_msg_repeated:nnN {#3} {#4} #5
24467       }
24468       \tl_build_put_right:Nx \l__regex_build_tl
```

```

24469         { \exp_not:o \l__regex_internal_a_tl }
24470     }
24471 }
24472 }

```

(End definition for __regex_show_class:NnnnN.)

__regex_show_anchor_to_str:N The argument is an integer telling us where the anchor is. We convert that to the relevant info.

```

24473 \cs_new:Npn \__regex_show_anchor_to_str:N #1
24474 {
24475     anchor~at~
24476     \str_case:nnF { #1 }
24477     {
24478         { \l__regex_min_pos_int } { start~(\iow_char:N\A) }
24479         { \l__regex_start_pos_int } { start~of~match~(\iow_char:N\G) }
24480         { \l__regex_max_pos_int } { end~(\iow_char:N\Z) }
24481     }
24482     { <error:~'#1'~not~recognized> }
24483 }

```

(End definition for __regex_show_anchor_to_str:N.)

__regex_show_item_catcode:NnT Produce a sequence of categories which the catcode bitmap #2 contains, and show it, indenting the tests on which this catcode constraint applies.

```

24484 \cs_new_protected:Npn \__regex_show_item_catcode:NnT #1#2
24485 {
24486     \seq_set_split:Nnn \l__regex_internal_seq { } { CBEMTPUDSLOA }
24487     \seq_set_filter:Nnn \l__regex_internal_seq \l__regex_internal_seq
24488     { \int_if_odd_p:n { #2 / \int_use:c { c__regex_catcode_##1_int } } }
24489     \__regex_show_scope:nn
24490     {
24491         categories~
24492         \seq_map_function:NN \l__regex_internal_seq \use:n
24493         , ~
24494         \bool_if:NF #1 { negative~ } class
24495     }
24496 }

```

(End definition for __regex_show_item_catcode:NnT.)

__regex_show_item_exact_cs:n

```

24497 \cs_new_protected:Npn \__regex_show_item_exact_cs:n #1
24498 {
24499     \seq_set_split:Nnn \l__regex_internal_seq { \scan_stop: } {#1}
24500     \seq_set_map:Nnn \l__regex_internal_seq
24501     \l__regex_internal_seq { \iow_char:N\##1 }
24502     \__regex_show_one:n
24503     { control~sequence~ \seq_use:Nn \l__regex_internal_seq { ~or~ } }
24504 }

```

(End definition for __regex_show_item_exact_cs:n.)

40.4 Building

40.4.1 Variables used while building

`\l__regex_min_state_int` The last state that was allocated is `\l__regex_max_state_int - 1`, so that `\l__regex_max_state_int` always points to a free state. The `min_state` variable is 1 to begin with, but gets shifted in nested calls to the matching code, namely in `\c{...}` constructions.

```
24505 \int_new:N \l__regex_min_state_int
24506 \int_set:Nn \l__regex_min_state_int { 1 }
24507 \int_new:N \l__regex_max_state_int
```

(End definition for `\l__regex_min_state_int` and `\l__regex_max_state_int`.)

`\l__regex_left_state_int` Alternatives are implemented by branching from a `left` state into the various choices, then merging those into a `right` state. We store information about those states in two sequences. Those states are also used to implement group quantifiers. Most often, the `\l__regex_right_state_int` left and right pointers only differ by 1.
`\l__regex_left_state_seq`
`\l__regex_right_state_seq`

```
24508 \int_new:N \l__regex_left_state_int
24509 \int_new:N \l__regex_right_state_int
24510 \seq_new:N \l__regex_left_state_seq
24511 \seq_new:N \l__regex_right_state_seq
```

(End definition for `\l__regex_left_state_int` and others.)

`\l__regex_capturing_group_int` `\l__regex_capturing_group_int` is the next ID number to be assigned to a capturing group. This starts at 0 for the group enclosing the full regular expression, and groups are counted in the order of their left parenthesis, except when encountering `resetting` groups.

```
24512 \int_new:N \l__regex_capturing_group_int
```

(End definition for `\l__regex_capturing_group_int`.)

40.4.2 Framework

This phase is about going from a compiled regex to an NFA. Each state of the NFA is stored in a `\toks`. The operations which can appear in the `\toks` are

- `__regex_action_start_wildcard`: inserted at the start of the regular expression to make it unanchored.
- `__regex_action_success`: marks the exit state of the NFA.
- `__regex_action_cost:n {⟨shift⟩}` is a transition from the current $\langle state \rangle$ to $\langle state \rangle + \langle shift \rangle$, which consumes the current character: the target state is saved and will be considered again when matching at the next position.
- `__regex_action_free:n {⟨shift⟩}`, and `__regex_action_free_group:n {⟨shift⟩}` are free transitions, which immediately perform the actions for the state $\langle state \rangle + \langle shift \rangle$ of the NFA. They differ in how they detect and avoid infinite loops. For now, we just need to know that the `group` variant must be used for transitions back to the start of a group.
- `__regex_action_submatch:n {⟨key⟩}` where the $\langle key \rangle$ is a group number followed by `<` or `>` for the beginning or end of group. This causes the current position in the query to be stored as the $\langle key \rangle$ submatch boundary.

We strive to preserve the following properties while building.

- The current capturing group is `capturing_group - 1`, and if a group opened now it would be labelled `capturing_group`.
- The last allocated state is `max_state - 1`, so `max_state` is a free state.
- The `left_state` points to a state to the left of the current group or of the last class.
- The `right_state` points to a newly created, empty state, with some transitions leading to it.
- The `left/right` sequences hold a list of the corresponding end-points of nested groups.

`__regex_build:n` The `n`-type function first compiles its argument. Reset some variables. Allocate two states, and put a wildcard in state 0 (transitions to state 1 and 0 state). Then build the regex within a (capturing) group numbered 0 (current value of `capturing_group`). Finally, if the match reaches the last state, it is successful.

```

24513 \cs_new_protected:Npn \__regex_build:n #1
24514 {
24515     \__regex_compile:n {#1}
24516     \__regex_build:N \l__regex_internal_regex
24517 }
24518 \__kernel_patch:nnNNpn
24519 { \__regex_trace_push:nnN { regex } { 1 } \__regex_build:N }
24520 {
24521     \__regex_trace_states:n { 2 }
24522     \__regex_trace_pop:nnN { regex } { 1 } \__regex_build:N
24523 }
24524 \cs_new_protected:Npn \__regex_build:N #1
24525 {
24526     \__regex_standard_escapechar:
24527     \int_zero:N \l__regex_capturing_group_int
24528     \int_set_eq:NN \l__regex_max_state_int \l__regex_min_state_int
24529     \__regex_build_new_state:
24530     \__regex_build_new_state:
24531     \__regex_toks_put_right:Nn \l__regex_left_state_int
24532     { \__regex_action_start_wildcard: }
24533     \__regex_group:nnnN {#1} { 1 } { 0 } \c_false_bool
24534     \__regex_toks_put_right:Nn \l__regex_right_state_int
24535     { \__regex_action_success: }
24536 }
```

(End definition for `__regex_build:n` and `__regex_build:N`.)

`__regex_build_for_cs:n` The matching code relies on some global intarray variables, but only uses a range of their entries. Specifically,

- `\g__regex_state_active_intarray` from `\l__regex_min_state_int` to `\l__regex_max_state_1`;
- `\g__regex_thread_state_intarray` from `\l__regex_min_active_int` to `\l__regex_max_activ_1`.

In fact, some data is stored in `\toks` registers (local) in the same ranges so these ranges mustn't overlap. This is done by setting `\l__regex_min_active_int` to `\l__regex_max_state_int` after building the NFA. Here, in this nested call to the matching code, we need the new versions of these ranges to involve completely new entries of the intarray variables, so we begin by setting (the new) `\l__regex_min_state_int` to (the old) `\l__regex_max_active_int` to use higher entries.

When using a regex to match a cs, we don't insert a wildcard, we anchor at the end, and since we ignore submatches, there is no need to surround the expression with a group. However, for branches to work properly at the outer level, we need to put the appropriate left and right states in their sequence.

```

24537 \__kernel_patch:nnNNpn
24538 { \__regex_trace_push:nnN { regex } { 1 } \__regex_build_for_cs:n }
24539 {
24540   \__regex_trace_states:n { 2 }
24541   \__regex_trace_pop:nnN { regex } { 1 } \__regex_build_for_cs:n
24542 }
24543 \cs_new_protected:Npn \__regex_build_for_cs:n #1
24544 {
24545   \int_set_eq:NN \l__regex_min_state_int \l__regex_max_active_int
24546   \int_set_eq:NN \l__regex_max_state_int \l__regex_min_state_int
24547   \__regex_build_new_state:
24548   \__regex_build_new_state:
24549   \__regex_push_lr_states:
24550   #1
24551   \__regex_pop_lr_states:
24552   \__regex_toks_put_right:Nn \l__regex_right_state_int
24553   {
24554     \if_int_compare:w \l__regex_curr_pos_int = \l__regex_max_pos_int
24555       \exp_after:wN \__regex_action_success:
24556     \fi:
24557   }
24558 }

```

(End definition for `__regex_build_for_cs:n`.)

40.4.3 Helpers for building an nfa

`__regex_push_lr_states:` When building the regular expression, we keep track of pointers to the left-end and
`__regex_pop_lr_states:` right-end of each group without help from T_EX's grouping.

```

24559 \cs_new_protected:Npn \__regex_push_lr_states:
24560 {
24561   \seq_push:No \l__regex_left_state_seq
24562   { \int_use:N \l__regex_left_state_int }
24563   \seq_push:No \l__regex_right_state_seq
24564   { \int_use:N \l__regex_right_state_int }
24565 }
24566 \cs_new_protected:Npn \__regex_pop_lr_states:
24567 {
24568   \seq_pop:NN \l__regex_left_state_seq \l__regex_internal_a_tl
24569   \int_set:Nn \l__regex_left_state_int \l__regex_internal_a_tl
24570   \seq_pop:NN \l__regex_right_state_seq \l__regex_internal_a_tl
24571   \int_set:Nn \l__regex_right_state_int \l__regex_internal_a_tl
24572 }

```

(End definition for `_regex_push_lr_states:` and `_regex_pop_lr_states:`)

`_regex_build_transition_left:NNN` Add a transition from #2 to #3 using the function #1. The `left` function is used for higher priority transitions, and the `right` function for lower priority transitions (which should be performed later). The signatures differ to reflect the differing usage later on. Both functions could be optimized.

`_regex_build_transition_right:nNn`

```
24573 \cs_new_protected:Npn \_regex_build_transition_left:NNN #1#2#3
24574 { \_regex_toks_put_left:Nx #2 { #1 { \int_eval:n { #3 - #2 } } } }
24575 \cs_new_protected:Npn \_regex_build_transition_right:nNn #1#2#3
24576 { \_regex_toks_put_right:Nx #2 { #1 { \int_eval:n { #3 - #2 } } } }
```

(End definition for `_regex_build_transition_left:NNN` and `_regex_build_transition_right:nNn`.)

`_regex_build_new_state:` Add a new empty state to the NFA. Then update the `left`, `right`, and `max` states, so that the `right` state is the new empty state, and the `left` state points to the previously “current” state.

```
24577 \__kernel_patch:nnNNpn
24578 {
24579   \_regex_trace:nxx { regex } { 2 }
24580   {
24581     regex~new~state~
24582     L=\int_use:N \l__regex_left_state_int ~ -> ~
24583     R=\int_use:N \l__regex_right_state_int ~ -> ~
24584     M=\int_use:N \l__regex_max_state_int ~ -> ~
24585     \int_eval:n { \l__regex_max_state_int + 1 }
24586   }
24587 }
24588 { }
24589 \cs_new_protected:Npn \_regex_build_new_state:
24590 {
24591   \_regex_toks_clear:N \l__regex_max_state_int
24592   \int_set_eq:NN \l__regex_left_state_int \l__regex_right_state_int
24593   \int_set_eq:NN \l__regex_right_state_int \l__regex_max_state_int
24594   \int_incr:N \l__regex_max_state_int
24595 }
```

(End definition for `_regex_build_new_state:`)

`_regex_build_transitions_lazy:NNNNN` This function creates a new state, and puts two transitions starting from the old current state. The order of the transitions is controlled by #1, true for lazy quantifiers, and false for greedy quantifiers.

```
24596 \cs_new_protected:Npn \_regex_build_transitions_lazy:NNNNN #1#2#3#4#5
24597 {
24598   \_regex_build_new_state:
24599   \_regex_toks_put_right:Nx \l__regex_left_state_int
24600   {
24601     \if_meaning:w \c_true_bool #1
24602       #2 { \int_eval:n { #3 - \l__regex_left_state_int } }
24603       #4 { \int_eval:n { #5 - \l__regex_left_state_int } }
24604     \else:
24605       #4 { \int_eval:n { #5 - \l__regex_left_state_int } }
24606       #2 { \int_eval:n { #3 - \l__regex_left_state_int } }
24607     \fi:
24608   }
24609 }
```

(End definition for `_regex_build_transitions_lazy:NNNN`.)

40.4.4 Building classes

`_regex_class:NnnnN` The arguments are: $\langle \text{boolean} \rangle$ $\{\langle \text{tests} \rangle\}$ $\{\langle \text{min} \rangle\}$ $\{\langle \text{more} \rangle\}$ $\langle \text{laziness} \rangle$. First store the tests with a trailing `_regex_action_cost:n`, in the true branch of `_regex_break_point:TF` for positive classes, or the false branch for negative classes. The integer $\langle \text{more} \rangle$ is 0 for fixed repetitions, -1 for unbounded repetitions, and $\langle \text{max} \rangle - \langle \text{min} \rangle$ for a range of repetitions.

```

24610 \cs_new_protected:Npn \_regex_class:NnnnN #1#2#3#4#5
24611 {
24612   \cs_set:Npx \_regex_tests_action_cost:n ##1
24613   {
24614     \exp_not:n { \exp_not:n {#2} }
24615     \bool_if:NTF #1
24616       { \_regex_break_point:TF { \_regex_action_cost:n {##1} } { } }
24617       { \_regex_break_point:TF { } { \_regex_action_cost:n {##1} } }
24618   }
24619   \if_case:w - #4 \exp_stop_f:
24620     \_regex_class_repeat:n {#3}
24621   \or: \_regex_class_repeat:nN {#3} #5
24622   \else: \_regex_class_repeat:nnN {#3} {#4} #5
24623   \fi:
24624 }
24625 \cs_new:Npn \_regex_tests_action_cost:n { \_regex_action_cost:n }

```

(End definition for `_regex_class:NnnnN` and `_regex_tests_action_cost:n`.)

`_regex_class_repeat:n` This is used for a fixed number of repetitions. Build one state for each repetition, with a transition controlled by the tests that we have collected. That works just fine for $\#1 = 0$ repetitions: nothing is built.

```

24626 \cs_new_protected:Npn \_regex_class_repeat:n #1
24627 {
24628   \prg_replicate:nn {#1}
24629   {
24630     \_regex_build_new_state:
24631     \_regex_build_transition_right:nNn \_regex_tests_action_cost:n
24632     \l__regex_left_state_int \l__regex_right_state_int
24633   }
24634 }

```

(End definition for `_regex_class_repeat:n`.)

`_regex_class_repeat:nN` This implements unbounded repetitions of a single class (e.g. the $*$ and $+$ quantifiers). If the minimum number $\#1$ of repetitions is 0, then build a transition from the current state to itself governed by the tests, and a free transition to a new state (hence skipping the tests). Otherwise, call `_regex_class_repeat:n` for the code to match $\#1$ repetitions, and add free transitions from the last state to the previous one, and to a new one. In both cases, the order of transitions is controlled by the laziness boolean $\#2$.

```

24635 \cs_new_protected:Npn \_regex_class_repeat:nN #1#2
24636 {
24637   \if_int_compare:w #1 = 0 \exp_stop_f:
24638     \_regex_build_transitions_lazy:NNNN #2

```

```

24639     \_regex_action_free:n      \l__regex_right_state_int
24640     \_regex_tests_action_cost:n \l__regex_left_state_int
24641   \else:
24642     \_regex_class_repeat:n {#1}
24643     \int_set_eq:NN \l__regex_internal_a_int \l__regex_left_state_int
24644     \_regex_build_transitions_lazyness:NNNN #2
24645     \_regex_action_free:n \l__regex_right_state_int
24646     \_regex_action_free:n \l__regex_internal_a_int
24647   \fi:
24648 }

```

(End definition for _regex_class_repeat:nn.)

_regex_class_repeat:nnN

We want to build the code to match from #1 to #1 + #2 repetitions. Match #1 repetitions (can be 0). Compute the final state of the next construction as **a**. Build #2 > 0 states, each with a transition to the next state governed by the tests, and a transition to the final state **a**. The computation of **a** is safe because states are allocated in order, starting from **max_state**.

```

24649 \cs_new_protected:Npn \_regex_class_repeat:nnN #1#2#3
24650 {
24651   \_regex_class_repeat:n {#1}
24652   \int_set:Nn \l__regex_internal_a_int
24653     { \l__regex_max_state_int + #2 - 1 }
24654   \prg_replicate:nn { #2 }
24655   {
24656     \_regex_build_transitions_lazyness:NNNN #3
24657     \_regex_action_free:n      \l__regex_internal_a_int
24658     \_regex_tests_action_cost:n \l__regex_right_state_int
24659   }
24660 }

```

(End definition for _regex_class_repeat:nnN.)

40.4.5 Building groups

_regex_group_aux:nnnnN

Arguments: {<label>} {<contents>} {<min>} {<more>} <lazyness>. If <min> is 0, we need to add a state before building the group, so that the thread which skips the group does not also set the start-point of the submatch. After adding one more state, the **left_state** is the left end of the group, from which all branches stem, and the **right_state** is the right end of the group, and all branches end their course in that state. We store those two integers to be queried for each branch, we build the NFA states for the contents #2 of the group, and we forget about the two integers. Once this is done, perform the repetition: either exactly #3 times, or #3 or more times, or between #3 and #3 + #4 times, with lazyness #5. The <label> #1 is used for submatch tracking. Each of the three auxiliaries expects **left_state** and **right_state** to be set properly.

```

24661 \_kernel_patch:nnNnpn
24662 { \_regex_trace_push:nnN { regex } { 1 } \_regex_group_aux:nnnnN }
24663 { \_regex_trace_pop:nnN { regex } { 1 } \_regex_group_aux:nnnnN }
24664 \cs_new_protected:Npn \_regex_group_aux:nnnnN #1#2#3#4#5
24665 {
24666   \if_int_compare:w #3 = 0 \exp_stop_f:
24667     \_regex_build_new_state:
24668   <assert>\assert_int:n { \l__regex_max_state_int = \l__regex_right_state_int + 1 }

```

```

24669     \_regex_build_transition_right:nNn \_regex_action_free_group:n
24670     \l__regex_left_state_int \l__regex_right_state_int
24671   \fi:
24672   \_regex_build_new_state:
24673   \_regex_push_lr_states:
24674   #2
24675   \_regex_pop_lr_states:
24676   \if_case:w - #4 \exp_stop_f:
24677     \_regex_group_repeat:nn {#1} {#3}
24678   \or:  \_regex_group_repeat:nnN {#1} {#3}      #5
24679   \else: \_regex_group_repeat:nnnN {#1} {#3} {#4} #5
24680   \fi:
24681 }

```

(End definition for _regex_group_aux:nnnnN.)

_regex_group:nnnN Hand to _regex_group_aux:nnnnN the label of that group (expanded), and the group itself, with some extra commands to perform.

```

24682 \cs_new_protected:Npn \_regex_group:nnnN #1
24683 {
24684   \exp_args:No \_regex_group_aux:nnnnN
24685   { \int_use:N \l__regex_capturing_group_int }
24686   {
24687     \int_incr:N \l__regex_capturing_group_int
24688     #1
24689   }
24690 }
24691 \cs_new_protected:Npn \_regex_group_no_capture:nnnN
24692 { \_regex_group_aux:nnnnN { -1 } }

```

(End definition for _regex_group:nnnN and _regex_group_no_capture:nnnN.)

_regex_group_resetting:nnnN Again, hand the label -1 to _regex_group_aux:nnnnN, but this time we work a little bit harder to keep track of the maximum group label at the end of any branch, and to reset the group number at each branch. This relies on the fact that a compiled regex always is a sequence of items of the form _regex_branch:n {<branch>}.

```

24693 \cs_new_protected:Npn \_regex_group_resetting:nnnN #1
24694 {
24695   \_regex_group_aux:nnnnN { -1 }
24696   {
24697     \exp_args:Noo \_regex_group_resetting_loop:nnNn
24698     { \int_use:N \l__regex_capturing_group_int }
24699     { \int_use:N \l__regex_capturing_group_int }
24700     #1
24701     { ?? \prg_break:n } { }
24702     \prg_break_point:
24703   }
24704 }
24705 \cs_new_protected:Npn \_regex_group_resetting_loop:nnNn #1#2#3#4
24706 {
24707   \use_none:nn #3 { \int_set:Nn \l__regex_capturing_group_int {#1} }
24708   \int_set:Nn \l__regex_capturing_group_int {#2}
24709   #3 {#4}
24710   \exp_args:Nf \_regex_group_resetting_loop:nnNn

```

```

24711     { \int_max:nn {#1} { \l__regex_capturing_group_int } }
24712     {#2}
24713 }

```

(End definition for __regex_group_resetting:nnnN and __regex_group_resetting_loop:nnNn.)

__regex_branch:n Add a free transition from the left state of the current group to a brand new state, starting point of this branch. Once the branch is built, add a transition from its last state to the right state of the group. The left and right states of the group are extracted from the relevant sequences.

```

24714 \__kernel_patch:nnNnpn
24715 { \__regex_trace_push:nnN { regex } { 1 } \__regex_branch:n }
24716 { \__regex_trace_pop:nnN { regex } { 1 } \__regex_branch:n }
24717 \cs_new_protected:Npn \__regex_branch:n #1
24718 {
24719   \__regex_build_new_state:
24720   \seq_get:NN \l__regex_left_state_seq \l__regex_internal_a_tl
24721   \int_set:Nn \l__regex_left_state_int \l__regex_internal_a_tl
24722   \__regex_build_transition_right:nNn \__regex_action_free:n
24723     \l__regex_left_state_int \l__regex_right_state_int
24724   #1
24725   \seq_get:NN \l__regex_right_state_seq \l__regex_internal_a_tl
24726   \__regex_build_transition_right:nNn \__regex_action_free:n
24727     \l__regex_right_state_int \l__regex_internal_a_tl
24728 }

```

(End definition for __regex_branch:n.)

__regex_group_repeat:nn This function is called to repeat a group a fixed number of times #2; if this is 0 we remove the group altogether (but don't reset the capturing_group label). Otherwise, the auxiliary __regex_group_repeat_aux:n copies #2 times the \toks for the group, and leaves internal_a pointing to the left end of the last repetition. We only record the submatch information at the last repetition. Finally, add a state at the end (the transition to it has been taken care of by the replicating auxiliary).

```

24729 \cs_new_protected:Npn \__regex_group_repeat:nn #1#2
24730 {
24731   \if_int_compare:w #2 = 0 \exp_stop_f:
24732     \int_set:Nn \l__regex_max_state_int
24733       { \l__regex_left_state_int - 1 }
24734     \__regex_build_new_state:
24735   \else:
24736     \__regex_group_repeat_aux:n {#2}
24737     \__regex_group_submatches:nnN {#1}
24738     \l__regex_internal_a_int \l__regex_right_state_int
24739     \__regex_build_new_state:
24740   \fi:
24741 }

```

(End definition for __regex_group_repeat:nn.)

__regex_group_submatches:nnN This inserts in states #2 and #3 the code for tracking submatches of the group #1, unless inhibited by a label of -1.

```

24742 \cs_new_protected:Npn \__regex_group_submatches:nnN #1#2#3
24743 {

```

```

24744 \if_int_compare:w #1 > - 1 \exp_stop_f:
24745   \__regex_toks_put_left:Nx #2 { \__regex_action_submatch:n { #1 < } }
24746   \__regex_toks_put_left:Nx #3 { \__regex_action_submatch:n { #1 > } }
24747 \fi:
24748 }

```

(End definition for __regex_group_submatches:nNN.)

__regex_group_repeat_aux:n Here we repeat \toks ranging from left_state to max_state, #1 > 0 times. First add a transition so that the copies “chain” properly. Compute the shift *c* between the original copy and the last copy we want. Shift the right_state and max_state to their final values. We then want to perform *c* copy operations. At the end, *b* is equal to the max_state, and *a* points to the left of the last copy of the group.

```

24749 \cs_new_protected:Npn \__regex_group_repeat_aux:n #1
24750 {
24751   \__regex_build_transition_right:nNn \__regex_action_free:n
24752   \l__regex_right_state_int \l__regex_max_state_int
24753   \int_set_eq:NN \l__regex_internal_a_int \l__regex_left_state_int
24754   \int_set_eq:NN \l__regex_internal_b_int \l__regex_max_state_int
24755   \if_int_compare:w \int_eval:n {#1} > 1 \exp_stop_f:
24756   \int_set:Nn \l__regex_internal_c_int
24757   {
24758     ( #1 - 1 )
24759     * ( \l__regex_internal_b_int - \l__regex_internal_a_int )
24760   }
24761   \int_add:Nn \l__regex_right_state_int { \l__regex_internal_c_int }
24762   \int_add:Nn \l__regex_max_state_int { \l__regex_internal_c_int }
24763   \__regex_toks_memcpy:NNn
24764   \l__regex_internal_b_int
24765   \l__regex_internal_a_int
24766   \l__regex_internal_c_int
24767 \fi:
24768 }

```

(End definition for __regex_group_repeat_aux:n.)

__regex_group_repeat:nnN This function is called to repeat a group at least *n* times; the case *n* = 0 is very different from *n* > 0. Assume first that *n* = 0. Insert submatch tracking information at the start and end of the group, add a free transition from the right end to the “true” left state *a* (remember: in this case we had added an extra state before the left state). This forms the loop, which we break away from by adding a free transition from *a* to a new state.

Now consider the case *n* > 0. Repeat the group *n* times, chaining various copies with a free transition. Add submatch tracking only to the last copy, then add a free transition from the right end back to the left end of the last copy, either before or after the transition to move on towards the rest of the NFA. This transition can end up before submatch tracking, but that is irrelevant since it only does so when going again through the group, recording new matches. Finally, add a state; we already have a transition pointing to it from __regex_group_repeat_aux:n.

```

24769 \cs_new_protected:Npn \__regex_group_repeat:nnN #1#2#3
24770 {
24771   \if_int_compare:w #2 = 0 \exp_stop_f:
24772   \__regex_group_submatches:nnN {#1}
24773   \l__regex_left_state_int \l__regex_right_state_int

```



```

24774     \int_set:Nn \l__regex_internal_a_int
24775     { \l__regex_left_state_int - 1 }
24776     \__regex_build_transition_right:nNn \__regex_action_free:n
24777     \l__regex_right_state_int \l__regex_internal_a_int
24778     \__regex_build_new_state:
24779     \if_meaning:w \c_true_bool #3
24780     \__regex_build_transition_left:NNN \__regex_action_free:n
24781     \l__regex_internal_a_int \l__regex_right_state_int
24782     \else:
24783     \__regex_build_transition_right:nNn \__regex_action_free:n
24784     \l__regex_internal_a_int \l__regex_right_state_int
24785     \fi:
24786   \else:
24787     \__regex_group_repeat_aux:n {#2}
24788     \__regex_group_submatches:nNN {#1}
24789     \l__regex_internal_a_int \l__regex_right_state_int
24790     \if_meaning:w \c_true_bool #3
24791     \__regex_build_transition_right:nNn \__regex_action_free_group:n
24792     \l__regex_right_state_int \l__regex_internal_a_int
24793     \else:
24794     \__regex_build_transition_left:NNN \__regex_action_free_group:n
24795     \l__regex_right_state_int \l__regex_internal_a_int
24796     \fi:
24797     \__regex_build_new_state:
24798   \fi:
24799 }

```

(End definition for __regex_group_repeat:nnN.)

__regex_group_repeat:nnnN

We wish to repeat the group between #2 and #2 + #3 times, with a laziness controlled by #4. We insert submatch tracking up front: in principle, we could avoid recording submatches for the first #2 copies of the group, but that forces us to treat specially the case #2 = 0. Repeat that group with submatch tracking #2 + #3 times (the maximum number of repetitions). Then our goal is to add #3 transitions from the end of the #2-th group, and each subsequent groups, to the end. For a lazy quantifier, we add those transitions to the left states, before submatch tracking. For the greedy case, we add the transitions to the right states, after submatch tracking and the transitions which go on with more repetitions. In the greedy case with #2 = 0, the transition which skips over all copies of the group must be added separately, because its starting state does not follow the normal pattern: we had to add it “by hand” earlier.

```

24800 \cs_new_protected:Npn \__regex_group_repeat:nnnN #1#2#3#4
24801 {
24802   \__regex_group_submatches:nNN {#1}
24803   \l__regex_left_state_int \l__regex_right_state_int
24804   \__regex_group_repeat_aux:n { #2 + #3 }
24805   \if_meaning:w \c_true_bool #4
24806   \int_set_eq:NN \l__regex_left_state_int \l__regex_max_state_int
24807   \prg_replicate:nn { #3 }
24808   {
24809     \int_sub:Nn \l__regex_left_state_int
24810     { \l__regex_internal_b_int - \l__regex_internal_a_int }
24811     \__regex_build_transition_left:NNN \__regex_action_free:n
24812     \l__regex_left_state_int \l__regex_max_state_int

```

```

24813     }
24814 \else:
24815   \prg_replicate:nn { #3 - 1 }
24816   {
24817     \int_sub:Nn \l__regex_right_state_int
24818     { \l__regex_internal_b_int - \l__regex_internal_a_int }
24819     \__regex_build_transition_right:nNn \__regex_action_free:n
24820     \l__regex_right_state_int \l__regex_max_state_int
24821   }
24822   \if_int_compare:w #2 = 0 \exp_stop_f:
24823   \int_set:Nn \l__regex_right_state_int
24824   { \l__regex_left_state_int - 1 }
24825 \else:
24826   \int_sub:Nn \l__regex_right_state_int
24827   { \l__regex_internal_b_int - \l__regex_internal_a_int }
24828 \fi:
24829 \__regex_build_transition_right:nNn \__regex_action_free:n
24830 \l__regex_right_state_int \l__regex_max_state_int
24831 \fi:
24832 \__regex_build_new_state:
24833 }

```

(End definition for __regex_group_repeat:nnnN.)

40.4.6 Others

__regex_assertion:Nn
 __regex_b_test:
 __regex_anchor:N

Usage: __regex_assertion:Nn *<boolean>* {*<test>*}, where the *<test>* is either of the two other functions. Add a free transition to a new state, conditionally to the assertion test. The __regex_b_test: test is used by the \b and \B escape: check if the last character was a word character or not, and do the same to the current character. The boundary-markers of the string are non-word characters for this purpose. Anchors at the start or end of match use __regex_anchor:N, with a position controlled by the integer #1.

```

24834 \cs_new_protected:Npn \__regex_assertion:Nn #1#2
24835 {
24836   \__regex_build_new_state:
24837   \__regex_toks_put_right:Nx \l__regex_left_state_int
24838   {
24839     \exp_not:n {#2}
24840     \__regex_break_point:TF
24841     \bool_if:NF #1 { { } }
24842     {
24843       \__regex_action_free:n
24844       {
24845         \int_eval:n
24846         { \l__regex_right_state_int - \l__regex_left_state_int }
24847       }
24848     }
24849     \bool_if:NT #1 { { } }
24850   }
24851 }
24852 \cs_new_protected:Npn \__regex_anchor:N #1
24853 {
24854   \if_int_compare:w #1 = \l__regex_curr_pos_int
24855     \exp_after:wN \__regex_break_true:w

```

```

24856     \fi:
24857   }
24858   \cs_new_protected:Npn \__regex_b_test:
24859   {
24860     \group_begin:
24861     \int_set_eq:NN \l__regex_curr_char_int \l__regex_last_char_int
24862     \__regex_prop_w:
24863     \__regex_break_point:TF
24864     { \group_end: \__regex_item_reverse:n \__regex_prop_w: }
24865     { \group_end: \__regex_prop_w: }
24866   }

```

(End definition for `__regex_assertion:Nn`, `__regex_b_test:`, and `__regex_anchor:N`.)

`__regex_command_K:` Change the starting point of the 0-th submatch (full match), and transition to a new state, pretending that this is a fresh thread.

```

24867   \cs_new_protected:Npn \__regex_command_K:
24868   {
24869     \__regex_build_new_state:
24870     \__regex_toks_put_right:Nx \l__regex_left_state_int
24871     {
24872       \__regex_action_submatch:n { 0< }
24873       \bool_set_true:N \l__regex_fresh_thread_bool
24874       \__regex_action_free:n
24875       {
24876         \int_eval:n
24877         { \l__regex_right_state_int - \l__regex_left_state_int }
24878       }
24879       \bool_set_false:N \l__regex_fresh_thread_bool
24880     }
24881   }

```

(End definition for `__regex_command_K:.`)

40.5 Matching

We search for matches by running all the execution threads through the NFA in parallel, reading one token of the query at each step. The NFA contains “free” transitions to other states, and transitions which “consume” the current token. For free transitions, the instruction at the new state of the NFA is performed immediately. When a transition consumes a character, the new state is appended to a list of “active states”, stored in `\g__regex_thread_state_intarray`: this thread is made active again when the next token is read from the query. At every step (for each token in the query), we unpack that list of active states and the corresponding submatch props, and empty those.

If two paths through the NFA “collide” in the sense that they reach the same state after reading a given token, then they only differ in how they previously matched, and any future execution would be identical for both. (Note that this would be wrong in the presence of back-references.) Hence, we only need to keep one of the two threads: the thread with the highest priority. Our NFA is built in such a way that higher priority actions always come before lower priority actions, which makes things work.

The explanation in the previous paragraph may make us think that we simply need to keep track of which states were visited at a given step: after all, the loop generated when matching `(a?)*` against `a` is broken, isn’t it? No. The group first matches `a`, as

it should, then repeats; it attempts to match **a** again but fails; it skips **a**, and finds out that this state has already been seen at this position in the query: the match stops. The capturing group is (wrongly) **a**. What went wrong is that a thread collided with itself, and the later version, which has gone through the group one more times with an empty match, should have a higher priority than not going through the group.

We solve this by distinguishing “normal” free transitions `_regex_action_free:n` from transitions `_regex_action_free_group:n` which go back to the start of the group. The former keeps threads unless they have been visited by a “completed” thread, while the latter kind of transition also prevents going back to a state visited by the current thread.

40.5.1 Variables used when matching

<code>\l__regex_min_pos_int</code> <code>\l__regex_max_pos_int</code> <code>\l__regex_curr_pos_int</code> <code>\l__regex_start_pos_int</code> <code>\l__regex_success_pos_int</code>	<p>The tokens in the query are indexed from <code>min_pos</code> for the first to <code>max_pos - 1</code> for the last, and their information is stored in several arrays and <code>\toks</code> registers with those numbers. We don’t start from 0 because the <code>\toks</code> registers with low numbers are used to hold the states of the NFA. We match without backtracking, keeping all threads in lockstep at the <code>current_pos</code> in the query. The starting point of the current match attempt is <code>start_pos</code>, and <code>success_pos</code>, updated whenever a thread succeeds, is used as the next starting position.</p>
---	--

```

24882 \int_new:N \l__regex_min_pos_int
24883 \int_new:N \l__regex_max_pos_int
24884 \int_new:N \l__regex_curr_pos_int
24885 \int_new:N \l__regex_start_pos_int
24886 \int_new:N \l__regex_success_pos_int

```

(End definition for `\l__regex_min_pos_int` and others.)

<code>\l__regex_curr_char_int</code> <code>\l__regex_curr_catcode_int</code> <code>\l__regex_last_char_int</code> <code>\l__regex_case_changed_char_int</code>	<p>The character and category codes of the token at the current position; the character code of the token at the previous position; and the character code of the result of changing the case of the current token (<code>A-Z↔a-z</code>). This last integer is only computed when necessary, and is otherwise <code>\c_max_int</code>. The <code>current_char</code> variable is also used in various other phases to hold a character code.</p>
---	---

```

24887 \int_new:N \l__regex_curr_char_int
24888 \int_new:N \l__regex_curr_catcode_int
24889 \int_new:N \l__regex_last_char_int
24890 \int_new:N \l__regex_case_changed_char_int

```

(End definition for `\l__regex_curr_char_int` and others.)

<code>\l__regex_curr_state_int</code>	<p>For every character in the token list, each of the active states is considered in turn. The variable <code>\l__regex_curr_state_int</code> holds the state of the NFA which is currently considered: transitions are then given as shifts relative to the current state.</p>
---------------------------------------	---

```

24891 \int_new:N \l__regex_curr_state_int

```

(End definition for `\l__regex_curr_state_int`.)

<code>\l__regex_curr_submatches_prop</code> <code>\l__regex_success_submatches_prop</code>	<p>The submatches for the thread which is currently active are stored in the <code>current_submatches</code> property list variable. This property list is stored by <code>_regex_action_cost:n</code> into the <code>\toks</code> register for the target state of the transition, to be retrieved when matching at the next position. When a thread succeeds, this property list is copied to <code>\l__regex_success_submatches_prop</code>: only the last successful thread remains there.</p>
---	---

```

24892 \prop_new:N \l__regex_curr_submatches_prop
24893 \prop_new:N \l__regex_success_submatches_prop

```

(End definition for `\l__regex_curr_submatches_prop` and `\l__regex_success_submatches_prop`.)

`\l__regex_step_int` This integer, always even, is increased every time a character in the query is read, and not reset when doing multiple matches. We store in `\g__regex_state_active_intarray` the last step in which each $\langle state \rangle$ in the NFA was encountered. This lets us break infinite loops by not visiting the same state twice in the same step. In fact, the step we store is equal to `step` when we have started performing the operations of `\toks\langle state \rangle`, but not finished yet. However, once we finish, we store `step + 1` in `\g__regex_state_active_intarray`. This is needed to track submatches properly (see building phase). The `step` is also used to attach each set of submatch information to a given iteration (and automatically discard it when it corresponds to a past step).

```

24894 \int_new:N \l__regex_step_int

```

(End definition for `\l__regex_step_int`.)

`\l__regex_min_active_int` All the currently active threads are kept in order of precedence in `\g__regex_thread_state_intarray`, and the corresponding submatches in the `\toks`. For our purposes, those serve as an array, indexed from `min_active` (inclusive) to `max_active` (excluded).
`\l__regex_max_active_int` At the start of every step, the whole array is unpacked, so that the space can immediately be reused, and `max_active` is reset to `min_active`, effectively clearing the array.

```

24895 \int_new:N \l__regex_min_active_int
24896 \int_new:N \l__regex_max_active_int

```

(End definition for `\l__regex_min_active_int` and `\l__regex_max_active_int`.)

`\g__regex_state_active_intarray` `\g__regex_state_active_intarray` stores the last $\langle step \rangle$ in which each $\langle state \rangle$ was active.
`\g__regex_thread_state_intarray` `\g__regex_thread_state_intarray` stores threads to be considered in the next step, more precisely the states in which these threads are.

```

24897 \intarray_new:Nn \g__regex_state_active_intarray { 65536 }
24898 \intarray_new:Nn \g__regex_thread_state_intarray { 65536 }

```

(End definition for `\g__regex_state_active_intarray` and `\g__regex_thread_state_intarray`.)

`\l__regex_every_match_tl` Every time a match is found, this token list is used. For single matching, the token list is empty. For multiple matching, the token list is set to repeat the matching, after performing some operation which depends on the user function. See `__regex_single_match:` and `__regex_multi_match:n`.

```

24899 \tl_new:N \l__regex_every_match_tl

```

(End definition for `\l__regex_every_match_tl`.)

`\l__regex_fresh_thread_bool` When doing multiple matches, we need to avoid infinite loops where each iteration matches the same empty token list. When an empty token list is matched, the next
`\l__regex_empty_success_bool` successful match of the same empty token list is suppressed. We detect empty matches
`__regex_if_two_empty_matches:F` by setting `\l__regex_fresh_thread_bool` to `true` for threads which directly come from the start of the regex or from the `\K` command, and testing that boolean whenever a thread succeeds. The function `__regex_if_two_empty_matches:F` is redefined at every match attempt, depending on whether the previous match was empty or not: if it was, then the function must cancel a purported success if it is empty and at the same spot

as the previous match; otherwise, we definitely don't have two identical empty matches, so the function is `\use:n`.

```
24900 \bool_new:N \l__regex_fresh_thread_bool
24901 \bool_new:N \l__regex_empty_success_bool
24902 \cs_new_eq:NN \__regex_if_two_empty_matches:F \use:n
```

(End definition for \l__regex_fresh_thread_bool, \l__regex_empty_success_bool, and __regex_if_two_empty_matches:F.)

```
\g__regex_success_bool
\l__regex_saved_success_bool
\l__regex_match_success_bool
```

The boolean `\l__regex_match_success_bool` is true if the current match attempt was successful, and `\g__regex_success_bool` is true if there was at least one successful match. This is the only global variable in this whole module, but we would need it to be local when matching a control sequence with `\c{...}`. This is done by saving the global variable into `\l__regex_saved_success_bool`, which is local, hence not affected by the changes due to inner regex functions.

```
24903 \bool_new:N \g__regex_success_bool
24904 \bool_new:N \l__regex_saved_success_bool
24905 \bool_new:N \l__regex_match_success_bool
```

(End definition for \g__regex_success_bool, \l__regex_saved_success_bool, and \l__regex_match_success_bool.)

40.5.2 Matching: framework

```
\__regex_match:n
\__regex_match_cs:n
\__regex_match_init:
```

First store the query into `\toks` registers and arrays (see `__regex_query_set:nnn`). Then initialize the variables that should be set once for each user function (even for multiple matches). Namely, the overall matching is not yet successful; none of the states should be marked as visited (`\g__regex_state_active_intarray`), and we start at step 0; we pretend that there was a previous match ending at the start of the query, which was not empty (to avoid smothering an empty match at the start). Once all this is set up, we are ready for the ride. Find the first match.

```
24906 \__kernel_patch:nnNNpn
24907 {
24908   \__regex_trace_push:nnN { regex } { 1 } \__regex_match:n
24909   \__regex_trace:nnx { regex } { 1 } { analyzing-query-token-list }
24910 }
24911 { \__regex_trace_pop:nnN { regex } { 1 } \__regex_match:n }
24912 \cs_new_protected:Npn \__regex_match:n #1
24913 {
24914   \int_zero:N \l__regex_balance_int
24915   \int_set:Nn \l__regex_curr_pos_int { 2 * \l__regex_max_state_int }
24916   \__regex_query_set:nnn { } { -1 } { -2 }
24917   \int_set_eq:NN \l__regex_min_pos_int \l__regex_curr_pos_int
24918   \tl_analysis_map_inline:nn {#1}
24919   { \__regex_query_set:nnn {##1} {"##3"} {##2} }
24920   \int_set_eq:NN \l__regex_max_pos_int \l__regex_curr_pos_int
24921   \__regex_query_set:nnn { } { -1 } { -2 }
24922   \__regex_match_init:
24923   \__regex_match_once:
24924 }
24925 \__kernel_patch:nnNNpn
24926 {
24927   \__regex_trace_push:nnN { regex } { 1 } \__regex_match_cs:n
```

```

24928     \__regex_trace:nnx { regex } { 1 } { analyzing-query~token~list }
24929 }
24930 { \__regex_trace_pop:nnN { regex } { 1 } \__regex_match_cs:n }
24931 \cs_new_protected:Npn \__regex_match_cs:n #1
24932 {
24933     \int_zero:N \l__regex_balance_int
24934     \int_set:Nn \l__regex_curr_pos_int
24935     {
24936         \int_max:nn { 2 * \l__regex_max_state_int - \l__regex_min_state_int }
24937         { \l__regex_max_pos_int }
24938         + 1
24939     }
24940     \__regex_query_set:nnn { } { -1 } { -2 }
24941     \int_set_eq:NN \l__regex_min_pos_int \l__regex_curr_pos_int
24942     \str_map_inline:nn {#1}
24943     {
24944         \__regex_query_set:nnn { \exp_not:n {##1} }
24945         { \tl_if_blank:nTF {##1} { 10 } { 12 } }
24946         { '##1 }
24947     }
24948     \int_set_eq:NN \l__regex_max_pos_int \l__regex_curr_pos_int
24949     \__regex_query_set:nnn { } { -1 } { -2 }
24950     \__regex_match_init:
24951     \__regex_match_once:
24952 }
24953 \__kernel_patch:nnNNpn
24954 { \__regex_trace:nnx { regex } { 1 } { initializing } }
24955 { }
24956 \cs_new_protected:Npn \__regex_match_init:
24957 {
24958     \bool_gset_false:N \g__regex_success_bool
24959     \int_step_inline:nnn
24960     \l__regex_min_state_int { \l__regex_max_state_int - 1 }
24961     {
24962         \__kernel_intarray_gset:Nnn
24963         \g__regex_state_active_intarray {##1} { 1 }
24964     }
24965     \int_set_eq:NN \l__regex_min_active_int \l__regex_max_state_int
24966     \int_zero:N \l__regex_step_int
24967     \int_set_eq:NN \l__regex_success_pos_int \l__regex_min_pos_int
24968     \int_set:Nn \l__regex_min_submatch_int
24969     { 2 * \l__regex_max_state_int }
24970     \int_set_eq:NN \l__regex_submatch_int \l__regex_min_submatch_int
24971     \bool_set_false:N \l__regex_empty_success_bool
24972 }

```

(End definition for __regex_match:n, __regex_match_cs:n, and __regex_match_init:.)

__regex_match_once: This function finds one match, then does some action defined by the `every_match` token list, which may recursively call `__regex_match_once:`. First initialize some variables: set the conditional which detects identical empty matches; this match attempt starts at the previous `success_pos`, is not yet successful, and has no submatches yet; clear the array of active threads, and put the starting state 0 in it. We are then almost ready to read our first token in the query, but we actually start one position earlier than the

start, and get that token, to set `last_char` properly for word boundaries. Then call `__regex_match_loop:`, which runs through the query until the end or until a successful match breaks early.

```

24973 \cs_new_protected:Npn \__regex_match_once:
24974 {
24975   \if_meaning:w \c_true_bool \l__regex_empty_success_bool
24976   \cs_set:Npn \__regex_if_two_empty_matches:F
24977   {
24978     \int_compare:nNnF
24979     \l__regex_start_pos_int = \l__regex_curr_pos_int
24980   }
24981   \else:
24982     \cs_set_eq:NN \__regex_if_two_empty_matches:F \use:n
24983   \fi:
24984   \int_set_eq:NN \l__regex_start_pos_int \l__regex_success_pos_int
24985   \bool_set_false:N \l__regex_match_success_bool
24986   \prop_clear:N \l__regex_curr_submatches_prop
24987   \int_set_eq:NN \l__regex_max_active_int \l__regex_min_active_int
24988   \__regex_store_state:n { \l__regex_min_state_int }
24989   \int_set:Nn \l__regex_curr_pos_int
24990   { \l__regex_start_pos_int - 1 }
24991   \__regex_query_get:
24992   \__regex_match_loop:
24993   \l__regex_every_match_tl
24994 }

```

(End definition for `__regex_match_once:`.)

`__regex_single_match:` For a single match, the overall success is determined by whether the only match attempt is a success. When doing multiple matches, the overall matching is successful as soon as any match succeeds. Perform the action #1, then find the next match.

```

24995 \cs_new_protected:Npn \__regex_single_match:
24996 {
24997   \tl_set:Nn \l__regex_every_match_tl
24998   {
24999     \bool_gset_eq:NN
25000     \g__regex_success_bool
25001     \l__regex_match_success_bool
25002   }
25003 }
25004 \cs_new_protected:Npn \__regex_multi_match:n #1
25005 {
25006   \tl_set:Nn \l__regex_every_match_tl
25007   {
25008     \if_meaning:w \c_true_bool \l__regex_match_success_bool
25009     \bool_gset_true:N \g__regex_success_bool
25010     #1
25011     \exp_after:wN \__regex_match_once:
25012   \fi:
25013 }
25014 }

```

(End definition for `__regex_single_match:` and `__regex_multi_match:n`.)

`__regex_match_loop:` At each new position, set some variables and get the new character and category from the query. Then unpack the array of active threads, and clear it by resetting its length (`max_active`). This results in a sequence of `__regex_use_state_and_submatches:nn` `{<state>}` `{<prop>}`, and we consider those states one by one in order. As soon as a thread succeeds, exit the step, and, if there are threads to consider at the next position, and we have not reached the end of the string, repeat the loop. Otherwise, the last thread that succeeded is what `__regex_match_once:` matches. We explain the `fresh_thread` business when describing `__regex_action_wildcard:`.

```

25015 \cs_new_protected:Npn __regex_match_loop:
25016 {
25017   \int_add:Nn \l__regex_step_int { 2 }
25018   \int_incr:N \l__regex_curr_pos_int
25019   \int_set_eq:NN \l__regex_last_char_int \l__regex_curr_char_int
25020   \int_set_eq:NN \l__regex_case_changed_char_int \c_max_int
25021   __regex_query_get:
25022   \use:x
25023   {
25024     \int_set_eq:NN \l__regex_max_active_int \l__regex_min_active_int
25025     \int_step_function:nnN
25026       { \l__regex_min_active_int }
25027       { \l__regex_max_active_int - 1 }
25028     __regex_match_one_active:n
25029   }
25030   \prg_break_point:
25031   \bool_set_false:N \l__regex_fresh_thread_bool
25032   \if_int_compare:w \l__regex_max_active_int > \l__regex_min_active_int
25033     \if_int_compare:w \l__regex_curr_pos_int < \l__regex_max_pos_int
25034       \exp_after:wN \exp_after:wN \exp_after:wN __regex_match_loop:
25035     \fi:
25036   \fi:
25037 }
25038 \cs_new:Npn __regex_match_one_active:n #1
25039 {
25040   __regex_use_state_and_submatches:nn
25041     { \__kernel_intarray_item:Nn \g__regex_thread_state_intarray {#1} }
25042     { __regex_toks_use:w #1 }
25043 }

```

(End definition for `__regex_match_loop:` and `__regex_match_one_active:n`.)

`__regex_query_set:nnn` The arguments are: tokens that `o` and `x` expand to one token of the query, the catcode, and the character code. Store those, and the current brace balance (used later to check for overall brace balance) in a `\toks` register and some arrays, then update the `balance`.

```

25044 \cs_new_protected:Npn __regex_query_set:nnn #1#2#3
25045 {
25046   __kernel_intarray_gset:Nnn \g__regex_charcode_intarray
25047     { \l__regex_curr_pos_int } {#3}
25048   __kernel_intarray_gset:Nnn \g__regex_catcode_intarray
25049     { \l__regex_curr_pos_int } {#2}
25050   __kernel_intarray_gset:Nnn \g__regex_balance_intarray
25051     { \l__regex_curr_pos_int } { \l__regex_balance_int }
25052   __regex_toks_set:Nn \l__regex_curr_pos_int {#1}
25053   \int_incr:N \l__regex_curr_pos_int

```

```

25054     \if_case:w #2 \exp_stop_f:
25055     \or: \int_incr:N \l__regex_balance_int
25056     \or: \int_decr:N \l__regex_balance_int
25057     \fi:
25058 }

```

(End definition for __regex_query_set:nnn.)

__regex_query_get: Extract the current character and category codes at the current position from the appropriate arrays.

```

25059 \cs_new_protected:Npn \__regex_query_get:
25060 {
25061     \l__regex_curr_char_int
25062     = \__kernel_intarray_item:Nn \g__regex_charcode_intarray
25063       { \l__regex_curr_pos_int } \scan_stop:
25064     \l__regex_curr_catcode_int
25065     = \__kernel_intarray_item:Nn \g__regex_catcode_intarray
25066       { \l__regex_curr_pos_int } \scan_stop:
25067 }

```

(End definition for __regex_query_get:.)

40.5.3 Using states of the nfa

__regex_use_state: Use the current NFA instruction. The state is initially marked as belonging to the current **step**: this allows normal free transition to repeat, but group-repeating transitions won't. Once we are done exploring all the branches it spawned, the state is marked as **step + 1**: any thread hitting it at that point will be terminated.

```

25068 \__kernel_patch:nnNNpn
25069 {
25070     \__regex_trace:nnx { regex } { 2 }
25071     { state~\int_use:N \l__regex_curr_state_int }
25072 }
25073 { }
25074 \cs_new_protected:Npn \__regex_use_state:
25075 {
25076     \__kernel_intarray_gset:Nnn \g__regex_state_active_intarray
25077       { \l__regex_curr_state_int } { \l__regex_step_int }
25078     \__regex_toks_use:w \l__regex_curr_state_int
25079     \__kernel_intarray_gset:Nnn \g__regex_state_active_intarray
25080       { \l__regex_curr_state_int }
25081       { \int_eval:n { \l__regex_step_int + 1 } }
25082 }

```

(End definition for __regex_use_state:.)

__regex_use_state_and_submatches:nn This function is called as one item in the array of active threads after that array has been unpacked for a new step. Update the **current_state** and **current_submatches** and use the state if it has not yet been encountered at this step.

```

25083 \cs_new_protected:Npn \__regex_use_state_and_submatches:nn #1 #2
25084 {
25085     \int_set:Nn \l__regex_curr_state_int {#1}
25086     \if_int_compare:w
25087         \__kernel_intarray_item:Nn \g__regex_state_active_intarray

```

```

25088         { \l__regex_curr_state_int }
25089             < \l__regex_step_int
25090         \tl_set:Nn \l__regex_curr_submatches_prop {#2}
25091         \exp_after:wN \__regex_use_state:
25092     \fi:
25093     \scan_stop:
25094 }

```

(End definition for __regex_use_state_and_submatches:nn.)

40.5.4 Actions when matching

__regex_action_start_wildcard: For an unanchored match, state 0 has a free transition to the next and a costly one to itself, to repeat at the next position. To catch repeated identical empty matches, we need to know if a successful thread corresponds to an empty match. The instruction resetting \l__regex_fresh_thread_bool may be skipped by a successful thread, hence we had to add it to __regex_match_loop: too.

```

25095 \cs_new_protected:Npn \__regex_action_start_wildcard:
25096 {
25097     \bool_set_true:N \l__regex_fresh_thread_bool
25098     \__regex_action_free:n {1}
25099     \bool_set_false:N \l__regex_fresh_thread_bool
25100     \__regex_action_cost:n {0}
25101 }

```

(End definition for __regex_action_start_wildcard:.)

```

\__regex_action_free:n
\__regex_action_free_group:n
\__regex_action_free_aux:nn

```

These functions copy a thread after checking that the NFA state has not already been used at this position. If not, store submatches in the new state, and insert the instructions for that state in the input stream. Then restore the old value of \l__regex_curr_state_int and of the current submatches. The two types of free transitions differ by how they test that the state has not been encountered yet: the **group** version is stricter, and will not use a state if it was used earlier in the current thread, hence forcefully breaking the loop, while the “normal” version will revisit a state even within the thread itself.

```

25102 \cs_new_protected:Npn \__regex_action_free:n
25103 { \__regex_action_free_aux:nn { > \l__regex_step_int \else: } }
25104 \cs_new_protected:Npn \__regex_action_free_group:n
25105 { \__regex_action_free_aux:nn { < \l__regex_step_int } }
25106 \cs_new_protected:Npn \__regex_action_free_aux:nn #1#2
25107 {
25108     \use:x
25109     {
25110         \int_add:Nn \l__regex_curr_state_int {#2}
25111         \exp_not:n
25112         {
25113             \if_int_compare:w
25114                 \__kernel_intarray_item:Nn \g__regex_state_active_intarray
25115                 { \l__regex_curr_state_int }
25116                 #1
25117                 \exp_after:wN \__regex_use_state:
25118             \fi:
25119         }
25120         \int_set:Nn \l__regex_curr_state_int

```

```

25121         { \int_use:N \l__regex_curr_state_int }
25122         \tl_set:Nn \exp_not:N \l__regex_curr_submatches_prop
25123         { \exp_not:o \l__regex_curr_submatches_prop }
25124     }
25125 }

```

(End definition for __regex_action_free:n, __regex_action_free_group:n, and __regex_action_free_aux:nn.)

`__regex_action_cost:n` A transition which consumes the current character and shifts the state by #1. The resulting state is stored in the appropriate array for use at the next position, and we also store the current submatches.

```

25126 \cs_new_protected:Npn \__regex_action_cost:n #1
25127 {
25128     \exp_args:Nx \__regex_store_state:n
25129     { \int_eval:n { \l__regex_curr_state_int + #1 } }
25130 }

```

(End definition for __regex_action_cost:n.)

`__regex_store_state:n` Put the given state in `\g__regex_thread_state_intarray`, and increment the length of the array. Also store the current submatch in the appropriate `\toks`.

```

25131 \cs_new_protected:Npn \__regex_store_state:n #1
25132 {
25133     \__regex_store_submatches:
25134     \__kernel_intarray_gset:Nnn \g__regex_thread_state_intarray
25135     { \l__regex_max_active_int } {#1}
25136     \int_incr:N \l__regex_max_active_int
25137 }
25138 \cs_new_protected:Npn \__regex_store_submatches:
25139 {
25140     \__regex_toks_set:No \l__regex_max_active_int
25141     { \l__regex_curr_submatches_prop }
25142 }

```

(End definition for __regex_store_state:n and __regex_store_submatches:.)

`__regex_disable_submatches:` Some user functions don't require tracking submatches. We get a performance improvement by simply defining the relevant functions to remove their argument and do nothing with it.

```

25143 \cs_new_protected:Npn \__regex_disable_submatches:
25144 {
25145     \cs_set_protected:Npn \__regex_store_submatches: { }
25146     \cs_set_protected:Npn \__regex_action_submatch:n ##1 { }
25147 }

```

(End definition for __regex_disable_submatches:.)

`__regex_action_submatch:n` Update the current submatches with the information from the current position. Maybe a bottleneck.

```

25148 \cs_new_protected:Npn \__regex_action_submatch:n #1
25149 {
25150     \prop_put:Nno \l__regex_curr_submatches_prop {#1}
25151     { \int_use:N \l__regex_curr_pos_int }
25152 }

```

(End definition for `_regex_action_submatch:n`.)

`_regex_action_success:` There is a successful match when an execution path reaches the last state in the NFA, unless this marks a second identical empty match. Then mark that there was a successful match; it is empty if it is “fresh”; and we store the current position and submatches. The current step is then interrupted with `\prg_break:`, and only paths with higher precedence are pursued further. The values stored here may be overwritten by a later success of a path with higher precedence.

```

25153 \cs_new_protected:Npn \_regex_action_success:
25154 {
25155   \_regex_if_two_empty_matches:F
25156   {
25157     \bool_set_true:N \l__regex_match_success_bool
25158     \bool_set_eq:NN \l__regex_empty_success_bool
25159     \l__regex_fresh_thread_bool
25160     \int_set_eq:NN \l__regex_success_pos_int \l__regex_curr_pos_int
25161     \prop_set_eq:NN \l__regex_success_submatches_prop
25162     \l__regex_curr_submatches_prop
25163     \prg_break:
25164   }
25165 }
```

(End definition for `_regex_action_success:.`)

40.6 Replacement

40.6.1 Variables and helpers used in replacement

`\l__regex_replacement_csnames_int` The behaviour of closing braces inside a replacement text depends on whether a sequences `\c{` or `\u{` has been encountered. The number of “open” such sequences that should be closed by `}` is stored in `\l__regex_replacement_csnames_int`, and decreased by 1 by each `}`.

```

25166 \int_new:N \l__regex_replacement_csnames_int
```

(End definition for `\l__regex_replacement_csnames_int`.)

`\l__regex_replacement_category_tl` This sequence of letters is used to correctly restore categories in nested constructions such as `\cL(abc\cD(_)d)`.

```

25167 \tl_new:N \l__regex_replacement_category_tl
25168 \seq_new:N \l__regex_replacement_category_seq
```

(End definition for `\l__regex_replacement_category_tl` and `\l__regex_replacement_category_seq`.)

`\l__regex_balance_tl` This token list holds the replacement text for `_regex_replacement_balance_one_match:n` while it is being built incrementally.

```

25169 \tl_new:N \l__regex_balance_tl
```

(End definition for `\l__regex_balance_tl`.)

`_regex_replacement_balance_one_match:n` This expects as an argument the first index of a set of entries in `\g__regex_submatch_begin_intarray` (and related arrays) which hold the submatch information for a given match. It can be used within an integer expression to obtain the brace balance incurred by performing the replacement on that match. This combines the braces lost by removing the match, braces added by all the submatches appearing in the replacement, and braces

appearing explicitly in the replacement. Even though it is always redefined before use, we initialize it as for an empty replacement. An important property is that concatenating several calls to that function must result in a valid integer expression (hence a leading + in the actual definition).

```
25170 \cs_new:Npn \__regex_replacement_balance_one_match:n #1
25171 { - \__regex_submatch_balance:n {#1} }
```

(End definition for __regex_replacement_balance_one_match:n.)

__regex_replacement_do_one_match:n

The input is the same as __regex_replacement_balance_one_match:n. This function is redefined to expand to the part of the token list from the end of the previous match to a given match, followed by the replacement text. Hence concatenating the result of this function with all possible arguments (one call for each match), as well as the range from the end of the last match to the end of the string, produces the fully replaced token list. The initialization does not matter, but (as an example) we set it as for an empty replacement.

```
25172 \cs_new:Npn \__regex_replacement_do_one_match:n #1
25173 {
25174   \__regex_query_range:nn
25175   { \__kernel_intarray_item:Nn \g__regex_submatch_prev_intarray {#1} }
25176   { \__kernel_intarray_item:Nn \g__regex_submatch_begin_intarray {#1} }
25177 }
```

(End definition for __regex_replacement_do_one_match:n.)

__regex_replacement_exp_not:N

This function lets us navigate around the fact that the primitive \exp_not:n requires a braced argument. As far as I can tell, it is only needed if the user tries to include in the replacement text a control sequence set equal to a macro parameter character, such as \c_parameter_token. Indeed, within an x-expanding assignment, \exp_not:N # behaves as a single #, whereas \exp_not:n {#} behaves as a doubled ##.

```
25178 \cs_new:Npn \__regex_replacement_exp_not:N #1 { \exp_not:n {#1} }
```

(End definition for __regex_replacement_exp_not:N.)

40.6.2 Query and brace balance

__regex_query_range:nn
__regex_query_range_loop:ww

When it is time to extract submatches from the token list, the various tokens are stored in \toks registers numbered from \l__regex_min_pos_int inclusive to \l__regex_max_pos_int exclusive. The function __regex_query_range:nn {<min>} {<max>} unpacks registers from the position <min> to the position <max> - 1 included. Once this is expanded, a second x-expansion results in the actual tokens from the query. That second expansion is only done by user functions at the very end of their operation, after checking (and correcting) the brace balance first.

```
25179 \cs_new:Npn \__regex_query_range:nn #1#2
25180 {
25181   \exp_after:wN \__regex_query_range_loop:ww
25182   \int_value:w \__regex_int_eval:w #1 \exp_after:wN ;
25183   \int_value:w \__regex_int_eval:w #2 ;
25184   \prg_break_point:
25185 }
25186 \cs_new:Npn \__regex_query_range_loop:ww #1 ; #2 ;
25187 {
25188   \if_int_compare:w #1 < #2 \exp_stop_f:
```

```

25189 \else:
25190 \exp_after:wN \prg_break:
25191 \fi:
25192 \__regex_toks_use:w #1 \exp_stop_f:
25193 \exp_after:wN \__regex_query_range_loop:ww
25194 \int_value:w \__regex_int_eval:w #1 + 1 ; #2 ;
25195 }

```

(End definition for __regex_query_range:nn and __regex_query_range_loop:ww.)

__regex_query_submatch:n Find the start and end positions for a given submatch (of a given match).

```

25196 \cs_new:Npn \__regex_query_submatch:n #1
25197 {
25198 \__regex_query_range:nn
25199 { \__kernel_intarray_item:Nn \g__regex_submatch_begin_intarray {#1} }
25200 { \__kernel_intarray_item:Nn \g__regex_submatch_end_intarray {#1} }
25201 }

```

(End definition for __regex_query_submatch:n.)

__regex_submatch_balance:n Every user function must result in a balanced token list (unbalanced token lists cannot be stored by TeX). When we unpacked the query, we kept track of the brace balance, hence the contribution from a given range is the difference between the brace balances at the $\langle max\ pos \rangle$ and $\langle min\ pos \rangle$. These two positions are found in the corresponding “submatch” arrays.

```

25202 \cs_new_protected:Npn \__regex_submatch_balance:n #1
25203 {
25204 \int_eval:n
25205 {
25206 \int_compare:nNnTF
25207 {
25208 \__kernel_intarray_item:Nn
25209 \g__regex_submatch_end_intarray {#1}
25210 }
25211 = 0
25212 { 0 }
25213 {
25214 \__kernel_intarray_item:Nn \g__regex_balance_intarray
25215 {
25216 \__kernel_intarray_item:Nn
25217 \g__regex_submatch_end_intarray {#1}
25218 }
25219 }
25220 -
25221 \int_compare:nNnTF
25222 {
25223 \__kernel_intarray_item:Nn
25224 \g__regex_submatch_begin_intarray {#1}
25225 }
25226 = 0
25227 { 0 }
25228 {
25229 \__kernel_intarray_item:Nn \g__regex_balance_intarray
25230 {

```

```

25231         \__kernel_intarray_item:Nn
25232         \g__regex_submatch_begin_intarray {#1}
25233     }
25234 }
25235 }
25236 }

```

(End definition for __regex_submatch_balance:n.)

40.6.3 Framework

```

\__regex_replacement:n
\__regex_replacement_aux:n

```

The replacement text is built incrementally. We keep track in \l__regex_balance_int of the balance of explicit begin- and end-group tokens and we store in \l__regex_balance_tl some code to compute the brace balance from submatches (see its description). Detect unescaped right braces, and escaped characters, with trailing \prg_do_nothing: because some of the later function look-ahead. Once the whole replacement text has been parsed, make sure that there is no open csname. Finally, define the balance_one_match and do_one_match functions.

```

25237 \__kernel_patch:nnNNpn
25238 { \__regex_trace_push:nnN { regex } { 1 } \__regex_replacement:n }
25239 { \__regex_trace_pop:nnN { regex } { 1 } \__regex_replacement:n }
25240 \cs_new_protected:Npn \__regex_replacement:n #1
25241 {
25242   \group_begin:
25243   \tl_build_begin:N \l__regex_build_tl
25244   \int_zero:N \l__regex_balance_int
25245   \tl_clear:N \l__regex_balance_tl
25246   \__regex_escape_use:nnnn
25247   {
25248     \if_charcode:w \c_right_brace_str ##1
25249       \__regex_replacement_rbrace:N
25250     \else:
25251       \__regex_replacement_normal:n
25252     \fi:
25253     ##1
25254   }
25255   { \__regex_replacement_escaped:N ##1 }
25256   { \__regex_replacement_normal:n ##1 }
25257   {#1}
25258   \prg_do_nothing: \prg_do_nothing:
25259   \if_int_compare:w \l__regex_replacement_csnames_int > 0 \exp_stop_f:
25260     \__kernel_msg_error:nnx { kernel } { replacement-missing-rbrace }
25261     { \int_use:N \l__regex_replacement_csnames_int }
25262     \tl_build_put_right:Nx \l__regex_build_tl
25263     { \prg_replicate:nn \l__regex_replacement_csnames_int \cs_end: }
25264   \fi:
25265   \seq_if_empty:NF \l__regex_replacement_category_seq
25266   {
25267     \__kernel_msg_error:nnx { kernel } { replacement-missing-rparen }
25268     { \seq_count:N \l__regex_replacement_category_seq }
25269     \seq_clear:N \l__regex_replacement_category_seq
25270   }
25271   \cs_gset:Npx \__regex_replacement_balance_one_match:n ##1
25272   {

```



```

25273         + \int_use:N \l__regex_balance_int
25274         \l__regex_balance_tl
25275         - \__regex_submatch_balance:n {##1}
25276     }
25277     \tl_build_end:N \l__regex_build_tl
25278     \exp_args:NNo
25279     \group_end:
25280     \__regex_replacement_aux:n \l__regex_build_tl
25281 }
25282 \cs_new_protected:Npn \__regex_replacement_aux:n #1
25283 {
25284     \cs_set:Npn \__regex_replacement_do_one_match:n ##1
25285     {
25286         \__regex_query_range:nn
25287         {
25288             \__kernel_intarray_item:Nn
25289             \g__regex_submatch_prev_intarray {##1}
25290         }
25291         {
25292             \__kernel_intarray_item:Nn
25293             \g__regex_submatch_begin_intarray {##1}
25294         }
25295     } #1
25296 }
25297 }

```

(End definition for `__regex_replacement:n` and `__regex_replacement_aux:n`.)

`__regex_replacement_normal:n` Most characters are simply sent to the output by `\tl_build_put_right:Nn`, unless a particular category code has been requested: then `__regex_replacement_c_A:w` or a similar auxiliary is called. One exception is right parentheses, which restore the category code in place before the group started. Note that the sequence is non-empty there: it contains an empty entry corresponding to the initial value of `\l__regex_replacement_category_tl`.

```

25298 \cs_new_protected:Npn \__regex_replacement_normal:n #1
25299 {
25300     \tl_if_empty:NTF \l__regex_replacement_category_tl
25301     { \tl_build_put_right:Nn \l__regex_build_tl {##1} }
25302     { % (
25303         \token_if_eq_charcode:NNTF #1 )
25304         {
25305             \seq_pop:NN \l__regex_replacement_category_seq
25306             \l__regex_replacement_category_tl
25307         }
25308         {
25309             \use:c
25310             {
25311                 __regex_replacement_c_
25312                 \l__regex_replacement_category_tl :w
25313             }
25314             \__regex_replacement_normal:n {##1}
25315         }
25316     }
25317 }

```

(End definition for `_regex_replacement_normal:n`.)

`_regex_replacement_escaped:N` As in parsing a regular expression, we use an auxiliary built from #1 if defined. Otherwise, check for escaped digits (standing from submatches from 0 to 9): anything else is a raw character. We use `\token_to_str:N` to give spaces the right category code.

```

25318 \cs_new_protected:Npn \_regex_replacement_escaped:N #1
25319 {
25320   \cs_if_exist_use:cF { \_regex_replacement_#1:w }
25321   {
25322     \if_int_compare:w 1 < 1#1 \exp_stop_f:
25323     \_regex_replacement_put_submatch:n {#1}
25324   \else:
25325     \exp_args:No \_regex_replacement_normal:n
25326     { \token_to_str:N #1 }
25327   \fi:
25328 }
25329 }
```

(End definition for `_regex_replacement_escaped:N`.)

40.6.4 Submatches

`_regex_replacement_put_submatch:n` Insert a submatch in the replacement text. This is dropped if the submatch number is larger than the number of capturing groups. Unless the submatch appears inside a `\c{...}` or `\u{...}` construction, it must be taken into account in the brace balance. Later on, `##1` will be replaced by a pointer to the 0-th submatch for a given match. There is an `\exp_not:N` here as at the point-of-use of `\l__regex_balance_tl` there is an x-type expansion which is needed to get `##1` in correctly.

```

25330 \cs_new_protected:Npn \_regex_replacement_put_submatch:n #1
25331 {
25332   \if_int_compare:w #1 < \l__regex_capturing_group_int
25333   \tl_build_put_right:Nn \l__regex_build_tl
25334   { \_regex_query_submatch:n { \int_eval:n { #1 + ##1 } } }
25335   \if_int_compare:w \l__regex_replacement_csnames_int = 0 \exp_stop_f:
25336   \tl_put_right:Nn \l__regex_balance_tl
25337   {
25338     + \_regex_submatch_balance:n
25339     { \exp_not:N \int_eval:n { #1 + ##1 } }
25340   }
25341   \fi:
25342 \fi:
25343 }
```

(End definition for `_regex_replacement_put_submatch:n`.)

`_regex_replacement_g:w` Grab digits for the `\g` escape sequence in a primitive assignment to the integer `\l__regex_internal_a_int`. At the end of the run of digits, check that it ends with a right brace.

`_regex_replacement_g_digits:NN`

```

25344 \cs_new_protected:Npn \_regex_replacement_g:w #1#2
25345 {
25346   \_regex_two_if_eq:NNNTF
25347   #1 #2 \_regex_replacement_normal:n \c_left_brace_str
25348   { \l__regex_internal_a_int = \_regex_replacement_g_digits:NN }
```

```

25349     { \_regex_replacement_error:NNN g #1 #2 }
25350   }
25351 \cs_new:Npn \_regex_replacement_g_digits:NN #1#2
25352 {
25353   \token_if_eq_meaning:NNTF #1 \_regex_replacement_normal:n
25354   {
25355     \if_int_compare:w 1 < 1#2 \exp_stop_f:
25356       #2
25357       \exp_after:wN \use_i:nnn
25358       \exp_after:wN \_regex_replacement_g_digits:NN
25359     \else:
25360       \exp_stop_f:
25361       \exp_after:wN \_regex_replacement_error:NNN
25362       \exp_after:wN g
25363     \fi:
25364   }
25365   {
25366     \exp_stop_f:
25367     \if_meaning:w \_regex_replacement_rbrace:N #1
25368       \exp_args:No \_regex_replacement_put_submatch:n
25369       { \int_use:N \l__regex_internal_a_int }
25370       \exp_after:wN \use_none:nn
25371     \else:
25372       \exp_after:wN \_regex_replacement_error:NNN
25373       \exp_after:wN g
25374     \fi:
25375   }
25376   #1 #2
25377 }

```

(End definition for _regex_replacement_g:w and _regex_replacement_g_digits:NN.)

40.6.5 Csnames in replacement

_regex_replacement_c:w \c may only be followed by an unescaped character. If followed by a left brace, start a control sequence by calling an auxiliary common with \u. Otherwise test whether the category is known; if it is not, complain.

```

25378 \cs_new_protected:Npn \_regex_replacement_c:w #1#2
25379 {
25380   \token_if_eq_meaning:NNTF #1 \_regex_replacement_normal:n
25381   {
25382     \exp_after:wN \token_if_eq_charcode:NNTF \c_left_brace_str #2
25383     { \_regex_replacement_cu_aux:Nw \_regex_replacement_exp_not:N }
25384     {
25385       \cs_if_exist:cTF { \_regex_replacement_c_#2:w }
25386       { \_regex_replacement_cat:NNN #2 }
25387       { \_regex_replacement_error:NNN c #1#2 }
25388     }
25389   }
25390   { \_regex_replacement_error:NNN c #1#2 }
25391 }

```

(End definition for _regex_replacement_c:w.)

`_regex_replacement_cu_aux:Nw` Start a control sequence with `\cs:w`, protected from expansion by `#1` (either `_regex_replacement_exp_not:N` or `\exp_not:V`), or turned to a string by `\tl_to_str:V` if inside another csname construction `\c` or `\u`. We use `\tl_to_str:V` rather than `\tl_to_str:N` to deal with integers and other registers.

```

25392 \cs_new_protected:Npn \_regex_replacement_cu_aux:Nw #1
25393 {
25394   \if_case:w \l__regex_replacement_csnames_int
25395     \tl_build_put_right:Nn \l__regex_build_tl
25396     { \exp_not:n { \exp_after:wN #1 \cs:w } }
25397   \else:
25398     \tl_build_put_right:Nn \l__regex_build_tl
25399     { \exp_not:n { \exp_after:wN \tl_to_str:V \cs:w } }
25400   \fi:
25401   \int_incr:N \l__regex_replacement_csnames_int
25402 }

```

(End definition for _regex_replacement_cu_aux:Nw.)

`_regex_replacement_u:w` Check that `\u` is followed by a left brace. If so, start a control sequence with `\cs:w`, which is then unpacked either with `\exp_not:V` or `\tl_to_str:V` depending on the current context.

```

25403 \cs_new_protected:Npn \_regex_replacement_u:w #1#2
25404 {
25405   \_regex_two_if_eq:NNNTF
25406   #1 #2 \_regex_replacement_normal:n \c_left_brace_str
25407   { \_regex_replacement_cu_aux:Nw \exp_not:V }
25408   { \_regex_replacement_error:NNN u #1#2 }
25409 }

```

(End definition for _regex_replacement_u:w.)

`_regex_replacement_rbrace:N` Within a `\c{...}` or `\u{...}` construction, end the control sequence, and decrease the brace count. Otherwise, this is a raw right brace.

```

25410 \cs_new_protected:Npn \_regex_replacement_rbrace:N #1
25411 {
25412   \if_int_compare:w \l__regex_replacement_csnames_int > 0 \exp_stop_f:
25413     \tl_build_put_right:Nn \l__regex_build_tl { \cs_end: }
25414     \int_decr:N \l__regex_replacement_csnames_int
25415   \else:
25416     \_regex_replacement_normal:n {#1}
25417   \fi:
25418 }

```

(End definition for _regex_replacement_rbrace:N.)

40.6.6 Characters in replacement

`_regex_replacement_cat:NNN` Here, `#1` is a letter among BEMTPUDSLOA and `#2#3` denote the next character. Complain if we reach the end of the replacement or if the construction appears inside `\c{...}` or `\u{...}`, and detect the case of a parenthesis. In that case, store the current category in a sequence and switch to a new one.

```

25419 \cs_new_protected:Npn \_regex_replacement_cat:NNN #1#2#3
25420 {

```

```

25421 \token_if_eq_meaning:NNTF \prg_do_nothing: #3
25422 { \__kernel_msg_error:nn { kernel } { replacement-catcode-end } }
25423 {
25424   \int_compare:nNnTF { \l__regex_replacement_csnames_int } > 0
25425   {
25426     \__kernel_msg_error:nnnn
25427     { kernel } { replacement-catcode-in-cs } {#1} {#3}
25428     #2 #3
25429   }
25430   {
25431     \__regex_two_if_eq:NNNNTF #2 #3 \__regex_replacement_normal:n (
25432     {
25433       \seq_push:NV \l__regex_replacement_category_seq
25434       \l__regex_replacement_category_tl
25435       \tl_set:Nn \l__regex_replacement_category_tl {#1}
25436     }
25437     {
25438       \token_if_eq_meaning:NNT #2 \__regex_replacement_escaped:N
25439       {
25440         \__regex_char_if_alphanumeric:NNTF #3
25441         {
25442           \__kernel_msg_error:nnnn
25443           { kernel } { replacement-catcode-escaped }
25444           {#1} {#3}
25445         }
25446         { }
25447       }
25448       \use:c { __regex_replacement_c_#1:w } #2 #3
25449     }
25450   }
25451 }
25452 }

```

(End definition for `__regex_replacement_cat:NNN`.)

We now need to change the category code of the null character many times, hence work in a group. The catcode-specific macros below are defined in alphabetical order; if you are trying to understand the code, start from the end of the alphabet as those categories are simpler than active or begin-group.

```

25453 \group_begin:

```

`__regex_replacement_char:nnN`

The only way to produce an arbitrary character-catcode pair is to use the `\lowercase` or `\uppercase` primitives. This is a wrapper for our purposes. The first argument is the null character with various catcodes. The second and third arguments are grabbed from the input stream: `#3` is the character whose character code to reproduce. We could use `\char_generate:nn` but only for some catcodes (active characters and spaces are not supported).

```

25454 \cs_new_protected:Npn \__regex_replacement_char:nnN #1#2#3
25455 {
25456   \tex_lccode:D 0 = '#3 \scan_stop:
25457   \tex_lowercase:D { \tl_build_put_right:Nn \l__regex_build_tl {#1} }
25458 }

```

(End definition for `__regex_replacement_char:nnN`.)

`__regex_replacement_c_A:w` For an active character, expansion must be avoided, twice because we later do two x-expansions, to unpack `\toks` for the query, and to expand their contents to tokens of the query.

```

25459 \char_set_catcode_active:N \^^@
25460 \cs_new_protected:Npn \__regex_replacement_c_A:w
25461 { \__regex_replacement_char:nNN { \exp_not:n { \exp_not:N \^^@ } } }

```

(End definition for __regex_replacement_c_A:w.)

`__regex_replacement_c_B:w` An explicit begin-group token increases the balance, unless within a `\c{...}` or `\u{...}` construction. Add the desired begin-group character, using the standard `\if_false:` trick. We eventually x-expand twice. The first time must yield a balanced token list, and the second one gives the bare begin-group token. The `\exp_after:wN` is not strictly needed, but is more consistent with l3tl-analysis.

```

25462 \char_set_catcode_group_begin:N \^^@
25463 \cs_new_protected:Npn \__regex_replacement_c_B:w
25464 {
25465   \if_int_compare:w \l__regex_replacement_csnames_int = 0 \exp_stop_f:
25466   \int_incr:N \l__regex_balance_int
25467   \fi:
25468   \__regex_replacement_char:nNN
25469   { \exp_not:n { \exp_after:wN \^^@ \if_false: } \fi: } }
25470 }

```

(End definition for __regex_replacement_c_B:w.)

`__regex_replacement_c_C:w` This is not quite catcode-related: when the user requests a character with category “control sequence”, the one-character control symbol is returned. As for the active character, we prepare for two x-expansions.

```

25471 \cs_new_protected:Npn \__regex_replacement_c_C:w #1#2
25472 {
25473   \tl_build_put_right:Nn \l__regex_build_tl
25474   { \exp_not:N \exp_not:N \exp_not:c {#2} }
25475 }

```

(End definition for __regex_replacement_c_C:w.)

`__regex_replacement_c_D:w` Subscripts fit the mould: `\lowercase` the null byte with the correct category.

```

25476 \char_set_catcode_math_subscript:N \^^@
25477 \cs_new_protected:Npn \__regex_replacement_c_D:w
25478 { \__regex_replacement_char:nNN { \^^@ } }

```

(End definition for __regex_replacement_c_D:w.)

`__regex_replacement_c_E:w` Similar to the begin-group case, the second x-expansion produces the bare end-group token.

```

25479 \char_set_catcode_group_end:N \^^@
25480 \cs_new_protected:Npn \__regex_replacement_c_E:w
25481 {
25482   \if_int_compare:w \l__regex_replacement_csnames_int = 0 \exp_stop_f:
25483   \int_decr:N \l__regex_balance_int
25484   \fi:
25485   \__regex_replacement_char:nNN
25486   { \exp_not:n { \if_false: { \fi: \^^@ } } }
25487 }

```

(End definition for `_regex_replacement_c_E:w`.)

`_regex_replacement_c_L:w` Simply `\lowercase` a letter null byte to produce an arbitrary letter.

```
25488 \char_set_catcode_letter:N \^^@
25489 \cs_new_protected:Npn \_regex_replacement_c_L:w
25490 { \_regex_replacement_char:nNN { ^^@ } }
```

(End definition for `_regex_replacement_c_L:w`.)

`_regex_replacement_c_M:w` No surprise here, we lowercase the null math toggle.

```
25491 \char_set_catcode_math_toggle:N \^^@
25492 \cs_new_protected:Npn \_regex_replacement_c_M:w
25493 { \_regex_replacement_char:nNN { ^^@ } }
```

(End definition for `_regex_replacement_c_M:w`.)

`_regex_replacement_c_O:w` Lowercase an other null byte.

```
25494 \char_set_catcode_other:N \^^@
25495 \cs_new_protected:Npn \_regex_replacement_c_O:w
25496 { \_regex_replacement_char:nNN { ^^@ } }
```

(End definition for `_regex_replacement_c_O:w`.)

`_regex_replacement_c_P:w` For macro parameters, expansion is a tricky issue. We need to prepare for two x-expansions and passing through various macro definitions. Note that we cannot replace one `\exp_not:n` by doubling the macro parameter characters because this would misbehave if a mischievous user asks for `\c{cP\#}`, since that macro parameter character would be doubled.

```
25497 \char_set_catcode_parameter:N \^^@
25498 \cs_new_protected:Npn \_regex_replacement_c_P:w
25499 {
25500   \_regex_replacement_char:nNN
25501   { \exp_not:n { \exp_not:n { ^^@^^@^^@^^@ } } }
25502 }
```

(End definition for `_regex_replacement_c_P:w`.)

`_regex_replacement_c_S:w` Spaces are normalized on input by \TeX to have character code 32. It is in fact impossible to get a token with character code 0 and category code 10. Hence we use 32 instead of 0 as our base character.

```
25503 \cs_new_protected:Npn \_regex_replacement_c_S:w #1#2
25504 {
25505   \if_int_compare:w '#2 = 0 \exp_stop_f:
25506   \_kernel_msg_error:nn { kernel } { replacement-null-space }
25507   \fi:
25508   \tex_lccode:D '\ = '#2 \scan_stop:
25509   \tex_lowercase:D { \tl_build_put_right:Nn \l__regex_build_tl {~} }
25510 }
```

(End definition for `_regex_replacement_c_S:w`.)

`_regex_replacement_c_T:w` No surprise for alignment tabs here. Those are surrounded by the appropriate braces whenever necessary, hence they don't cause trouble in alignment settings.

```
25511 \char_set_catcode_alignment:N \^^@
25512 \cs_new_protected:Npn \_regex_replacement_c_T:w
25513 { \_regex_replacement_char:nNN { ^^@ } }
```

(End definition for `_regex_replacement_c_T:w`.)

`_regex_replacement_c_U:w` Simple call to `_regex_replacement_char:nNN` which lowercases the math superscript `^^@`.

```
25514 \char_set_catcode_math_superscript:N \^^@
25515 \cs_new_protected:Npn \_regex_replacement_c_U:w
25516 { \_regex_replacement_char:nNN { ^^@ } }
```

(End definition for `_regex_replacement_c_U:w`.)

Restore the catcode of the null byte.

```
25517 \group_end:
```

40.6.7 An error

`_regex_replacement_error:NNN` Simple error reporting by calling one of the messages `replacement-c`, `replacement-g`, or `replacement-u`.

```
25518 \cs_new_protected:Npn \_regex_replacement_error:NNN #1#2#3
25519 {
25520   \__kernel_msg_error:nxx { kernel } { replacement-#1 } {#3}
25521   #2 #3
25522 }
```

(End definition for `_regex_replacement_error:NNN`.)

40.7 User functions

`\regex_new:N` Before being assigned a sensible value, a regex variable matches nothing.

```
25523 \cs_new_protected:Npn \regex_new:N #1
25524 { \cs_new_eq:NN #1 \c__regex_no_match_regex }
```

(End definition for `\regex_new:N`. This function is documented on page 222.)

`\l_tmpa_regex` The usual scratch space.

```
\l_tmpb_regex 25525 \regex_new:N \l_tmpa_regex
\g_tmpa_regex 25526 \regex_new:N \l_tmpb_regex
\g_tmpb_regex 25527 \regex_new:N \g_tmpa_regex
25528 \regex_new:N \g_tmpb_regex
```

(End definition for `\l_tmpa_regex` and others. These variables are documented on page 224.)

`\regex_set:Nn` Compile, then store the result in the user variable with the appropriate assignment function.
`\regex_gset:Nn`
`\regex_const:Nn`

```
25529 \cs_new_protected:Npn \regex_set:Nn #1#2
25530 {
25531   \__regex_compile:n {#2}
25532   \tl_set_eq:NN #1 \l__regex_internal_regex
25533 }
25534 \cs_new_protected:Npn \regex_gset:Nn #1#2
25535 {
25536   \__regex_compile:n {#2}
25537   \tl_gset_eq:NN #1 \l__regex_internal_regex
25538 }
25539 \cs_new_protected:Npn \regex_const:Nn #1#2
25540 {
```



```

25541     \__regex_compile:n {#2}
25542     \tl_const:Nx #1 { \exp_not:o \l__regex_internal_regex }
25543 }

```

(End definition for `\regex_set:Nn`, `\regex_gset:Nn`, and `\regex_const:Nn`. These functions are documented on page 222.)

`\regex_show:N` User functions: the `n` variant requires compilation first. Then show the variable with
`\regex_show:n` some appropriate text. The auxiliary is defined in a different section.

```

25544 \cs_new_protected:Npn \regex_show:n #1
25545 {
25546     \__regex_compile:n {#1}
25547     \__regex_show:N \l__regex_internal_regex
25548     \msg_show:nnxxxx { LaTeX / kernel } { show-regex }
25549     { \tl_to_str:n {#1} } { }
25550     { \l__regex_internal_a_tl } { }
25551 }
25552 \cs_new_protected:Npn \regex_show:N #1
25553 {
25554     \__kernel_chk_defined:NT #1
25555     {
25556         \__regex_show:N #1
25557         \msg_show:nnxxxx { LaTeX / kernel } { show-regex }
25558         { } { \token_to_str:N #1 }
25559         { \l__regex_internal_a_tl } { }
25560     }
25561 }

```

(End definition for `\regex_show:N` and `\regex_show:n`. These functions are documented on page 222.)

`\regex_match:nnTF` Those conditionals are based on a common auxiliary defined later. Its first argument
`\regex_match:NnTF` builds the NFA corresponding to the regex, and the second argument is the query token
list. Once we have performed the match, convert the resulting boolean to `\prg_return_`
`true:` or `false`.

```

25562 \prg_new_protected_conditional:Npnn \regex_match:nn #1#2 { T , F , TF }
25563 {
25564     \__regex_if_match:nn { \__regex_build:n {#1} } {#2}
25565     \__regex_return:
25566 }
25567 \prg_new_protected_conditional:Npnn \regex_match:Nn #1#2 { T , F , TF }
25568 {
25569     \__regex_if_match:nn { \__regex_build:N #1 } {#2}
25570     \__regex_return:
25571 }

```

(End definition for `\regex_match:nnTF` and `\regex_match:NnTF`. These functions are documented on page 222.)

`\regex_count:nnN` Again, use an auxiliary whose first argument builds the NFA.
`\regex_count:NnN`

```

25572 \cs_new_protected:Npn \regex_count:nnN #1
25573 { \__regex_count:nnN { \__regex_build:n {#1} } }
25574 \cs_new_protected:Npn \regex_count:NnN #1
25575 { \__regex_count:nnN { \__regex_build:N #1 } }

```

(End definition for `\regex_count:nnN` and `\regex_count:NnN`. These functions are documented on page 223.)

```

\regex_extract_once:nnN
\regex_extract_once:nnNTF
\regex_extract_once:NnN
\regex_extract_once:NnNTF
\regex_extract_all:nnN
\regex_extract_all:nnNTF
\regex_extract_all:NnN
\regex_extract_all:NnNTF
\regex_replace_once:nnN
\regex_replace_once:nnNTF
\regex_replace_once:NnN
\regex_replace_once:NnNTF
\regex_replace_all:nnN
\regex_replace_all:nnNTF
\regex_replace_all:NnN
\regex_replace_all:NnNTF
\regex_split:nnN
\regex_split:nnNTF
\regex_split:NnN
\regex_split:NnNTF

```

We define here 40 user functions, following a common pattern in terms of :nnN auxiliaries, defined in the coming subsections. The auxiliary is handed __regex_build:n or __regex_build:N with the appropriate regex argument, then all other necessary arguments (replacement text, token list, *etc.* The conditionals call __regex_return: to return either true or false once matching has been performed.

```

25576 \cs_set_protected:Npn \__regex_tmp:w #1#2#3
25577 {
25578   \cs_new_protected:Npn #2 ##1 { #1 { \__regex_build:n {##1} } }
25579   \cs_new_protected:Npn #3 ##1 { #1 { \__regex_build:N ##1 } }
25580   \prg_new_protected_conditional:Npnn #2 ##1##2##3 { T , F , TF }
25581     { #1 { \__regex_build:n {##1} } {##2} ##3 \__regex_return: }
25582   \prg_new_protected_conditional:Npnn #3 ##1##2##3 { T , F , TF }
25583     { #1 { \__regex_build:N ##1 } {##2} ##3 \__regex_return: }
25584 }
25585 \__regex_tmp:w \__regex_extract_once:nnN
25586 \__regex_tmp:w \__regex_extract_once:nnNTF
25587 \__regex_tmp:w \__regex_extract_all:nnN
25588 \__regex_tmp:w \__regex_extract_all:NnN
25589 \__regex_tmp:w \__regex_replace_once:nnN
25590 \__regex_tmp:w \__regex_replace_once:nnNTF
25591 \__regex_tmp:w \__regex_replace_all:nnN
25592 \__regex_tmp:w \__regex_replace_all:NnN
25593 \__regex_tmp:w \__regex_split:nnN
\__regex_split:NnN

```

(End definition for \regex_extract_once:nnN and others. These functions are documented on page 223.)

40.7.1 Variables and helpers for user functions

\l__regex_match_count_int The number of matches found so far is stored in \l__regex_match_count_int. This is only used in the \regex_count:nnN functions.

```
25594 \int_new:N \l__regex_match_count_int
```

(End definition for \l__regex_match_count_int.)

__regex_begin __regex_end Those flags are raised to indicate extra begin-group or end-group tokens when extracting submatches.

```
25595 \flag_new:n { __regex_begin }
25596 \flag_new:n { __regex_end }
```

(End definition for __regex_begin and __regex_end.)

\l__regex_min_submatch_int \l__regex_submatch_int \l__regex_zeroth_submatch_int The end-points of each submatch are stored in two arrays whose index $\langle submatch \rangle$ ranges from \l__regex_min_submatch_int (inclusive) to \l__regex_submatch_int (exclusive). Each successful match comes with a 0-th submatch (the full match), and one match for each capturing group: submatches corresponding to the last successful match are labelled starting at zeroth_submatch. The entry \l__regex_zeroth_submatch_int in \g__regex_submatch_prev_intarray holds the position at which that match attempt started: this is used for splitting and replacements.

```
25597 \int_new:N \l__regex_min_submatch_int
25598 \int_new:N \l__regex_submatch_int
25599 \int_new:N \l__regex_zeroth_submatch_int
```

(End definition for `\l__regex_min_submatch_int`, `\l__regex_submatch_int`, and `\l__regex_zeroth_submatch_int`.)

`\g__regex_submatch_prev_intarray` Hold the place where the match attempt begun and the end-points of each submatch.
`\g__regex_submatch_begin_intarray` 25600 `\intarray_new:Nn \g__regex_submatch_prev_intarray { 65536 }`
`\g__regex_submatch_end_intarray` 25601 `\intarray_new:Nn \g__regex_submatch_begin_intarray { 65536 }`
25602 `\intarray_new:Nn \g__regex_submatch_end_intarray { 65536 }`

(End definition for `\g__regex_submatch_prev_intarray`, `\g__regex_submatch_begin_intarray`, and `\g__regex_submatch_end_intarray`.)

`__regex_return:` This function triggers either `\prg_return_false:` or `\prg_return_true:` as appropriate to whether a match was found or not. It is used by all user conditionals.

```
25603 \cs_new_protected:Npn \__regex_return:
25604 {
25605   \if_meaning:w \c_true_bool \g__regex_success_bool
25606     \prg_return_true:
25607   \else:
25608     \prg_return_false:
25609   \fi:
25610 }
```

(End definition for `__regex_return:`.)

40.7.2 Matching

`__regex_if_match:nn` We don't track submatches, and stop after a single match. Build the NFA with #1, and perform the match on the query #2.

```
25611 \cs_new_protected:Npn \__regex_if_match:nn #1#2
25612 {
25613   \group_begin:
25614   \__regex_disable_submatches:
25615   \__regex_single_match:
25616   #1
25617   \__regex_match:n {#2}
25618   \group_end:
25619 }
```

(End definition for `__regex_if_match:nn`.)

`__regex_count:nnN` Again, we don't care about submatches. Instead of aborting after the first "longest match" is found, we search for multiple matches, incrementing `\l__regex_match_count_int` every time to record the number of matches. Build the NFA and match. At the end, store the result in the user's variable.

```
25620 \cs_new_protected:Npn \__regex_count:nnN #1#2#3
25621 {
25622   \group_begin:
25623   \__regex_disable_submatches:
25624   \int_zero:N \l__regex_match_count_int
25625   \__regex_multi_match:n { \int_incr:N \l__regex_match_count_int }
25626   #1
25627   \__regex_match:n {#2}
25628   \exp_args:NNNo
25629   \group_end:
25630   \int_set:Nn #3 { \int_use:N \l__regex_match_count_int }
25631 }
```

(End definition for `_regex_count:nnN`.)

40.7.3 Extracting submatches

`_regex_extract_once:nnN` Match once or multiple times. After each match (or after the only match), extract the submatches using `_regex_extract:.` At the end, store the sequence containing all the submatches into the user variable `#3` after closing the group.

```

25632 \cs_new_protected:Npn \_regex_extract_once:nnN #1#2#3
25633 {
25634   \group_begin:
25635     \_regex_single_match:
25636     #1
25637     \_regex_match:n {#2}
25638     \_regex_extract:
25639     \_regex_group_end_extract_seq:N #3
25640   }
25641 \cs_new_protected:Npn \_regex_extract_all:nnN #1#2#3
25642 {
25643   \group_begin:
25644     \_regex_multi_match:n { \_regex_extract: }
25645     #1
25646     \_regex_match:n {#2}
25647     \_regex_group_end_extract_seq:N #3
25648   }

```

(End definition for `_regex_extract_once:nnN` and `_regex_extract_all:nnN`.)

`_regex_split:nnN` Splitting at submatches is a bit more tricky. For each match, extract all submatches, and replace the zeroth submatch by the part of the query between the start of the match attempt and the start of the zeroth submatch. This is inhibited if the delimiter matched an empty token list at the start of this match attempt. After the last match, store the last part of the token list, which ranges from the start of the match attempt to the end of the query. This step is inhibited if the last match was empty and at the very end: decrement `\l__regex_submatch_int`, which controls which matches will be used.

```

25649 \cs_new_protected:Npn \_regex_split:nnN #1#2#3
25650 {
25651   \group_begin:
25652     \_regex_multi_match:n
25653     {
25654       \if_int_compare:w
25655         \l__regex_start_pos_int < \l__regex_success_pos_int
25656         \_regex_extract:
25657         \__kernel_intarray_gset:Nnn \g__regex_submatch_prev_intarray
25658         { \l__regex_zeroth_submatch_int } { 0 }
25659         \__kernel_intarray_gset:Nnn \g__regex_submatch_end_intarray
25660         { \l__regex_zeroth_submatch_int }
25661         {
25662           \__kernel_intarray_item:Nn \g__regex_submatch_begin_intarray
25663           { \l__regex_zeroth_submatch_int }
25664         }
25665         \__kernel_intarray_gset:Nnn \g__regex_submatch_begin_intarray
25666         { \l__regex_zeroth_submatch_int }
25667         { \l__regex_start_pos_int }

```

```

25668         \fi:
25669     }
25670     #1
25671     \__regex_match:n {#2}
25672 (assert)\assert_int:n { \l__regex_curr_pos_int = \l__regex_max_pos_int }
25673     \__kernel_intarray_gset:Nnn \g__regex_submatch_prev_intarray
25674     { \l__regex_submatch_int } { 0 }
25675     \__kernel_intarray_gset:Nnn \g__regex_submatch_end_intarray
25676     { \l__regex_submatch_int }
25677     { \l__regex_max_pos_int }
25678     \__kernel_intarray_gset:Nnn \g__regex_submatch_begin_intarray
25679     { \l__regex_submatch_int }
25680     { \l__regex_start_pos_int }
25681     \int_incr:N \l__regex_submatch_int
25682     \if_meaning:w \c_true_bool \l__regex_empty_success_bool
25683     \if_int_compare:w \l__regex_start_pos_int = \l__regex_max_pos_int
25684     \int_decr:N \l__regex_submatch_int
25685     \fi:
25686     \fi:
25687     \__regex_group_end_extract_seq:N #3
25688 }

```

(End definition for __regex_split:nnN.)

__regex_group_end_extract_seq:N The end-points of submatches are stored as entries of two arrays from \l__regex_min_submatch_int to \l__regex_submatch_int (exclusive). Extract the relevant ranges into \l__regex_internal_a_tl. We detect unbalanced results using the two flags __regex_begin and __regex_end, raised whenever we see too many begin-group or end-group tokens in a submatch.

```

25689 \cs_new_protected:Npn \__regex_group_end_extract_seq:N #1
25690 {
25691     \flag_clear:n { __regex_begin }
25692     \flag_clear:n { __regex_end }
25693     \seq_set_from_function:NnN \l__regex_internal_seq
25694     {
25695         \int_step_function:nnN { \l__regex_min_submatch_int }
25696         { \l__regex_submatch_int - 1 }
25697     }
25698     \__regex_extract_seq_aux:n
25699     \int_compare:nNnF
25700     {
25701         \flag_height:n { __regex_begin } +
25702         \flag_height:n { __regex_end }
25703     }
25704     = 0
25705     {
25706         \__kernel_msg_error:nnxxx { kernel } { result-unbalanced }
25707         { splitting~or~extracting~submatches }
25708         { \flag_height:n { __regex_end } }
25709         { \flag_height:n { __regex_begin } }
25710     }
25711     \seq_set_map:NnN \l__regex_internal_seq \l__regex_internal_seq {##1}
25712     \exp_args:NNNo
25713     \group_end:

```

```

25714         \tl_set:Nn #1 { \l__regex_internal_seq }
25715     }

```

(End definition for __regex_group_end_extract_seq:N.)

__regex_extract_seq_aux:n The :n auxiliary builds one item of the sequence of submatches. First compute the brace balance of the submatch, then extract the submatch from the query, adding the appropriate braces and raising a flag if the submatch is not balanced.

```

25716 \cs_new:Npn \__regex_extract_seq_aux:n #1
25717 {
25718     \exp_after:wN \__regex_extract_seq_aux:ww
25719     \int_value:w \__regex_submatch_balance:n {#1} ; #1;
25720 }
25721 \cs_new:Npn \__regex_extract_seq_aux:ww #1; #2;
25722 {
25723     \if_int_compare:w #1 < 0 \exp_stop_f:
25724         \flag_raise:n { __regex_end }
25725         \prg_replicate:nn {-#1} { \exp_not:n { { \if_false: } \fi: } }
25726     \fi:
25727     \__regex_query_submatch:n {#2}
25728     \if_int_compare:w #1 > 0 \exp_stop_f:
25729         \flag_raise:n { __regex_begin }
25730         \prg_replicate:nn {#1} { \exp_not:n { \if_false: { \fi: } } }
25731     \fi:
25732 }

```

(End definition for __regex_extract_seq_aux:n and __regex_extract_seq_aux:ww.)

__regex_extract: Our task here is to extract from the property list \l__regex_success_submatches_prop the list of end-points of submatches, and store them in appropriate array entries, from \l__regex_extract_b:wn the list of start-points of submatches, and store them in appropriate array entries, from \l__regex_extract_e:wn \l__regex_zeroth_submatch_int upwards. We begin by emptying those entries. This is somewhat a hack: the <key>-<value> pair in the property list update the appropriate entry. This is a comparison to -1. At the end, store the information about the position at which the match attempt started, in \g__regex_submatch_prev_intarray.

```

25733 \cs_new_protected:Npn \__regex_extract:
25734 {
25735     \if_meaning:w \c_true_bool \g__regex_success_bool
25736         \int_set_eq:NN \l__regex_zeroth_submatch_int \l__regex_submatch_int
25737         \prg_replicate:nn \l__regex_capturing_group_int
25738         {
25739             \__kernel_intarray_gset:Nnn \g__regex_submatch_begin_intarray
25740                 { \l__regex_submatch_int } { 0 }
25741             \__kernel_intarray_gset:Nnn \g__regex_submatch_end_intarray
25742                 { \l__regex_submatch_int } { 0 }
25743             \__kernel_intarray_gset:Nnn \g__regex_submatch_prev_intarray
25744                 { \l__regex_submatch_int } { 0 }
25745             \int_incr:N \l__regex_submatch_int
25746         }
25747     \prop_map_inline:Nn \l__regex_success_submatches_prop
25748     {
25749         \if_int_compare:w ##1 - 1 \exp_stop_f:
25750             \exp_after:wN \__regex_extract_e:wn \int_value:w
25751         \else:

```

```

25752         \exp_after:wN \_regex_extract_b:wn \int_value:w
25753         \fi:
25754         \_regex_int_eval:w \l__regex_zeroth_submatch_int + ##1 {##2}
25755     }
25756     \_kernel_intarray_gset:Nnn \g__regex_submatch_prev_intarray
25757     { \l__regex_zeroth_submatch_int } { \l__regex_start_pos_int }
25758 \fi:
25759 }
25760 \cs_new_protected:Npn \_regex_extract_b:wn #1 < #2
25761 {
25762     \_kernel_intarray_gset:Nnn
25763     \g__regex_submatch_begin_intarray {#1} {#2}
25764 }
25765 \cs_new_protected:Npn \_regex_extract_e:wn #1 > #2
25766 { \_kernel_intarray_gset:Nnn \g__regex_submatch_end_intarray {#1} {#2} }

```

(End definition for _regex_extract:, _regex_extract_b:wn, and _regex_extract_e:wn.)

40.7.4 Replacement

_regex_replace_once:nnN

Build the NFA and the replacement functions, then find a single match. If the match failed, simply exit the group. Otherwise, we do the replacement. Extract submatches. Compute the brace balance corresponding to replacing this match by the replacement (this depends on submatches). Prepare the replaced token list: the replacement function produces the tokens from the start of the query to the start of the match and the replacement text for this match; we need to add the tokens from the end of the match to the end of the query. Finally, store the result in the user's variable after closing the group: this step involves an additional x-expansion, and checks that braces are balanced in the final result.

```

25767 \cs_new_protected:Npn \_regex_replace_once:nnN #1#2#3
25768 {
25769     \group_begin:
25770     \_regex_single_match:
25771     #1
25772     \_regex_replacement:n {#2}
25773     \exp_args:No \_regex_match:n { #3 }
25774     \if_meaning:w \c_false_bool \g__regex_success_bool
25775     \group_end:
25776     \else:
25777         \_regex_extract:
25778         \int_set:Nn \l__regex_balance_int
25779         {
25780             \_regex_replacement_balance_one_match:n
25781             { \l__regex_zeroth_submatch_int }
25782         }
25783         \tl_set:Nx \l__regex_internal_a_tl
25784         {
25785             \_regex_replacement_do_one_match:n
25786             { \l__regex_zeroth_submatch_int }
25787             \_regex_query_range:nn
25788             {
25789                 \_kernel_intarray_item:Nn \g__regex_submatch_end_intarray
25790                 { \l__regex_zeroth_submatch_int }
25791             }
25792             { \l__regex_max_pos_int }

```

```

25793     }
25794     \__regex_group_end_replace:N #3
25795   \fi:
25796 }

```

(End definition for __regex_replace_once:nnN.)

__regex_replace_all:nnN Match multiple times, and for every match, extract submatches and additionally store the position at which the match attempt started. The entries from \l__regex_min_submatch_int to \l__regex_submatch_int hold information about submatches of every match in order; each match corresponds to \l__regex_capturing_group_int consecutive entries. Compute the brace balance corresponding to doing all the replacements: this is the sum of brace balances for replacing each match. Join together the replacement texts for each match (including the part of the query before the match), and the end of the query.

```

25797 \cs_new_protected:Npn \__regex_replace_all:nnN #1#2#3
25798 {
25799   \group_begin:
25800   \__regex_multi_match:n { \__regex_extract: }
25801   #1
25802   \__regex_replacement:n {#2}
25803   \exp_args:No \__regex_match:n {#3}
25804   \int_set:Nn \l__regex_balance_int
25805   {
25806     0
25807     \int_step_function:nnnN
25808       { \l__regex_min_submatch_int }
25809       \l__regex_capturing_group_int
25810       { \l__regex_submatch_int - 1 }
25811       \__regex_replacement_balance_one_match:n
25812   }
25813   \tl_set:Nx \l__regex_internal_a_tl
25814   {
25815     \int_step_function:nnnN
25816       { \l__regex_min_submatch_int }
25817       \l__regex_capturing_group_int
25818       { \l__regex_submatch_int - 1 }
25819       \__regex_replacement_do_one_match:n
25820     \__regex_query_range:nn
25821       \l__regex_start_pos_int \l__regex_max_pos_int
25822   }
25823   \__regex_group_end_replace:N #3
25824 }

```

(End definition for __regex_replace_all:nnN.)

__regex_group_end_replace:N If the brace balance is not 0, raise an error. Then set the user's variable #1 to the x-expansion of \l__regex_internal_a_tl, adding the appropriate braces to produce a balanced result. And end the group.

```

25825 \cs_new_protected:Npn \__regex_group_end_replace:N #1
25826 {
25827   \if_int_compare:w \l__regex_balance_int = 0 \exp_stop_f:
25828   \else:
25829     \__kernel_msg_error:nnxxx { kernel } { result-unbalanced }

```



```

25830     { replacing }
25831     { \int_max:nn { - \l__regex_balance_int } { 0 } }
25832     { \int_max:nn { \l__regex_balance_int } { 0 } }
25833 \fi:
25834 \use:x
25835 {
25836     \group_end:
25837     \tl_set:Nn \exp_not:N #1
25838     {
25839         \if_int_compare:w \l__regex_balance_int < 0 \exp_stop_f:
25840         \prg_replicate:nn { - \l__regex_balance_int }
25841         { { \if_false: } \fi: }
25842         \fi:
25843         \l__regex_internal_a_tl
25844         \if_int_compare:w \l__regex_balance_int > 0 \exp_stop_f:
25845         \prg_replicate:nn { \l__regex_balance_int }
25846         { \if_false: { \fi: } }
25847         \fi:
25848     }
25849 }
25850 }

```

(End definition for `__regex_group_end_replace:N`.)

40.7.5 Storing and showing compiled patterns

40.8 Messages

Messages for the preparsing phase.

```

25851 \use:x
25852 {
25853     \__kernel_msg_new:nnn { kernel } { trailing-backslash }
25854     { Trailing-escape-char~'\iow_char:N\\'~in-regex-or~replacement. }
25855     \__kernel_msg_new:nnn { kernel } { x-missing-rbrace }
25856     {
25857         Missing~brace~'\iow_char:N\}'~in-regex~
25858         '...\iow_char:N\x\iow_char:N\{...##1'.
25859     }
25860     \__kernel_msg_new:nnn { kernel } { x-overflow }
25861     {
25862         Character-code-##1~too~large~in~
25863         \iow_char:N\x\iow_char:N\{##2\iow_char:N\}~regex.
25864     }
25865 }

```

Invalid quantifier.

```

25866 \__kernel_msg_new:nnnn { kernel } { invalid-quantifier }
25867 { Braced~quantifier~'##1'~may~not~be~followed~by~'##2'. }
25868 {
25869     The~character~'##2'~is~invalid~in~the~braced~quantifier~'##1'.~
25870     The~only~valid~quantifiers~are~'*',~'?',~'+',~'{<int>}',~
25871     '{<min>}',~and~'{<min>,<max>}',~optionally~followed~by~'?''.
25872 }

```

Messages for missing or extra closing brackets and parentheses, with some fancy singular/plural handling for the case of parentheses.

```

25873 \__kernel_msg_new:nnnn { kernel } { missing-rbrack }
25874 { Missing-right-bracket-inserted-in-regular-expression. }
25875 {
25876   LaTeX-was-given-a-regular-expression-where-a-character-class-
25877   was-started-with~'[,~but~the~matching~'~is~missing.
25878 }
25879 \__kernel_msg_new:nnnn { kernel } { missing-rparen }
25880 {
25881   Missing-right~
25882   \int_compare:nTF { #1 = 1 } { parenthesis } { parentheses } ~
25883   inserted-in-regular-expression.
25884 }
25885 {
25886   LaTeX-was-given-a-regular-expression-with~\int_eval:n {#1} ~
25887   more-left-parentheses-than-right-parentheses.
25888 }
25889 \__kernel_msg_new:nnnn { kernel } { extra-rparen }
25890 { Extra-right-parenthesis-ignored-in-regular-expression. }
25891 {
25892   LaTeX-came-across-a-closing-parenthesis-when-no-submatch-group-
25893   was-open.~The-parenthesis-will-be-ignored.
25894 }

```

Some escaped alphanumerics are not allowed everywhere.

```

25895 \__kernel_msg_new:nnnn { kernel } { bad-escape }
25896 {
25897   Invalid-escape~'\iow_char:N\\#1'~
25898   \__regex_if_in_cs:TF { within-a-control-sequence. }
25899   {
25900     \__regex_if_in_class:TF
25901     { in-a-character-class. }
25902     { following-a-category-test. }
25903   }
25904 }
25905 {
25906   The-escape-sequence~'\iow_char:N\\#1'~may-not-appear~
25907   \__regex_if_in_cs:TF
25908   {
25909     within-a-control-sequence-test-introduced-by~
25910     '\iow_char:N\\c\iow_char:N{'~
25911   }
25912   {
25913     \__regex_if_in_class:TF
25914     { within-a-character-class~ }
25915     { following-a-category-test-such-as~'\iow_char:N\\cL'~ }
25916     because-it-does-not-match-exactly-one-character.
25917   }
25918 }

```

Range errors.

```

25919 \__kernel_msg_new:nnnn { kernel } { range-missing-end }
25920 { Invalid-end-point-for-range~'#1-#2'~in-character-class. }
25921 {

```

```

25922     The~end~point~'#2'~of~the~range~'#1-#2'~may~not~serve~as~an~
25923     end~point~for~a~range:~alphanumeric~characters~should~not~be~
25924     escaped,~and~non~alphanumeric~characters~should~be~escaped.
25925 }
25926 \__kernel_msg_new:nnnn { kernel } { range-backwards }
25927 { Range~'#1-#2'~out~of~order~in~character~class. }
25928 {
25929     In~ranges~of~characters~'[x-y]'~appearing~in~character~classes,~
25930     the~first~character~code~must~not~be~larger~than~the~second.~
25931     Here,~'#1'~has~character~code~\int_eval:n {'#1},~while~
25932     '#2'~has~character~code~\int_eval:n {'#2}.
25933 }
    Errors related to \c and \u.
25934 \__kernel_msg_new:nnnn { kernel } { c-bad-mode }
25935 { Invalid~nested~'\iow_char:N\\c'~escape~in~regular~expression. }
25936 {
25937     The~'\iow_char:N\\c'~escape~cannot~be~used~within~
25938     a~control~sequence~test~'\iow_char:N\\c{...}'~
25939     nor~another~category~test.~
25940     To~combine~several~category~tests,~use~'\iow_char:N\\c[...]'.
25941 }
25942 \__kernel_msg_new:nnnn { kernel } { c-C-invalid }
25943 { '\iow_char:N\\c'~should~be~followed~by~'.'~or~'(',~not~'#1'. }
25944 {
25945     The~'\iow_char:N\\c'~construction~restricts~the~next~item~to~be~a~
25946     control~sequence~or~the~next~group~to~be~made~of~control~sequences.~
25947     It~only~makes~sense~to~follow~it~by~'.'~or~by~a~group.
25948 }
25949 \__kernel_msg_new:nnnn { kernel } { c-lparen-in-class }
25950 { Catcode~test~cannot~apply~to~group~in~character~class }
25951 {
25952     Construction~such~as~'\iow_char:N\\cL(abc)'~are~not~allowed~inside~a~
25953     class~'[...]'~because~classes~do~not~match~multiple~characters~at~once.
25954 }
25955 \__kernel_msg_new:nnnn { kernel } { c-missing-rbrace }
25956 { Missing~right~brace~inserted~for~'\iow_char:N\\c'~escape. }
25957 {
25958     LaTeX~was~given~a~regular~expression~where~a~
25959     '\iow_char:N\\c\iow_char:N\{...'~construction~was~not~ended~
25960     with~a~closing~brace~'\iow_char:N\}'.
25961 }
25962 \__kernel_msg_new:nnnn { kernel } { c-missing-rbrack }
25963 { Missing~right~bracket~inserted~for~'\iow_char:N\\c'~escape. }
25964 {
25965     A~construction~'\iow_char:N\\c[...]~appears~in~a~
25966     regular~expression,~but~the~closing~'~is~not~present.
25967 }
25968 \__kernel_msg_new:nnnn { kernel } { c-missing-category }
25969 { Invalid~character~'#1'~following~'\iow_char:N\\c'~escape. }
25970 {
25971     In~regular~expressions,~the~'\iow_char:N\\c'~escape~sequence~
25972     may~only~be~followed~by~a~left~brace,~a~left~bracket,~or~a~
25973     capital~letter~representing~a~character~category,~namely~
25974     one~of~'ABCDELMOPTU'.

```

```

25975 }
25976 \__kernel_msg_new:nnnn { kernel } { c-trailing }
25977 { Trailing~category~code~escape~'\iow_char:N\\c'... }
25978 {
25979   A~regular~expression~ends~with~'\iow_char:N\\c'~followed~
25980   by~a~letter.~It~will~be~ignored.
25981 }
25982 \__kernel_msg_new:nnnn { kernel } { u-missing-lbrace }
25983 { Missing~left~brace~following~'\iow_char:N\\u'~escape. }
25984 {
25985   The~'\iow_char:N\\u'~escape~sequence~must~be~followed~by~
25986   a~brace~group~with~the~name~of~the~variable~to~use.
25987 }
25988 \__kernel_msg_new:nnnn { kernel } { u-missing-rbrace }
25989 { Missing~right~brace~inserted~for~'\iow_char:N\\u'~escape. }
25990 {
25991   LaTeX~
25992   \str_if_eq:eeTF { } {#2}
25993   { reached~the~end~of~the~string~ }
25994   { encountered~an~escaped~alphanumeric~character '\iow_char:N\\#2'~
25995   when~parsing~the~argument~of~an~
25996   '\iow_char:N\\u\iow_char:N{...}\'}~escape.
25997 }

```

Errors when encountering the POSIX syntax [:...:].

```

25998 \__kernel_msg_new:nnnn { kernel } { posix-unsupported }
25999 { POSIX~collating~element~'[#1 ~ #1]\'~not~supported. }
26000 {
26001   The~'[.foo.]\'~and~'[=bar=]\'~syntaxes~have~a~special~meaning~
26002   in~POSIX~regular~expressions.~This~is~not~supported~by~LaTeX.~
26003   Maybe~you~forgot~to~escape~a~left~bracket~in~a~character~class?
26004 }
26005 \__kernel_msg_new:nnnn { kernel } { posix-unknown }
26006 { POSIX~class~'[[:#1:]]\'~unknown. }
26007 {
26008   '[[:#1:]]\'~is~not~among~the~known~POSIX~classes~
26009   '[[:alnum:]]\'~,~'[[:alpha:]]\'~,~'[[:ascii:]]\'~,~'[[:blank:]]\'~,~
26010   '[[:cntrl:]]\'~,~'[[:digit:]]\'~,~'[[:graph:]]\'~,~'[[:lower:]]\'~,~
26011   '[[:print:]]\'~,~'[[:punct:]]\'~,~'[[:space:]]\'~,~'[[:upper:]]\'~,~
26012   '[[:word:]]\'~,~and~'[[:xdigit:]]\''.
26013 }
26014 \__kernel_msg_new:nnnn { kernel } { posix-missing-close }
26015 { Missing~closing~':'\'~for~POSIX~class. }
26016 { The~POSIX~syntax~'#1\'~must~be~followed~by~':'\'~,~not~'#2\''. }

```

In various cases, the result of a `l3regex` operation can leave us with an unbalanced token list, which we must re-balance by adding begin-group or end-group character tokens.

```

26017 \__kernel_msg_new:nnnn { kernel } { result-unbalanced }
26018 { Missing~brace~inserted~when~#1. }
26019 {
26020   LaTeX~was~asked~to~do~some~regular~expression~operation,~
26021   and~the~resulting~token~list~would~not~have~the~same~number~
26022   of~begin~group~and~end~group~tokens.~Braces~were~inserted:~
26023   #2~left,~#3~right.

```

```

26024 }
Error message for unknown options.
26025 \__kernel_msg_new:nnnn { kernel } { unknown-option }
26026 { Unknown~option~'#1'~for~regular~expressions. }
26027 {
26028     The~only~available~option~is~'case-insensitive',~toggled-by~
26029     '(?i)'~and~'(?-i)'.
26030 }
26031 \__kernel_msg_new:nnnn { kernel } { special-group-unknown }
26032 { Unknown~special~group~'#1...'~in~a~regular~expression. }
26033 {
26034     The~only~valid~constructions~starting~with~'?'~are~
26035     '(:~...~)',~'(?|~...~)',~'(?i)',~and~'(?-i)'.
26036 }
Errors in the replacement text.
26037 \__kernel_msg_new:nnnn { kernel } { replacement-c }
26038 { Misused~'\iow_char:N\\c'~command~in~a~replacement~text. }
26039 {
26040     In~a~replacement~text,~the~'\iow_char:N\\c'~escape~sequence~
26041     can~be~followed~by~one~of~the~letters~'ABCDELMPSTU'~
26042     or~a~brace~group,~not~by~'#1'.
26043 }
26044 \__kernel_msg_new:nnnn { kernel } { replacement-u }
26045 { Misused~'\iow_char:N\\u'~command~in~a~replacement~text. }
26046 {
26047     In~a~replacement~text,~the~'\iow_char:N\\u'~escape~sequence~
26048     must~be~followed~by~a~brace~group~holding~the~name~of~the~
26049     variable~to~use.
26050 }
26051 \__kernel_msg_new:nnnn { kernel } { replacement-g }
26052 {
26053     Missing~brace~for~the~'\iow_char:N\\g'~construction~
26054     in~a~replacement~text.
26055 }
26056 {
26057     In~the~replacement~text~for~a~regular~expression~search,~
26058     submatches~are~represented~either~as~'\iow_char:N \\g{dd..d}',~
26059     or~'\d',~where~'d'~are~single~digits.~Here,~a~brace~is~missing.
26060 }
26061 \__kernel_msg_new:nnnn { kernel } { replacement-catcode-end }
26062 {
26063     Missing~character~for~the~'\iow_char:N\\c<category><character>'~
26064     construction~in~a~replacement~text.
26065 }
26066 {
26067     In~a~replacement~text,~the~'\iow_char:N\\c'~escape~sequence~
26068     can~be~followed~by~one~of~the~letters~'ABCDELMPSTU'~representing~
26069     the~character~category.~Then,~a~character~must~follow.~LaTeX~
26070     reached~the~end~of~the~replacement~when~looking~for~that.
26071 }
26072 \__kernel_msg_new:nnnn { kernel } { replacement-catcode-escaped }
26073 {
26074     Escaped~letter~or~digit~after~category~code~in~replacement~text.

```

```

26075 }
26076 {
26077   In~a~replacement~text,~the~'\iow_char:N\c'~escape~sequence~
26078   can~be~followed~by~one~of~the~letters~'ABCDELMOPTU'~representing~
26079   the~character~category.~Then,~a~character~must~follow,~not~
26080   '\iow_char:N\#2'.
26081 }
26082 \__kernel_msg_new:nnnn { kernel } { replacement-catcode-in-cs }
26083 {
26084   Category~code~'\iow_char:N\c#1#3'~ignored~inside~
26085   '\iow_char:N\c\{...\}'~in~a~replacement~text.
26086 }
26087 {
26088   In~a~replacement~text,~the~category~codes~of~the~argument~of~
26089   '\iow_char:N\c\{...\}'~are~ignored~when~building~the~control~
26090   sequence~name.
26091 }
26092 \__kernel_msg_new:nnnn { kernel } { replacement-null-space }
26093 { TeX~cannot~build~a~space~token~with~character~code~0. }
26094 {
26095   You~asked~for~a~character~token~with~category~space,~
26096   and~character~code~0,~for~instance~through~
26097   '\iow_char:N\cS\iow_char:N\cx00'.~
26098   This~specific~case~is~impossible~and~will~be~replaced~
26099   by~a~normal~space.
26100 }
26101 \__kernel_msg_new:nnnn { kernel } { replacement-missing-rbrace }
26102 { Missing~right~brace~inserted~in~replacement~text. }
26103 {
26104   There~ \int_compare:nTF { #1 = 1 } { was } { were } ~ #1~
26105   missing~right~\int_compare:nTF { #1 = 1 } { brace } { braces } .
26106 }
26107 \__kernel_msg_new:nnnn { kernel } { replacement-missing-rparen }
26108 { Missing~right~parenthesis~inserted~in~replacement~text. }
26109 {
26110   There~ \int_compare:nTF { #1 = 1 } { was } { were } ~ #1~
26111   missing~right~
26112   \int_compare:nTF { #1 = 1 } { parenthesis } { parentheses } .
26113 }

```

Used when showing a regex.

```

26114 \__kernel_msg_new:nnn { kernel } { show-regex }
26115 {
26116   >~Compiled~regex~
26117   \tl_if_empty:nTF {#1} { variable~ #2 } { {#1} } :
26118   #3
26119 }

```

`__regex_msg_repeated:nnN` This is not technically a message, but seems related enough to go there. The arguments are: #1 is the minimum number of repetitions; #2 is the number of allowed extra repetitions (−1 for infinite number), and #3 tells us about laziness.

```

26120 \cs_new:Npn \__regex_msg_repeated:nnN #1#2#3
26121 {
26122   \str_if_eq:eeF { #1 #2 } { 1 0 }

```

```

26123     {
26124     , ~ repeated ~
26125     \int_case:nnF {#2}
26126     {
26127     { -1 } { #1~or-more-times,~\bool_if:NTF #3 { lazy } { greedy } }
26128     { 0 } { #1~times }
26129     }
26130     {
26131     between~#1~and~\int_eval:n {#1+#2}~times,~
26132     \bool_if:NTF #3 { lazy } { greedy }
26133     }
26134     }
26135     }

```

(End definition for _regex_msg_repeated:nnN.)

40.9 Code for tracing

There is a more extensive implementation of tracing in the l3trial package l3trace. Function names are a bit different but could be merged.

_regex_trace_push:nnN Here #1 is the module name (regex) and #2 is typically 1. If the module's current tracing level is less than #2 show nothing, otherwise write #3 to the terminal.

```

\_regex_trace_pop:nnN
\_regex_trace:nnx
26136 \_kernel_if_debug:TF
26137 {
26138   \cs_new_protected:Npn \_regex_trace_push:nnN #1#2#3
26139   { \_regex_trace:nnx {#1} {#2} { entering~ \token_to_str:N #3 } }
26140   \cs_new_protected:Npn \_regex_trace_pop:nnN #1#2#3
26141   { \_regex_trace:nnx {#1} {#2} { leaving~ \token_to_str:N #3 } }
26142   \cs_new_protected:Npn \_regex_trace:nnx #1#2#3
26143   {
26144     \int_compare:nNnF
26145     { \int_use:c { g\_regex_trace_#1_int } } < {#2}
26146     { \iow_term:x { Trace:~#3 } }
26147   }
26148 }
26149 { }

```

(End definition for _regex_trace_push:nnN, _regex_trace_pop:nnN, and _regex_trace:nnx.)

\g__regex_trace_regex_int No tracing when that is zero.

```

26150 \int_new:N \g__regex_trace_regex_int

```

(End definition for \g__regex_trace_regex_int.)

_regex_trace_states:n This function lists the contents of all states of the NFA, stored in \toks from 0 to \l__-regex_max_state_int (excluded).

```

26151 \_kernel_if_debug:TF
26152 {
26153   \cs_new_protected:Npn \_regex_trace_states:n #1
26154   {
26155     \int_step_inline:nnn
26156     \l__regex_min_state_int
26157     { \l__regex_max_state_int - 1 }

```

```

26158         {
26159             \__regex_trace:nmx { regex } {#1}
26160             { \iow_char:N \toks ##1 = { \__regex_toks_use:w ##1 } }
26161         }
26162     }
26163 }
26164 { }

```

(End definition for __regex_trace_states:n.)

```
26165 </initex | package>
```

41 l3box implementation

```
26166 <*initex | package>
```

```
26167 <@@=box>
```

41.1 Support code

__box_dim_eval:w Evaluating a dimension expression expandably. The only difference with \dim_eval:n is the lack of \dim_use:N, to produce an internal dimension rather than expand it into characters.

```

26168 \cs_new_eq:NN \__box_dim_eval:w \tex_dimexpr:D
26169 \__kernel_patch_args:nNnpn
26170 {
26171     {
26172         \__kernel_chk_expr:nNnN {#1}
26173         \__box_dim_eval:w { } \__box_dim_eval:n
26174     }
26175 }
26176 \cs_new:Npn \__box_dim_eval:n #1
26177 { \__box_dim_eval:w #1 \scan_stop: }

```

(End definition for __box_dim_eval:w and __box_dim_eval:n.)

41.2 Creating and initialising boxes

The following test files are used for this code: m3box001.lvt.

\box_new:N Defining a new $\langle box \rangle$ register: remember that box 255 is not generally available.

```

\box_new:c 26178 <*package>
26179 \cs_new_protected:Npn \box_new:N #1
26180 {
26181     \__kernel_chk_if_free_cs:N #1
26182     \cs:w newbox \cs_end: #1
26183 }
26184 </package>
26185 \cs_generate_variant:Nn \box_new:N { c }

```

Clear a $\langle box \rangle$ register.

```

\box_clear:N 26186 \cs_new_protected:Npn \box_clear:N #1
26187 { \box_set_eq:NN #1 \c_empty_box }
\box_clear:c 26188 \cs_new_protected:Npn \box_gclear:N #1
\box_gclear:N 26189 { \box_gset_eq:NN #1 \c_empty_box }
\box_gclear:c

```



```

26190 \cs_generate_variant:Nn \box_clear:N { c }
26191 \cs_generate_variant:Nn \box_gclear:N { c }

```

Clear or new.

```

26192 \cs_new_protected:Npn \box_clear_new:N #1
\box_clear_new:N 26193 { \box_if_exist:NTF #1 { \box_clear:N #1 } { \box_new:N #1 } }
\box_clear_new:c 26194 \cs_new_protected:Npn \box_gclear_new:N #1
\box_gclear_new:N 26195 { \box_if_exist:NTF #1 { \box_gclear:N #1 } { \box_new:N #1 } }
\box_gclear_new:c 26196 \cs_generate_variant:Nn \box_clear_new:N { c }
26197 \cs_generate_variant:Nn \box_gclear_new:N { c }

```

Assigning the contents of a box to be another box.

```

26198 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\box_set_eq:NN 26199 \cs_new_protected:Npn \box_set_eq:NN #1#2
\box_set_eq:cN 26200 { \tex_setbox:D #1 \tex_copy:D #2 }
\box_set_eq:Nc 26201 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
\box_set_eq:cc 26202 \cs_new_protected:Npn \box_gset_eq:NN #1#2
\box_gset_eq:NN 26203 { \tex_global:D \tex_setbox:D #1 \tex_copy:D #2 }
\box_gset_eq:cN 26204 \cs_generate_variant:Nn \box_set_eq:NN { c , Nc , cc }
\box_gset_eq:Nc 26205 \cs_generate_variant:Nn \box_gset_eq:NN { c , Nc , cc }
\box_gset_eq:cc

```

Assigning the contents of a box to be another box, then drops the original box.

```

26206 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\box_set_eq_drop:NN 26207 \cs_new_protected:Npn \box_set_eq_drop:NN #1#2
\box_set_eq_drop:cN 26208 { \tex_setbox:D #1 \tex_box:D #2 }
\box_set_eq_drop:Nc 26209 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
\box_set_eq_drop:cc 26210 \cs_new_protected:Npn \box_gset_eq_drop:NN #1#2
\box_gset_eq_drop:NN 26211 { \tex_global:D \tex_setbox:D #1 \tex_box:D #2 }
\box_gset_eq_drop:cN 26212 \cs_generate_variant:Nn \box_set_eq_drop:NN { c , Nc , cc }
\box_gset_eq_drop:Nc 26213 \cs_generate_variant:Nn \box_gset_eq_drop:NN { c , Nc , cc }
\box_gset_eq_drop:cc

```

Copies of the cs functions defined in l3basics.

```

26214 \prg_new_eq_conditional:NNn \box_if_exist:N \cs_if_exist:N
\box_if_exist_p:N 26215 { TF , T , F , p }
\box_if_exist_p:c 26216 \prg_new_eq_conditional:NNn \box_if_exist:c \cs_if_exist:c
\box_if_exist:NTF 26217 { TF , T , F , p }
\box_if_exist:cTF

```

41.3 Measuring and setting box dimensions

Accessing the height, depth, and width of a *box* register.

```

26218 \cs_new_eq:NN \box_ht:N \tex_ht:D
\box_ht:N 26219 \cs_new_eq:NN \box_dp:N \tex_dp:D
\box_ht:c 26220 \cs_new_eq:NN \box_wd:N \tex_wd:D
\box_dp:N 26221 \cs_generate_variant:Nn \box_ht:N { c }
\box_dp:c 26222 \cs_generate_variant:Nn \box_dp:N { c }
\box_wd:N 26223 \cs_generate_variant:Nn \box_wd:N { c }
\box_wd:c

```

Setting the size whilst respecting local scope requires copying; the same issue does not come up when working globally. When debugging, the dimension expression #2 is surrounded by parentheses to catch early termination.

```

\box_set_ht:NN 26224 \cs_new_protected:Npn \box_set_dp:Nn #1#2
\box_set_ht:cn 26225 {
\box_set_dp:Nn 26226 \tex_setbox:D #1 = \tex_copy:D #1
\box_set_wd:NN
\box_set_wd:cn

```

```

26227 \box_dp:N #1 \_box_dim_eval:n {#2}
26228 }
26229 \cs_generate_variant:Nn \box_set_dp:Nn { c }
26230 \cs_new_protected:Npn \box_gset_dp:Nn #1#2
26231 { \box_dp:N #1 \_box_dim_eval:n {#2} }
26232 \cs_generate_variant:Nn \box_gset_dp:Nn { c }
26233 \cs_new_protected:Npn \box_set_ht:Nn #1#2
26234 {
26235 \tex_setbox:D #1 = \tex_copy:D #1
26236 \box_ht:N #1 \_box_dim_eval:n {#2}
26237 }
26238 \cs_generate_variant:Nn \box_set_ht:Nn { c }
26239 \cs_new_protected:Npn \box_gset_ht:Nn #1#2
26240 { \box_ht:N #1 \_box_dim_eval:n {#2} }
26241 \cs_generate_variant:Nn \box_gset_ht:Nn { c }
26242 \cs_new_protected:Npn \box_set_wd:Nn #1#2
26243 {
26244 \tex_setbox:D #1 = \tex_copy:D #1
26245 \box_wd:N #1 \_box_dim_eval:n {#2}
26246 }
26247 \cs_generate_variant:Nn \box_set_wd:Nn { c }
26248 \cs_new_protected:Npn \box_gset_wd:Nn #1#2
26249 { \box_wd:N #1 \_box_dim_eval:n {#2} }
26250 \cs_generate_variant:Nn \box_gset_wd:Nn { c }

```

41.4 Using boxes

Using a $\langle box \rangle$. These are just TeX primitives with meaningful names.

```

26251 \cs_new_eq:NN \box_use_drop:N \tex_box:D
26252 \cs_new_eq:NN \box_use:N \tex_copy:D
\box_use_drop:c
26253 \cs_generate_variant:Nn \box_use_drop:N { c }
\box_use:N
26254 \cs_generate_variant:Nn \box_use:N { c }
\box_use:c

```

Move box material in different directions. When debugging, the dimension expression #1 is surrounded by parentheses to catch early termination.

```

\box_move_left:nn
26255 \cs_new_protected:Npn \box_move_left:nn #1#2
\box_move_right:nn
26256 { \tex_moveleft:D \_box_dim_eval:n {#1} #2 }
\box_move_up:nn
26257 \cs_new_protected:Npn \box_move_right:nn #1#2
\box_move_down:nn
26258 { \tex_moveright:D \_box_dim_eval:n {#1} #2 }
26259 \cs_new_protected:Npn \box_move_up:nn #1#2
26260 { \tex_raise:D \_box_dim_eval:n {#1} #2 }
26261 \cs_new_protected:Npn \box_move_down:nn #1#2
26262 { \tex_lower:D \_box_dim_eval:n {#1} #2 }

```

41.5 Box conditionals

The primitives for testing if a $\langle box \rangle$ is empty/void or which type of box it is.

```

26263 \cs_new_eq:NN \if_hbox:N \tex_ifhbox:D
26264 \cs_new_eq:NN \if_vbox:N \tex_ifvbox:D
26265 \cs_new_eq:NN \if_box_empty:N \tex_ifvoid:D
\if_hbox:N
\if_vbox:N
\if_box_empty:N

```

```

26266 \prg_new_conditional:Npnn \box_if_horizontal:N #1 { p , T , F , TF }

\box_if_horizontal_p:N
\box_if_horizontal_p:c
\box_if_horizontal:N $\underline{TF}$ 
\box_if_horizontal:c $\underline{TF}$ 
\box_if_vertical_p:N
\box_if_vertical_p:c
\box_if_vertical:N $\underline{TF}$ 
\box_if_vertical:c $\underline{TF}$ 

```

```

26267 { \if_hbox:N #1 \prg_return_true: \else: \prg_return_false: \fi: }
26268 \prg_new_conditional:Npnn \box_if_vertical:N #1 { p , T , F , TF }
26269 { \if_vbox:N #1 \prg_return_true: \else: \prg_return_false: \fi: }
26270 \prg_generate_conditional_variant:Nnn \box_if_horizontal:N
26271 { c } { p , T , F , TF }
26272 \prg_generate_conditional_variant:Nnn \box_if_vertical:N
26273 { c } { p , T , F , TF }

```

Testing if a $\langle box \rangle$ is empty/void.

```

\box_if_empty_p:N 26274 \prg_new_conditional:Npnn \box_if_empty:N #1 { p , T , F , TF }
\box_if_empty_p:c 26275 { \if_box_empty:N #1 \prg_return_true: \else: \prg_return_false: \fi: }
\box_if_empty:NTF 26276 \prg_generate_conditional_variant:Nnn \box_if_empty:N
\box_if_empty:cTF 26277 { c } { p , T , F , TF }

```

(End definition for $\backslash box_new:N$ and others. These functions are documented on page 228.)

41.6 The last box inserted

```

\box_set_to_last:N Set a box to the previous box.
\box_set_to_last:c 26278 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\box_gset_to_last:N 26279 \cs_new_protected:Npn \box_set_to_last:N #1
\box_gset_to_last:c 26280 { \tex_setbox:D #1 \tex_lastbox:D }
26281 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
26282 \cs_new_protected:Npn \box_gset_to_last:N #1
26283 { \tex_global:D \tex_setbox:D #1 \tex_lastbox:D }
26284 \cs_generate_variant:Nn \box_set_to_last:N { c }
26285 \cs_generate_variant:Nn \box_gset_to_last:N { c }

```

(End definition for $\backslash box_set_to_last:N$ and $\backslash box_gset_to_last:N$. These functions are documented on page 230.)

41.7 Constant boxes

```

\c_empty_box A box we never use.
26286 \box_new:N \c_empty_box

```

(End definition for $\backslash c_empty_box$. This variable is documented on page 230.)

41.8 Scratch boxes

```

\l_tmpa_box Scratch boxes.
\l_tmpb_box 26287 \box_new:N \l_tmpa_box
\g_tmpa_box 26288 \box_new:N \l_tmpb_box
\g_tmpb_box 26289 \box_new:N \g_tmpa_box
26290 \box_new:N \g_tmpb_box

```

(End definition for $\backslash l_tmpa_box$ and others. These variables are documented on page 231.)

41.9 Viewing box contents

TeX's `\showbox` is not really that helpful in many cases, and it is also inconsistent with other L^AT_EX3 show functions as it does not actually shows material in the terminal. So we provide a richer set of functionality.

`\box_show:N` Essentially a wrapper around the internal function, but evaluating the breadth and depth arguments now outside the group.
`\box_show:c`
`\box_show:Nnn` 26291 `\cs_new_protected:Npn \box_show:N #1`
`\box_show:cnn` 26292 `{ \box_show:Nnn #1 \c_max_int \c_max_int }`
26293 `\cs_generate_variant:Nn \box_show:N { c }`
26294 `\cs_new_protected:Npn \box_show:Nnn #1#2#3`
26295 `{ __box_show:NNff 1 #1 { \int_eval:n {#2} } { \int_eval:n {#3} } }`
26296 `\cs_generate_variant:Nn \box_show:Nnn { c }`

(End definition for `\box_show:N` and `\box_show:Nnn`. These functions are documented on page 231.)

`\box_log:N` Getting TeX to write to the log without interruption the run is done by altering the
`\box_log:c` interaction mode. For that, the ε -TeX extensions are needed.
`\box_log:Nnn` 26297 `\cs_new_protected:Npn \box_log:N #1`
`\box_log:cnn` 26298 `{ \box_log:Nnn #1 \c_max_int \c_max_int }`
`__box_log:nNnn` 26299 `\cs_generate_variant:Nn \box_log:N { c }`
26300 `\cs_new_protected:Npn \box_log:Nnn`
26301 `{ \exp_args:No __box_log:nNnn { \tex_the:D \tex_interactionmode:D } }`
26302 `\cs_new_protected:Npn __box_log:nNnn #1#2#3#4`
26303 `{`
26304 `\int_set:Nn \tex_interactionmode:D { 0 }`
26305 `__box_show:NNff 0 #2 { \int_eval:n {#3} } { \int_eval:n {#4} }`
26306 `\int_set:Nn \tex_interactionmode:D {#1}`
26307 `}`
26308 `\cs_generate_variant:Nn \box_log:Nnn { c }`

(End definition for `\box_log:N`, `\box_log:Nnn`, and `__box_log:nNnn`. These functions are documented on page 231.)

`__box_show:NNnn` The internal auxiliary to actually do the output uses a group to deal with breadth and
`__box_show:NNff` depth values. The `\use:n` here gives better output appearance. Setting `\tracingonline` and `\errorcontextlines` is used to control what appears in the terminal.

26309 `\cs_new_protected:Npn __box_show:NNnn #1#2#3#4`
26310 `{`
26311 `\box_if_exist:NTF #2`
26312 `{`
26313 `\group_begin:`
26314 `\int_set:Nn \tex_showboxbreadth:D {#3}`
26315 `\int_set:Nn \tex_showboxdepth:D {#4}`
26316 `\int_set:Nn \tex_tracingonline:D {#1}`
26317 `\int_set:Nn \tex_errorcontextlines:D { -1 }`
26318 `\tex_showbox:D \use:n {#2}`
26319 `\group_end:`
26320 `}`
26321 `{`
26322 `_kernel_msg_error:nx { kernel } { variable-not-defined }`
26323 `{ \token_to_str:N #2 }`
26324 `}`

```

26325 }
26326 \cs_generate_variant:Nn \_box_show:NNnn { NNff }

```

(End definition for `_box_show:NNnn`.)

41.10 Horizontal mode boxes

`\hbox:n` (The test suite for this command, and others in this file, is `m3box002.lvt`.)
Put a horizontal box directly into the input stream.

```

26327 \cs_new_protected:Npn \hbox:n #1
26328 { \tex_hbox:D \scan_stop: { \color_group_begin: #1 \color_group_end: } }

```

(End definition for `\hbox:n`. This function is documented on page 231.)

```

\hbox_set:Nn
\hbox_set:cn 26329 \_kernel_patch:nnNNpn { \_kernel_chk_var_local:N #1 } { }
\hbox_gset:Nn 26330 \cs_new_protected:Npn \hbox_set:Nn #1#2
\hbox_gset:cn 26331 {
26332   \tex_setbox:D #1 \tex_hbox:D
26333   { \color_group_begin: #2 \color_group_end: }
26334 }
26335 \_kernel_patch:nnNNpn { \_kernel_chk_var_global:N #1 } { }
26336 \cs_new_protected:Npn \hbox_gset:Nn #1#2
26337 {
26338   \tex_global:D \tex_setbox:D #1 \tex_hbox:D
26339   { \color_group_begin: #2 \color_group_end: }
26340 }
26341 \cs_generate_variant:Nn \hbox_set:Nn { c }
26342 \cs_generate_variant:Nn \hbox_gset:Nn { c }

```

(End definition for `\hbox_set:Nn` and `\hbox_gset:Nn`. These functions are documented on page 232.)

`\hbox_set_to_wd:Nnn` Storing material in a horizontal box with a specified width. Again, put the dimension expression in parentheses when debugging.

```

\hbox_set_to_wd:cn 26343 \_kernel_patch:nnNNpn { \_kernel_chk_var_local:N #1 } { }
\hbox_gset_to_wd:Nnn 26344 \cs_new_protected:Npn \hbox_set_to_wd:Nnn #1#2#3
\hbox_gset_to_wd:cn 26345 {
26346   \tex_setbox:D #1 \tex_hbox:D to \_box_dim_eval:n {#2}
26347   { \color_group_begin: #3 \color_group_end: }
26348 }
26349 \_kernel_patch:nnNNpn { \_kernel_chk_var_global:N #1 } { }
26350 \cs_new_protected:Npn \hbox_gset_to_wd:Nnn #1#2#3
26351 {
26352   \tex_global:D \tex_setbox:D #1 \tex_hbox:D to \_box_dim_eval:n {#2}
26353   { \color_group_begin: #3 \color_group_end: }
26354 }
26355 \cs_generate_variant:Nn \hbox_set_to_wd:Nnn { c }
26356 \cs_generate_variant:Nn \hbox_gset_to_wd:Nnn { c }

```

(End definition for `\hbox_set_to_wd:Nnn` and `\hbox_gset_to_wd:Nnn`. These functions are documented on page 232.)

\hbox_set:Nw Storing material in a horizontal box. This type is useful in environment definitions.

```

\hbox_set:cnw 26357 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\hbox_gset:Nw 26358 \cs_new_protected:Npn \hbox_set:Nw #1
\hbox_gset:cnw 26359 {
\hbox_set_end: 26360 \tex_setbox:D #1 \tex_hbox:D
\hbox_gset_end: 26361 \c_group_begin_token
26362 \color_group_begin:
26363 }
26364 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
26365 \cs_new_protected:Npn \hbox_gset:Nw #1
26366 {
26367 \tex_global:D \tex_setbox:D #1 \tex_hbox:D
26368 \c_group_begin_token
26369 \color_group_begin:
26370 }
26371 \cs_generate_variant:Nn \hbox_set:Nw { c }
26372 \cs_generate_variant:Nn \hbox_gset:Nw { c }
26373 \cs_new_protected:Npn \hbox_set_end:
26374 {
26375 \color_group_end:
26376 \c_group_end_token
26377 }
26378 \cs_new_eq:NN \hbox_gset_end: \hbox_set_end:

```

(End definition for `\hbox_set:Nw` and others. These functions are documented on page 232.)

\hbox_set_to_wd:Nnw Combining the above ideas.

```

\hbox_set_to_wd:cnw 26379 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\hbox_gset_to_wd:Nnw 26380 \cs_new_protected:Npn \hbox_set_to_wd:Nnw #1#2
\hbox_gset_to_wd:cnw 26381 {
26382 \tex_setbox:D #1 \tex_hbox:D to \__box_dim_eval:n {#2}
26383 \c_group_begin_token
26384 \color_group_begin:
26385 }
26386 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
26387 \cs_new_protected:Npn \hbox_gset_to_wd:Nnw #1#2
26388 {
26389 \tex_global:D \tex_setbox:D #1 \tex_hbox:D to \__box_dim_eval:n {#2}
26390 \c_group_begin_token
26391 \color_group_begin:
26392 }
26393 \cs_generate_variant:Nn \hbox_set_to_wd:Nnw { c }
26394 \cs_generate_variant:Nn \hbox_gset_to_wd:Nnw { c }

```

(End definition for `\hbox_set_to_wd:Nnw` and `\hbox_gset_to_wd:Nnw`. These functions are documented on page 232.)

\hbox_to_wd:nn Put a horizontal box directly into the input stream.

\hbox_to_zero:n

```

26395 \cs_new_protected:Npn \hbox_to_wd:nn #1#2
26396 {
26397 \tex_hbox:D to \__box_dim_eval:n {#1}
26398 { \color_group_begin: #2 \color_group_end: }
26399 }
26400 \cs_new_protected:Npn \hbox_to_zero:n #1

```

```

26401 {
26402   \tex_hbox:D to \c_zero_dim
26403   { \color_group_begin: #1 \color_group_end: }
26404 }

```

(End definition for \hbox_to_wd:nn and \hbox_to_zero:n. These functions are documented on page 232.)

\hbox_overlap_left:n Put a zero-sized box with the contents pushed against one side (which makes it stick out on the other) directly into the input stream.

```

26405 \cs_new_protected:Npn \hbox_overlap_left:n #1
26406 { \hbox_to_zero:n { \tex_hss:D #1 } }
26407 \cs_new_protected:Npn \hbox_overlap_right:n #1
26408 { \hbox_to_zero:n { #1 \tex_hss:D } }

```

(End definition for \hbox_overlap_left:n and \hbox_overlap_right:n. These functions are documented on page 232.)

\hbox_unpack:N Unpacking a box and if requested also clear it.

```

\hbox_unpack:c 26409 \cs_new_eq:NN \hbox_unpack:N \tex_unhcopy:D
\hbox_unpack_drop:N 26410 \cs_new_eq:NN \hbox_unpack_drop:N \tex_unhbox:D
\hbox_unpack_drop:c 26411 \cs_generate_variant:Nn \hbox_unpack:N { c }
26412 \cs_generate_variant:Nn \hbox_unpack_drop:N { c }

```

(End definition for \hbox_unpack:N and \hbox_unpack_drop:N. These functions are documented on page 232.)

41.11 Vertical mode boxes

TeX ends these boxes directly with the internal *end_graf* routine. This means that there is no \par at the end of vertical boxes unless we insert one. Thus all vertical boxes include a \par just before closing the color group.

\vbox:n The following test files are used for this code: m3box003.lvt.

The following test files are used for this code: m3box003.lvt.

\vbox_top:n Put a vertical box directly into the input stream.

```

26413 \cs_new_protected:Npn \vbox:n #1
26414 { \tex_vbox:D { \color_group_begin: #1 \par \color_group_end: } }
26415 \cs_new_protected:Npn \vbox_top:n #1
26416 { \tex_vtop:D { \color_group_begin: #1 \par \color_group_end: } }

```

(End definition for \vbox:n and \vbox_top:n. These functions are documented on page 233.)

\vbox_to_ht:nn Put a vertical box directly into the input stream.

```

\vbox_to_zero:n 26417 \cs_new_protected:Npn \vbox_to_ht:nn #1#2
\vbox_to_ht:nn 26418 {
\vbox_to_zero:n 26419   \tex_vbox:D to \__box_dim_eval:n {#1}
26420   { \color_group_begin: #2 \par \color_group_end: }
26421 }
26422 \cs_new_protected:Npn \vbox_to_zero:n #1
26423 {
26424   \tex_vbox:D to \c_zero_dim
26425   { \color_group_begin: #1 \par \color_group_end: }
26426 }

```

(End definition for `\vbox_to_ht:n` and others. These functions are documented on page 233.)

`\vbox_set:Nn` Storing material in a vertical box with a natural height.
`\vbox_set:cn` 26427 `__kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }`
`\vbox_gset:Nn` 26428 `\cs_new_protected:Npn \vbox_set:Nn #1#2`
`\vbox_gset:cn` 26429 `{`
26430 `\tex_setbox:D #1 \tex_vbox:D`
26431 `{ \color_group_begin: #2 \par \color_group_end: }`
26432 `}`
26433 `__kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }`
26434 `\cs_new_protected:Npn \vbox_gset:Nn #1#2`
26435 `{`
26436 `\tex_global:D \tex_setbox:D #1 \tex_vbox:D`
26437 `{ \color_group_begin: #2 \par \color_group_end: }`
26438 `}`
26439 `\cs_generate_variant:Nn \vbox_set:Nn { c }`
26440 `\cs_generate_variant:Nn \vbox_gset:Nn { c }`

(End definition for `\vbox_set:Nn` and `\vbox_gset:Nn`. These functions are documented on page 233.)

`\vbox_set_top:Nn` Storing material in a vertical box with a natural height and reference point at the baseline of the first object in the box.
`\vbox_set_top:cn`
`\vbox_gset_top:Nn` 26441 `__kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }`
`\vbox_gset_top:cn` 26442 `\cs_new_protected:Npn \vbox_set_top:Nn #1#2`
26443 `{`
26444 `\tex_setbox:D #1 \tex_vtop:D`
26445 `{ \color_group_begin: #2 \par \color_group_end: }`
26446 `}`
26447 `__kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }`
26448 `\cs_new_protected:Npn \vbox_gset_top:Nn #1#2`
26449 `{`
26450 `\tex_global:D \tex_setbox:D #1 \tex_vtop:D`
26451 `{ \color_group_begin: #2 \par \color_group_end: }`
26452 `}`
26453 `\cs_generate_variant:Nn \vbox_set_top:Nn { c }`
26454 `\cs_generate_variant:Nn \vbox_gset_top:Nn { c }`

(End definition for `\vbox_set_top:Nn` and `\vbox_gset_top:Nn`. These functions are documented on page 233.)

`\vbox_set_to_ht:Nnn` Storing material in a vertical box with a specified height.
`\vbox_set_to_ht:cnn` 26455 `__kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }`
`\vbox_gset_to_ht:Nnn` 26456 `\cs_new_protected:Npn \vbox_set_to_ht:Nnn #1#2#3`
`\vbox_gset_to_ht:cnn` 26457 `{`
26458 `\tex_setbox:D #1 \tex_vbox:D to __box_dim_eval:n {#2}`
26459 `{ \color_group_begin: #3 \par \color_group_end: }`
26460 `}`
26461 `__kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }`
26462 `\cs_new_protected:Npn \vbox_gset_to_ht:Nnn #1#2#3`
26463 `{`
26464 `\tex_global:D \tex_setbox:D #1 \tex_vbox:D to __box_dim_eval:n {#2}`
26465 `{ \color_group_begin: #3 \par \color_group_end: }`
26466 `}`
26467 `\cs_generate_variant:Nn \vbox_set_to_ht:Nnn { c }`
26468 `\cs_generate_variant:Nn \vbox_gset_to_ht:Nnn { c }`

(End definition for `\vbox_set_to_ht:Nnn` and `\vbox_gset_to_ht:Nnn`. These functions are documented on page 233.)

`\vbox_set:Nw` Storing material in a vertical box. This type is useful in environment definitions.

`\vbox_set:cw` 26469 `__kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }`

`\vbox_gset:Nw` 26470 `\cs_new_protected:Npn \vbox_set:Nw #1`

`\vbox_gset:cw` 26471 `{`

`\vbox_set_end:` 26472 `\tex_setbox:D #1 \tex_vbox:D`

`\vbox_gset_end:` 26473 `\c_group_begin_token`

26474 `\color_group_begin:`

26475 `}`

26476 `__kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }`

26477 `\cs_new_protected:Npn \vbox_gset:Nw #1`

26478 `{`

26479 `\tex_global:D \tex_setbox:D #1 \tex_vbox:D`

26480 `\c_group_begin_token`

26481 `\color_group_begin:`

26482 `}`

26483 `\cs_generate_variant:Nn \vbox_set:Nw { c }`

26484 `\cs_generate_variant:Nn \vbox_gset:Nw { c }`

26485 `\cs_new_protected:Npn \vbox_set_end:`

26486 `{`

26487 `\par`

26488 `\color_group_end:`

26489 `\c_group_end_token`

26490 `}`

26491 `\cs_new_eq:NN \vbox_gset_end: \vbox_set_end:`

(End definition for `\vbox_set:Nw` and others. These functions are documented on page 234.)

`\vbox_set_to_ht:Nnw` A combination of the above ideas.

`\vbox_set_to_ht:cnw` 26492 `__kernel_patch:nnNNpn { __kernel_chk_var_local:N #1 } { }`

`\vbox_gset_to_ht:Nnw` 26493 `\cs_new_protected:Npn \vbox_set_to_ht:Nnw #1#2`

`\vbox_gset_to_ht:cnw` 26494 `{`

26495 `\tex_setbox:D #1 \tex_vbox:D to __box_dim_eval:n {#2}`

26496 `\c_group_begin_token`

26497 `\color_group_begin:`

26498 `}`

26499 `__kernel_patch:nnNNpn { __kernel_chk_var_global:N #1 } { }`

26500 `\cs_new_protected:Npn \vbox_gset_to_ht:Nnw #1#2`

26501 `{`

26502 `\tex_global:D \tex_setbox:D #1 \tex_vbox:D to __box_dim_eval:n {#2}`

26503 `\c_group_begin_token`

26504 `\color_group_begin:`

26505 `}`

26506 `\cs_generate_variant:Nn \vbox_set_to_ht:Nnw { c }`

26507 `\cs_generate_variant:Nn \vbox_gset_to_ht:Nnw { c }`

(End definition for `\vbox_set_to_ht:Nnw` and `\vbox_gset_to_ht:Nnw`. These functions are documented on page 234.)

`\vbox_unpack:N` Unpacking a box and if requested also clear it.

`\vbox_unpack:c` 26508 `\cs_new_eq:NN \vbox_unpack:N \tex_unvcopy:D`

`\vbox_unpack_drop:N` 26509 `\cs_new_eq:NN \vbox_unpack_drop:N \tex_unvbox:D`

`\vbox_unpack_drop:c` 26510 `\cs_generate_variant:Nn \vbox_unpack:N { c }`

26511 `\cs_generate_variant:Nn \vbox_unpack_drop:N { c }`

(End definition for `\vbox_unpack:N` and `\vbox_unpack_drop:N`. These functions are documented on page 234.)

`\vbox_set_split_to_ht:NNn` Splitting a vertical box in two.

```

\vbox_set_split_to_ht:cNn 26512 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
\vbox_set_split_to_ht:Ncn 26513 \cs_new_protected:Npn \vbox_set_split_to_ht:NNn #1#2#3
\vbox_set_split_to_ht:ccn 26514 { \tex_setbox:D #1 \tex_vsplit:D #2 to \__box_dim_eval:n {#3} }
\vbox_gset_split_to_ht:NNn 26515 \cs_generate_variant:Nn \vbox_set_split_to_ht:NNn { c , Nc , cc }
\vbox_gset_split_to_ht:cNn 26516 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
\vbox_gset_split_to_ht:Ncn 26517 \cs_new_protected:Npn \vbox_gset_split_to_ht:NNn #1#2#3
\vbox_gset_split_to_ht:ccn 26518 {
26519     \tex_global:D \tex_setbox:D #1
26520     \tex_vsplit:D #2 to \__box_dim_eval:n {#3}
26521 }
26522 \cs_generate_variant:Nn \vbox_gset_split_to_ht:NNn { c , Nc , cc }
```

(End definition for `\vbox_set_split_to_ht:NNn` and `\vbox_gset_split_to_ht:NNn`. These functions are documented on page 234.)

41.12 Affine transformations

`\l__box_angle_fp` When rotating boxes, the angle itself may be needed by the engine-dependent code. This is done using the `fp` module so that the value is tidied up properly.

```
26523 \fp_new:N \l__box_angle_fp
```

(End definition for `\l__box_angle_fp`.)

`\l__box_cos_fp` These are used to hold the calculated sine and cosine values while carrying out a rotation.

```

\vbox_sin_fp 26524 \fp_new:N \l__box_cos_fp
26525 \fp_new:N \l__box_sin_fp
```

(End definition for `\l__box_cos_fp` and `\l__box_sin_fp`.)

`\l__box_top_dim` These are the positions of the four edges of a box before manipulation.

```

\vbox_bottom_dim 26526 \dim_new:N \l__box_top_dim
\vbox_left_dim 26527 \dim_new:N \l__box_bottom_dim
\vbox_right_dim 26528 \dim_new:N \l__box_left_dim
26529 \dim_new:N \l__box_right_dim
```

(End definition for `\l__box_top_dim` and others.)

`\l__box_top_new_dim` These are the positions of the four edges of a box after manipulation.

```

\vbox_bottom_new_dim 26530 \dim_new:N \l__box_top_new_dim
\vbox_left_new_dim 26531 \dim_new:N \l__box_bottom_new_dim
\vbox_right_new_dim 26532 \dim_new:N \l__box_left_new_dim
26533 \dim_new:N \l__box_right_new_dim
```

(End definition for `\l__box_top_new_dim` and others.)

`\l__box_internal_box` Scratch space, but also needed by some parts of the driver.

```
26534 \box_new:N \l__box_internal_box
```

(End definition for `\l__box_internal_box`.)

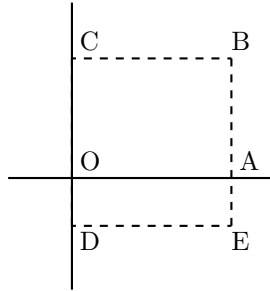


Figure 1: Co-ordinates of a box prior to rotation.

\box_rotate:Nn Rotation of a box starts with working out the relevant sine and cosine. The actual
\box_rotate:cn rotation is in an auxiliary to keep the flow slightly clearer

\box_grotate:Nn 26535 \cs_new_protected:Npn \box_rotate:Nn #1#2

\box_grotate:cn 26536 { __box_rotate:NnN #1 {#2} \hbox_set:Nn }

__box_rotate:NnN 26537 \cs_generate_variant:Nn \box_rotate:Nn { c }

__box_rotate:N 26538 \cs_new_protected:Npn \box_grotate:Nn #1#2

__box_rotate_xdir:nnN 26539 { __box_rotate:NnN #1 {#2} \hbox_gset:Nn }

__box_rotate_ydir:nnN 26540 \cs_generate_variant:Nn \box_grotate:Nn { c }

__box_rotate_quadrant_one: 26541 \cs_new_protected:Npn __box_rotate:NnN #1#2#3

__box_rotate_quadrant_two: 26542 {

__box_rotate_quadrant_three: 26543 #3 #1

__box_rotate_quadrant_four: 26544 {

26545 \fp_set:Nn \l__box_angle_fp {#2}

26546 \fp_set:Nn \l__box_sin_fp { sind (\l__box_angle_fp) }

26547 \fp_set:Nn \l__box_cos_fp { cosd (\l__box_angle_fp) }

26548 __box_rotate:N #1

26549 }

26550 }

The edges of the box are then recorded: the left edge is always at zero. Rotation of the four edges then takes place: this is most efficiently done on a quadrant by quadrant basis.

26551 \cs_new_protected:Npn __box_rotate:N #1

26552 {

26553 \dim_set:Nn \l__box_top_dim { \box_ht:N #1 }

26554 \dim_set:Nn \l__box_bottom_dim { -\box_dp:N #1 }

26555 \dim_set:Nn \l__box_right_dim { \box_wd:N #1 }

26556 \dim_zero:N \l__box_left_dim

The next step is to work out the x and y coordinates of vertices of the rotated box in relation to its original coordinates. The box can be visualized with vertices B , C , D and E is illustrated (Figure 1). The vertex O is the reference point on the baseline, and in this implementation is also the centre of rotation. The formulae are, for a point P and angle α :

$$\begin{aligned} P'_x &= P_x - O_x \\ P'_y &= P_y - O_y \\ P''_x &= (P'_x \cos(\alpha)) - (P'_y \sin(\alpha)) \\ P''_y &= (P'_x \sin(\alpha)) + (P'_y \cos(\alpha)) \\ P'''_x &= P''_x + O_x + L_x \\ P'''_y &= P''_y + O_y \end{aligned}$$

The “extra” horizontal translation L_x at the end is calculated so that the leftmost point of the resulting box has x -coordinate 0. This is desirable as \TeX boxes must have the reference point at the left edge of the box. (As O is always $(0,0)$, this part of the calculation is omitted here.)

```

26557 \fp_compare:nNnTF \l__box_sin_fp > \c_zero_fp
26558 {
26559     \fp_compare:nNnTF \l__box_cos_fp > \c_zero_fp
26560     { \__box_rotate_quadrant_one: }
26561     { \__box_rotate_quadrant_two: }
26562 }
26563 {
26564     \fp_compare:nNnTF \l__box_cos_fp < \c_zero_fp
26565     { \__box_rotate_quadrant_three: }
26566     { \__box_rotate_quadrant_four: }
26567 }

```

The position of the box edges are now known, but the box at this stage be misplaced relative to the current \TeX reference point. So the content of the box is moved such that the reference point of the rotated box is in the same place as the original.

```

26568 \hbox_set:Nn \l__box_internal_box { \box_use:N #1 }
26569 \hbox_set:Nn \l__box_internal_box
26570 {
26571     \tex_kern:D -\l__box_left_new_dim
26572     \hbox:n
26573     {
26574         \__box_backend_rotate:Nn
26575         \l__box_internal_box
26576         \l__box_angle_fp
26577     }
26578 }

```

Tidy up the size of the box so that the material is actually inside the bounding box. The result can then be used to reset the original box.

```

26579 \box_set_ht:Nn \l__box_internal_box { \l__box_top_new_dim }
26580 \box_set_dp:Nn \l__box_internal_box { -\l__box_bottom_new_dim }
26581 \box_set_wd:Nn \l__box_internal_box
26582 { \l__box_right_new_dim - \l__box_left_new_dim }
26583 \box_use_drop:N \l__box_internal_box
26584 }

```

These functions take a general point $(\#1,\#2)$ and rotate its location about the origin, using the previously-set sine and cosine values. Each function gives only one component of the location of the updated point. This is because for rotation of a box each step needs only one value, and so performance is gained by avoiding working out both x' and y' at the same time. Contrast this with the equivalent function in the `l3coffins` module, where both parts are needed.

```

26585 \cs_new_protected:Npn \__box_rotate_xdir:nnN #1#2#3
26586 {
26587     \dim_set:Nn #3
26588     {
26589         \fp_to_dim:n
26590         {
26591             \l__box_cos_fp * \dim_to_fp:n {#1}
26592             - \l__box_sin_fp * \dim_to_fp:n {#2}

```

```

26593     }
26594   }
26595 }
26596 \cs_new_protected:Npn \__box_rotate_ydir:nnN #1#2#3
26597 {
26598   \dim_set:Nn #3
26599   {
26600     \fp_to_dim:n
26601     {
26602       \l__box_sin_fp * \dim_to_fp:n {#1}
26603       + \l__box_cos_fp * \dim_to_fp:n {#2}
26604     }
26605   }
26606 }

```

Rotation of the edges is done using a different formula for each quadrant. In every case, the top and bottom edges only need the resulting y -values, whereas the left and right edges need the x -values. Each case is a question of picking out which corner ends up at with the maximum top, bottom, left and right value. Doing this by hand means a lot less calculating and avoids lots of comparisons.

```

26607 \cs_new_protected:Npn \__box_rotate_quadrant_one:
26608 {
26609   \__box_rotate_ydir:nnN \l__box_right_dim \l__box_top_dim
26610   \l__box_top_new_dim
26611   \__box_rotate_ydir:nnN \l__box_left_dim \l__box_bottom_dim
26612   \l__box_bottom_new_dim
26613   \__box_rotate_xdir:nnN \l__box_left_dim \l__box_top_dim
26614   \l__box_left_new_dim
26615   \__box_rotate_xdir:nnN \l__box_right_dim \l__box_bottom_dim
26616   \l__box_right_new_dim
26617 }
26618 \cs_new_protected:Npn \__box_rotate_quadrant_two:
26619 {
26620   \__box_rotate_ydir:nnN \l__box_right_dim \l__box_bottom_dim
26621   \l__box_top_new_dim
26622   \__box_rotate_ydir:nnN \l__box_left_dim \l__box_top_dim
26623   \l__box_bottom_new_dim
26624   \__box_rotate_xdir:nnN \l__box_right_dim \l__box_top_dim
26625   \l__box_left_new_dim
26626   \__box_rotate_xdir:nnN \l__box_left_dim \l__box_bottom_dim
26627   \l__box_right_new_dim
26628 }
26629 \cs_new_protected:Npn \__box_rotate_quadrant_three:
26630 {
26631   \__box_rotate_ydir:nnN \l__box_left_dim \l__box_bottom_dim
26632   \l__box_top_new_dim
26633   \__box_rotate_ydir:nnN \l__box_right_dim \l__box_top_dim
26634   \l__box_bottom_new_dim
26635   \__box_rotate_xdir:nnN \l__box_right_dim \l__box_bottom_dim
26636   \l__box_left_new_dim
26637   \__box_rotate_xdir:nnN \l__box_left_dim \l__box_top_dim
26638   \l__box_right_new_dim
26639 }
26640 \cs_new_protected:Npn \__box_rotate_quadrant_four:

```

```

26641 {
26642   \__box_rotate_ydir:nnN \l__box_left_dim \l__box_top_dim
26643   \l__box_top_new_dim
26644   \__box_rotate_ydir:nnN \l__box_right_dim \l__box_bottom_dim
26645   \l__box_bottom_new_dim
26646   \__box_rotate_xdir:nnN \l__box_left_dim \l__box_bottom_dim
26647   \l__box_left_new_dim
26648   \__box_rotate_xdir:nnN \l__box_right_dim \l__box_top_dim
26649   \l__box_right_new_dim
26650 }

```

(End definition for `\box_rotate:Nn` and others. These functions are documented on page 238.)

`\l__box_scale_x_fp` Scaling is potentially-different in the two axes.
`\l__box_scale_y_fp`

```

26651 \fp_new:N \l__box_scale_x_fp
26652 \fp_new:N \l__box_scale_y_fp

```

(End definition for `\l__box_scale_x_fp` and `\l__box_scale_y_fp`.)

`\box_resize_to_wd_and_ht_plus_dp:Nnn` Resizing a box starts by working out the various dimensions of the existing box.

```

\box_resize_to_wd_and_ht_plus_dp:cmn
\box_gresize_to_wd_and_ht_plus_dp:Nnn
\box_gresize_to_wd_and_ht_plus_dp:cmn
\__box_resize_to_wd_and_ht_plus_dp:NnnN
\__box_resize_set_corners:N
\__box_resize:N
\__box_resize:NNN
26653 \cs_new_protected:Npn \box_resize_to_wd_and_ht_plus_dp:Nnn #1#2#3
26654 {
26655   \__box_resize_to_wd_and_ht_plus_dp:NnnN #1 {#2} {#3}
26656   \hbox_set:Nn
26657 }
26658 \cs_generate_variant:Nn \box_resize_to_wd_and_ht_plus_dp:Nnn { c }
26659 \cs_new_protected:Npn \box_gresize_to_wd_and_ht_plus_dp:Nnn #1#2#3#4
26660 {
26661   \__box_resize_to_wd_and_ht_plus_dp:NnnN #1 {#2} {#3}
26662   \hbox_gset:Nn
26663 }
26664 \cs_generate_variant:Nn \box_gresize_to_wd_and_ht_plus_dp:Nnn { c }
26665 \cs_new_protected:Npn \__box_resize_to_wd_and_ht_plus_dp:NnnN #1#2#3#4
26666 {
26667   #4 #1
26668   {
26669     \__box_resize_set_corners:N #1

```

The *x*-scaling and resulting box size is easy enough to work out: the dimension is that given as #2, and the scale is simply the new width divided by the old one.

```

26670 \fp_set:Nn \l__box_scale_x_fp
26671 { \dim_to_fp:n {#2} / \dim_to_fp:n { \l__box_right_dim } }

```

The *y*-scaling needs both the height and the depth of the current box.

```

26672 \fp_set:Nn \l__box_scale_y_fp
26673 {
26674   \dim_to_fp:n {#3}
26675   / \dim_to_fp:n { \l__box_top_dim - \l__box_bottom_dim }
26676 }

```

Hand off to the auxiliary which does the rest of the work.

```

26677 \__box_resize:N #1
26678 }
26679 }
26680 \cs_new_protected:Npn \__box_resize_set_corners:N #1
26681 {

```

```

26682 \dim_set:Nn \l__box_top_dim { \box_ht:N #1 }
26683 \dim_set:Nn \l__box_bottom_dim { -\box_dp:N #1 }
26684 \dim_set:Nn \l__box_right_dim { \box_wd:N #1 }
26685 \dim_zero:N \l__box_left_dim
26686 }

```

With at least one real scaling to do, the next phase is to find the new edge co-ordinates. In the x direction this is relatively easy: just scale the right edge. In the y direction, both dimensions have to be scaled, and this again needs the absolute scale value. Once that is all done, the common resize/rescale code can be employed.

```

26687 \cs_new_protected:Npn \__box_resize:N #1
26688 {
26689   \__box_resize:NNN \l__box_right_new_dim
26690   \l__box_scale_x_fp \l__box_right_dim
26691   \__box_resize:NNN \l__box_bottom_new_dim
26692   \l__box_scale_y_fp \l__box_bottom_dim
26693   \__box_resize:NNN \l__box_top_new_dim
26694   \l__box_scale_y_fp \l__box_top_dim
26695   \__box_resize_common:N #1
26696 }
26697 \cs_new_protected:Npn \__box_resize:NNN #1#2#3
26698 {
26699   \dim_set:Nn #1
26700   { \fp_to_dim:n { \fp_abs:n { #2 } * \dim_to_fp:n { #3 } } }
26701 }

```

(End definition for `\box_resize_to_wd_and_ht_plus_dp:Nnn` and others. These functions are documented on page 237.)

```

\box_resize_to_ht:Nn Scaling to a (total) height or to a width is a simplified version of the main resizing
\box_resize_to_ht:cn operation, with the scale simply copied between the two parts. The internal auxiliary is
\box_gresize_to_ht:Nn called using the scaling value twice, as the sign for both parts is needed (as this allows
\box_gresize_to_ht:cn the same internal code to be used as for the general case).
\__box_resize_to_ht:NnN
\box_resize_to_ht_plus_dp:Nn
\box_resize_to_ht_plus_dp:cn
\box_gresize_to_ht_plus_dp:Nn
\box_gresize_to_ht_plus_dp:cn
\__box_resize_to_ht_plus_dp:NnN
\box_resize_to_wd:Nn
\box_resize_to_wd:cn
\box_gresize_to_wd:Nn
\box_gresize_to_wd:cn
\__box_resize_to_wd:NnN
\box_resize_to_wd_and_ht:Nnn
\box_gresize_to_wd_and_ht:Nnn
\box_gresize_to_wd_and_ht:cn
\__box_resize_to_wd_ht:NnnN
26702 \cs_new_protected:Npn \box_resize_to_ht:Nn #1#2
26703 { \__box_resize_to_ht:NnN #1 {#2} \hbox_set:Nn }
26704 \cs_generate_variant:Nn \box_resize_to_ht:Nn { c }
26705 \cs_new_protected:Npn \box_gresize_to_ht:Nn #1#2
26706 { \__box_resize_to_ht:NnN #1 {#2} \hbox_gset:Nn }
26707 \cs_generate_variant:Nn \box_gresize_to_ht:Nn { c }
26708 \cs_new_protected:Npn \__box_resize_to_ht:NnN #1#2#3
26709 {
26710   #3 #1
26711   {
26712     \__box_resize_set_corners:N #1
26713     \fp_set:Nn \l__box_scale_y_fp
26714     {
26715       \dim_to_fp:n {#2}
26716       / \dim_to_fp:n { \l__box_top_dim }
26717     }
26718     \fp_set_eq:NN \l__box_scale_x_fp \l__box_scale_y_fp
26719     \__box_resize:N #1
26720   }
26721 }
26722 \cs_new_protected:Npn \box_resize_to_ht_plus_dp:Nn #1#2

```

```

26723 { \_box_resize_to_ht_plus_dp:NnN #1 {#2} \hbox_set:Nn }
26724 \cs_generate_variant:Nn \box_resize_to_ht_plus_dp:Nn { c }
26725 \cs_new_protected:Npn \box_gresize_to_ht_plus_dp:Nn #1#2
26726 { \_box_resize_to_ht_plus_dp:NnN #1 {#2} \hbox_gset:Nn }
26727 \cs_generate_variant:Nn \box_gresize_to_ht_plus_dp:Nn { c }
26728 \cs_new_protected:Npn \_box_resize_to_ht_plus_dp:NnN #1#2#3
26729 {
26730   \hbox_set:Nn #1
26731   {
26732     \_box_resize_set_corners:N #1
26733     \fp_set:Nn \l__box_scale_y_fp
26734     {
26735       \dim_to_fp:n {#2}
26736       / \dim_to_fp:n { \l__box_top_dim - \l__box_bottom_dim }
26737     }
26738     \fp_set_eq:NN \l__box_scale_x_fp \l__box_scale_y_fp
26739     \_box_resize:N #1
26740   }
26741 }
26742 \cs_new_protected:Npn \box_resize_to_wd:Nn #1#2
26743 { \_box_resize_to_wd:NnN #1 {#2} \hbox_set:Nn }
26744 \cs_generate_variant:Nn \box_resize_to_wd:Nn { c }
26745 \cs_new_protected:Npn \box_gresize_to_wd:Nn #1#2
26746 { \_box_resize_to_wd:NnN #1 {#2} \hbox_gset:Nn }
26747 \cs_generate_variant:Nn \box_gresize_to_wd:Nn { c }
26748 \cs_new_protected:Npn \_box_resize_to_wd:NnN #1#2#3
26749 {
26750   #3 #1
26751   {
26752     \_box_resize_set_corners:N #1
26753     \fp_set:Nn \l__box_scale_x_fp
26754     { \dim_to_fp:n {#2} / \dim_to_fp:n { \l__box_right_dim } }
26755     \fp_set_eq:NN \l__box_scale_y_fp \l__box_scale_x_fp
26756     \_box_resize:N #1
26757   }
26758 }
26759 \cs_new_protected:Npn \box_resize_to_wd_and_ht:Nnn #1#2#3
26760 { \_box_resize_to_wd_and_ht:NnnN #1 {#2} {#3} \hbox_set:Nn }
26761 \cs_generate_variant:Nn \box_resize_to_wd_and_ht:Nnn { c }
26762 \cs_new_protected:Npn \box_gresize_to_wd_and_ht:Nnn #1#2#3
26763 { \_box_resize_to_wd_and_ht:NnnN #1 {#2} {#3} \hbox_gset:Nn }
26764 \cs_generate_variant:Nn \box_gresize_to_wd_and_ht:Nnn { c }
26765 \cs_new_protected:Npn \_box_resize_to_wd_and_ht:NnnN #1#2#3#4
26766 {
26767   #4 #1
26768   {
26769     \_box_resize_set_corners:N #1
26770     \fp_set:Nn \l__box_scale_x_fp
26771     { \dim_to_fp:n {#2} / \dim_to_fp:n { \l__box_right_dim } }
26772     \fp_set:Nn \l__box_scale_y_fp
26773     {
26774       \dim_to_fp:n {#3}
26775       / \dim_to_fp:n { \l__box_top_dim }
26776     }

```



```

26777         \_box_resize:N #1
26778     }
26779 }

```

(End definition for `\box_resize_to_ht:Nn` and others. These functions are documented on page 236.)

`\box_scale:Nnn` When scaling a box, setting the scaling itself is easy enough. The new dimensions are also relatively easy to find, allowing only for the need to keep them positive in all cases. `\box_scale:cnn` Once that is done then after a check for the trivial scaling a hand-off can be made to the common code. `\box_gscale:Nnn` The code here is split into two as this allows sharing with the auto-resizing functions. `\box_gscale:cnn`

```

\__box_scale:NnnN
\__box_scale:N
26780 \cs_new_protected:Npn \box_scale:Nnn #1#2#3
26781 { \__box_scale:NnnN #1 {#2} {#3} \hbox_set:Nn }
26782 \cs_generate_variant:Nn \box_scale:Nnn { c }
26783 \cs_new_protected:Npn \box_gscale:Nnn #1#2#3
26784 { \__box_scale:NnnN #1 {#2} {#3} \hbox_gset:Nn }
26785 \cs_generate_variant:Nn \box_gscale:Nnn { c }
26786 \cs_new_protected:Npn \__box_scale:NnnN #1#2#3#4
26787 {
26788     #4 #1
26789     {
26790         \fp_set:Nn \l__box_scale_x_fp {#2}
26791         \fp_set:Nn \l__box_scale_y_fp {#3}
26792         \__box_scale:N #1
26793     }
26794 }
26795 \cs_new_protected:Npn \__box_scale:N #1
26796 {
26797     \dim_set:Nn \l__box_top_dim { \box_ht:N #1 }
26798     \dim_set:Nn \l__box_bottom_dim { -\box_dp:N #1 }
26799     \dim_set:Nn \l__box_right_dim { \box_wd:N #1 }
26800     \dim_zero:N \l__box_left_dim
26801     \dim_set:Nn \l__box_top_new_dim
26802     { \fp_abs:n { \l__box_scale_y_fp } \l__box_top_dim }
26803     \dim_set:Nn \l__box_bottom_new_dim
26804     { \fp_abs:n { \l__box_scale_y_fp } \l__box_bottom_dim }
26805     \dim_set:Nn \l__box_right_new_dim
26806     { \fp_abs:n { \l__box_scale_x_fp } \l__box_right_dim }
26807     \__box_resize_common:N #1
26808 }

```

(End definition for `\box_scale:Nnn` and others. These functions are documented on page 238.)

`\box_autosize_to_wd_and_ht:Nnn` Although autosizing a box uses dimensions, it has more in common in implementation with scaling. As such, most of the real work here is done elsewhere. `\box_autosize_to_wd_and_ht:cnn`

```

\box_gautosize_to_wd_and_ht:Nnn
\box_gautosize_to_wd_and_ht:cnn
26809 \cs_new_protected:Npn \box_autosize_to_wd_and_ht:Nnn #1#2#3
26810 { \__box_autosize:NnnN #1 {#2} {#3} { \box_ht:N #1 } \hbox_set:Nn }
26811 \cs_generate_variant:Nn \box_autosize_to_wd_and_ht:Nnn { c }
26812 \cs_new_protected:Npn \box_gautosize_to_wd_and_ht:Nnn #1#2#3
26813 { \__box_autosize:NnnN #1 {#2} {#3} { \box_ht:N #1 } \hbox_gset:Nn }
26814 \cs_generate_variant:Nn \box_gautosize_to_wd_and_ht:Nnn { c }
26815 \cs_new_protected:Npn \box_autosize_to_wd_and_ht_plus_dp:Nnn #1#2#3
26816 {
26817     \__box_autosize:NnnN #1 {#2} {#3} { \box_ht:N #1 + \box_dp:N #1 }

```

```

26818     \hbox_set:Nn
26819   }
26820 \cs_generate_variant:Nn \box_autosize_to_wd_and_ht_plus_dp:Nnn { c }
26821 \cs_new_protected:Npn \box_gautosize_to_wd_and_ht_plus_dp:Nnn #1#2#3
26822 {
26823   \__box_autosize:NnnN #1 {#2} {#3} { \box_ht:N #1 + \box_dp:N #1 }
26824   \hbox_gset:Nn
26825 }
26826 \cs_generate_variant:Nn \box_gautosize_to_wd_and_ht_plus_dp:Nnn { c }
26827 \cs_new_protected:Npn \__box_autosize:NnnN #1#2#3#4#5
26828 {
26829   #5 #1
26830   {
26831     \fp_set:Nn \l__box_scale_x_fp { ( #2 ) / \box_wd:N #1 }
26832     \fp_set:Nn \l__box_scale_y_fp { ( #3 ) / ( #4 ) }
26833     \fp_compare:nNnTF \l__box_scale_x_fp > \l__box_scale_y_fp
26834       { \fp_set_eq:NN \l__box_scale_x_fp \l__box_scale_y_fp }
26835       { \fp_set_eq:NN \l__box_scale_y_fp \l__box_scale_x_fp }
26836     \__box_scale:N #1
26837   }
26838 }

```

(End definition for `\box_autosize_to_wd_and_ht:Nnn` and others. These functions are documented on page 236.)

`__box_resize_common:N` The main resize function places its input into a box which start off with zero width, and includes the handles for engine rescaling.

```

26839 \cs_new_protected:Npn \__box_resize_common:N #1
26840 {
26841   \hbox_set:Nn \l__box_internal_box
26842   {
26843     \__box_backend_scale:Nnn
26844     #1
26845     \l__box_scale_x_fp
26846     \l__box_scale_y_fp
26847   }

```

The new height and depth can be applied directly.

```

26848   \fp_compare:nNnTF \l__box_scale_y_fp > \c_zero_fp
26849   {
26850     \box_set_ht:Nn \l__box_internal_box { \l__box_top_new_dim }
26851     \box_set_dp:Nn \l__box_internal_box { -\l__box_bottom_new_dim }
26852   }
26853   {
26854     \box_set_dp:Nn \l__box_internal_box { \l__box_top_new_dim }
26855     \box_set_ht:Nn \l__box_internal_box { -\l__box_bottom_new_dim }
26856   }

```

Things are not quite as obvious for the width, as the reference point needs to remain unchanged. For positive scaling factors resizing the box is all that is needed. However, for case of a negative scaling the material must be shifted such that the reference point ends up in the right place.

```

26857   \fp_compare:nNnTF \l__box_scale_x_fp < \c_zero_fp
26858   {
26859     \hbox_to_wd:nn { \l__box_right_new_dim }

```

```

26860         {
26861             \tex_kern:D \l__box_right_new_dim
26862             \box_use_drop:N \l__box_internal_box
26863             \tex_hss:D
26864         }
26865     }
26866     {
26867         \box_set_wd:Nn \l__box_internal_box { \l__box_right_new_dim }
26868         \hbox:n
26869         {
26870             \tex_kern:D \c_zero_dim
26871             \box_use_drop:N \l__box_internal_box
26872             \tex_hss:D
26873         }
26874     }
26875 }

```

(End definition for `__box_resize_common:N`.)

```
26876 \</initex | package>
```

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```
26877 \<*initex | package>
```

```
26878 \<@@=coffin>
```

42.1 Coffins: data structures and general variables

```

\l__coffin_internal_box
\l__coffin_internal_dim
\l__coffin_internal_tl

```

Scratch variables.

```

26879 \box_new:N \l__coffin_internal_box
26880 \dim_new:N \l__coffin_internal_dim
26881 \tl_new:N \l__coffin_internal_tl

```

(End definition for `\l__coffin_internal_box`, `\l__coffin_internal_dim`, and `\l__coffin_internal_tl`.)

```
\c__coffin_corners_prop
```

The “corners”; of a coffin define the real content, as opposed to the \TeX bounding box. They all start off in the same place, of course.

```

26882 \prop_const_from_keyval:Nn \c__coffin_corners_prop
26883 {
26884     tl = { Opt } { Opt } ,
26885     tr = { Opt } { Opt } ,
26886     bl = { Opt } { Opt } ,
26887     br = { Opt } { Opt } ,
26888 }

```

(End definition for `\c__coffin_corners_prop`.)

```
\c__coffin_poles_prop
```

Pole positions are given for horizontal, vertical and reference-point based values.

```

26889 \prop_const_from_keyval:Nn \c__coffin_poles_prop
26890 {
26891     l  = { Opt } { Opt } { Opt } { 1000pt } ,
26892     hc = { Opt } { Opt } { Opt } { 1000pt } ,
26893     r  = { Opt } { Opt } { Opt } { 1000pt } ,

```

```

26894      b = { 0pt } { 0pt } { 1000pt } { 0pt } ,
26895      vc = { 0pt } { 0pt } { 1000pt } { 0pt } ,
26896      t  = { 0pt } { 0pt } { 1000pt } { 0pt } ,
26897      B  = { 0pt } { 0pt } { 1000pt } { 0pt } ,
26898      H  = { 0pt } { 0pt } { 1000pt } { 0pt } ,
26899      T  = { 0pt } { 0pt } { 1000pt } { 0pt } ,
26900  }

```

(End definition for \c__coffin_poles_prop.)

\l__coffin_slope_x_fp Used for calculations of intersections.

```

\l__coffin_slope_y_fp
26901 \fp_new:N \l__coffin_slope_x_fp
26902 \fp_new:N \l__coffin_slope_y_fp

```

(End definition for \l__coffin_slope_x_fp and \l__coffin_slope_y_fp.)

\l__coffin_error_bool For propagating errors so that parts of the code can work around them.

```

26903 \bool_new:N \l__coffin_error_bool

```

(End definition for \l__coffin_error_bool.)

\l__coffin_offset_x_dim The offset between two sets of coffin handles when typesetting. These values are corrected from those requested in an alignment for the positions of the handles.

```

26904 \dim_new:N \l__coffin_offset_x_dim
26905 \dim_new:N \l__coffin_offset_y_dim

```

(End definition for \l__coffin_offset_x_dim and \l__coffin_offset_y_dim.)

\l__coffin_pole_a_tl Needed for finding the intersection of two poles.

```

\l__coffin_pole_b_tl
26906 \tl_new:N \l__coffin_pole_a_tl
26907 \tl_new:N \l__coffin_pole_b_tl

```

(End definition for \l__coffin_pole_a_tl and \l__coffin_pole_b_tl.)

\l__coffin_x_dim For calculating intersections and so forth.

```

\l__coffin_y_dim
26908 \dim_new:N \l__coffin_x_dim
\l__coffin_x_prime_dim 26909 \dim_new:N \l__coffin_y_dim
\l__coffin_y_prime_dim 26910 \dim_new:N \l__coffin_x_prime_dim
26911 \dim_new:N \l__coffin_y_prime_dim

```

(End definition for \l__coffin_x_dim and others.)

42.2 Basic coffin functions

There are a number of basic functions needed for creating coffins and placing material in them. This all relies on the following data structures.

__coffin_to_value:N Coffins are a two-part structure and we rely on the internal nature of box allocation to make everything work. As such, we need an interface to turn coffin identifiers into numbers. For the purposes here, the signature allowed is N despite the nature of the underlying primitive.

```

26912 \cs_new_eq:NN \__coffin_to_value:N \tex_number:D

```

(End definition for __coffin_to_value:N.)

`\coffin_if_exist_p:N` Several of the higher-level coffin functions would give multiple errors if the coffin does not exist. A cleaner way to handle this is provided here: both the box and the coffin structure are checked.

```

\coffin_if_exist_p:c
\coffin_if_exist:NTF
\coffin_if_exist:cTF
26913 \prg_new_conditional:Npnn \coffin_if_exist:N #1 { p , T , F , TF }
26914 {
26915     \cs_if_exist:NTF #1
26916     {
26917         \cs_if_exist:cTF { coffin ~ \__coffin_to_value:N #1 ~ poles }
26918         { \prg_return_true: }
26919         { \prg_return_false: }
26920     }
26921     { \prg_return_false: }
26922 }
26923 \prg_generate_conditional_variant:Nnn \coffin_if_exist:N
26924 { c } { p , T , F , TF }

```

(End definition for `\coffin_if_exist:NTF`. This function is documented on page 239.)

`__coffin_if_exist:NT` Several of the higher-level coffin functions would give multiple errors if the coffin does not exist. So a wrapper is provided to deal with this correctly, issuing an error on erroneous use.

```

26925 \cs_new_protected:Npn \__coffin_if_exist:NT #1#2
26926 {
26927     \coffin_if_exist:NTF #1
26928     { #2 }
26929     {
26930         \_kernel_msg_error:nxx { kernel } { unknown-coffin }
26931         { \token_to_str:N #1 }
26932     }
26933 }

```

(End definition for `__coffin_if_exist:NT`.)

`\coffin_clear:N` Clearing coffins means emptying the box and resetting all of the structures.

```

\coffin_clear:c
\coffin_gclear:N
\coffin_gclear:c
26934 \cs_new_protected:Npn \coffin_clear:N #1
26935 {
26936     \__coffin_if_exist:NT #1
26937     {
26938         \box_clear:N #1
26939         \__coffin_reset_structure:N #1
26940     }
26941 }
26942 \cs_generate_variant:Nn \coffin_clear:N { c }
26943 \cs_new_protected:Npn \coffin_gclear:N #1
26944 {
26945     \__coffin_if_exist:NT #1
26946     {
26947         \box_gclear:N #1
26948         \__coffin_greset_structure:N #1
26949     }
26950 }
26951 \cs_generate_variant:Nn \coffin_gclear:N { c }

```

(End definition for `\coffin_clear:N` and `\coffin_gclear:N`. These functions are documented on page 239.)

\coffin_new:N Creating a new coffin means making the underlying box and adding the data structures. The **\debug_suspend:** and **\debug_resume:** functions prevent **\prop_gclear_new:c** from writing useless information to the log file.

```

26952 \cs_new_protected:Npn \coffin_new:N #1
26953 {
26954   \box_new:N #1
26955   \debug_suspend:
26956   \prop_gclear_new:c { coffin ~ \__coffin_to_value:N #1 ~ corners }
26957   \prop_gclear_new:c { coffin ~ \__coffin_to_value:N #1 ~ poles }
26958   \prop_gset_eq:cN { coffin ~ \__coffin_to_value:N #1 ~ corners }
26959     \c__coffin_corners_prop
26960   \prop_gset_eq:cN { coffin ~ \__coffin_to_value:N #1 ~ poles }
26961     \c__coffin_poles_prop
26962   \debug_resume:
26963 }
26964 \cs_generate_variant:Nn \coffin_new:N { c }

```

(End definition for **\coffin_new:N**. This function is documented on page 239.)

\hcoffin_set:Nn Horizontal coffins are relatively easy: set the appropriate box, reset the structures then update the handle positions.

```

\hcoffin_set:cn
\hcoffin_gset:Nn
\hcoffin_gset:cn
26965 \cs_new_protected:Npn \hcoffin_set:Nn #1#2
26966 {
26967   \__coffin_if_exist:NT #1
26968   {
26969     \hbox_set:Nn #1
26970     {
26971       \color_ensure_current:
26972       #2
26973     }
26974     \__coffin_update:N #1
26975   }
26976 }
26977 \cs_generate_variant:Nn \hcoffin_set:Nn { c }
26978 \cs_new_protected:Npn \hcoffin_gset:Nn #1#2
26979 {
26980   \__coffin_if_exist:NT #1
26981   {
26982     \hbox_gset:Nn #1
26983     {
26984       \color_ensure_current:
26985       #2
26986     }
26987     \__coffin_gupdate:N #1
26988   }
26989 }
26990 \cs_generate_variant:Nn \hcoffin_gset:Nn { c }

```

(End definition for **\hcoffin_set:Nn** and **\hcoffin_gset:Nn**. These functions are documented on page 239.)

\vcoffin_set:Nnn Setting vertical coffins is more complex. First, the material is typeset with a given width. The default handles and poles are set as for a horizontal coffin, before finding the top baseline using a temporary box. No **\color_ensure_current:** here as that would add a

\vcoffin_gset:Nnn
__coffin_set_vertical:NnnNN

whatsit to the start of the vertical box and mess up the location of the T pole (see *T_EX by Topic* for discussion of the `\vtop` primitive, used to do the measuring).

```

26991 \cs_new_protected:Npn \vcoffin_set:Nnn #1#2#3
26992 {
26993   \__coffin_set_vertical:NnnNN #1 {#2} {#3}
26994   \vbox_set:Nn \__coffin_update:N
26995 }
26996 \cs_generate_variant:Nn \vcoffin_set:Nnn { c }
26997 \cs_new_protected:Npn \vcoffin_gset:Nnn #1#2#3
26998 {
26999   \__coffin_set_vertical:NnnNN #1 {#2} {#3}
27000   \vbox_gset:Nn \__coffin_gupdate:N
27001 }
27002 \cs_generate_variant:Nn \vcoffin_gset:Nnn { c }
27003 \cs_new_protected:Npn \__coffin_set_vertical:NnnNN #1#2#3#4#5
27004 {
27005   \__coffin_if_exist:NT #1
27006   {
27007     #4 #1
27008     {
27009       \dim_set:Nn \tex_hsize:D {#2}
27010       (*package)
27011       \dim_set_eq:NN \linewidth \tex_hsize:D
27012       \dim_set_eq:NN \columnwidth \tex_hsize:D
27013       (/package)
27014       #3
27015     }
27016     #5 #1
27017     \vbox_set_top:Nn \l__coffin_internal_box { \vbox_unpack:N #1 }
27018     \__coffin_set_pole:Nnx #1 { T }
27019     {
27020       { 0pt }
27021       {
27022         \dim_eval:n
27023         { \box_ht:N #1 - \box_ht:N \l__coffin_internal_box }
27024       }
27025       { 1000pt }
27026       { 0pt }
27027     }
27028     \box_clear:N \l__coffin_internal_box
27029   }
27030 }

```

(End definition for `\vcoffin_set:Nnn`, `\vcoffin_gset:Nnn`, and `__coffin_set_vertical:NnnNN`. These functions are documented on page 240.)

`\hcoffin_set:Nw` These are the “begin”/“end” versions of the above: watch the grouping!

```

\hcoffin_set:cw 27031 \cs_new_protected:Npn \hcoffin_set:Nw #1
\hcoffin_gset:Nw 27032 {
\hcoffin_gset:cw 27033   \__coffin_if_exist:NT #1
\hcoffin_set_end: 27034   {
\hcoffin_gset_end: 27035     \hbox_set:Nw #1 \color_ensure_current:
27036     \cs_set_protected:Npn \hcoffin_set_end:
27037     {

```

```

27038             \hbox_set_end:
27039             \__coffin_update:N #1
27040         }
27041     }
27042 }
27043 \cs_generate_variant:Nn \hcoffin_set:Nw { c }
27044 \cs_new_protected:Npn \hcoffin_gset:Nw #1
27045 {
27046     \__coffin_if_exist:NT #1
27047     {
27048         \hbox_gset:Nw #1 \color_ensure_current:
27049         \cs_set_protected:Npn \hcoffin_gset_end:
27050         {
27051             \hbox_gset_end:
27052             \__coffin_gupdate:N #1
27053         }
27054     }
27055 }
27056 \cs_generate_variant:Nn \hcoffin_gset:Nw { c }
27057 \cs_new_protected:Npn \hcoffin_set_end: { }
27058 \cs_new_protected:Npn \hcoffin_gset_end: { }

```

(End definition for `\hcoffin_set:Nw` and others. These functions are documented on page 240.)

```

\vcoffin_set:Nnw The same for vertical coffins.
\vcoffin_set:cnw
\vcoffin_gset:Nnw
\vcoffin_gset:cnw
\__coffin_set_vertical:NnNNNNw
\vcoffin_set_end:
\vcoffin_gset_end:
27059 \cs_new_protected:Npn \vcoffin_set:Nnw #1#2
27060 {
27061     \__coffin_set_vertical:NnNNNNw #1 {#2} \vbox_set:Nw
27062     \vcoffin_set_end:
27063     \vbox_set_end: \__coffin_update:N
27064 }
27065 \cs_generate_variant:Nn \vcoffin_set:Nnw { c }
27066 \cs_new_protected:Npn \vcoffin_gset:Nnw #1#2
27067 {
27068     \__coffin_set_vertical:NnNNNNw #1 {#2} \vbox_gset:Nw
27069     \vcoffin_gset_end:
27070     \vbox_gset_end: \__coffin_gupdate:N
27071 }
27072 \cs_generate_variant:Nn \vcoffin_gset:Nnw { c }
27073 \cs_new_protected:Npn \__coffin_set_vertical:NnNNNNw #1#2#3#4#5#6
27074 {
27075     \__coffin_if_exist:NT #1
27076     {
27077         #3 #1
27078         \dim_set:Nn \tex_hsize:D {#2}
27079         \*package>
27080             \dim_set_eq:NN \linewidth \tex_hsize:D
27081             \dim_set_eq:NN \columnwidth \tex_hsize:D
27082         </package>
27083         \cs_set_protected:Npn #4
27084         {
27085             #5
27086             #6 #1
27087             \vbox_set_top:Nn \l__coffin_internal_box { \vbox_unpack:N #1 }

```



```

27088         \__coffin_set_pole:Nnx #1 { T }
27089         {
27090             { Opt }
27091             {
27092                 \dim_eval:n
27093                 { \box_ht:N #1 - \box_ht:N \l__coffin_internal_box }
27094             }
27095             { 1000pt }
27096             { Opt }
27097         }
27098         \box_clear:N \l__coffin_internal_box
27099     }
27100 }
27101 }
27102 \cs_new_protected:Npn \vcoffin_set_end: { }
27103 \cs_new_protected:Npn \vcoffin_gset_end: { }

```

(End definition for \vcoffin_set:Nnw and others. These functions are documented on page 240.)

```

\coffin_set_eq:NN Setting two coffins equal is just a wrapper around other functions.
\coffin_set_eq:Nc
\coffin_gset_eq:cN
\coffin_gset_eq:cc
27104 \cs_new_protected:Npn \coffin_set_eq:NN #1#2
27105 {
27106     \__coffin_if_exist:NT #1
27107     {
27108         \box_set_eq:NN #1 #2
27109         \prop_set_eq:cc { coffin ~ \__coffin_to_value:N #1 ~ corners }
27110         { coffin ~ \__coffin_to_value:N #2 ~ corners }
27111         \prop_set_eq:cc { coffin ~ \__coffin_to_value:N #1 ~ poles }
27112         { coffin ~ \__coffin_to_value:N #2 ~ poles }
27113     }
27114 }
27115 \cs_generate_variant:Nn \coffin_set_eq:NN { c , Nc , cc }
27116 \cs_new_protected:Npn \coffin_gset_eq:NN #1#2
27117 {
27118     \__coffin_if_exist:NT #1
27119     {
27120         \box_gset_eq:NN #1 #2
27121         \prop_gset_eq:cc { coffin ~ \__coffin_to_value:N #1 ~ corners }
27122         { coffin ~ \__coffin_to_value:N #2 ~ corners }
27123         \prop_gset_eq:cc { coffin ~ \__coffin_to_value:N #1 ~ poles }
27124         { coffin ~ \__coffin_to_value:N #2 ~ poles }
27125     }
27126 }
27127 \cs_generate_variant:Nn \coffin_gset_eq:NN { c , Nc , cc }

```

(End definition for \coffin_set_eq:NN and \coffin_gset_eq:cN. These functions are documented on page 239.)

```

\c_empty_coffin Special coffins: these cannot be set up earlier as they need \coffin_new:N. The empty
\l__coffin_aligned_coffin coffin is set as a box as the full coffin-setting system needs some material which is not
\l__coffin_aligned_internal_coffin yet available. The empty coffin is created entirely by hand: not everything is in place yet.
27128 \coffin_new:N \c_empty_coffin
27129 \coffin_new:N \l__coffin_aligned_coffin
27130 \coffin_new:N \l__coffin_aligned_internal_coffin

```

(End definition for `\c_empty_coffin`, `\l__coffin_aligned_coffin`, and `\l__coffin_aligned_internal_coffin`. This variable is documented on page 243.)

```
\l_tmpa_coffin The usual scratch space.
\l_tmpb_coffin 27131 \coffin_new:N \l_tmpa_coffin
\g_tmpa_coffin 27132 \coffin_new:N \l_tmpb_coffin
\g_tmpb_coffin 27133 \coffin_new:N \g_tmpa_coffin
                27134 \coffin_new:N \g_tmpb_coffin
```

(End definition for `\l_tmpa_coffin` and others. These variables are documented on page 243.)

42.3 Measuring coffins

`\coffin_dp:N` Coffins are just boxes when it comes to measurement. However, semantically a separate set of functions are required.

```
\coffin_dp:c 27135 \cs_new_eq:NN \coffin_dp:N \box_dp:N
\coffin_ht:N 27136 \cs_new_eq:NN \coffin_dp:c \box_dp:c
\coffin_ht:c 27137 \cs_new_eq:NN \coffin_ht:N \box_ht:N
\coffin_wd:N 27138 \cs_new_eq:NN \coffin_ht:c \box_ht:c
\coffin_wd:c 27139 \cs_new_eq:NN \coffin_wd:N \box_wd:N
                27140 \cs_new_eq:NN \coffin_wd:c \box_wd:c
```

(End definition for `\coffin_dp:N`, `\coffin_ht:N`, and `\coffin_wd:N`. These functions are documented on page 242.)

42.4 Coffins: handle and pole management

`__coffin_get_pole:NnN` A simple wrapper around the recovery of a coffin pole, with some error checking and recovery built-in.

```
27141 \cs_new_protected:Npn \__coffin_get_pole:NnN #1#2#3
27142 {
27143   \prop_get:cnNF
27144     { coffin ~ \__coffin_to_value:N #1 ~ poles } {#2} #3
27145     {
27146       \__kernel_msg_error:nxxx { kernel } { unknown-coffin-pole }
27147       { \exp_not:n {#2} } { \token_to_str:N #1 }
27148       \tl_set:Nn #3 { { Opt } { Opt } { Opt } { Opt } }
27149     }
27150 }
```

(End definition for `__coffin_get_pole:NnN`.)

`__coffin_reset_structure:N` Resetting the structure is a simple copy job.

```
\__coffin_greset_structure:N 27151 \cs_new_protected:Npn \__coffin_reset_structure:N #1
27152 {
27153   \prop_set_eq:cN { coffin ~ \__coffin_to_value:N #1 ~ corners }
27154   \c__coffin_corners_prop
27155   \prop_set_eq:cN { coffin ~ \__coffin_to_value:N #1 ~ poles }
27156   \c__coffin_poles_prop
27157 }
27158 \cs_new_protected:Npn \__coffin_greset_structure:N #1
27159 {
27160   \prop_gset_eq:cN { coffin ~ \__coffin_to_value:N #1 ~ corners }
27161   \c__coffin_corners_prop
```

```

27162     \prop_gset_eq:cN { coffin ~ \__coffin_to_value:N #1 ~ poles }
27163     \c__coffin_poles_prop
27164 }

```

(End definition for __coffin_reset_structure:N and __coffin_greset_structure:N.)

`\coffin_set_horizontal_pole:Nnn` Setting the pole of a coffin at the user/designer level requires a bit more care. The idea here is to provide a reasonable interface to the system, then to do the setting with full expansion. The three-argument version is used internally to do a direct setting.

```

\coffin_set_horizontal_pole:cnn
\coffin_gset_horizontal_pole:Nnn
\coffin_gset_horizontal_pole:cnn
\__coffin_set_horizontal_pole:NnnN
\coffin_set_vertical_pole:Nnn
\coffin_set_vertical_pole:cnn
\coffin_gset_vertical_pole:Nnn
\coffin_gset_vertical_pole:cnn
\__coffin_set_vertical_pole:NnnN
\__coffin_set_pole:Nnn
\__coffin_set_pole:Nnx
27165 \cs_new_protected:Npn \coffin_set_horizontal_pole:Nnn #1#2#3
27166 { \__coffin_set_horizontal_pole:NnnN #1 {#2} {#3} \prop_put:cnx }
27167 \cs_generate_variant:Nn \coffin_set_horizontal_pole:Nnn { c }
27168 \cs_new_protected:Npn \coffin_gset_horizontal_pole:Nnn #1#2#3
27169 { \__coffin_set_horizontal_pole:NnnN #1 {#2} {#3} \prop_gput:cnx }
27170 \cs_generate_variant:Nn \coffin_gset_horizontal_pole:Nnn { c }
27171 \cs_new_protected:Npn \__coffin_set_horizontal_pole:NnnN #1#2#3#4
27172 {
27173   \__coffin_if_exist:NT #1
27174   {
27175     #4 { coffin ~ \__coffin_to_value:N #1 ~ poles }
27176     {#2}
27177     {
27178       { Opt } { \dim_eval:n {#3} }
27179       { 1000pt } { Opt }
27180     }
27181   }
27182 }
27183 \cs_new_protected:Npn \coffin_set_vertical_pole:Nnn #1#2#3
27184 { \__coffin_set_vertical_pole:NnnN #1 {#2} {#3} \prop_put:cnx }
27185 \cs_generate_variant:Nn \coffin_set_vertical_pole:Nnn { c }
27186 \cs_new_protected:Npn \coffin_gset_vertical_pole:Nnn #1#2#3
27187 { \__coffin_set_vertical_pole:NnnN #1 {#2} {#3} \prop_gput:cnx }
27188 \cs_generate_variant:Nn \coffin_gset_vertical_pole:Nnn { c }
27189 \cs_new_protected:Npn \__coffin_set_vertical_pole:NnnN #1#2#3#4
27190 {
27191   \__coffin_if_exist:NT #1
27192   {
27193     #4 { coffin ~ \__coffin_to_value:N #1 ~ poles }
27194     {#2}
27195     {
27196       { \dim_eval:n {#3} } { Opt }
27197       { Opt } { 1000pt }
27198     }
27199   }
27200 }
27201 \cs_new_protected:Npn \__coffin_set_pole:Nnn #1#2#3
27202 {
27203   \prop_put:cnn { coffin ~ \__coffin_to_value:N #1 ~ poles }
27204   {#2} {#3}
27205 }
27206 \cs_generate_variant:Nn \__coffin_set_pole:Nnn { Nnx }

```

(End definition for \coffin_set_horizontal_pole:Nnn and others. These functions are documented on page 240.)

```

\__coffin_update:N
\__coffin_gupdate:N
27207 \cs_new_protected:Npn \__coffin_update:N #1
27208 {
27209     \__coffin_reset_structure:N #1
27210     \__coffin_update_corners:N #1
27211     \__coffin_update_poles:N #1
27212 }
27213 \cs_new_protected:Npn \__coffin_gupdate:N #1
27214 {
27215     \__coffin_greset_structure:N #1
27216     \__coffin_gupdate_corners:N #1
27217     \__coffin_gupdate_poles:N #1
27218 }

```

Simple shortcuts.

(End definition for `__coffin_update:N` and `__coffin_gupdate:N`.)

```

\__coffin_update_corners:N
\__coffin_gupdate_corners:N
\__coffin_update_corners:NN
\__coffin_update_corners:NNN
27219 \cs_new_protected:Npn \__coffin_update_corners:N #1
27220 { \__coffin_update_corners:NN #1 \prop_put:Nnx }
27221 \cs_new_protected:Npn \__coffin_gupdate_corners:N #1
27222 { \__coffin_update_corners:NN #1 \prop_gput:Nnx }
27223 \cs_new_protected:Npn \__coffin_update_corners:NN #1#2
27224 {
27225     \exp_args:Nc \__coffin_update_corners:NNN
27226     { coffin ~ \__coffin_to_value:N #1 ~ corners }
27227     #1 #2
27228 }
27229 \cs_new_protected:Npn \__coffin_update_corners:NNN #1#2#3
27230 {
27231     #3 #1
27232     { tl }
27233     { { Opt } { \dim_eval:n { \box_ht:N #2 } } }
27234     #3 #1
27235     { tr }
27236     {
27237         { \dim_eval:n { \box_wd:N #2 } }
27238         { \dim_eval:n { \box_ht:N #2 } }
27239     }
27240     #3 #1
27241     { bl }
27242     { { Opt } { \dim_eval:n { -\box_dp:N #2 } } }
27243     #3 #1
27244     { br }
27245     {
27246         { \dim_eval:n { \box_wd:N #2 } }
27247         { \dim_eval:n { -\box_dp:N #2 } }
27248     }
27249 }

```

Updating the corners of a coffin is straight-forward as at this stage there can be no rotation. So the corners of the content are just those of the underlying `TeX` box.

(End definition for `__coffin_update_corners:N` and others.)

```

\__coffin_update_poles:N
\__coffin_gupdate_poles:N
\__coffin_update_poles:NN
\__coffin_update_poles:NNN

```

This function is called when a coffin is set, and updates the poles to reflect the nature of size of the box. Thus this function only alters poles where the default position is

dependent on the size of the box. It also does not set poles which are relevant only to vertical coffins.

```

27250 \cs_new_protected:Npn \__coffin_update_poles:N #1
27251 { \__coffin_update_poles:NN #1 \prop_put:Nnx }
27252 \cs_new_protected:Npn \__coffin_gupdate_poles:N #1
27253 { \__coffin_update_poles:NN #1 \prop_gput:Nnx }
27254 \cs_new_protected:Npn \__coffin_update_poles:NN #1#2
27255 {
27256   \exp_args:Nc \__coffin_update_poles:NNN
27257   { coffin ~ \__coffin_to_value:N #1 ~ poles }
27258   #1 #2
27259 }
27260 \cs_new_protected:Npn \__coffin_update_poles:NNN #1#2#3
27261 {
27262   #3 #1 { hc }
27263   {
27264     { \dim_eval:n { 0.5 \box_wd:N #2 } }
27265     { Opt } { Opt } { 1000pt }
27266   }
27267   #3 #1 { r }
27268   {
27269     { \dim_eval:n { \box_wd:N #2 } }
27270     { Opt } { Opt } { 1000pt }
27271   }
27272   #3 #1 { vc }
27273   {
27274     { Opt }
27275     { \dim_eval:n { ( \box_ht:N #2 - \box_dp:N #2 ) / 2 } }
27276     { 1000pt }
27277     { Opt }
27278   }
27279   #3 #1 { t }
27280   {
27281     { Opt }
27282     { \dim_eval:n { \box_ht:N #2 } }
27283     { 1000pt }
27284     { Opt }
27285   }
27286   #3 #1 { b }
27287   {
27288     { Opt }
27289     { \dim_eval:n { -\box_dp:N #2 } }
27290     { 1000pt }
27291     { Opt }
27292   }
27293 }

```

(End definition for `__coffin_update_poles:N` and others.)

42.5 Coffins: calculation of pole intersections

The lead off in finding intersections is to recover the two poles and then hand off to the auxiliary for the actual calculation. There may of course not be an intersection, for which an error trap is needed.

```

27294 \cs_new_protected:Npn \__coffin_calculate_intersection:Nnn #1#2#3
27295 {
27296   \__coffin_get_pole:NnN #1 {#2} \l__coffin_pole_a_tl
27297   \__coffin_get_pole:NnN #1 {#3} \l__coffin_pole_b_tl
27298   \bool_set_false:N \l__coffin_error_bool
27299   \exp_last_two_unbraced:Noo
27300   \__coffin_calculate_intersection:nnnnnnnn
27301   \l__coffin_pole_a_tl \l__coffin_pole_b_tl
27302   \bool_if:NT \l__coffin_error_bool
27303   {
27304     \__kernel_msg_error:nn { kernel } { no-pole-intersection }
27305     \dim_zero:N \l__coffin_x_dim
27306     \dim_zero:N \l__coffin_y_dim
27307   }
27308 }

```

The two poles passed here each have four values (as dimensions), (a, b, c, d) and (a', b', c', d') . These are arguments 1–4 and 5–8, respectively. In both cases a and b are the co-ordinates of a point on the pole and c and d define the direction of the pole. Finding the intersection depends on the directions of the poles, which are given by d/c and d'/c' . However, if one of the poles is either horizontal or vertical then one or more of c , d , c' and d' are zero and a special case is needed.

```

27309 \cs_new_protected:Npn \__coffin_calculate_intersection:nnnnnnnn
27310 #1#2#3#4#5#6#7#8
27311 {
27312   \dim_compare:nNnTF {#3} = { \c_zero_dim }

```

The case where the first pole is vertical. So the x -component of the interaction is at a . There is then a test on the second pole: if it is also vertical then there is an error.

```

27313 {
27314   \dim_set:Nn \l__coffin_x_dim {#1}
27315   \dim_compare:nNnTF {#7} = { \c_zero_dim
27316     { \bool_set_true:N \l__coffin_error_bool }

```

The second pole may still be horizontal, in which case the y -component of the intersection is b' . If not,

$$y = \frac{d'}{c'}(x - a') + b'$$

with the x -component already known to be #1. This calculation is done as a generalised auxiliary.

```

27317 {
27318   \dim_compare:nNnTF {#8} = { \c_zero_dim
27319     { \dim_set:Nn \l__coffin_y_dim {#6} }
27320     {
27321       \__coffin_calculate_intersection_aux:nnnnnN
27322       {#1} {#5} {#6} {#7} {#8} \l__coffin_y_dim
27323     }
27324   }
27325 }

```

If the first pole is not vertical then it may be horizontal. If so, then the procedure is essentially the same as that already done but with the x - and y -components interchanged.

```

27326 {
27327   \dim_compare:nNnTF {#4} = { \c_zero_dim

```

```

27328     {
27329         \dim_set:Nn \l__coffin_y_dim {#2}
27330         \dim_compare:nNnTF {#8} = { \c_zero_dim }
27331         { \bool_set_true:N \l__coffin_error_bool }
27332     {
27333         \dim_compare:nNnTF {#7} = \c_zero_dim
27334         { \dim_set:Nn \l__coffin_x_dim {#5} }

```

The formula for the case where the second pole is neither horizontal nor vertical is

$$x = \frac{c'}{d'}(y - b') + a'$$

which is again handled by the same auxiliary.

```

27335     {
27336         \__coffin_calculate_intersection_aux:nnnnnN
27337         {#2} {#6} {#5} {#8} {#7} \l__coffin_x_dim
27338     }
27339 }
27340 }

```

The first pole is neither horizontal nor vertical. This still leaves the second pole, which may be a special case. For those possibilities, the calculations are the same as above with the first and second poles interchanged.

```

27341 {
27342     \dim_compare:nNnTF {#7} = \c_zero_dim
27343     {
27344         \dim_set:Nn \l__coffin_x_dim {#5}
27345         \__coffin_calculate_intersection_aux:nnnnnN
27346         {#5} {#1} {#2} {#3} {#4} \l__coffin_y_dim
27347     }
27348     {
27349         \dim_compare:nNnTF {#8} = \c_zero_dim
27350         {
27351             \dim_set:Nn \l__coffin_y_dim {#6}
27352             \__coffin_calculate_intersection_aux:nnnnnN
27353             {#6} {#2} {#1} {#4} {#3} \l__coffin_x_dim
27354         }

```

If none of the special cases apply then there is still a need to check that there is a unique intersection between the two pole. This is the case if they have different slopes.

```

27355     {
27356         \fp_set:Nn \l__coffin_slope_x_fp
27357         { \dim_to_fp:n {#4} / \dim_to_fp:n {#3} }
27358         \fp_set:Nn \l__coffin_slope_y_fp
27359         { \dim_to_fp:n {#8} / \dim_to_fp:n {#7} }
27360         \fp_compare:nNnTF
27361         \l__coffin_slope_x_fp = \l__coffin_slope_y_fp
27362         { \bool_set_true:N \l__coffin_error_bool }

```

All of the tests pass, so there is the full complexity of the calculation:

$$x = \frac{a(d/c) - a'(d'/c') - b + b'}{(d/c) - (d'/c')}$$

and noting that the two ratios are already worked out from the test just performed. There is quite a bit of shuffling from dimensions to floating points in order to do the

work. The y -values is then worked out using the standard auxiliary starting from the x -position.

```

27363 {
27364   \dim_set:Nn \l__coffin_x_dim
27365   {
27366     \fp_to_dim:n
27367     {
27368       (
27369         \dim_to_fp:n {#1} *
27370         \l__coffin_slope_x_fp
27371       - ( \dim_to_fp:n {#5} *
27372         \l__coffin_slope_y_fp )
27373       - \dim_to_fp:n {#2}
27374       + \dim_to_fp:n {#6}
27375     )
27376     /
27377     (
27378       \l__coffin_slope_x_fp -
27379       \l__coffin_slope_y_fp
27380     )
27381   }
27382 }
27383 \__coffin_calculate_intersection_aux:nnnnnN
27384 { \l__coffin_x_dim }
27385 {#5} {#6} {#8} {#7} \l__coffin_y_dim
27386 }
27387 }
27388 }
27389 }
27390 }
27391 }

```

The formula for finding the intersection point is in most cases the same. The formula here is

$$\#6 = \#4 \cdot \left(\frac{\#1 - \#2}{\#5} \right) \#3$$

Thus #4 and #5 should be the directions of the pole while #2 and #3 are co-ordinates.

```

27392 \cs_new_protected:Npn \__coffin_calculate_intersection_aux:nnnnnN
27393   #1#2#3#4#5#6
27394   {
27395     \dim_set:Nn #6
27396     {
27397       \fp_to_dim:n
27398       {
27399         \dim_to_fp:n {#4} *
27400         ( \dim_to_fp:n {#1} - \dim_to_fp:n {#2} ) /
27401         \dim_to_fp:n {#5}
27402         + \dim_to_fp:n {#3}
27403       }
27404     }
27405   }

```

(End definition for __coffin_calculate_intersection:Nnn, __coffin_calculate_intersection:nnnnnnnn, and __coffin_calculate_intersection_aux:nnnnnN.)

42.6 Affine transformations

`\l__coffin_sin_fp` Used for rotations to get the sine and cosine values.

`\l__coffin_cos_fp` 27406 `\fp_new:N \l__coffin_sin_fp`

27407 `\fp_new:N \l__coffin_cos_fp`

(End definition for \l__coffin_sin_fp and \l__coffin_cos_fp.)

`\l__coffin_bounding_prop` A property list for the bounding box of a coffin. This is only needed during the rotation, so there is just the one.

27408 `\prop_new:N \l__coffin_bounding_prop`

(End definition for \l__coffin_bounding_prop.)

`\l__coffin_corners_prop` Used to avoid needing to track scope for intermediate steps.

`\l__coffin_poles_prop` 27409 `\prop_new:N \l__coffin_corners_prop`

27410 `\prop_new:N \l__coffin_poles_prop`

(End definition for \l__coffin_corners_prop and \l__coffin_poles_prop.)

`\l__coffin_bounding_shift_dim` The shift of the bounding box of a coffin from the real content.

27411 `\dim_new:N \l__coffin_bounding_shift_dim`

(End definition for \l__coffin_bounding_shift_dim.)

`\l__coffin_left_corner_dim` These are used to hold maxima for the various corner values: these thus define the minimum size of the bounding box after rotation.

`\l__coffin_right_corner_dim`

`\l__coffin_bottom_corner_dim`

27412 `\dim_new:N \l__coffin_left_corner_dim`

27413 `\dim_new:N \l__coffin_right_corner_dim`

27414 `\dim_new:N \l__coffin_bottom_corner_dim`

27415 `\dim_new:N \l__coffin_top_corner_dim`

(End definition for \l__coffin_left_corner_dim and others.)

`\coffin_rotate:Nn` Rotating a coffin requires several steps which can be conveniently run together. The sine and cosine of the angle in degrees are computed. This is then used to set `\l__coffin_sin_fp` and `\l__coffin_cos_fp`, which are carried through unchanged for the rest of the procedure.

`\coffin_rotate:cn`

`\coffin_grotate:Nn`

`\coffin_grotate:cn`

`__coffin_rotate:NnNNN`

27416 `\cs_new_protected:Npn \coffin_rotate:Nn #1#2`

27417 `{ __coffin_rotate:NnNNN #1 {#2} \box_rotate:Nn \prop_set_eq:cn \hbox_set:Nn }`

27418 `\cs_generate_variant:Nn \coffin_rotate:Nn { c }`

27419 `\cs_new_protected:Npn \coffin_grotate:Nn #1#2`

27420 `{ __coffin_rotate:NnNNN #1 {#2} \box_grotate:Nn \prop_gset_eq:cn \hbox_gset:Nn }`

27421 `\cs_generate_variant:Nn \coffin_grotate:Nn { c }`

27422 `\cs_new_protected:Npn __coffin_rotate:NnNNN #1#2#3#4#5`

27423 `{`

27424 `\fp_set:Nn \l__coffin_sin_fp { sind (#2) }`

27425 `\fp_set:Nn \l__coffin_cos_fp { cosd (#2) }`

Use a local copy of the property lists to avoid needing to pass the name and scope around.

27426 `\prop_set_eq:Nc \l__coffin_corners_prop`

27427 `{ coffin ~ __coffin_to_value:N #1 ~ corners }`

27428 `\prop_set_eq:Nc \l__coffin_poles_prop`

27429 `{ coffin ~ __coffin_to_value:N #1 ~ poles }`

The corners and poles of the coffin can now be rotated around the origin. This is best achieved using mapping functions.

```

27430 \prop_map_inline:Nn \l__coffin_corners_prop
27431 { \__coffin_rotate_corner:Nnnn #1 {##1} ##2 }
27432 \prop_map_inline:Nn \l__coffin_poles_prop
27433 { \__coffin_rotate_pole:Nnnnnn #1 {##1} ##2 }

```

The bounding box of the coffin needs to be rotated, and to do this the corners have to be found first. They are then rotated in the same way as the corners of the coffin material itself.

```

27434 \__coffin_set_bounding:N #1
27435 \prop_map_inline:Nn \l__coffin_bounding_prop
27436 { \__coffin_rotate_bounding:nnn {##1} ##2 }

```

At this stage, there needs to be a calculation to find where the corners of the content and the box itself will end up.

```

27437 \__coffin_find_corner_maxima:N #1
27438 \__coffin_find_bounding_shift:
27439 #3 #1 {#2}

```

The correction of the box position itself takes place here. The idea is that the bounding box for a coffin is tight up to the content, and has the reference point at the bottom-left. The x -direction is handled by moving the content by the difference in the positions of the bounding box and the content left edge. The y -direction is dealt with by moving the box down by any depth it has acquired. The internal box is used here to allow for the next step.

```

27440 \hbox_set:Nn \l__coffin_internal_box
27441 {
27442   \tex_kern:D
27443   \dim_eval:n
27444     { \l__coffin_bounding_shift_dim - \l__coffin_left_corner_dim }
27445   \exp_stop_f:
27446   \box_move_down:nn { \l__coffin_bottom_corner_dim }
27447   { \box_use:N #1 }
27448 }

```

If there have been any previous rotations then the size of the bounding box will be bigger than the contents. This can be corrected easily by setting the size of the box to the height and width of the content. As this operation requires setting box dimensions and these transcend grouping, the safe way to do this is to use the internal box and to reset the result into the target box.

```

27449 \box_set_ht:Nn \l__coffin_internal_box
27450 { \l__coffin_top_corner_dim - \l__coffin_bottom_corner_dim }
27451 \box_set_dp:Nn \l__coffin_internal_box { 0pt }
27452 \box_set_wd:Nn \l__coffin_internal_box
27453 { \l__coffin_right_corner_dim - \l__coffin_left_corner_dim }
27454 #5 #1 { \box_use_drop:N \l__coffin_internal_box }

```

The final task is to move the poles and corners such that they are back in alignment with the box reference point.

```

27455 \prop_map_inline:Nn \l__coffin_corners_prop
27456 { \__coffin_shift_corner:Nnnn #1 {##1} ##2 }
27457 \prop_map_inline:Nn \l__coffin_poles_prop
27458 { \__coffin_shift_pole:Nnnnnn #1 {##1} ##2 }

```

Update the coffin data.

```

27459     #4 { coffin ~ \__coffin_to_value:N #1 ~ corners }
27460     \l__coffin_corners_prop
27461     #4 { coffin ~ \__coffin_to_value:N #1 ~ poles }
27462     \l__coffin_poles_prop
27463 }

```

(End definition for \coffin_rotate:Nn, \coffin_grotate:Nn, and __coffin_rotate:NnNNN. These functions are documented on page 241.)

__coffin_set_bounding:N The bounding box corners for a coffin are easy enough to find: this is the same code as for the corners of the material itself, but using a dedicated property list.

```

27464 \cs_new_protected:Npn \__coffin_set_bounding:N #1
27465 {
27466   \prop_put:Nnx \l__coffin_bounding_prop { tl }
27467   { { Opt } { \dim_eval:n { \box_ht:N #1 } } }
27468   \prop_put:Nnx \l__coffin_bounding_prop { tr }
27469   {
27470     { \dim_eval:n { \box_wd:N #1 } }
27471     { \dim_eval:n { \box_ht:N #1 } }
27472   }
27473   \dim_set:Nn \l__coffin_internal_dim { -\box_dp:N #1 }
27474   \prop_put:Nnx \l__coffin_bounding_prop { bl }
27475   { { Opt } { \dim_use:N \l__coffin_internal_dim } }
27476   \prop_put:Nnx \l__coffin_bounding_prop { br }
27477   {
27478     { \dim_eval:n { \box_wd:N #1 } }
27479     { \dim_use:N \l__coffin_internal_dim }
27480   }
27481 }

```

(End definition for __coffin_set_bounding:N.)

__coffin_rotate_bounding:nnn __coffin_rotate_corner:Nnnn Rotating the position of the corner of the coffin is just a case of treating this as a vector from the reference point. The same treatment is used for the corners of the material itself and the bounding box.

```

27482 \cs_new_protected:Npn \__coffin_rotate_bounding:nnn #1#2#3
27483 {
27484   \__coffin_rotate_vector:nnNN {#2} {#3} \l__coffin_x_dim \l__coffin_y_dim
27485   \prop_put:Nnx \l__coffin_bounding_prop {#1}
27486   { { \dim_use:N \l__coffin_x_dim } { \dim_use:N \l__coffin_y_dim } }
27487 }
27488 \cs_new_protected:Npn \__coffin_rotate_corner:Nnnn #1#2#3#4
27489 {
27490   \__coffin_rotate_vector:nnNN {#3} {#4} \l__coffin_x_dim \l__coffin_y_dim
27491   \prop_put:Nnx \l__coffin_corners_prop {#2}
27492   { { \dim_use:N \l__coffin_x_dim } { \dim_use:N \l__coffin_y_dim } }
27493 }

```

(End definition for __coffin_rotate_bounding:nnn and __coffin_rotate_corner:Nnnn.)

__coffin_rotate_pole:Nnnnnn Rotating a single pole simply means shifting the co-ordinate of the pole and its direction. The rotation here is about the bottom-left corner of the coffin.

```

27494 \cs_new_protected:Npn \__coffin_rotate_pole:Nnnnnn #1#2#3#4#5#6

```

```

27495 {
27496   \__coffin_rotate_vector:nnNN {#3} {#4} \l__coffin_x_dim \l__coffin_y_dim
27497   \__coffin_rotate_vector:nnNN {#5} {#6}
27498     \l__coffin_x_prime_dim \l__coffin_y_prime_dim
27499   \prop_put:Nnx \l__coffin_poles_prop {#2}
27500   {
27501     { \dim_use:N \l__coffin_x_dim } { \dim_use:N \l__coffin_y_dim }
27502     { \dim_use:N \l__coffin_x_prime_dim }
27503     { \dim_use:N \l__coffin_y_prime_dim }
27504   }
27505 }

```

(End definition for __coffin_rotate_pole:Nnnnnn.)

__coffin_rotate_vector:nnNN A rotation function, which needs only an input vector (as dimensions) and an output space. The values \l__coffin_cos_fp and \l__coffin_sin_fp should previously have been set up correctly. Working this way means that the floating point work is kept to a minimum: for any given rotation the sin and cosine values do no change, after all.

```

27506 \cs_new_protected:Npn \__coffin_rotate_vector:nnNN #1#2#3#4
27507 {
27508   \dim_set:Nn #3
27509   {
27510     \fp_to_dim:n
27511     {
27512       \dim_to_fp:n {#1} * \l__coffin_cos_fp
27513       - \dim_to_fp:n {#2} * \l__coffin_sin_fp
27514     }
27515   }
27516   \dim_set:Nn #4
27517   {
27518     \fp_to_dim:n
27519     {
27520       \dim_to_fp:n {#1} * \l__coffin_sin_fp
27521       + \dim_to_fp:n {#2} * \l__coffin_cos_fp
27522     }
27523   }
27524 }

```

(End definition for __coffin_rotate_vector:nnNN.)

__coffin_find_corner_maxima:N
 __coffin_find_corner_maxima_aux:nn The idea here is to find the extremities of the content of the coffin. This is done by looking for the smallest values for the bottom and left corners, and the largest values for the top and right corners. The values start at the maximum dimensions so that the case where all are positive or all are negative works out correctly.

```

27525 \cs_new_protected:Npn \__coffin_find_corner_maxima:N #1
27526 {
27527   \dim_set:Nn \l__coffin_top_corner_dim { -\c_max_dim }
27528   \dim_set:Nn \l__coffin_right_corner_dim { -\c_max_dim }
27529   \dim_set:Nn \l__coffin_bottom_corner_dim { \c_max_dim }
27530   \dim_set:Nn \l__coffin_left_corner_dim { \c_max_dim }
27531   \prop_map_inline:Nn \l__coffin_corners_prop
27532   { \__coffin_find_corner_maxima_aux:nn ##2 }
27533 }
27534 \cs_new_protected:Npn \__coffin_find_corner_maxima_aux:nn #1#2

```

```

27535 {
27536   \dim_set:Nn \l__coffin_left_corner_dim
27537   { \dim_min:nn { \l__coffin_left_corner_dim } {#1} }
27538   \dim_set:Nn \l__coffin_right_corner_dim
27539   { \dim_max:nn { \l__coffin_right_corner_dim } {#1} }
27540   \dim_set:Nn \l__coffin_bottom_corner_dim
27541   { \dim_min:nn { \l__coffin_bottom_corner_dim } {#2} }
27542   \dim_set:Nn \l__coffin_top_corner_dim
27543   { \dim_max:nn { \l__coffin_top_corner_dim } {#2} }
27544 }

```

(End definition for __coffin_find_corner_maxima:N and __coffin_find_corner_maxima_aux:nn.)

__coffin_find_bounding_shift:
__coffin_find_bounding_shift_aux:nn

The approach to finding the shift for the bounding box is similar to that for the corners. However, there is only one value needed here and a fixed input property list, so things are a bit clearer.

```

27545 \cs_new_protected:Npn \__coffin_find_bounding_shift:
27546 {
27547   \dim_set:Nn \l__coffin_bounding_shift_dim { \c_max_dim }
27548   \prop_map_inline:Nn \l__coffin_bounding_prop
27549   { \__coffin_find_bounding_shift_aux:nn ##2 }
27550 }
27551 \cs_new_protected:Npn \__coffin_find_bounding_shift_aux:nn #1#2
27552 {
27553   \dim_set:Nn \l__coffin_bounding_shift_dim
27554   { \dim_min:nn { \l__coffin_bounding_shift_dim } {#1} }
27555 }

```

(End definition for __coffin_find_bounding_shift: and __coffin_find_bounding_shift_aux:nn.)

__coffin_shift_corner:Nnnn
__coffin_shift_pole:Nnnnnn

Shifting the corners and poles of a coffin means subtracting the appropriate values from the x - and y -components. For the poles, this means that the direction vector is unchanged.

```

27556 \cs_new_protected:Npn \__coffin_shift_corner:Nnnn #1#2#3#4
27557 {
27558   \prop_put:Nnx \l__coffin_corners_prop {#2}
27559   {
27560     { \dim_eval:n { #3 - \l__coffin_left_corner_dim } }
27561     { \dim_eval:n { #4 - \l__coffin_bottom_corner_dim } }
27562   }
27563 }
27564 \cs_new_protected:Npn \__coffin_shift_pole:Nnnnnn #1#2#3#4#5#6
27565 {
27566   \prop_put:Nnx \l__coffin_poles_prop {#2}
27567   {
27568     { \dim_eval:n { #3 - \l__coffin_left_corner_dim } }
27569     { \dim_eval:n { #4 - \l__coffin_bottom_corner_dim } }
27570     {#5} {#6}
27571   }
27572 }

```

(End definition for __coffin_shift_corner:Nnnn and __coffin_shift_pole:Nnnnnn.)

`\l__coffin_scale_x_fp` Storage for the scaling factors in x and y , respectively.

`\l__coffin_scale_y_fp` 27573 `\fp_new:N \l__coffin_scale_x_fp`
27574 `\fp_new:N \l__coffin_scale_y_fp`

(End definition for `\l__coffin_scale_x_fp` and `\l__coffin_scale_y_fp`.)

`\l__coffin_scaled_total_height_dim` When scaling, the values given have to be turned into absolute values.
`\l__coffin_scaled_width_dim` 27575 `\dim_new:N \l__coffin_scaled_total_height_dim`
27576 `\dim_new:N \l__coffin_scaled_width_dim`

(End definition for `\l__coffin_scaled_total_height_dim` and `\l__coffin_scaled_width_dim`.)

`\coffin_resize:Nnn` Resizing a coffin begins by setting up the user-friendly names for the dimensions of the
`\coffin_resize:cnn` coffin box. The new sizes are then turned into scale factor. This is the same operation
`\coffin_gresize:Nnn` as takes place for the underlying box, but that operation is grouped and so the same
`\coffin_gresize:cnn` calculation is done here.

`__coffin_resize:NnnNN` 27577 `\cs_new_protected:Npn \coffin_resize:Nnn #1#2#3`
27578 `{`
27579 `__coffin_resize:NnnNN #1 {#2} {#3}`
27580 `\box_resize_to_wd_and_ht_plus_dp:Nnn`
27581 `\prop_set_eq:cN`
27582 `}`
27583 `\cs_generate_variant:Nn \coffin_resize:Nnn { c }`
27584 `\cs_new_protected:Npn \coffin_gresize:Nnn #1#2#3`
27585 `{`
27586 `__coffin_resize:NnnNN #1 {#2} {#3}`
27587 `\box_gresize_to_wd_and_ht_plus_dp:Nnn`
27588 `\prop_gset_eq:cN`
27589 `}`
27590 `\cs_generate_variant:Nn \coffin_gresize:Nnn { c }`
27591 `\cs_new_protected:Npn __coffin_resize:NnnNN #1#2#3#4#5`
27592 `{`
27593 `\fp_set:Nn \l__coffin_scale_x_fp`
27594 `{ \dim_to_fp:n {#2} / \dim_to_fp:n { \coffin_wd:N #1 } }`
27595 `\fp_set:Nn \l__coffin_scale_y_fp`
27596 `{`
27597 `\dim_to_fp:n {#3}`
27598 `/ \dim_to_fp:n { \coffin_ht:N #1 + \coffin_dp:N #1 }`
27599 `}`
27600 `#4 #1 {#2} {#3}`
27601 `__coffin_resize_common:NnnN #1 {#2} {#3} #5`
27602 `}`

(End definition for `\coffin_resize:Nnn`, `\coffin_gresize:Nnn`, and `__coffin_resize:NnnNN`. These functions are documented on page 241.)

`__coffin_resize_common:NnnN` The poles and corners of the coffin are scaled to the appropriate places before actually
resizing the underlying box.

27603 `\cs_new_protected:Npn __coffin_resize_common:NnnN #1#2#3#4`
27604 `{`
27605 `\prop_set_eq:Nc \l__coffin_corners_prop`
27606 `{ coffin ~ __coffin_to_value:N #1 ~ corners }`
27607 `\prop_set_eq:Nc \l__coffin_poles_prop`
27608 `{ coffin ~ __coffin_to_value:N #1 ~ poles }`

```

27609 \prop_map_inline:Nn \l__coffin_corners_prop
27610 { \__coffin_scale_corner:Nnnn #1 {##1} ##2 }
27611 \prop_map_inline:Nn \l__coffin_poles_prop
27612 { \__coffin_scale_pole:Nnnnnn #1 {##1} ##2 }

```

Negative x -scaling values place the poles in the wrong location: this is corrected here.

```

27613 \fp_compare:nNnT \l__coffin_scale_x_fp < \c_zero_fp
27614 {
27615   \prop_map_inline:Nn \l__coffin_corners_prop
27616   { \__coffin_x_shift_corner:Nnnn #1 {##1} ##2 }
27617   \prop_map_inline:Nn \l__coffin_poles_prop
27618   { \__coffin_x_shift_pole:Nnnnnn #1 {##1} ##2 }
27619 }
27620 #4 { coffin ~ \__coffin_to_value:N #1 ~ corners }
27621 \l__coffin_corners_prop
27622 #4 { coffin ~ \__coffin_to_value:N #1 ~ poles }
27623 \l__coffin_poles_prop
27624 }

```

(End definition for `__coffin_resize_common:NnnN`.)

`\coffin_scale:Nnn` For scaling, the opposite calculation is done to find the new dimensions for the coffin.
`\coffin_scale:cnn` Only the total height is needed, as this is the shift required for corners and poles. The
`\coffin_gscale:Nnn` scaling is done the T_EX way as this works properly with floating point values without
`\coffin_gscale:cnn` needing to use the fp module.
`\coffin_scale:NnnNN`

```

27625 \cs_new_protected:Npn \coffin_scale:Nnn #1#2#3
27626 { \__coffin_scale:NnnNN #1 {#2} {#3} \box_scale:Nnn \prop_set_eq:cN }
27627 \cs_generate_variant:Nn \coffin_scale:Nnn { c }
27628 \cs_new_protected:Npn \coffin_gscale:Nnn #1#2#3
27629 { \__coffin_scale:NnnNN #1 {#2} {#3} \box_gscale:Nnn \prop_gset_eq:cN }
27630 \cs_generate_variant:Nn \coffin_gscale:Nnn { c }
27631 \cs_new_protected:Npn \__coffin_scale:NnnNN #1#2#3#4#5
27632 {
27633   \fp_set:Nn \l__coffin_scale_x_fp {#2}
27634   \fp_set:Nn \l__coffin_scale_y_fp {#3}
27635   #4 #1 { \l__coffin_scale_x_fp } { \l__coffin_scale_y_fp }
27636   \dim_set:Nn \l__coffin_internal_dim
27637   { \coffin_ht:N #1 + \coffin_dp:N #1 }
27638   \dim_set:Nn \l__coffin_scaled_total_height_dim
27639   { \fp_abs:n { \l__coffin_scale_y_fp } \l__coffin_internal_dim }
27640   \dim_set:Nn \l__coffin_scaled_width_dim
27641   { -\fp_abs:n { \l__coffin_scale_x_fp } \coffin_wd:N #1 }
27642   \__coffin_resize_common:NnnN #1
27643   { \l__coffin_scaled_width_dim } { \l__coffin_scaled_total_height_dim }
27644   #5
27645 }

```

(End definition for `\coffin_scale:Nnn`, `\coffin_gscale:Nnn`, and `\coffin_scale:NnnNN`. These functions are documented on page 241.)

`__coffin_scale_vector:nnNN` This functions scales a vector from the origin using the pre-set scale factors in x and y . This is a much less complex operation than rotation, and as a result the code is a lot clearer.

```

27646 \cs_new_protected:Npn \__coffin_scale_vector:nnNN #1#2#3#4
27647 {

```

```

27648 \dim_set:Nn #3
27649 { \fp_to_dim:n { \dim_to_fp:n {#1} * \l__coffin_scale_x_fp } }
27650 \dim_set:Nn #4
27651 { \fp_to_dim:n { \dim_to_fp:n {#2} * \l__coffin_scale_y_fp } }
27652 }

```

(End definition for `__coffin_scale_vector:nnNN`.)

`__coffin_scale_corner:Nnnn`
`__coffin_scale_pole:Nnnnnn`

Scaling both corners and poles is a simple calculation using the preceding vector scaling.

```

27653 \cs_new_protected:Npn \__coffin_scale_corner:Nnnn #1#2#3#4
27654 {
27655   \__coffin_scale_vector:nnNN {#3} {#4} \l__coffin_x_dim \l__coffin_y_dim
27656   \prop_put:Nnx \l__coffin_corners_prop {#2}
27657   { { \dim_use:N \l__coffin_x_dim } { \dim_use:N \l__coffin_y_dim } }
27658 }
27659 \cs_new_protected:Npn \__coffin_scale_pole:Nnnnnn #1#2#3#4#5#6
27660 {
27661   \__coffin_scale_vector:nnNN {#3} {#4} \l__coffin_x_dim \l__coffin_y_dim
27662   \prop_put:Nnx \l__coffin_poles_prop {#2}
27663   {
27664     { \dim_use:N \l__coffin_x_dim } { \dim_use:N \l__coffin_y_dim }
27665     {#5} {#6}
27666   }
27667 }

```

(End definition for `__coffin_scale_corner:Nnnn` and `__coffin_scale_pole:Nnnnnn`.)

`__coffin_x_shift_corner:Nnnn`
`__coffin_x_shift_pole:Nnnnnn`

These functions correct for the x displacement that takes place with a negative horizontal scaling.

```

27668 \cs_new_protected:Npn \__coffin_x_shift_corner:Nnnn #1#2#3#4
27669 {
27670   \prop_put:Nnx \l__coffin_corners_prop {#2}
27671   {
27672     { \dim_eval:n { #3 + \box_wd:N #1 } } {#4}
27673   }
27674 }
27675 \cs_new_protected:Npn \__coffin_x_shift_pole:Nnnnnn #1#2#3#4#5#6
27676 {
27677   \prop_put:Nnx \l__coffin_poles_prop {#2}
27678   {
27679     { \dim_eval:n { #3 + \box_wd:N #1 } } {#4}
27680     {#5} {#6}
27681   }
27682 }

```

(End definition for `__coffin_x_shift_corner:Nnnn` and `__coffin_x_shift_pole:Nnnnnn`.)

42.7 Aligning and typesetting of coffins

`\coffin_join:NnnNnnnn`
`\coffin_join:cnnNnnnn`
`\coffin_join:Nnncnnnn`
`\coffin_join:cnncnnnn`
`\coffin_gjoin:NnnNnnnn`
`\coffin_gjoin:cnnNnnnn`
`\coffin_gjoin:Nnncnnnn`
`\coffin_gjoin:cnncnnnn`
`__coffin_join:NnnNnnnnN`

This command joins two coffins, using a horizontal and vertical pole from each coffin and making an offset between the two. The result is stored as the as a third coffin, which has all of its handles reset to standard values. First, the more basic alignment function is used to get things started.

```

27683 \cs_new_protected:Npn \coffin_join:NnnNnnnn #1#2#3#4#5#6#7#8

```



```

27684 {
27685   \__coffin_join:NnnNnnnnN #1 {#2} {#3} #4 {#5} {#6} {#7} {#8}
27686   \coffin_set_eq:NN
27687 }
27688 \cs_generate_variant:Nn \coffin_join:NnnNnnnn { c , Nnnc , cnnc }
27689 \cs_new_protected:Npn \coffin_gjoin:NnnNnnnn #1#2#3#4#5#6#7#8
27690 {
27691   \__coffin_join:NnnNnnnnN #1 {#2} {#3} #4 {#5} {#6} {#7} {#8}
27692   \coffin_gset_eq:NN
27693 }
27694 \cs_generate_variant:Nn \coffin_gjoin:NnnNnnnn { c , Nnnc , cnnc }
27695 \cs_new_protected:Npn \__coffin_join:NnnNnnnnN #1#2#3#4#5#6#7#8#9
27696 {
27697   \__coffin_align:NnnNnnnnN
27698   #1 {#2} {#3} #4 {#5} {#6} {#7} {#8} \l__coffin_aligned_coffin

```

Correct the placement of the reference point. If the x -offset is negative then the reference point of the second box is to the left of that of the first, which is corrected using a kern. On the right side the first box might stick out, which would show up if it is wider than the sum of the x -offset and the width of the second box. So a second kern may be needed.

```

27699   \hbox_set:Nn \l__coffin_aligned_coffin
27700   {
27701     \dim_compare:nNnT { \l__coffin_offset_x_dim } < \c_zero_dim
27702     { \tex_kern:D -\l__coffin_offset_x_dim }
27703     \hbox_unpack:N \l__coffin_aligned_coffin
27704     \dim_set:Nn \l__coffin_internal_dim
27705     { \l__coffin_offset_x_dim - \box_wd:N #1 + \box_wd:N #4 }
27706     \dim_compare:nNnT \l__coffin_internal_dim < \c_zero_dim
27707     { \tex_kern:D -\l__coffin_internal_dim }
27708   }

```

The coffin structure is reset, and the corners are cleared: only those from the two parent coffins are needed.

```

27709   \__coffin_reset_structure:N \l__coffin_aligned_coffin
27710   \prop_clear:c
27711   {
27712     coffin ~ \__coffin_to_value:N \l__coffin_aligned_coffin
27713     \c_space_tl corners
27714   }
27715   \__coffin_update_poles:N \l__coffin_aligned_coffin

```

The structures of the parent coffins are now transferred to the new coffin, which requires that the appropriate offsets are applied. That then depends on whether any shift was needed.

```

27716   \dim_compare:nNnTF \l__coffin_offset_x_dim < \c_zero_dim
27717   {
27718     \__coffin_offset_poles:Nnn #1 { -\l__coffin_offset_x_dim } { Opt }
27719     \__coffin_offset_poles:Nnn #4 { Opt } { \l__coffin_offset_y_dim }
27720     \__coffin_offset_corners:Nnn #1 { -\l__coffin_offset_x_dim } { Opt }
27721     \__coffin_offset_corners:Nnn #4 { Opt } { \l__coffin_offset_y_dim }
27722   }
27723   {
27724     \__coffin_offset_poles:Nnn #1 { Opt } { Opt }
27725     \__coffin_offset_poles:Nnn #4
27726     { \l__coffin_offset_x_dim } { \l__coffin_offset_y_dim }

```

```

27727         \__coffin_offset_corners:Nnn #1 { Opt } { Opt }
27728         \__coffin_offset_corners:Nnn #4
27729         { \l__coffin_offset_x_dim } { \l__coffin_offset_y_dim }
27730     }
27731     \__coffin_update_vertical_poles:NNN #1 #4 \l__coffin_aligned_coffin
27732     #9 #1 \l__coffin_aligned_coffin
27733 }

```

(End definition for \coffin_join:NnnNnnnn, \coffin_gjoin:NnnNnnnn, and __coffin_join:NnnNnnnnN. These functions are documented on page 241.)

\coffin_attach:NnnNnnnn A more simple version of the above, as it simply uses the size of the first coffin for the new one. This means that the work here is rather simplified compared to the above code. The function used when marking a position is hear also as it is similar but without the structure updates.

\coffin_gattach:NnnNnnnn

```

27734 \cs_new_protected:Npn \coffin_attach:NnnNnnnn #1#2#3#4#5#6#7#8
27735 {
27736     \__coffin_attach:NnnNnnnnN #1 {#2} {#3} #4 {#5} {#6} {#7} {#8}
27737     \coffin_set_eq:NN
27738 }
27739 \cs_generate_variant:Nn \coffin_attach:NnnNnnnn { c , Nnnc , cnnc }
27740 \cs_new_protected:Npn \coffin_gattach:NnnNnnnn #1#2#3#4#5#6#7#8
27741 {
27742     \__coffin_attach:NnnNnnnnN #1 {#2} {#3} #4 {#5} {#6} {#7} {#8}
27743     \coffin_gset_eq:NN
27744 }
27745 \cs_generate_variant:Nn \coffin_gattach:NnnNnnnn { c , Nnnc , cnnc }
27746 \cs_new_protected:Npn \__coffin_attach:NnnNnnnnN #1#2#3#4#5#6#7#8#9
27747 {
27748     \__coffin_align:NnnNnnnnN
27749     #1 {#2} {#3} #4 {#5} {#6} {#7} {#8} \l__coffin_aligned_coffin
27750     \box_set_ht:Nn \l__coffin_aligned_coffin { \box_ht:N #1 }
27751     \box_set_dp:Nn \l__coffin_aligned_coffin { \box_dp:N #1 }
27752     \box_set_wd:Nn \l__coffin_aligned_coffin { \box_wd:N #1 }
27753     \__coffin_reset_structure:N \l__coffin_aligned_coffin
27754     \prop_set_eq:cc
27755     {
27756         coffin ~ \__coffin_to_value:N \l__coffin_aligned_coffin
27757         \c_space_tl corners
27758     }
27759     { coffin ~ \__coffin_to_value:N #1 ~ corners }
27760     \__coffin_update_poles:N \l__coffin_aligned_coffin
27761     \__coffin_offset_poles:Nnn #1 { Opt } { Opt }
27762     \__coffin_offset_poles:Nnn #4
27763     { \l__coffin_offset_x_dim } { \l__coffin_offset_y_dim }
27764     \__coffin_update_vertical_poles:NNN #1 #4 \l__coffin_aligned_coffin
27765     \coffin_set_eq:NN #1 \l__coffin_aligned_coffin
27766 }
27767 \cs_new_protected:Npn \__coffin_attach_mark:NnnNnnnn #1#2#3#4#5#6#7#8
27768 {
27769     \__coffin_align:NnnNnnnnN
27770     #1 {#2} {#3} #4 {#5} {#6} {#7} {#8} \l__coffin_aligned_coffin
27771     \box_set_ht:Nn \l__coffin_aligned_coffin { \box_ht:N #1 }
27772     \box_set_dp:Nn \l__coffin_aligned_coffin { \box_dp:N #1 }

```

```

27773 \box_set_wd:Nn \l__coffin_aligned_coffin { \box_wd:N #1 }
27774 \box_set_eq:NN #1 \l__coffin_aligned_coffin
27775 }

```

(End definition for \coffin_attach:NnnNnnnn and others. These functions are documented on page 241.)

__coffin_align:NnnNnnnnN

The internal function aligns the two coffins into a third one, but performs no corrections on the resulting coffin poles. The process begins by finding the points of intersection for the poles for each of the input coffins. Those for the first coffin are worked out after those for the second coffin, as this allows the ‘primed’ storage area to be used for the second coffin. The ‘real’ box offsets are then calculated, before using these to re-box the input coffins. The default poles are then set up, but the final result depends on how the bounding box is being handled.

```

27776 \cs_new_protected:Npn \__coffin_align:NnnNnnnnN #1#2#3#4#5#6#7#8#9
27777 {
27778   \__coffin_calculate_intersection:Nnn #4 {#5} {#6}
27779   \dim_set:Nn \l__coffin_x_prime_dim { \l__coffin_x_dim }
27780   \dim_set:Nn \l__coffin_y_prime_dim { \l__coffin_y_dim }
27781   \__coffin_calculate_intersection:Nnn #1 {#2} {#3}
27782   \dim_set:Nn \l__coffin_offset_x_dim
27783     { \l__coffin_x_dim - \l__coffin_x_prime_dim + #7 }
27784   \dim_set:Nn \l__coffin_offset_y_dim
27785     { \l__coffin_y_dim - \l__coffin_y_prime_dim + #8 }
27786   \hbox_set:Nn \l__coffin_aligned_internal_coffin
27787     {
27788     \box_use:N #1
27789     \tex_kern:D -\box_wd:N #1
27790     \tex_kern:D \l__coffin_offset_x_dim
27791     \box_move_up:nn { \l__coffin_offset_y_dim } { \box_use:N #4 }
27792   }
27793   \coffin_set_eq:NN #9 \l__coffin_aligned_internal_coffin
27794 }

```

(End definition for __coffin_align:NnnNnnnnN.)

__coffin_offset_poles:Nnn
 __coffin_offset_pole:Nnnnnnn

Transferring structures from one coffin to another requires that the positions are updated by the offset between the two coffins. This is done by mapping to the property list of the source coffins, moving as appropriate and saving to the new coffin data structures. The test for a - means that the structures from the parent coffins are uniquely labelled and do not depend on the order of alignment. The pay off for this is that - should not be used in coffin pole or handle names, and that multiple alignments do not result in a whole set of values.

```

27795 \cs_new_protected:Npn \__coffin_offset_poles:Nnn #1#2#3
27796 {
27797   \prop_map_inline:cn { coffin ~ \__coffin_to_value:N #1 ~ poles }
27798     { \__coffin_offset_pole:Nnnnnnn #1 {##1} ##2 {#2} {#3} }
27799 }
27800 \cs_new_protected:Npn \__coffin_offset_pole:Nnnnnnn #1#2#3#4#5#6#7#8
27801 {
27802   \dim_set:Nn \l__coffin_x_dim { #3 + #7 }
27803   \dim_set:Nn \l__coffin_y_dim { #4 + #8 }
27804   \tl_if_in:nnTF {#2} { - }
27805     { \tl_set:Nn \l__coffin_internal_tl { {#2} } }

```

```

27806     { \tl_set:Nn \l__coffin_internal_tl { { #1 - #2 } } }
27807 \exp_last_unbraced:NNo \__coffin_set_pole:Nnx \l__coffin_aligned_coffin
27808 { \l__coffin_internal_tl }
27809 {
27810     { \dim_use:N \l__coffin_x_dim } { \dim_use:N \l__coffin_y_dim }
27811     {#5} {#6}
27812 }
27813 }

```

(End definition for __coffin_offset_poles:Nnn and __coffin_offset_pole:Nnnnnnn.)

__coffin_offset_corners:Nnn Saving the offset corners of a coffin is very similar, except that there is no need to worry
 __coffin_offset_corner:Nnnnnn about naming: every corner can be saved here as order is unimportant.

```

27814 \cs_new_protected:Npn \__coffin_offset_corners:Nnn #1#2#3
27815 {
27816     \prop_map_inline:cn { coffin ~ \__coffin_to_value:N #1 ~ corners }
27817     { \__coffin_offset_corner:Nnnnn #1 {##1} ##2 {#2} {#3} }
27818 }
27819 \cs_new_protected:Npn \__coffin_offset_corner:Nnnnnn #1#2#3#4#5#6
27820 {
27821     \prop_put:cnx
27822     {
27823         coffin ~ \__coffin_to_value:N \l__coffin_aligned_coffin
27824         \c_space_tl corners
27825     }
27826     { #1 - #2 }
27827     {
27828         { \dim_eval:n { #3 + #5 } }
27829         { \dim_eval:n { #4 + #6 } }
27830     }
27831 }

```

(End definition for __coffin_offset_corners:Nnn and __coffin_offset_corner:Nnnnnn.)

__coffin_update_vertical_poles:NNN The T and B poles need to be recalculated after alignment. These functions find the
 __coffin_update_T:nnnnnnnnN larger absolute value for the poles, but this is of course only logical when the poles are
 __coffin_update_B:nnnnnnnnN horizontal.

```

27832 \cs_new_protected:Npn \__coffin_update_vertical_poles:NNN #1#2#3
27833 {
27834     \__coffin_get_pole:NnN #3 { #1 -T } \l__coffin_pole_a_tl
27835     \__coffin_get_pole:NnN #3 { #2 -T } \l__coffin_pole_b_tl
27836     \exp_last_two_unbraced:Noo \__coffin_update_T:nnnnnnnnN
27837     \l__coffin_pole_a_tl \l__coffin_pole_b_tl #3
27838     \__coffin_get_pole:NnN #3 { #1 -B } \l__coffin_pole_a_tl
27839     \__coffin_get_pole:NnN #3 { #2 -B } \l__coffin_pole_b_tl
27840     \exp_last_two_unbraced:Noo \__coffin_update_B:nnnnnnnnN
27841     \l__coffin_pole_a_tl \l__coffin_pole_b_tl #3
27842 }
27843 \cs_new_protected:Npn \__coffin_update_T:nnnnnnnnN #1#2#3#4#5#6#7#8#9
27844 {
27845     \dim_compare:nNnTF {#2} < {#6}
27846     {
27847         \__coffin_set_pole:Nnx #9 { T }
27848         { { Opt } {#6} { 1000pt } { Opt } }

```

```

27849     }
27850     {
27851         \__coffin_set_pole:Nnx #9 { T }
27852         { { Opt } {#2} { 1000pt } { Opt } }
27853     }
27854 }
27855 \cs_new_protected:Npn \__coffin_update_B:nnnnnnnnN #1#2#3#4#5#6#7#8#9
27856 {
27857     \dim_compare:nNnTF {#2} < {#6}
27858     {
27859         \__coffin_set_pole:Nnx #9 { B }
27860         { { Opt } {#2} { 1000pt } { Opt } }
27861     }
27862     {
27863         \__coffin_set_pole:Nnx #9 { B }
27864         { { Opt } {#6} { 1000pt } { Opt } }
27865     }
27866 }

```

(End definition for __coffin_update_vertical_poles:NNN, __coffin_update_T:nnnnnnnnN, and __coffin_update_B:nnnnnnnnN.)

\c__coffin_empty_coffin An empty-but-horizontal coffin.

```

27867 \coffin_new:N \c__coffin_empty_coffin
27868 \tex_setbox:D \c__coffin_empty_coffin = \tex_hbox:D { }

```

(End definition for \c__coffin_empty_coffin.)

\coffin_typeset:Nnnnn Typesetting a coffin means aligning it with the current position, which is done using a coffin with no content at all. As well as aligning to the empty coffin, there is also a need to leave vertical mode, if necessary.

\coffin_typeset:cnnnn

```

27869 \cs_new_protected:Npn \coffin_typeset:Nnnnn #1#2#3#4#5
27870 {
27871     \mode_leave_vertical:
27872     \__coffin_align:NnnNnnnnN \c__coffin_empty_coffin { H } { 1 }
27873     #1 {#2} {#3} {#4} {#5} \l__coffin_aligned_coffin
27874     \box_use_drop:N \l__coffin_aligned_coffin
27875 }
27876 \cs_generate_variant:Nn \coffin_typeset:Nnnnn { c }

```

(End definition for \coffin_typeset:Nnnnn. This function is documented on page 242.)

42.8 Coffin diagnostics

\l__coffin_display_coffin Used for printing coffins with data structures attached.

```

\l__coffin_display_coord_coffin 27877 \coffin_new:N \l__coffin_display_coffin
\l__coffin_display_pole_coffin 27878 \coffin_new:N \l__coffin_display_coord_coffin
27879 \coffin_new:N \l__coffin_display_pole_coffin

```

(End definition for \l__coffin_display_coffin, \l__coffin_display_coord_coffin, and \l__coffin_display_pole_coffin.)

`\l_coffin_display_handles_prop` This property list is used to print coffin handles at suitable positions. The offsets are expressed as multiples of the basic offset value, which therefore acts as a scale-factor.

```

27880 \prop_new:N \l__coffin_display_handles_prop
27881 \prop_put:Nnn \l__coffin_display_handles_prop { tl }
27882   { { b } { r } { -1 } { 1 } }
27883 \prop_put:Nnn \l__coffin_display_handles_prop { thc }
27884   { { b } { hc } { 0 } { 1 } }
27885 \prop_put:Nnn \l__coffin_display_handles_prop { tr }
27886   { { b } { l } { 1 } { 1 } }
27887 \prop_put:Nnn \l__coffin_display_handles_prop { vcl }
27888   { { vc } { r } { -1 } { 0 } }
27889 \prop_put:Nnn \l__coffin_display_handles_prop { vhc }
27890   { { vc } { hc } { 0 } { 0 } }
27891 \prop_put:Nnn \l__coffin_display_handles_prop { vcr }
27892   { { vc } { l } { 1 } { 0 } }
27893 \prop_put:Nnn \l__coffin_display_handles_prop { bl }
27894   { { t } { r } { -1 } { -1 } }
27895 \prop_put:Nnn \l__coffin_display_handles_prop { bhc }
27896   { { t } { hc } { 0 } { -1 } }
27897 \prop_put:Nnn \l__coffin_display_handles_prop { br }
27898   { { t } { l } { 1 } { -1 } }
27899 \prop_put:Nnn \l__coffin_display_handles_prop { Tl }
27900   { { t } { r } { -1 } { -1 } }
27901 \prop_put:Nnn \l__coffin_display_handles_prop { Thc }
27902   { { t } { hc } { 0 } { -1 } }
27903 \prop_put:Nnn \l__coffin_display_handles_prop { Tr }
27904   { { t } { l } { 1 } { -1 } }
27905 \prop_put:Nnn \l__coffin_display_handles_prop { Hl }
27906   { { vc } { r } { -1 } { 1 } }
27907 \prop_put:Nnn \l__coffin_display_handles_prop { Hhc }
27908   { { vc } { hc } { 0 } { 1 } }
27909 \prop_put:Nnn \l__coffin_display_handles_prop { Hr }
27910   { { vc } { l } { 1 } { 1 } }
27911 \prop_put:Nnn \l__coffin_display_handles_prop { Bl }
27912   { { b } { r } { -1 } { -1 } }
27913 \prop_put:Nnn \l__coffin_display_handles_prop { Bhc }
27914   { { b } { hc } { 0 } { -1 } }
27915 \prop_put:Nnn \l__coffin_display_handles_prop { Br }
27916   { { b } { l } { 1 } { -1 } }

```

(End definition for \l__coffin_display_handles_prop.)

`\l_coffin_display_offset_dim` The standard offset for the label from the handle position when displaying handles.

```

27917 \dim_new:N \l__coffin_display_offset_dim
27918 \dim_set:Nn \l__coffin_display_offset_dim { 2pt }

```

(End definition for \l__coffin_display_offset_dim.)

`\l_coffin_display_x_dim` As the intersections of poles have to be calculated to find which ones to print, there is
`\l_coffin_display_y_dim` a need to avoid repetition. This is done by saving the intersection into two dedicated values.

```

27919 \dim_new:N \l__coffin_display_x_dim
27920 \dim_new:N \l__coffin_display_y_dim

```

(End definition for \l__coffin_display_x_dim and \l__coffin_display_y_dim.)

`\l_coffin_display_poles_prop` A property list for printing poles: various things need to be deleted from this to get a “nice” output.

```
27921 \prop_new:N \l__coffin_display_poles_prop
```

(End definition for `\l__coffin_display_poles_prop`.)

`\l__coffin_display_font_tl` Stores the settings used to print coffin data: this keeps things flexible.

```
27922 \tl_new:N \l__coffin_display_font_tl
27923 \*initex
27924 \tl_set:Nn \l__coffin_display_font_tl { } % TODO
27925 \*initex
27926 \*package
27927 \tl_set:Nn \l__coffin_display_font_tl { \sffamily \tiny }
27928 \*package
```

(End definition for `\l__coffin_display_font_tl`.)

`__coffin_color:n` Calls `\color`, and otherwise does nothing if `\color` is not defined.

```
27929 \cs_new_protected:Npn \__coffin_color:n #1
27930 { \cs_if_exist:NT \color { \color {#1} } }
```

(End definition for `__coffin_color:n`.)

`\coffin_mark_handle:Nnnn` Marking a single handle is relatively easy. The standard attachment function is used, meaning that there are two calculations for the location. However, this is likely to be okay given the load expected. Contrast with the more optimised version for showing all handles which comes next.

`\coffin_mark_handle:cnnn`
`__coffin_mark_handle_aux:nnnnNnn`

```
27931 \cs_new_protected:Npn \coffin_mark_handle:Nnnn #1#2#3#4
27932 {
27933   \hcoffin_set:Nn \l__coffin_display_pole_coffin
27934   {
27935     \*initex
27936     \hbox:n { \tex_vrule:D width 1pt height 1pt \scan_stop: } % TODO
27937   }
27938   \*package
27939   \__coffin_color:n {#4}
27940   \rule { 1pt } { 1pt }
27941 \*package
27942 }
27943 \__coffin_attach_mark:NnnNnnnn #1 {#2} {#3}
27944 \l__coffin_display_pole_coffin { hc } { vc } { Opt } { Opt }
27945 \hcoffin_set:Nn \l__coffin_display_coord_coffin
27946 {
27947 \*initex
27948 % TODO
27949 \*initex
27950 \*package
27951 \__coffin_color:n {#4}
27952 \*package
27953 \l__coffin_display_font_tl
27954 ( \tl_to_str:n { #2 , #3 } )
27955 }
27956 \prop_get:NnN \l__coffin_display_handles_prop
27957 { #2 #3 } \l__coffin_internal_tl
```

```

27958 \quark_if_no_value:NTF \l__coffin_internal_tl
27959 {
27960   \prop_get:NnN \l__coffin_display_handles_prop
27961   { #3 #2 } \l__coffin_internal_tl
27962   \quark_if_no_value:NTF \l__coffin_internal_tl
27963   {
27964     \__coffin_attach_mark:NnnNnnnn #1 {#2} {#3}
27965     \l__coffin_display_coord_coffin { l } { vc }
27966     { 1pt } { Opt }
27967   }
27968   {
27969     \exp_last_unbraced:No \__coffin_mark_handle_aux:nnnnNnn
27970     \l__coffin_internal_tl #1 {#2} {#3}
27971   }
27972 }
27973 {
27974   \exp_last_unbraced:No \__coffin_mark_handle_aux:nnnnNnn
27975   \l__coffin_internal_tl #1 {#2} {#3}
27976 }
27977 }
27978 \cs_new_protected:Npn \__coffin_mark_handle_aux:nnnnNnn #1#2#3#4#5#6#7
27979 {
27980   \__coffin_attach_mark:NnnNnnnn #5 {#6} {#7}
27981   \l__coffin_display_coord_coffin {#1} {#2}
27982   { #3 \l__coffin_display_offset_dim }
27983   { #4 \l__coffin_display_offset_dim }
27984 }
27985 \cs_generate_variant:Nn \coffin_mark_handle:Nnnn { c }

```

(End definition for `\coffin_mark_handle:Nnnn` and `__coffin_mark_handle_aux:nnnnNnn`. This function is documented on page 242.)

\coffin_display_handles:Nn
\coffin_display_handles:cn
 __coffin_display_handles_aux:nnnnnn
 __coffin_display_handles_aux:nnnn
 __coffin_display_attach:Nnnnn

Printing the poles starts by removing any duplicates, for which the H poles is used as the definitive version for the baseline and bottom. Two loops are then used to find the combinations of handles for all of these poles. This is done such that poles are removed during the loops to avoid duplication.

```

27986 \cs_new_protected:Npn \coffin_display_handles:Nn #1#2
27987 {
27988   \hcoffin_set:Nn \l__coffin_display_pole_coffin
27989   {
27990     \*initex
27991     \hbox:n { \tex_vrule:D width 1pt height 1pt \scan_stop: } % TODO
27992     \*initex
27993     \*package
27994     \__coffin_color:n {#2}
27995     \rule { 1pt } { 1pt }
27996   }
27997 }
27998 \prop_set_eq:Nc \l__coffin_display_poles_prop
27999 { coffin ~ \__coffin_to_value:N #1 ~ poles }
28000 \__coffin_get_pole:NnN #1 { H } \l__coffin_pole_a_tl
28001 \__coffin_get_pole:NnN #1 { T } \l__coffin_pole_b_tl
28002 \tl_if_eq:NNT \l__coffin_pole_a_tl \l__coffin_pole_b_tl
28003 { \prop_remove:Nn \l__coffin_display_poles_prop { T } }

```



```

28004 \__coffin_get_pole:NnN #1 { B } \l__coffin_pole_b_tl
28005 \tl_if_eq:NNT \l__coffin_pole_a_tl \l__coffin_pole_b_tl
28006 { \prop_remove:Nn \l__coffin_display_poles_prop { B } }
28007 \coffin_set_eq:NN \l__coffin_display_coffin #1
28008 \prop_map_inline:Nn \l__coffin_display_poles_prop
28009 {
28010   \prop_remove:Nn \l__coffin_display_poles_prop {##1}
28011   \__coffin_display_handles_aux:nnnnnn {##1} ##2 {#2}
28012 }
28013 \box_use_drop:N \l__coffin_display_coffin
28014 }

```

For each pole there is a check for an intersection, which here does not give an error if none is found. The successful values are stored and used to align the pole coffin with the main coffin for output. The positions are recovered from the preset list if available.

```

28015 \cs_new_protected:Npn \__coffin_display_handles_aux:nnnnnn #1#2#3#4#5#6
28016 {
28017   \prop_map_inline:Nn \l__coffin_display_poles_prop
28018   {
28019     \bool_set_false:N \l__coffin_error_bool
28020     \__coffin_calculate_intersection:nnnnnnnn {#2} {#3} {#4} {#5} ##2
28021     \bool_if:NF \l__coffin_error_bool
28022     {
28023       \dim_set:Nn \l__coffin_display_x_dim { \l__coffin_x_dim }
28024       \dim_set:Nn \l__coffin_display_y_dim { \l__coffin_y_dim }
28025       \__coffin_display_attach:Nnnnn
28026       \l__coffin_display_pole_coffin { hc } { vc }
28027       { Opt } { Opt }
28028       \hcoffin_set:Nn \l__coffin_display_coord_coffin
28029       {
28030         \*initex>
28031           % TODO
28032         \*initex>
28033         \*package>
28034           \__coffin_color:n {#6}
28035         \*package>
28036         \l__coffin_display_font_tl
28037         ( \tl_to_str:n { #1 , ##1 } )
28038       }
28039       \prop_get:NnN \l__coffin_display_handles_prop
28040       { #1 ##1 } \l__coffin_internal_tl
28041       \quark_if_no_value:NTF \l__coffin_internal_tl
28042       {
28043         \prop_get:NnN \l__coffin_display_handles_prop
28044         { ##1 #1 } \l__coffin_internal_tl
28045         \quark_if_no_value:NTF \l__coffin_internal_tl
28046         {
28047           \__coffin_display_attach:Nnnnn
28048           \l__coffin_display_coord_coffin { l } { vc }
28049           { 1pt } { Opt }
28050         }
28051       }
28052       \exp_last_unbraced:No
28053       \__coffin_display_handles_aux:nnnn

```

```

28054         \l__coffin_internal_tl
28055     }
28056 }
28057 {
28058     \exp_last_unbraced:No \__coffin_display_handles_aux:nnnn
28059     \l__coffin_internal_tl
28060 }
28061 }
28062 }
28063 }
28064 \cs_new_protected:Npn \__coffin_display_handles_aux:nnnn #1#2#3#4
28065 {
28066     \__coffin_display_attach:Nnnnn
28067     \l__coffin_display_coord_coffin {#1} {#2}
28068     { #3 \l__coffin_display_offset_dim }
28069     { #4 \l__coffin_display_offset_dim }
28070 }
28071 \cs_generate_variant:Nn \coffin_display_handles:Nn { c }

```

This is a dedicated version of `\coffin_attach:NnnNnnnn` with a hard-wired first coffin. As the intersection is already known and stored for the display coffin the code simply uses it directly, with no calculation.

```

28072 \cs_new_protected:Npn \__coffin_display_attach:Nnnnn #1#2#3#4#5
28073 {
28074     \__coffin_calculate_intersection:Nnn #1 {#2} {#3}
28075     \dim_set:Nn \l__coffin_x_prime_dim { \l__coffin_x_dim }
28076     \dim_set:Nn \l__coffin_y_prime_dim { \l__coffin_y_dim }
28077     \dim_set:Nn \l__coffin_offset_x_dim
28078     { \l__coffin_display_x_dim - \l__coffin_x_prime_dim + #4 }
28079     \dim_set:Nn \l__coffin_offset_y_dim
28080     { \l__coffin_display_y_dim - \l__coffin_y_prime_dim + #5 }
28081     \hbox_set:Nn \l__coffin_aligned_coffin
28082     {
28083         \box_use:N \l__coffin_display_coffin
28084         \tex_kern:D -\box_wd:N \l__coffin_display_coffin
28085         \tex_kern:D \l__coffin_offset_x_dim
28086         \box_move_up:nn { \l__coffin_offset_y_dim } { \box_use:N #1 }
28087     }
28088     \box_set_ht:Nn \l__coffin_aligned_coffin
28089     { \box_ht:N \l__coffin_display_coffin }
28090     \box_set_dp:Nn \l__coffin_aligned_coffin
28091     { \box_dp:N \l__coffin_display_coffin }
28092     \box_set_wd:Nn \l__coffin_aligned_coffin
28093     { \box_wd:N \l__coffin_display_coffin }
28094     \box_set_eq:NN \l__coffin_display_coffin \l__coffin_aligned_coffin
28095 }

```

(End definition for `\coffin_display_handles:Nn` and others. This function is documented on page 242.)

`\coffin_show_structure:N` For showing the various internal structures attached to a coffin in a way that keeps things relatively readable. If there is no apparent structure then the code complains.

```

\coffin_show_structure:c
\coffin_log_structure:N
\coffin_log_structure:c
\__coffin_show_structure:NN
28096 \cs_new_protected:Npn \coffin_show_structure:N
28097 { \__coffin_show_structure:NN \msg_show:nnxxxx }
28098 \cs_generate_variant:Nn \coffin_show_structure:N { c }

```

```

28099 \cs_new_protected:Npn \coffin_log_structure:N
28100 { \__coffin_show_structure:NN \msg_log:nnxxxx }
28101 \cs_generate_variant:Nn \coffin_log_structure:N { c }
28102 \cs_new_protected:Npn \__coffin_show_structure:NN #1#2
28103 {
28104   \__coffin_if_exist:NT #2
28105   {
28106     #1 { LaTeX / kernel } { show-coffin }
28107     { \token_to_str:N #2 }
28108     {
28109       \iow_newline: >~ ht ~~~ \dim_eval:n { \coffin_ht:N #2 }
28110       \iow_newline: >~ dp ~~~ \dim_eval:n { \coffin_dp:N #2 }
28111       \iow_newline: >~ wd ~~~ \dim_eval:n { \coffin_wd:N #2 }
28112     }
28113     {
28114       \prop_map_function:cN
28115       { coffin ~ \__coffin_to_value:N #2 ~ poles }
28116       \msg_show_item_unbraced:nn
28117     }
28118   } }
28119 }
28120 }

```

(End definition for `\coffin_show_structure:N`, `\coffin_log_structure:N`, and `__coffin_show_structure:NN`. These functions are documented on page 242.)

42.9 Messages

```

28121 \__kernel_msg_new:nnnn { kernel } { no-pole-intersection }
28122 { No-intersection-between-coffin-poles. }
28123 {
28124   LaTeX-was-asked-to-find-the-intersection-between-two-poles,~
28125   but-they-do-not-have-a-unique-meeting-point:~
28126   the-value-(Opt,~Opt)-will-be-used.
28127 }
28128 \__kernel_msg_new:nnnn { kernel } { unknown-coffin }
28129 { Unknown-coffin-#1'. }
28130 { The-coffin-#1'-was-never-defined. }
28131 \__kernel_msg_new:nnnn { kernel } { unknown-coffin-pole }
28132 { Pole-#1'-unknown-for-coffin-#2'. }
28133 {
28134   LaTeX-was-asked-to-find-a-typesetting-pole-for-a-coffin,~
28135   but-either-the-coffin-does-not-exist-or-the-pole-name-is-wrong.
28136 }
28137 \__kernel_msg_new:nnn { kernel } { show-coffin }
28138 {
28139   Size-of-coffin-#1 : #2 \\
28140   Poles-of-coffin-#1 : #3 .
28141 }
28142 </initex | package>

```

43 l3color-base Implementation

```

28143 <*initex | package>

```

28144 `<@@=color>`

`\l__color_current_tl` The color currently active for foreground (text, *etc.*) material. This is stored in the form of a color model followed by one or more values. There are four pre-defined models, three of which take numerical values in the range [0, 1]:

- `gray` `<gray>` Grayscale color with the `<gray>` value running from 0 (fully black) to 1 (fully white)
- `cmk` `<cyan>` `<magenta>` `<yellow>` `<black>`
- `rgb` `<red>` `<green>` `<blue>`

Notice that the value are separated by spaces. There is a fourth pre-defined model using a string value and a numerical one:

- `spot` `<name>` `<tint>` A pre-defined spot color, where the `<name>` should be a pre-defined string color name and the `<tint>` should be in the range [0, 1].

Additional models may be created to allow mixing of spot colors. The number of data entries these require will depend on the number of colors to be mixed.

T_EXhackers note: The content of `\l__color_current_tl` is space-separated as this allows it to be used directly in specials in many common cases. This internal representation is close to that used by the `dvips` program.

(End definition for `\l__color_current_tl`.)

`\color_group_begin:` Grouping for color is the same as using the basic `\group_begin:` and `\group_end:` functions. However, for semantic reasons, they are renamed here.

28145 `\cs_new_eq:NN \color_group_begin: \group_begin:`
 28146 `\cs_new_eq:NN \color_group_end: \group_end:`

(End definition for `\color_group_begin:` and `\color_group_end:`. These functions are documented on page 244.)

`\color_ensure_current:` A driver-independent wrapper for setting the foreground color to the current color “now”.

28147 `\cs_new_protected:Npn \color_ensure_current:`
 28148 `{`
 28149 `<*package>`
 28150 `__color_backend_pickup:N \l__color_current_tl`
 28151 `</package>`
 28152 `__color_select:V \l__color_current_tl`
 28153 `}`

(End definition for `\color_ensure_current:`. This function is documented on page 244.)

`__color_select:n` Take an internal color specification and pass it to the driver. This code is needed to ensure the current color but will also be used by the higher-level experimental material.

`__color_select:V`

`__color_select:w`

28154 `\cs_new_protected:Npn __color_select:n #1`
 28155 `{ __color_select:w #1 \q_stop }`

`__color_select_cmyk:w`

28156 `\cs_generate_variant:Nn __color_select:n { V }`

`__color_select_gray:w`

28157 `\cs_new_protected:Npn __color_select:w #1 ~ #2 \q_stop`

`__color_select_rgb:w`

28158 `{ \use:c { __color_select_ #1 :w } #2 \q_stop }`

`__color_select_spot:w`

28159 `\cs_new_protected:Npn __color_select_cmyk:w #1 ~ #2 ~ #3 ~ #4 \q_stop`

```

28160 { \_color_backend_cmyk:nnnn {#1} {#2} {#3} {#4} }
28161 \cs_new_protected:Npn \_color_select_gray:w #1 \q_stop
28162 { \_color_backend_gray:n {#1} }
28163 \cs_new_protected:Npn \_color_select_rgb:w #1 ~ #2 ~ #3 \q_stop
28164 { \_color_backend_rgb:nnn {#1} {#2} {#3} }
28165 \cs_new_protected:Npn \_color_select_spot:w #1 ~ #2 \q_stop
28166 { \_color_backend_spot:nn {#1} {#2} }

```

(End definition for _color_select:n and others.)

\l_color_current_tl As the setting data is used only for specials, and those are always space-separated, it makes most sense to hold the internal information in that form.

```

28167 \tl_new:N \l_color_current_tl
28168 \tl_set:Nn \l_color_current_tl { gray~0 }

```

(End definition for \l_color_current_tl.)

```

28169 </initex | package>

```

44 l3luatex implementation

```

28170 <*initex | package>

```

44.1 Breaking out to Lua

```

28171 <*tex>

```

```

28172 <@@=lua>

```

```

\_lua_escape:n Copies of primitives.
\_lua_now:n
\_lua_shipout:n
28173 \cs_new_eq:NN \_lua_escape:n \tex_luaescapestring:D
28174 \cs_new_eq:NN \_lua_now:n \tex_directlua:D
28175 \cs_new_eq:NN \_lua_shipout:n \tex_latelua:D

```

(End definition for _lua_escape:n, _lua_now:n, and _lua_shipout:n.)

These functions are set up in l3str for bootstrapping: we want to replace them with a “proper” version at this stage, so clean up.

```

28176 \cs_undefine:N \lua_escape:e
28177 \cs_undefine:N \lua_now:e

```

\lua_now:n Wrappers around the primitives. As with engines other than LuaTeX these have to be macros, we give them the same status in all cases. When LuaTeX is not in use, simply give an error message/
 \lua_now:e
 \lua_shipout:e
 \lua_shipout:n
 \lua_escape:n
 \lua_escape:e

```

28178 \cs_new:Npn \lua_now:e #1 { \_lua_now:n {#1} }
28179 \cs_new:Npn \lua_now:n #1 { \lua_now:e { \exp_not:n {#1} } }
28180 \cs_new_protected:Npn \lua_shipout_e:n #1 { \_lua_shipout:n {#1} }
28181 \cs_new_protected:Npn \lua_shipout:n #1
28182 { \lua_shipout_e:n { \exp_not:n {#1} } }
28183 \cs_new:Npn \lua_escape:e #1 { \_lua_escape:n {#1} }
28184 \cs_new:Npn \lua_escape:n #1 { \lua_escape:e { \exp_not:n {#1} } }
28185 \sys_if_engine luatex:F
28186 {
28187   \clist_map_inline:nn
28188   {
28189     \lua_escape:n , \lua_escape:e ,

```

```

28190     \lua_now:n , \lua_now:e
28191   }
28192   {
28193     \cs_set:Npn #1 ##1
28194     {
28195       \__kernel_msg_expandable_error:nnn
28196       { kernel } { luatex-required } { #1 }
28197     }
28198   }
28199   \clist_map_inline:nn
28200   { \lua_shipout_e:n , \lua_shipout:n }
28201   {
28202     \cs_set_protected:Npn #1 ##1
28203     {
28204       \__kernel_msg_error:nnn
28205       { kernel } { luatex-required } { #1 }
28206     }
28207   }
28208 }

```

(End definition for `\lua_now:n` and others. These functions are documented on page 245.)

44.2 Messages

```

28209 \__kernel_msg_new:nnnn { kernel } { luatex-required }
28210 { LuaTeX-engine-not-in-use!~Ignoring~#1. }
28211 {
28212   The~feature~you~are~using~is~only~available~
28213   with~the~LuaTeX-engine.~LaTeX3~ignored~'~#1'.
28214 }
28215 </tex>

```

44.3 Lua functions for internal use

```

28216 (*lua)

```

Most of the emulation of pdfTeX here is based heavily on Heiko Oberdiek's `pdfTeX-cmds` package.

13kernel Create a table for the kernel's own use.

```

28217 13kernel = 13kernel or { }

```

(End definition for `13kernel`. This function is documented on page 246.)

Local copies of global tables.

```

28218 local io      = io
28219 local kpse    = kpse
28220 local lfs     = lfs
28221 local math    = math
28222 local md5     = md5
28223 local os      = os
28224 local string  = string
28225 local tex     = tex
28226 local unicode = unicode

```

Local copies of standard functions.

```

28227 local abs      = math.abs
28228 local byte      = string.byte
28229 local floor     = math.floor
28230 local format    = string.format
28231 local gsub      = string.gsub
28232 local lfs_attr  = lfs.attributes
28233 local md5_sum   = md5.sum
28234 local open     = io.open
28235 local os_clock  = os.clock
28236 local os_date   = os.date
28237 local setcatcode = tex.setcatcode
28238 local sprint    = tex.sprint
28239 local write     = tex.write

```

Newer ConTEX releases replace the `unicode` library by `utf`.

```

28240 local utf8_char = (utf and utf.char) or unicode.utf8.char

```

Deal with ConTEX: doesn't use `kpse` library.

```

28241 local kpse_find = (resolvers and resolvers.findfile) or kpse.find_file

```

`escapehex` An internal auxiliary to convert a string to the matching hex escape. This works on a byte basis: extension to handled UTF-8 input is covered in `pdftexcmds` but is not currently required here.

```

28242 local function escapehex(str)
28243   write((gsub(str, ".",
28244     function (ch) return format("%02X", byte(ch)) end)))
28245 end

```

(End definition for `escapehex`.)

13kernel.charcat Creating arbitrary chars needs a category code table. As set up here, one may have been assigned earlier (see `l3bootstrap`) or a hard-coded one is used. The latter is intended for format mode and should be adjusted to match an eventual allocator.

```

28246 local charcat_table = 13kernel.charcat_table or 1
28247 local function charcat(charcode, catcode)
28248   setcatcode(charcat_table, charcode, catcode)
28249   sprint(charcat_table, utf8_char(charcode))
28250 end
28251 13kernel.charcat = charcat

```

(End definition for `13kernel.charcat`. This function is documented on page 246.)

13kernel.elapsedtime Simple timing set up: give the result from the system clock in scaled seconds.

```

13kernel.resettimer
28252 local base_time = 0
28253 local function elapsedtime()
28254   local val = (os_clock() - base_time) * 65536 + 0.5
28255   if val > 2147483647 then
28256     val = 2147483647
28257   end
28258   write(format("%d", floor(val)))
28259 end
28260 13kernel.elapsedtime = elapsedtime
28261 local function resettimer()

```

```

28262     base_time = os_clock()
28263 end
28264 l3kernel.resettimer = resettimer

```

(End definition for `l3kernel.elapsedtime` and `l3kernel.resettimer`. These functions are documented on page 246.)

l3kernel.filemdfivesum Read an entire file and hash it: the hash function itself is a built-in. As Lua is byte-based there is no work needed here in terms of UTF-8 (see `pdfetexcmds` and how it handles strings that have passed through LuaTeX). The file is read in binary mode so that no line ending normalisation occurs.

```

28265 local function filemdfivesum(name)
28266     local file = kpse_find(name, "tex", true)
28267     if file then
28268         local f = open(file, "rb")
28269         if f then
28270             local data = f:read("*a")
28271             escapehex(md5_sum(data))
28272             f:close()
28273         end
28274     end
28275 end
28276 l3kernel.filemdfivesum = filemdfivesum

```

(End definition for `l3kernel.filemdfivesum`. This function is documented on page 246.)

l3kernel.filemoddate See procedure `makepdftime` in `utils.c` of pdfTeX.

```

28277 local function filemoddate(name)
28278     local file = kpse_find(name, "tex", true)
28279     if file then
28280         local date = lfs_attr(file, "modification")
28281         if date then
28282             local d = os_date("!*t", date)
28283             if d.sec >= 60 then
28284                 d.sec = 59
28285             end
28286             local u = os_date("!*t", date)
28287             local off = 60 * (d.hour - u.hour) + d.min - u.min
28288             if d.year ~= u.year then
28289                 if d.year > u.year then
28290                     off = off + 1440
28291                 else
28292                     off = off - 1440
28293                 end
28294             elseif d.yday ~= u.yday then
28295                 if d.yday > u.yday then
28296                     off = off + 1440
28297                 else
28298                     off = off - 1440
28299                 end
28300             end
28301             local timezone
28302             if off == 0 then
28303                 timezone = "Z"

```



```

28304     else
28305         local hours = floor(off / 60)
28306         local mins  = abs(off - hours * 60)
28307         timezone = format("%+03d", hours)
28308         .. "" .. format("%02d", mins) .. ""
28309     end
28310     write("D:"
28311         .. format("%04d", d.year)
28312         .. format("%02d", d.month)
28313         .. format("%02d", d.day)
28314         .. format("%02d", d.hour)
28315         .. format("%02d", d.min)
28316         .. format("%02d", d.sec)
28317         .. timezone)
28318     end
28319 end
28320 end
28321 l3kernel.filemoddate = filemoddate

```

(End definition for `l3kernel.filemoddate`. This function is documented on page 246.)

l3kernel.filesize A simple disk lookup.

```

28322 local function filesize(name)
28323     local file = kpse_find(name, "tex", true)
28324     if file then
28325         local size = lfs_attr(file, "size")
28326         if size then
28327             write(size)
28328         end
28329     end
28330 end
28331 l3kernel.filesize = filesize

```

(End definition for `l3kernel.filesize`. This function is documented on page 246.)

l3kernel.strcmp String comparison which gives the same results as pdfTeX's `\pdfstrcmp`, although the ordering should likely not be relied upon!

```

28332 local function strcmp(A, B)
28333     if A == B then
28334         write("0")
28335     elseif A < B then
28336         write("-1")
28337     else
28338         write("1")
28339     end
28340 end
28341 l3kernel.strcmp = strcmp

```

(End definition for `l3kernel.strcmp`. This function is documented on page 246.)

44.4 Generic Lua and font support

```

28342 <*initex>
28343 <@@=alloc>

```

A small amount of generic code is used by almost all LuaTeX material so needs to be loaded by the format.

```

28344 attribute_count_name = "g__alloc_attribute_int"
28345 bytecode_count_name  = "g__alloc_bytecode_int"
28346 chunkname_count_name = "g__alloc_chunkname_int"
28347 whatsit_count_name    = "g__alloc_whatsit_int"
28348 require("ltxlua")

```

With the above available the font loader code used by plain TeX and L^AT_EX 2_ε when used with LuaTeX can be loaded here. This is thus being treated more-or-less as part of the engine itself.

```

28349 require("luaotfload-main")
28350 local _void = luaotfload.main()

28351 </initex>
28352 </lua>
28353 </initex | package>

```

45 l3unicode implementation

```

28354 <*initex | package>
28355 <@@=char>

```

Case changing both for strings and “text” requires data from the Unicode Consortium. Some of this is build in to the format (as `\lccode` and `\uccode` values) but this covers only the simple one-to-one situations and does not fully handle for example case folding.

As only the data needs to remain at the end of this process, everything is set up inside a group. The only thing that is outside is creating a stream: they are global anyway and it is best to force a stream for all engines. For performance reasons, some of the code here is very low-level: the material is read during loading `expl3` in package mode.

```

28356 \ior_new:N \g__char_data_ior
28357 \bool_lazy_or:nnTF { \sys_if_engine luatex_p: } { \sys_if_engine xetex_p: }
28358 {
28359   \group_begin:

```

Set up a private copy of the char-generation primitive.

```

28360   \cs_set_eq:NN \__char_generate:w \tex_Uchar:D

```

A fast local implementation for generating characters.

```

28361   \cs_set:Npx \__char_generate:n #1
28362   {
28363     \sys_if_engine luatex:TF
28364     {
28365       \exp_not:N \lua_now:e
28366       {
28367         l3kernel.charcat
28368         (
28369           \exp_not:N \tex_number:D #1 ,
28370           \exp_not:N \tex_the:D \tex_catcode:D #1
28371         )
28372       }
28373     }
28374   }

```

```

28375         \exp_not:N \tex_Ucharcat:D
28376         #1 ~
28377         \tex_catcode:D #1 ~
28378     }
28379 }

```

Parse the main Unicode data file for title case exceptions (the one-to-one lower and upper case mappings it contains are all be covered by the $\text{T}_{\text{E}}\text{X}$ data). There are no comments in the main data file so this can be done using a standard mapping and no checks.

```

28380 \ior_open:Nn \g__char_data_ior { UnicodeData.txt }
28381 \cs_set_protected:Npn \__char_data_auxi:w
28382   #1 ; #2 ; #3 ; #4 ; #5 ; #6 ; #7 ; #8 ; #9 ;
28383   { \__char_data_auxii:w #1 ; }
28384 \cs_set_protected:Npn \__char_data_auxii:w
28385   #1 ; #2 ; #3 ; #4 ; #5 ; #6 ; #7 \q_stop
28386   {
28387     \cs_set_nopar:Npn \l__char_tmpa_tl {#7}
28388     \reverse_if:N \if_meaning:w \l__char_tmpa_tl \c_empty_tl
28389     \cs_set_nopar:Npn \l__char_tmpb_tl {#5}
28390     \reverse_if:N \if_meaning:w \l__char_tmpa_tl \l__char_tmpb_tl
28391     \tl_const:cx
28392       { c__char_mixed_case_ \__char_generate:w "#1 _tl }
28393       { \__char_generate:n { "#7 } }
28394     \fi:
28395   \fi:
28396   }
28397 \ior_map_variable:NNn \g__char_data_ior \l__char_tmpa_tl
28398 {
28399   \if_meaning:w \l__char_tmpa_tl \c_space_tl
28400   \exp_after:wN \ior_map_break:
28401   \fi:
28402   \exp_after:wN \__char_data_auxi:w \l__char_tmpa_tl \q_stop
28403 }
28404 \ior_close:N \g__char_data_ior

```

The other data files all use C-style comments so we have to worry about # tokens (and reading as strings). The set up for case folding is in two parts. For the basic (core) mappings, folding is the same as lower casing in most positions so only store the differences. For the more complex foldings, always store the result, splitting up the two or three code points in the input as required.

```

28405 \ior_open:Nn \g__char_data_ior { CaseFolding.txt }
28406 \cs_set_protected:Npn \__char_data_auxi:w #1 ; ~ #2 ; ~ #3 ; #4 \q_stop
28407 {
28408   \if:w \tl_head:n { #2 ? } C
28409   \reverse_if:N \if_int_compare:w
28410     \char_value_lccode:n {"#1} = "#3 ~
28411   \tl_const:cx
28412     { c__char_fold_case_ \__char_generate:w "#1 _tl }
28413     { \__char_generate:n { "#3 } }
28414   \fi:
28415 \else:
28416   \if:w \tl_head:n { #2 ? } F
28417   \__char_data_auxii:w #1 ~ #3 ~ \q_stop
28418   \fi:
28419 \fi:

```

```

28420     }
28421 \cs_set_protected:Npn \__char_data_auxii:w #1 ~ #2 ~ #3 ~ #4 \q_stop
28422 {
28423     \tl_const:cx { c__char_fold_case_ \__char_generate:w "#1 _tl }
28424     {
28425         \__char_generate:n { "#2 }
28426         \__char_generate:n { "#3 }
28427         \tl_if_blank:nF {#4}
28428         { \__char_generate:n { \int_value:w "#4 } }
28429     }
28430 }
28431 \ior_str_map_inline:Nn \g__char_data_ior
28432 {
28433     \reverse_if:N \if:w \c_hash_str \tl_head:w #1 \c_hash_str \q_stop
28434     \__char_data_auxi:w #1 \q_stop
28435     \fi:
28436 }
28437 \ior_close:N \g__char_data_ior

```

For upper and lower casing special situations, there is a bit more to do as we also have title casing to consider, plus we need to stop part-way through the file.

```

28438 \ior_open:Nn \g__char_data_ior { SpecialCasing.txt }
28439 \cs_set_protected:Npn \__char_data_auxi:w
28440 #1 ;~ #2 ;~ #3 ;~ #4 ; #5 \q_stop
28441 {
28442     \use:n { \__char_data_auxii:w #1 ~ lower ~ #2 ~ } ~ \q_stop
28443     \use:n { \__char_data_auxii:w #1 ~ upper ~ #4 ~ } ~ \q_stop
28444     \str_if_eq:nnF {#3} {#4}
28445     { \use:n { \__char_data_auxii:w #1 ~ mixed ~ #3 ~ } ~ \q_stop }
28446 }
28447 \cs_set_protected:Npn \__char_data_auxii:w
28448 #1 ~ #2 ~ #3 ~ #4 ~ #5 \q_stop
28449 {
28450     \tl_if_empty:nF {#4}
28451     {
28452         \tl_const:cx { c__char_ #2 _case_ \__char_generate:w "#1 _tl }
28453         {
28454             \__char_generate:n { "#3 }
28455             \__char_generate:n { "#4 }
28456             \tl_if_blank:nF {#5}
28457             { \__char_generate:n { "#5 } }
28458         }
28459     }
28460 }
28461 \ior_str_map_inline:Nn \g__char_data_ior
28462 {
28463     \str_if_eq:eeTF
28464     { \tl_head:w #1 \c_hash_str \q_stop }
28465     { \c_hash_str }
28466     {
28467         \str_if_eq:eeT
28468         {#1}
28469         { \c_hash_str \c_space_tl Conditional-Mappings }
28470         { \ior_map_break: }
28471     }

```

```

28472         { \__char_data_auxi:w #1 \q_stop }
28473     }
28474     \ior_close:N \g__char_data_ior
28475 \group_end:
28476 }

```

For the 8-bit engines, the above is skipped but there is still some set up required. As case changing can only be applied to bytes, and they have to be in the ASCII range, we define a series of data stores to represent them, and the data are used such that only these are ever case-changed. We do open and close one file to force allocation of a read: this keeps all engines in line.

```

28477 {
28478 \group_begin:
28479 \cs_set_protected:Npn \__char_tmp:NN #1#2
28480 {
28481 \quark_if_recursion_tail_stop:N #2
28482 \tl_const:cn { c__char_upper_case_ #2 _t1 } {#1}
28483 \tl_const:cn { c__char_lower_case_ #1 _t1 } {#2}
28484 \tl_const:cn { c__char_fold_case_ #1 _t1 } {#2}
28485 \__char_tmp:NN
28486 }
28487 \__char_tmp:NN
28488 AaBbCcDdEeFfGgHhIiJjKkLlMmNnOoPpQqRrSsTtUuVvWwXxYyZz
28489 ? \q_recursion_tail \q_recursion_stop
28490 \ior_open:Nn \g__char_data_ior { UnicodeData.txt }
28491 \ior_close:N \g__char_data_ior
28492 \group_end:
28493 }
28494 \</initex | package>

```

46 l3legacy Implementation

```

28495 \< *package>
28496 \< @@=legacy>
\legacy_if_p:n A friendly wrapper.
\legacy_if:nTF
28497 \prg_new_conditional:Npnn \legacy_if:n #1 { p , T , F , TF }
28498 {
28499 \exp_args:Nc \if_meaning:w { if#1 } \iftrue
28500 \prg_return_true:
28501 \else:
28502 \prg_return_false:
28503 \fi:
28504 }

```

(End definition for \legacy_if:nTF. This function is documented on page 248.)

```

28505 \</package>

```

47 l3candidates Implementation

```

28506 \< *initex | package>

```

47.1 Additions to l3basics

\mode_leave_vertical: The approach here is different to that used by L^AT_EX 2_ε or plain T_EX, which unbox a void box to force horizontal mode. That inserts the `\everypar` tokens *before* the re-inserted unboxing tokens. The approach here uses either the `\quitvmode` primitive or the equivalent protected macro. In vertical mode, the `\indent` primitive is inserted: this will switch to horizontal mode and insert `\everypar` tokens and nothing else. Unlike the L^AT_EX 2_ε version, the availability of ε-T_EX means using a mode test can be done at for example the start of an `\halign`.

```
28507 \cs_new_protected:Npn \mode_leave_vertical:
28508 {
28509   \if_mode_vertical:
28510     \exp_after:wN \tex_indent:D
28511   \fi:
28512 }
```

(End definition for `\mode_leave_vertical:`. This function is documented on page 250.)

47.2 Additions to l3box

```
28513 <@<=box>
```

47.2.1 Viewing part of a box

\box_clip:N A wrapper around the driver-dependent code.
\box_clip:c
\box_gclip:N
\box_gclip:c

```
28514 \cs_new_protected:Npn \box_clip:N #1
28515 { \hbox_set:Nn #1 { \__box_backend_clip:N #1 } }
28516 \cs_generate_variant:Nn \box_clip:N { c }
28517 \cs_new_protected:Npn \box_gclip:N #1
28518 { \hbox_gset:Nn #1 { \__box_backend_clip:N #1 } }
28519 \cs_generate_variant:Nn \box_gclip:N { c }
```

(End definition for `\box_clip:N` and `\box_gclip:N`. These functions are documented on page 251.)

\box_set_trim:Nnnnn Trimming from the left- and right-hand edges of the box is easy: kern the appropriate parts off each side.
\box_set_trim:cnnnn
\box_gset_trim:Nnnnn
\box_gset_trim:cnnnn
__box_set_trim:NnnnnN

```
28520 \cs_new_protected:Npn \box_set_trim:Nnnnn #1#2#3#4#5
28521 { \__box_set_trim:NnnnnN #1 {#2} {#3} {#4} {#5} \box_set_eq:NN }
28522 \cs_generate_variant:Nn \box_set_trim:Nnnnn { c }
28523 \cs_new_protected:Npn \box_gset_trim:Nnnnn #1#2#3#4#5
28524 { \__box_set_trim:NnnnnN #1 {#2} {#3} {#4} {#5} \box_gset_eq:NN }
28525 \cs_generate_variant:Nn \box_gset_trim:Nnnnn { c }
28526 \cs_new_protected:Npn \__box_set_trim:NnnnnN #1#2#3#4#5#6
28527 {
28528   \hbox_set:Nn \l__box_internal_box
28529   {
28530     \tex_kern:D - \__box_dim_eval:n {#2}
28531     \box_use:N #1
28532     \tex_kern:D - \__box_dim_eval:n {#4}
28533   }
```

For the height and depth, there is a need to watch the baseline is respected. Material always has to stay on the correct side, so trimming has to check that there is enough material to trim. First, the bottom edge. If there is enough depth, simply set the depth, or if not move down so the result is zero depth. `\box_move_down:nn` is used in both

cases so the resulting box always contains a `\lower` primitive. The internal box is used here as it allows safe use of `\box_set_dp:Nn`.

```

28534 \dim_compare:nNnTF { \box_dp:N #1 } > {#3}
28535 {
28536   \hbox_set:Nn \l__box_internal_box
28537   {
28538     \box_move_down:nn \c_zero_dim
28539     { \box_use_drop:N \l__box_internal_box }
28540   }
28541   \box_set_dp:Nn \l__box_internal_box { \box_dp:N #1 - (#3) }
28542 }
28543 {
28544   \hbox_set:Nn \l__box_internal_box
28545   {
28546     \box_move_down:nn { (#3) - \box_dp:N #1 }
28547     { \box_use_drop:N \l__box_internal_box }
28548   }
28549   \box_set_dp:Nn \l__box_internal_box \c_zero_dim
28550 }

```

Same thing, this time from the top of the box.

```

28551 \dim_compare:nNnTF { \box_ht:N \l__box_internal_box } > {#5}
28552 {
28553   \hbox_set:Nn \l__box_internal_box
28554   {
28555     \box_move_up:nn \c_zero_dim
28556     { \box_use_drop:N \l__box_internal_box }
28557   }
28558   \box_set_ht:Nn \l__box_internal_box
28559   { \box_ht:N \l__box_internal_box - (#5) }
28560 }
28561 {
28562   \hbox_set:Nn \l__box_internal_box
28563   {
28564     \box_move_up:nn { (#5) - \box_ht:N \l__box_internal_box }
28565     { \box_use_drop:N \l__box_internal_box }
28566   }
28567   \box_set_ht:Nn \l__box_internal_box \c_zero_dim
28568 }
28569 #6 #1 \l__box_internal_box
28570 }

```

(End definition for `\box_set_trim:Nnnnn`, `\box_gset_trim:Nnnnn`, and `__box_set_trim:NnnnnN`. These functions are documented on page 251.)

`\box_set_viewport:Nnnnn`

`\box_set_viewport:cnnnn`

`\box_gset_viewport:Nnnnn`

`\box_gset_viewport:cnnnn`

`__box_viewport:NnnnnN`

The same general logic as for the trim operation, but with absolute dimensions. As a result, there are some things to watch out for in the vertical direction.

```

28571 \cs_new_protected:Npn \box_set_viewport:Nnnnn #1#2#3#4#5
28572 { \__box_set_viewport:NnnnnN #1 {#2} {#3} {#4} {#5} \box_set_eq:NN }
28573 \cs_generate_variant:Nn \box_set_viewport:Nnnnn { c }
28574 \cs_new_protected:Npn \box_gset_viewport:Nnnnn #1#2#3#4#5
28575 { \__box_set_viewport:NnnnnN #1 {#2} {#3} {#4} {#5} \box_gset_eq:NN }
28576 \cs_generate_variant:Nn \box_gset_viewport:Nnnnn { c }
28577 \cs_new_protected:Npn \__box_set_viewport:NnnnnN #1#2#3#4#5#6

```

```

28578 {
28579   \hbox_set:Nn \l__box_internal_box
28580   {
28581     \tex_kern:D - \__box_dim_eval:n {#2}
28582     \box_use:N #1
28583     \tex_kern:D \__box_dim_eval:n { #4 - \box_wd:N #1 }
28584   }
28585   \dim_compare:nNnTF {#3} < \c_zero_dim
28586   {
28587     \hbox_set:Nn \l__box_internal_box
28588     {
28589       \box_move_down:nn \c_zero_dim
28590       { \box_use_drop:N \l__box_internal_box }
28591     }
28592     \box_set_dp:Nn \l__box_internal_box { - \__box_dim_eval:n {#3} }
28593   }
28594   {
28595     \hbox_set:Nn \l__box_internal_box
28596     { \box_move_down:nn {#3} { \box_use_drop:N \l__box_internal_box } }
28597     \box_set_dp:Nn \l__box_internal_box \c_zero_dim
28598   }
28599   \dim_compare:nNnTF {#5} > \c_zero_dim
28600   {
28601     \hbox_set:Nn \l__box_internal_box
28602     {
28603       \box_move_up:nn \c_zero_dim
28604       { \box_use_drop:N \l__box_internal_box }
28605     }
28606     \box_set_ht:Nn \l__box_internal_box
28607     {
28608       (#5)
28609       \dim_compare:nNnT {#3} > \c_zero_dim
28610       { - (#3) }
28611     }
28612   }
28613   {
28614     \hbox_set:Nn \l__box_internal_box
28615     {
28616       \box_move_up:nn { - \__box_dim_eval:n {#5} }
28617       { \box_use_drop:N \l__box_internal_box }
28618     }
28619     \box_set_ht:Nn \l__box_internal_box \c_zero_dim
28620   }
28621   #6 #1 \l__box_internal_box
28622 }

```

(End definition for `\box_set_viewport:Nnnnn`, `\box_gset_viewport:Nnnnn`, and `__box_viewport:NnnnnN`.
These functions are documented on page 251.)

47.3 Additions to l3fp-convert

28623 `<@@=fp>`

`\fp_sign:n` Trivial but useful. See the implementation of `\fp_add:Nn` for an explanation of why to use `__fp_parse:n`, namely, for better error reporting.


```

28624 \cs_new:Npn \fp_sign:n #1
28625 { \fp_to_decimal:n { sign \__fp_parse:n {#1} } }

```

(End definition for \fp_sign:n. This function is documented on page 252.)

47.4 Additions to l3flag

```

28626 <@@=flag>

```

\flag_raise_if_clear:n It might be faster to just call the “trap” function in all cases but conceptually the function name suggests we should only run it if the flag is zero in case the “trap” made customizable in the future.

```

28627 \__kernel_patch:nnNpn { \__flag_chk_exist:n {#1} } { }
28628 \cs_new:Npn \flag_raise_if_clear:n #1
28629 {
28630   \if_cs_exist:w flag~#1-0 \cs_end:
28631   \else:
28632     \cs:w flag~#1 \cs_end: 0 ;
28633   \fi:
28634 }

```

(End definition for \flag_raise_if_clear:n. This function is documented on page 254.)

47.5 Additions to l3int

```

28635 <@@=int>

```

\int_sign:n See \int_abs:n. Evaluate the expression once (and when debugging is enabled, check that the expression is well-formed), then test the first character to determine the sign. **__int_sign:Nw** This is wrapped in \int_value:w ... \exp_stop_f: to ensure a fixed number of expansions and to avoid dealing with closing the conditionals.

```

28636 \__kernel_patch_args:nnNpn
28637 { { \__kernel_chk_expr:nNnN {#1} \__int_eval:w { } \int_sign:n } }
28638 \cs_new:Npn \int_sign:n #1
28639 {
28640   \int_value:w \exp_after:wN \__int_sign:Nw
28641   \int_value:w \__int_eval:w #1 \__int_eval_end: ;
28642   \exp_stop_f:
28643 }
28644 \cs_new:Npn \__int_sign:Nw #1#2 ;
28645 {
28646   \if_meaning:w 0 #1
28647   0
28648   \else:
28649     \if_meaning:w - #1 - \fi: 1
28650   \fi:
28651 }

```

(End definition for \int_sign:n and __int_sign:Nw. This function is documented on page 254.)

47.6 Additions to l3msg

28652 (@@=msg)

Pass to an auxiliary the message to display and the module name

```

28653 \cs_new:Npn \msg_expandable_error:nnnnnn #1#2#3#4#5#6
28654 {
28655   \exp_args:Ne \_msg_expandable_error_module:nn
28656   {
28657     \exp_args:Nc \exp_args:Noooo
28658     { \c_msg_text_prefix_tl #1 / #2 }
28659     { \tl_to_str:n {#3} }
28660     { \tl_to_str:n {#4} }
28661     { \tl_to_str:n {#5} }
28662     { \tl_to_str:n {#6} }
28663   }
28664   {#1}
28665 }
28666 \cs_new:Npn \msg_expandable_error:nnnnn #1#2#3#4#5
28667 { \msg_expandable_error:nnnnnn {#1} {#2} {#3} {#4} {#5} { } }
28668 \cs_new:Npn \msg_expandable_error:nnnn #1#2#3#4
28669 { \msg_expandable_error:nnnnnn {#1} {#2} {#3} {#4} { } { } }
28670 \cs_new:Npn \msg_expandable_error:nnn #1#2#3
28671 { \msg_expandable_error:nnnnnn {#1} {#2} {#3} { } { } { } }
28672 \cs_new:Npn \msg_expandable_error:nn #1#2
28673 { \msg_expandable_error:nnnnnn {#1} {#2} { } { } { } { } }
28674 \cs_generate_variant:Nn \msg_expandable_error:nnnnnn { nnffff }
28675 \cs_generate_variant:Nn \msg_expandable_error:nnnnnn { nnfff }
28676 \cs_generate_variant:Nn \msg_expandable_error:nnnnn { nnff }
28677 \cs_generate_variant:Nn \msg_expandable_error:nnnn { nnf }
28678 \cs_new:Npn \_msg_expandable_error_module:nn #1#2
28679 {
28680   \exp_after:wN \exp_after:wN
28681   \exp_after:wN \use_none_delimit_by_q_stop:w
28682   \use:n { \::error ! ~ #2 : ~ #1 } \q_stop
28683 }

```

(End definition for `\msg_expandable_error:nnnnnn` and others. These functions are documented on page 255.)

```

\msg_show_eval:Nn
\msg_log_eval:Nn
\_msg_show_eval:nnN

```

A short-hand used for `\int_show:n` and similar functions that passes to `\tl_show:n` the result of applying `#1` (a function such as `\int_eval:n`) to the expression `#2`. The use of `f`-expansion ensures that `#1` is expanded in the scope in which the show command is called, rather than in the group created by `\iow_wrap:nnnN`. This is only important for expressions involving the `\currentgrouplevel` or `\currentgrouptype`. On the other hand we want the expression to be converted to a string with the usual escape character, hence within the wrapping code.

```

28684 \cs_new_protected:Npn \msg_show_eval:Nn #1#2
28685 { \exp_args:Nf \_msg_show_eval:nnN { #1 {#2} } {#2} \tl_show:n }
28686 \cs_new_protected:Npn \msg_log_eval:Nn #1#2
28687 { \exp_args:Nf \_msg_show_eval:nnN { #1 {#2} } {#2} \tl_log:n }
28688 \cs_new_protected:Npn \_msg_show_eval:nnN #1#2#3 { #3 { #2 = #1 } }

```

(End definition for `\msg_show_eval:Nn`, `\msg_log_eval:Nn`, and `_msg_show_eval:nnN`. These functions are documented on page 255.)

`\msg_show_item:n` Each item in the variable is formatted using one of the following functions. We cannot use
`\msg_show_item_unbraced:n` `\` and so on because these short-hands cannot be used inside the arguments of messages,
`\msg_show_item:nn` only when defining the messages.

```

28689 \cs_new:Npx \msg_show_item:n #1
28690 { \iow_newline: > ~ \c_space_tl \exp_not:N \tl_to_str:n { {#1} } }
28691 \cs_new:Npx \msg_show_item_unbraced:n #1
28692 { \iow_newline: > ~ \c_space_tl \exp_not:N \tl_to_str:n {#1} }
28693 \cs_new:Npx \msg_show_item:nn #1#2
28694 {
28695   \iow_newline: > \use:nn { ~ } { ~ }
28696   \exp_not:N \tl_to_str:n { {#1} }
28697   \use:nn { ~ } { ~ } => \use:nn { ~ } { ~ }
28698   \exp_not:N \tl_to_str:n { {#2} }
28699 }
28700 \cs_new:Npx \msg_show_item_unbraced:nn #1#2
28701 {
28702   \iow_newline: > \use:nn { ~ } { ~ }
28703   \exp_not:N \tl_to_str:n {#1}
28704   \use:nn { ~ } { ~ } => \use:nn { ~ } { ~ }
28705   \exp_not:N \tl_to_str:n {#2}
28706 }

```

(End definition for `\msg_show_item:n` and others. These functions are documented on page 256.)

47.7 Additions to l3prg

`\bool_const:Nn` A merger between `\tl_const:Nn` and `\bool_set:Nn`.

```

28707 \__kernel_patch:nnNNpn { \__kernel_chk_var_scope:NN c #1 } { }
28708 \cs_new_protected:Npn \bool_const:Nn #1#2
28709 {
28710   \__kernel_chk_if_free_cs:N #1
28711   \tex_global:D \tex_chardef:D #1 = \bool_if_p:n {#2}
28712 }
28713 \cs_generate_variant:Nn \bool_const:Nn { c }

```

(End definition for `\bool_const:Nn`. This function is documented on page 256.)

`\bool_set_inverse:N` Set to false or true locally or globally.

```

28714 \cs_new_protected:Npn \bool_set_inverse:N #1
28715 { \bool_if:NTF #1 { \bool_set_false:N } { \bool_set_true:N } #1 }
28716 \cs_generate_variant:Nn \bool_set_inverse:N { c }
28717 \cs_new_protected:Npn \bool_gset_inverse:N #1
28718 { \bool_if:NTF #1 { \bool_gset_false:N } { \bool_gset_true:N } #1 }
28719 \cs_generate_variant:Nn \bool_gset_inverse:N { c }

```

(End definition for `\bool_set_inverse:N` and `\bool_gset_inverse:N`. These functions are documented on page 256.)

47.8 Additions to l3prop

28720 `<@@=prop>`

`\prop_map_tokens:Nn` The mapping is very similar to `\prop_map_function:NN`. The `\use_i:nn` removes the
`\prop_map_tokens:cn` leading `\s__prop`. The odd construction `\use:n {#1}` allows #1 to contain any token

`__prop_map_tokens:nwwn`

without interfering with `\prop_map_break:`. The loop stops when the argument delimited by `__prop_pair:wn` is `\prg_break:` instead of being empty.

```

28721 \cs_new:Npn \prop_map_tokens:Nn #1#2
28722 {
28723   \exp_last_unbraced:Nno
28724     \use_i:nn { \__prop_map_tokens:nwn {#2} } #1
28725   \prg_break: \__prop_pair:wn \s__prop { } \prg_break_point:
28726   \prg_break_point:Nn \prop_map_break: { }
28727 }
28728 \cs_new:Npn \__prop_map_tokens:nwn #1#2 \__prop_pair:wn #3 \s__prop #4
28729 {
28730   #2
28731   \use:n {#1} {#3} {#4}
28732   \__prop_map_tokens:nwn {#1}
28733 }
28734 \cs_generate_variant:Nn \prop_map_tokens:Nn { c }

```

(End definition for `\prop_map_tokens:Nn` and `__prop_map_tokens:nwn`. This function is documented on page 256.)

```

\prop_rand_key_value:N
\prop_rand_key_value:c
  \__prop_rand_item:w

```

Contrarily to `clist`, `seq` and `tl`, there is no function to get an item of a `prop` given an integer between 1 and the number of items, so we write the appropriate code. There is no bounds checking because `\int_rand:nn` is always within bounds. The initial `\int_value:w` is stopped by the first `\s__prop` in #1.

```

28735 \cs_new:Npn \prop_rand_key_value:N #1
28736 {
28737   \prop_if_empty:NF #1
28738   {
28739     \exp_after:wN \__prop_rand_item:w
28740     \int_value:w \int_rand:nn { 1 } { \prop_count:N #1 }
28741     #1 \q_stop
28742   }
28743 }
28744 \cs_generate_variant:Nn \prop_rand_key_value:N { c }
28745 \cs_new:Npn \__prop_rand_item:w #1 \s__prop \__prop_pair:wn #2 \s__prop #3
28746 {
28747   \int_compare:nNnF {#1} > 1
28748   { \use_i_delimit_by_q_stop:nw { \exp_not:n { {#2} {#3} } } }
28749   \exp_after:wN \__prop_rand_item:w
28750   \int_value:w \int_eval:n { #1 - 1 } \s__prop
28751 }

```

(End definition for `\prop_rand_key_value:N` and `__prop_rand_item:w`. This function is documented on page 257.)

47.9 Additions to `l3seq`

```

28752 <@@=seq>

```

```

\seq_mapthread_function:NNN
\seq_mapthread_function:NcN
\seq_mapthread_function:cNN
\seq_mapthread_function:ccN
  \__seq_mapthread_function:wNN
  \__seq_mapthread_function:wNw
  \__seq_mapthread_function:Nnnwnn

```

The idea is to first expand both sequences, adding the usual `{ ? \prg_break: } { }` to the end of each one. This is most conveniently done in two steps using an auxiliary function. The mapping then throws away the first tokens of #2 and #5, which for items in both sequences are `\s__seq` `__seq_item:n`. The function to be mapped are then be applied to the two entries. When the code hits the end of one of the sequences, the break

material stops the entire loop and tidy up. This avoids needing to find the count of the two sequences, or worrying about which is longer.

```

28753 \cs_new:Npn \seq_mapthread_function:NNN #1#2#3
28754 { \exp_after:wN \__seq_mapthread_function:wNN #2 \q_stop #1 #3 }
28755 \cs_new:Npn \__seq_mapthread_function:wNN \s__seq #1 \q_stop #2#3
28756 {
28757   \exp_after:wN \__seq_mapthread_function:wNw #2 \q_stop #3
28758   #1 { ? \prg_break: } { }
28759   \prg_break_point:
28760 }
28761 \cs_new:Npn \__seq_mapthread_function:wNw \s__seq #1 \q_stop #2
28762 {
28763   \__seq_mapthread_function:Nnnwnn #2
28764   #1 { ? \prg_break: } { }
28765   \q_stop
28766 }
28767 \cs_new:Npn \__seq_mapthread_function:Nnnwnn #1#2#3#4 \q_stop #5#6
28768 {
28769   \use_none:n #2
28770   \use_none:n #5
28771   #1 {#3} {#6}
28772   \__seq_mapthread_function:Nnnwnn #1 #4 \q_stop
28773 }
28774 \cs_generate_variant:Nn \seq_mapthread_function:NNN { Nc , c , cc }

```

(End definition for `\seq_mapthread_function:NNN` and others. This function is documented on page 257.)

`\seq_set_filter:NNn` Similar to `\seq_map_inline:Nn`, without a `\prg_break_point:` because the user's code is performed within the evaluation of a boolean expression, and skipping out of that would break horribly. The `__seq_wrap_item:n` function inserts the relevant `__seq_item:n` without expansion in the input stream, hence in the x-expanding assignment.

`\seq_gset_filter:NNn`
`__seq_set_filter:NNNn`

```

28775 \cs_new_protected:Npn \seq_set_filter:NNn
28776 { \__seq_set_filter:NNNn \tl_set:Nx }
28777 \cs_new_protected:Npn \seq_gset_filter:NNn
28778 { \__seq_set_filter:NNNn \tl_gset:Nx }
28779 \cs_new_protected:Npn \__seq_set_filter:NNNn #1#2#3#4
28780 {
28781   \__seq_push_item_def:n { \bool_if:nT {#4} { \__seq_wrap_item:n {##1} } }
28782   #1 #2 { #3 }
28783   \__seq_pop_item_def:
28784 }

```

(End definition for `\seq_set_filter:NNn`, `\seq_gset_filter:NNn`, and `__seq_set_filter:NNNn`. These functions are documented on page 257.)

`\seq_set_map:NNn` Very similar to `\seq_set_filter:NNn`. We could actually merge the two within a single function, but it would have weird semantics.

`\seq_gset_map:NNn`
`__seq_set_map:NNNn`

```

28785 \cs_new_protected:Npn \seq_set_map:NNn
28786 { \__seq_set_map:NNNn \tl_set:Nx }
28787 \cs_new_protected:Npn \seq_gset_map:NNn
28788 { \__seq_set_map:NNNn \tl_gset:Nx }
28789 \cs_new_protected:Npn \__seq_set_map:NNNn #1#2#3#4
28790 {

```

```

28791     \__seq_push_item_def:n { \exp_not:N \__seq_item:n {#4} }
28792     #1 #2 { #3 }
28793     \__seq_pop_item_def:
28794 }

```

(End definition for `\seq_set_map:Nnn`, `\seq_gset_map:Nnn`, and `__seq_set_map:NNNn`. These functions are documented on page 258.)

`\seq_set_from_inline_x:Nnn`
`\seq_gset_from_inline_x:Nnn`
`__seq_set_from_inline_x:NNnn`

Set `__seq_item:n` then map it using the loop code.

```

28795 \cs_new_protected:Npn \seq_set_from_inline_x:Nnn
28796 { \__seq_set_from_inline_x:NNnn \tl_set:Nx }
28797 \cs_new_protected:Npn \seq_gset_from_inline_x:Nnn
28798 { \__seq_set_from_inline_x:NNnn \tl_gset:Nx }
28799 \cs_new_protected:Npn \__seq_set_from_inline_x:NNnn #1#2#3#4
28800 {
28801     \__seq_push_item_def:n { \exp_not:N \__seq_item:n {#4} }
28802     #1 #2 { \s__seq #3 \__seq_item:n }
28803     \__seq_pop_item_def:
28804 }

```

(End definition for `\seq_set_from_inline_x:Nnn`, `\seq_gset_from_inline_x:Nnn`, and `__seq_set_from_inline_x:NNnn`. These functions are documented on page 258.)

`\seq_set_from_function:NnN`
`\seq_gset_from_function:NnN`

Reuse `\seq_set_from_inline_x:Nnn`.

```

28805 \cs_new_protected:Npn \seq_set_from_function:NnN #1#2#3
28806 { \seq_set_from_inline_x:Nnn #1 {#2} { #3 {##1} } }
28807 \cs_new_protected:Npn \seq_gset_from_function:NnN #1#2#3
28808 { \seq_gset_from_inline_x:Nnn #1 {#2} { #3 {##1} } }

```

(End definition for `\seq_set_from_function:NnN` and `\seq_gset_from_function:NnN`. These functions are documented on page 258.)

`\seq_const_from_clist:Nn`
`\seq_const_from_clist:cn`

Almost identical to `\seq_set_from_clist:Nn`.

```

28809 \cs_new_protected:Npn \seq_const_from_clist:Nn #1#2
28810 {
28811     \tl_const:Nx #1
28812     { \s__seq \clist_map_function:nN {#2} \__seq_wrap_item:n }
28813 }
28814 \cs_generate_variant:Nn \seq_const_from_clist:Nn { c }

```

(End definition for `\seq_const_from_clist:Nn`. This function is documented on page 258.)

`\seq_shuffle:N`
`\seq_gshuffle:N`
`__seq_shuffle:NN`
`__seq_shuffle_item:n`
`\g__seq_internal_seq`
`\l__seq_internal_a_int`
`\l__seq_internal_b_int`

We apply the Fisher–Yates shuffle, storing items in `\toks` registers. We use the primitive `\tex_uniformdeviate:D` for speed reasons. Its non-uniformity is of order its argument divided by 2^{28} , not too bad for small lists. For sequences with more than 13 elements there are more possible permutations than possible seeds ($13! > 2^{28}$) so the question of uniformity is somewhat moot.

```

28815 \cs_if_exist:NTF \tex_uniformdeviate:D
28816 {
28817     \int_new:N \l__seq_internal_a_int
28818     \int_new:N \l__seq_internal_b_int
28819     \seq_new:N \g__seq_internal_seq
28820     \cs_new_protected:Npn \seq_shuffle:N { \__seq_shuffle:NN \seq_set_eq:NN }
28821     \cs_new_protected:Npn \seq_gshuffle:N { \__seq_shuffle:NN \seq_gset_eq:NN }
28822     \cs_new_protected:Npn \__seq_shuffle:NN #1#2

```

```

28823 {
28824   \int_compare:nNnTF { \seq_count:N #2 } > \c_max_register_int
28825   {
28826     \__kernel_msg_error:nnx { kernel } { shuffle-too-large }
28827     { \token_to_str:N #2 }
28828   }
28829   {
28830     \group_begin:
28831     \cs_set_eq:NN \__seq_item:n \__seq_shuffle_item:n
28832     \int_zero:N \l__seq_internal_a_int
28833     #2
28834     \seq_gset_from_inline_x:Nnn \g__seq_internal_seq
28835     { \int_step_function:nN { \l__seq_internal_a_int } }
28836     { \tex_the:D \tex_toks:D ##1 }
28837     \group_end:
28838     #1 #2 \g__seq_internal_seq
28839     \seq_gclear:N \g__seq_internal_seq
28840   }
28841 }
28842 \cs_new_protected:Npn \__seq_shuffle_item:n
28843 {
28844   \int_incr:N \l__seq_internal_a_int
28845   \int_set:Nn \l__seq_internal_b_int
28846   { 1 + \tex_uniformdeviate:D \l__seq_internal_a_int }
28847   \tex_toks:D \l__seq_internal_a_int
28848   = \tex_toks:D \l__seq_internal_b_int
28849   \tex_toks:D \l__seq_internal_b_int
28850 }
28851 \__kernel_msg_new:nnnn { kernel } { shuffle-too-large }
28852 { The~sequence~#1~is~too~long~to~be~shuffled~by~TeX. }
28853 {
28854   TeX~has~ \int_eval:n { \c_max_register_int + 1 } ~
28855   toks~registers:~this~only~allows~to~shuffle~up~to~
28856   \int_use:N \c_max_register_int \ items.~
28857   The~list~will~not~be~shuffled.
28858 }
28859 }
28860 {
28861   \cs_new_protected:Npn \seq_shuffle:N #1
28862   {
28863     \__kernel_msg_error:nnn { kernel } { fp-no-random }
28864     { \seq_shuffle:N #1 }
28865   }
28866   \cs_new_eq:NN \seq_gshuffle:N \seq_shuffle:N
28867 }

```

(End definition for `\seq_shuffle:N` and others. These functions are documented on page 258.)

`\seq_indexed_map_function:NN` Similar to `\seq_map_function:NN` but we keep track of the item index as a ;-delimited argument of `__seq_indexed_map:Nw`.

`\seq_indexed_map_inline:Nn`

```

28868 \cs_new:Npn \seq_indexed_map_function:NN #1#2
28869 {
28870   \__seq_indexed_map:NN #1#2
28871   \prg_break_point:Nn \seq_map_break: { }

```

```

28872 }
28873 \cs_new_protected:Npn \seq_indexed_map_inline:Nn #1#2
28874 {
28875   \int_gincr:N \g__kernel_prg_map_int
28876   \cs_gset_protected:cpn
28877     { __seq_map_ \int_use:N \g__kernel_prg_map_int :w } ##1##2 {#2}
28878   \exp_args:Nnc \__seq_indexed_map:NN #1
28879     { __seq_map_ \int_use:N \g__kernel_prg_map_int :w }
28880   \prg_break_point:Nn \seq_map_break:
28881     { \int_gdecr:N \g__kernel_prg_map_int }
28882 }
28883 \cs_new:Npn \__seq_indexed_map:NN #1#2
28884 {
28885   \exp_after:wN \__seq_indexed_map:Nw
28886   \exp_after:wN #2
28887   \int_value:w 1
28888   \exp_after:wN \use_i:nn
28889   \exp_after:wN ;
28890   #1
28891   \prg_break: \__seq_item:n { } \prg_break_point:
28892 }
28893 \cs_new:Npn \__seq_indexed_map:Nw #1#2 ; #3 \__seq_item:n #4
28894 {
28895   #3
28896   #1 {#2} {#4}
28897   \exp_after:wN \__seq_indexed_map:Nw
28898   \exp_after:wN #1
28899   \int_value:w \int_eval:w 1 + #2 ;
28900 }

```

(End definition for `\seq_indexed_map_function:NN` and others. These functions are documented on page 259.)

47.10 Additions to l3skip

28901 (@@=dim)

\dim_sign:n See `\dim_abs:n`. Contrarily to `\int_sign:n` the case of a zero dimension cannot be distinguished from a positive dimension by looking only at the first character, since `0.2pt` and `0pt` start the same way. We need explicit comparisons. We start by distinguishing the most common case of a positive dimension.

__dim_sign:Nw

```

28902 \__kernel_patch_args:nNnNpn
28903 { { \__kernel_chk_expr:nNnN {#1} \__dim_eval:w { } \dim_sign:n } }
28904 \cs_new:Npn \dim_sign:n #1
28905 {
28906   \int_value:w \exp_after:wN \__dim_sign:Nw
28907   \dim_use:N \__dim_eval:w #1 \__dim_eval_end: ;
28908   \exp_stop_f:
28909 }
28910 \cs_new:Npn \__dim_sign:Nw #1#2 ;
28911 {
28912   \if_dim:w #1#2 > \c_zero_dim
28913     1
28914   \else:

```



```

28915     \if_meaning:w - #1
28916     -1
28917     \else:
28918     0
28919     \fi:
28920 \fi:
28921 }

```

(End definition for `\dim_sign:n` and `_dim_sign:Nw`. This function is documented on page [259](#).)

47.11 Additions to l3sys

```

28922 (@@=sys)

```

`\c_sys_engine_version_str` Various different engines, various different ways to extract the data!

```

28923 \str_const:Nx \c_sys_engine_version_str
28924 {
28925   \str_case:on \c_sys_engine_str
28926   {
28927     { pdftex }
28928     {
28929       \fp_eval:n { round(\int_use:N \tex_pdftexversion:D / 100 , 2) }
28930       .
28931       \tex_pdftexrevision:D
28932     }
28933     { ptex }
28934     {
28935       \cs_if_exist:NT \tex_ptexversion:D
28936       {
28937         p
28938         \int_use:N \tex_ptexversion:D
28939         \int_use:N \tex_ptexminorversion:D
28940         \tex_ptexrevision:D
28941         -
28942         \int_use:N \tex_epTeXversion:D
28943       }
28944     }
28945     { luatex }
28946     {
28947       \fp_eval:n { round(\int_use:N \tex_luatexversion:D / 100, 2) }
28948       .
28949       \tex_luatexrevision:D
28950     }
28951     { uptex }
28952     {
28953       \cs_if_exist:NT \tex_ptexversion:D
28954       {
28955         p
28956         \int_use:N \tex_ptexversion:D
28957         \int_use:N \tex_ptexminorversion:D
28958         \tex_ptexrevision:D
28959         -
28960         u
28961         \int_use:N \tex_uptexversion:D
28962         \tex_uptexrevision:D

```

```

28963         -
28964         \int_use:N \tex_epTeXversion:D
28965     }
28966 }
28967 { xetex }
28968 {
28969     \int_use:N \tex_XeTeXversion:D
28970     \tex_XeTeXrevision:D
28971 }
28972 }
28973 }

```

(End definition for `\c_sys_engine_version_str`. This variable is documented on page 259.)

`\sys_rand_seed:` Unpack the primitive. When random numbers are not available, we return zero after an error (and incidentally make sure the number of expansions needed is the same as with random numbers available).

```

28974 \sys_if_rand_exist:TF
28975 { \cs_new:Npn \sys_rand_seed: { \tex_the:D \tex_randomseed:D } }
28976 {
28977     \cs_new:Npn \sys_rand_seed:
28978     {
28979         \int_value:w
28980         \__kernel_msg_expandable_error:nnn { kernel } { fp-no-random }
28981         { \sys_rand_seed: }
28982         \c_zero_int
28983     }
28984 }

```

(End definition for `\sys_rand_seed:.` This function is documented on page 260.)

`\sys_gset_rand_seed:n` The primitive always assigns the seed globally.

```

28985 \sys_if_rand_exist:TF
28986 {
28987     \cs_new_protected:Npn \sys_gset_rand_seed:n #1
28988     { \tex_setrandomseed:D \int_eval:n {#1} \exp_stop_f: }
28989 }
28990 {
28991     \cs_new_protected:Npn \sys_gset_rand_seed:n #1
28992     {
28993         \__kernel_msg_error:nnn { kernel } { fp-no-random }
28994         { \sys_gset_rand_seed:n {#1} }
28995     }
28996 }

```

(End definition for `\sys_gset_rand_seed:n`. This function is documented on page 260.)

`\c_sys_shell_escape_int` Expose the engine's shell escape status to the user.

```

28997 \int_const:Nn \c_sys_shell_escape_int
28998 {
28999     \sys_if_engine luatex:TF
29000     {
29001         \tex_directlua:D
29002         { tex.sprint(status.shell_escape~or~os.execute()) }
29003     }

```

```

29004     {
29005     \tex_shellescape:D
29006     }
29007 }

```

(End definition for `\c_sys_shell_escape_int`. This variable is documented on page 260.)

`\l__sys_internal_tl`

```

29008 \tl_new:N \l__sys_internal_tl

```

(End definition for `\l__sys_internal_tl`.)

`\c__sys_marker_tl`

The same idea as the marker for rescanning token lists.

```

29009 \tl_const:Nx \c__sys_marker_tl { : \token_to_str:N : }

```

(End definition for `\c__sys_marker_tl`.)

`\sys_shell_get:nnTF`

Setting using a shell is at this level just a slightly specialised file operation, with an additional check for quotes, as these are not supported.

`\sys_shell_get:nnN`

`__sys_get:nnN`

`__sys_get_do:Nw`

```

29010 \cs_new_protected:Npn \sys_shell_get:nnN #1#2#3
29011 {
29012   \sys_shell_get:nnNF {#1} {#2} #3
29013   { \tl_set:Nn #3 { \q_no_value } }
29014 }
29015 \prg_new_protected_conditional:Npnn \sys_shell_get:nnN #1#2#3 { T , F , TF }
29016 {
29017   \sys_if_shell:TF
29018   { \exp_args:No \__sys_get:nnN { \tl_to_str:n {#1} } {#2} #3 }
29019   { \prg_return_false: }
29020 }
29021 \cs_new_protected:Npn \__sys_get:nnN #1#2#3
29022 {
29023   \tl_if_in:nnTF {#1} { " }
29024   {
29025     \__kernel_msg_error:nnx
29026     { kernel } { quote-in-shell } {#1}
29027     \prg_return_false:
29028   }
29029   {
29030     \group_begin:
29031     \if_false: { \fi:
29032       \int_set_eq:NN \tex_tracingnesting:D \c_zero_int
29033       \exp_args:No \tex_everyeof:D { \c__sys_marker_tl }
29034       #2 \scan_stop:
29035       \exp_after:wN \__sys_get_do:Nw
29036       \exp_after:wN #3
29037       \exp_after:wN \prg_do_nothing:
29038       \tex_input:D | "#1" \scan_stop:
29039     \if_false: } \fi:
29040     \prg_return_true:
29041   }
29042 }
29043 \exp_args:Nno \use:nn
29044 { \cs_new_protected:Npn \__sys_get_do:Nw #1#2 }
29045 { \c__sys_marker_tl }

```

```

29046 {
29047   \group_end:
29048   \tl_set:No #1 {#2}
29049 }
29050 \__kernel_msg_new:nnnn { kernel } { quote-in-shell }
29051 { Quotes~in~shell~command~'~#1'. }
29052 { Shell~commands~cannot~contain~quotes~( ). }

```

(End definition for `\sys_shell_get:nnTF` and others. These functions are documented on page 259.)

`\c_sys_platform_str` Detecting the platform on LuaTeX is easy: for other engines, we use the fact that the two common cases have special null files. It is possible to probe further (see package `platform`), but that requires shell escape and seems unlikely to be useful.

```

29053 \sys_if_engine luatex:TF
29054 {
29055   \str_const:Nx \c_sys_platform_str
29056   { \lua_now:n { tex.print(os.type) } }
29057 }
29058 {
29059   \file_if_exist:nTF { nul: }
29060   {
29061     \file_if_exist:nF { /dev/null }
29062     { \str_const:Nn \c_sys_platform_str { windows } }
29063   }
29064   {
29065     \file_if_exist:nT { /dev/null }
29066     { \str_const:Nn \c_sys_platform_str { unix } }
29067   }
29068 }
29069 \cs_if_exist:NF \c_sys_platform_str
29070 { \str_const:Nn \c_sys_platform_str { unknown } }

```

(End definition for `\c_sys_platform_str`. This variable is documented on page 260.)

`\sys_if_platform_unix_p:` We can now set up the tests.

```

\sys_if_platform_unix:TF
\sys_if_platform_windows_p:
\sys_if_platform_windows:TF
29071 \clist_map_inline:nn { unix , windows }
29072 {
29073   \__sys_const:nn { sys_if_platform_ #1 }
29074   { \str_if_eq_p:Vn \c_sys_platform_str { #1 } }
29075 }

```

(End definition for `\sys_if_platform_unix:TF` and `\sys_if_platform_windows:TF`. These functions are documented on page 260.)

`\sys_if_shell_p:` Performs a check for whether shell escape is enabled. The first set of functions returns true if either of restricted or unrestricted shell escape is enabled, while the other two sets of functions return true in only one of these two cases.

```

\sys_if_shell:TF
\sys_if_shell_unrestricted_p:
\sys_if_shell_unrestricted:TF
\sys_if_shell_restricted_p:
\sys_if_shell_restricted:TF
29076 \__sys_const:nn { sys_if_shell }
29077 { \int_compare_p:nNn \c_sys_shell_escape_int > 0 }
29078 \__sys_const:nn { sys_if_shell_unrestricted }
29079 { \int_compare_p:nNn \c_sys_shell_escape_int = 1 }
29080 \__sys_const:nn { sys_if_shell_restricted }
29081 { \int_compare_p:nNn \c_sys_shell_escape_int = 2 }

```

(End definition for `\sys_if_shell:TF`, `\sys_if_shell_unrestricted:TF`, and `\sys_if_shell_restricted:TF`. These functions are documented on page 260.)

`\c__sys_shell_stream_int` This is not needed for LuaTeX: shell escape there isn't done using a TeX interface.

```
29082 \sys_if_engine luatex:F
29083   { \int_const:Nn \c__sys_shell_stream_int { 18 } }
```

(End definition for `\c__sys_shell_stream_int`.)

`\sys_shell_now:n` Execute commands through shell escape immediately.

```
29084 \sys_if_engine luatex:TF
29085   {
29086     \cs_new_protected:Npn \sys_shell_now:n #1
29087     {
29088       \lua_now:e
29089       { os.execute(" \lua_escape:e { \tl_to_str:n {#1} } ") }
29090     }
29091   }
29092   {
29093     \cs_new_protected:Npn \sys_shell_now:n #1
29094     { \iow_now:Nn \c__sys_shell_stream_int {#1} }
29095   }
29096   \cs_generate_variant:Nn \sys_shell_now:n { x }
```

(End definition for `\sys_shell_now:n`. This function is documented on page 261.)

`\sys_shell_shipout:n` Execute commands through shell escape at shipout.

```
29097 \sys_if_engine luatex:TF
29098   {
29099     \cs_new_protected:Npn \sys_shell_shipout:n #1
29100     {
29101       \lua_shipout_e:n
29102       { os.execute(" \lua_escape:e { \tl_to_str:n {#1} } ") }
29103     }
29104   }
29105   {
29106     \cs_new_protected:Npn \sys_shell_shipout:n #1
29107     { \iow_shipout:Nn \c__sys_shell_stream_int {#1} }
29108   }
29109   \cs_generate_variant:Nn \sys_shell_shipout:n { x }
```

(End definition for `\sys_shell_shipout:n`. This function is documented on page 261.)

47.12 Additions to l3file

```
29110 <@=file>
```

`__file_str_cmp:nn` As we are doing a fixed-length “big” integer comparison, it is easiest to use the low-level behavior of string comparisons.

`__file_str_escape:n`

```
29111 \cs_new:Npn \__file_str_cmp:nn #1#2 { \tex_strcmp:D {#1} {#2} }
29112 \sys_if_engine luatex:T
29113   {
29114     \cs_set:Npn \__file_str_cmp:nn #1#2
29115     {
29116       \lua_now:e
```

```

29117         {
29118             l3kernel.strcmp
29119             (
29120                 " \_\_file_str_escape:n {#1}",
29121                 " \_\_file_str_escape:n {#2}"
29122             )
29123         }
29124     }
29125     \cs_new:Npn \_\_file_str_escape:n #1
29126     {
29127         \lua_escape:e
29128         { \_\_kernel_tl_to_str:w \use:e { {#1} } }
29129     }
29130 }

```

(End definition for __file_str_cmp:nn and __file_str_escape:n.)

```

\l__file_first_tl
\l__file_second_tl
29131 \tl_new:N \l__file_first_tl
29132 \tl_new:N \l__file_second_tl

```

(End definition for \l__file_first_tl and \l__file_second_tl.)

\file_compare_timestamp:nNnTF Comparison of file date can be done by using the low-level nature of the string comparison functions. This could be expandable but that would skip any file look-up: to stay consistent we retain that at the cost of expansion.

```

\__file_timestamp:n
29133 \prg_new_protected_conditional:Npnn \file_compare_timestamp:nNn #1#2#3
29134 { T , F , TF }
29135 {
29136     \group_begin:
29137     \file_get_full_name:nNTF {#1} \l__file_first_tl
29138     {
29139         \file_get_full_name:nNTF {#3} \l__file_second_tl
29140         {
29141             \if_int_compare:w
29142                 \_\_file_str_cmp:nn
29143                 { \__file_timestamp:n \exp_after:wN { \l__file_first_tl } }
29144                 { \__file_timestamp:n \exp_after:wN { \l__file_second_tl } }
29145                 #2 0 \exp_stop_f:
29146             \group_end:
29147             \prg_return_true:
29148         \else:
29149             \group_end:
29150             \prg_return_false:
29151         \fi:
29152     }
29153     {
29154         \group_end:
29155         \if_charcode:w #2 >
29156             \prg_return_true:
29157         \else:
29158             \prg_return_false:
29159         \fi:
29160     }
}

```

```

29161     }
29162     {
29163         \group_end:
29164         \if_charcode:w #2 <
29165         \prg_return_true:
29166         \else:
29167         \prg_return_false:
29168         \fi:
29169     }
29170 }
29171 \sys_if_engine luatex:TF
29172 {
29173     \cs_new:Npn \__file_timestamp:n #1
29174     {
29175         \lua_now:e
29176         { l3kernel.filemoddate ( " \lua_escape:e {#1} " ) }
29177     }
29178 }
29179 { \cs_new_eq:NN \__file_timestamp:n \tex_filemoddate:D }

```

(End definition for `\file_compare_timestamp:nNnTF` and `__file_timestamp:n`. This function is documented on page 253.)

```

29180 <@@=ior>

```

```

\ior_shell_open:Nn Actually much easier than either the standard open or input versions!
\__ior_shell_open:nN
29181 \cs_new_protected:Npn \ior_shell_open:Nn #1#2
29182 {
29183     \sys_if_shell:TF
29184     { \exp_args:No \__ior_shell_open:nN { \tl_to_str:n {#2} } #1 }
29185     { \__kernel_msg_error:nn { kernel } { pipe-failed } }
29186 }
29187 \cs_new_protected:Npn \__ior_shell_open:nN #1#2
29188 {
29189     \tl_if_in:nnTF {#1} { " }
29190     {
29191         \__kernel_msg_error:nnx
29192         { kernel } { quote-in-shell } {#1}
29193     }
29194     { \__kernel_ior_open:Nn #2 { "|#1" } }
29195 }
29196 \__kernel_msg_new:nnnn { kernel } { pipe-failed }
29197 { Cannot~run~piped~system~commands. }
29198 {
29199     LaTeX~tried~to~call~a~system~process~but~this~was~not~possible.\\
29200     Try~the~"--shell-escape"~(or~"--enable-pipes")~option.
29201 }

```

(End definition for `\ior_shell_open:Nn` and `__ior_shell_open:nN`. This function is documented on page 254.)

47.13 Additions to l3tl

47.13.1 Unicode case changing

The mechanisms needed for case changing are somewhat involved, particularly to allow for all of the special cases. These functions also require the appropriate data extracted from the Unicode documentation (either manually or automatically).

First, some code which “belongs” in l3tokens but has to come here.

29202 <@@=char>

`\char_lower_case:N`
`\char_upper_case:N`
`\char_mixed_case:N`
`\char_fold_case:N`

Expandable character generation is done using a two-part approach. First, see if the current character has a special mapping for the current transformation. If it does, insert that. Otherwise, use the TeX data to look up the one-to-one mapping, and generate the appropriate character with the appropriate category code. Mixed case needs an extra step as it may be special-cased or might be a special upper case outcome. The internal when using non-Unicode engines has to be set up to only do anything with ASCII characters.

To ensure that the category codes produced are predictable, every character is re-generated even if it is otherwise unchanged. This makes life a little interesting when we might have multiple output characters: we have to grab each of them and case change them in reverse order to maintain f-type expandability.

`__char_change_case:nNN`
`__char_change_case:nN`
`__char_change_case_multi:n`
`__char_change_case_multi:v`
`__char_change_case_multi:NNw`
`__char_change_case:NN`
`__char_change_case:NNN`
`__char_change_case:N`
`\char_str_lower_case:N`
`\char_str_upper_case:N`
`\char_str_mixed_case:N`
`\char_str_fold_case:N`
`__char_str_change_case:nNN`
`__char_str_change_case:nN`

29203 `\cs_new:Npn \char_lower_case:N #1`
29204 `{ __char_change_case:nNN { lower } \char_value_lccode:n #1 }`
29205 `\cs_new:Npn \char_upper_case:N #1`
29206 `{ __char_change_case:nNN { upper } \char_value_uccode:n #1 }`
29207 `\cs_new:Npn \char_mixed_case:N #1`
29208 `{`
29209 `\tl_if_exist:cTF { c__char_mixed_case_ \token_to_str:N #1 _tl }`
29210 `{`
29211 `__char_change_case_multi:v`
29212 `{ c__char_mixed_case_ \token_to_str:N #1 _tl }`
29213 `}`
29214 `{ \char_upper_case:N #1 }`
29215 `}`
29216 `\cs_new:Npn \char_fold_case:N #1`
29217 `{ __char_change_case:nNN { fold } \char_value_lccode:n #1 }`
29218 `\cs_new:Npn __char_change_case:nNN #1#2#3`
29219 `{`
29220 `\tl_if_exist:cTF { c__char_ #1 _case_ \token_to_str:N #3 _tl }`
29221 `{`
29222 `__char_change_case_multi:v`
29223 `{ c__char_ #1 _case_ \token_to_str:N #3 _tl }`
29224 `}`
29225 `{ \exp_args:Nf __char_change_case:nN { #2 { ‘#3 } } #3 }`
29226 `}`
29227 `\cs_new:Npn __char_change_case:nN #1#2`
29228 `{`
29229 `\int_compare:nNnTF {#1} = 0`
29230 `{ __char_change_case:N #2 }`
29231 `{ \char_generate:nn {#1} { \char_value_catcode:n {#1} } }`
29232 `}`
29233 `\cs_new:Npn __char_change_case_multi:n #1`
29234 `{ __char_change_case_multi:NNNw #1 \q_no_value \q_no_value \q_stop }`
29235 `\cs_new:Npn __char_change_case_multi:NNNw #1#2#3#4 \q_stop`


```

29236 {
29237   \quark_if_no_value:NTF #3
29238   {
29239     \quark_if_no_value:NTF #2
29240     { \__char_change_case:N #1 }
29241     { \__char_change_case:NN #1#2 }
29242   }
29243   { \__char_change_case:NNN #1#2#3 }
29244 }
29245 \cs_generate_variant:Nn \__char_change_case_multi:n { v }
29246 \cs_new:Npn \__char_change_case:NN #1#2
29247 {
29248   \exp_args:Nnf \use:nn
29249   { \__char_change_case:N #1 }
29250   { \__char_change_case:N #2 }
29251 }
29252 \cs_new:Npn \__char_change_case:NNN #1#2#3
29253 {
29254   \exp_args:Nnff \use:nnn
29255   { \__char_change_case:N #1 }
29256   { \__char_change_case:N #2 }
29257   { \__char_change_case:N #3 }
29258 }
29259 \cs_new:Npn \__char_change_case:N #1
29260 { \char_generate:nn { '#1 } { \char_value_catcode:n { '#1 } } }
29261 \bool_lazy_or:nnF { \sys_if_engine luatex_p: } { \sys_if_engine xetex_p: }
29262 {
29263   \cs_set_eq:NN \__char_change_case:nN \use_ii:nn
29264 }

```

Same story for the string version, except category code is easier to follow. This of course makes this version significantly faster.

```

29265 \cs_new:Npn \char_str_lower_case:N #1
29266 { \__char_str_change_case:nNN { lower } \char_value_lccode:n #1 }
29267 \cs_new:Npn \char_str_upper_case:N #1
29268 { \__char_str_change_case:nNN { upper } \char_value_uccode:n #1 }
29269 \cs_new:Npn \char_str_mixed_case:N #1
29270 {
29271   \tl_if_exist:cTF { c__char_mixed_case_ \token_to_str:N #1 _tl }
29272   { \tl_to_str:c { c__char_mixed_case_ \token_to_str:N #1 _tl } }
29273   { \char_str_upper_case:N #1 }
29274 }
29275 \cs_new:Npn \char_str_fold_case:N #1
29276 { \__char_str_change_case:nNN { fold } \char_value_lccode:n #1 }
29277 \cs_new:Npn \__char_str_change_case:nNN #1#2#3
29278 {
29279   \tl_if_exist:cTF { c__char_ #1 _case_ \token_to_str:N #3 _tl }
29280   { \tl_to_str:c { c__char_ #1 _case_ \token_to_str:N #3 _tl } }
29281   { \exp_args:Nf \__char_str_change_case:nN { #2 { '#3 } } #3 }
29282 }
29283 \cs_new:Npn \__char_str_change_case:nN #1#2
29284 {
29285   \int_compare:nNnTF {#1} = 0
29286   { \tl_to_str:n {#2} }

```

```

29287     { \char_generate:nn {#1} { 12 } }
29288   }
29289 \bool_lazy_or:nnF { \sys_if_engine luatex_p: } { \sys_if_engine_xetex_p: }
29290 {
29291   \cs_set:Npn \__char_str_change_case:nN #1#2
29292     { \tl_to_str:n {#2} }
29293 }

```

(End definition for `\char_lower_case:N` and others. These functions are documented on page 266.)

\char_codepoint_to_bytes:n This code converts a codepoint into the correct UTF-8 representation. In terms of the algorithm itself, see <https://en.wikipedia.org/wiki/UTF-8> for the octet pattern.

```

\char_codepoint_to_bytes_auxi:n
\char_codepoint_to_bytes_auxii:Nnn
\char_codepoint_to_bytes_auxiii:n
\char_codepoint_to_bytes_outputi:nw
\char_codepoint_to_bytes_outputii:nw
\char_codepoint_to_bytes_outputiii:nw
\char_codepoint_to_bytes_outputiv:nw
\char_codepoint_to_bytes_output:nnn
\char_codepoint_to_bytes_output:fnm
\char_codepoint_to_bytes_end:
29294 \cs_new:Npn \char_codepoint_to_bytes:n #1
29295 {
29296   \exp_args:Nf \__char_codepoint_to_bytes_auxi:n
29297   { \int_eval:n {#1} }
29298 }
29299 \cs_new:Npn \__char_codepoint_to_bytes_auxi:n #1
29300 {
29301   \if_int_compare:w #1 > "80 \exp_stop_f:
29302   \if_int_compare:w #1 < "800 \exp_stop_f:
29303     \__char_codepoint_to_bytes_outputi:nw
29304     { \__char_codepoint_to_bytes_auxii:Nnn C {#1} { 64 } }
29305     \__char_codepoint_to_bytes_outputii:nw
29306     { \__char_codepoint_to_bytes_auxiii:n {#1} }
29307   \else:
29308     \if_int_compare:w #1 < "10000 \exp_stop_f:
29309     \__char_codepoint_to_bytes_outputi:nw
29310     { \__char_codepoint_to_bytes_auxii:Nnn E {#1} { 64 * 64 } }
29311     \__char_codepoint_to_bytes_outputii:nw
29312     {
29313       \__char_codepoint_to_bytes_auxiii:n
29314       { \int_div_truncate:nn {#1} { 64 } }
29315     }
29316     \__char_codepoint_to_bytes_outputiii:nw
29317     { \__char_codepoint_to_bytes_auxiii:n {#1} }
29318   \else:
29319     \__char_codepoint_to_bytes_outputi:nw
29320     {
29321       \__char_codepoint_to_bytes_auxii:Nnn F
29322       {#1} { 64 * 64 * 64 }
29323     }
29324     \__char_codepoint_to_bytes_outputii:nw
29325     {
29326       \__char_codepoint_to_bytes_auxiii:n
29327       { \int_div_truncate:nn {#1} { 64 * 64 } }
29328     }
29329     \__char_codepoint_to_bytes_outputiii:nw
29330     {
29331       \__char_codepoint_to_bytes_auxiii:n
29332       { \int_div_truncate:nn {#1} { 64 } }
29333     }
29334     \__char_codepoint_to_bytes_outputiv:nw
29335     { \__char_codepoint_to_bytes_auxiii:n {#1} }

```

```

29336         \fi:
29337         \fi:
29338     \else:
29339         \__char_codepoint_to_bytes_outputi:nw {#1}
29340         \fi:
29341         \__char_codepoint_to_bytes_end: { } { } { } { }
29342     }
29343 \cs_new:Npn \__char_codepoint_to_bytes_auxii:Nnn #1#2#3
29344 { "#10 + \int_div_truncate:nn {#2} {#3} }
29345 \cs_new:Npn \__char_codepoint_to_bytes_auxiii:n #1
29346 { \int_mod:nn {#1} { 64 } + 128 }
29347 \cs_new:Npn \__char_codepoint_to_bytes_outputi:nw
29348 #1 #2 \__char_codepoint_to_bytes_end: #3
29349 { \__char_codepoint_to_bytes_output:fnn { \int_eval:n {#1} } { } {#2} }
29350 \cs_new:Npn \__char_codepoint_to_bytes_outputii:nw
29351 #1 #2 \__char_codepoint_to_bytes_end: #3#4
29352 { \__char_codepoint_to_bytes_output:fnn { \int_eval:n {#1} } { {#3} } {#2} }
29353 \cs_new:Npn \__char_codepoint_to_bytes_outputiii:nw
29354 #1 #2 \__char_codepoint_to_bytes_end: #3#4#5
29355 {
29356     \__char_codepoint_to_bytes_output:fnn
29357     { \int_eval:n {#1} } { {#3} {#4} } {#2}
29358 }
29359 \cs_new:Npn \__char_codepoint_to_bytes_outputiv:nw
29360 #1 #2 \__char_codepoint_to_bytes_end: #3#4#5#6
29361 {
29362     \__char_codepoint_to_bytes_output:fnn
29363     { \int_eval:n {#1} } { {#3} {#4} {#5} } {#2}
29364 }
29365 \cs_new:Npn \__char_codepoint_to_bytes_output:nnn #1#2#3
29366 {
29367     #3
29368     \__char_codepoint_to_bytes_end: #2 {#1}
29369 }
29370 \cs_generate_variant:Nn \__char_codepoint_to_bytes_output:nnn { f }
29371 \cs_new:Npn \__char_codepoint_to_bytes_end: { }

```

(End definition for `\char_codepoint_to_bytes:n` and others. This function is documented on page 266.)

```

29372 <@@=tl>

```

`\tl_if_head_eq_catcode:oNTF` Extra variants.

```

29373 \cs_generate_variant:Nn \tl_if_head_eq_catcode:nNTF { o }

```

(End definition for `\tl_if_head_eq_catcode:nNTF`. This function is documented on page 48.)

`\tl_lower_case:n` `\tl_upper_case:n` `\tl_mixed_case:n` The user level functions here are all wrappers around the internal functions for case changing.

```

29374 \cs_new:Npn \tl_lower_case:n { \__tl_change_case:nnn { lower } { } }
29375 \cs_new:Npn \tl_upper_case:n { \__tl_change_case:nnn { upper } { } }
29376 \cs_new:Npn \tl_mixed_case:n { \__tl_change_case:nnn { mixed } { } }
29377 \cs_new:Npn \tl_lower_case:nn { \__tl_change_case:nnn { lower } }
29378 \cs_new:Npn \tl_upper_case:nn { \__tl_change_case:nnn { upper } }
29379 \cs_new:Npn \tl_mixed_case:nn { \__tl_change_case:nnn { mixed } }

```

(End definition for `\tl_lower_case:n` and others. These functions are documented on page 261.)

```

\__tl_change_case:nnn
\__tl_change_case_aux:nnn
\__tl_change_case_loop:wnn
\__tl_change_case_output:nwn
\__tl_change_case_output:Vwn
\__tl_change_case_output:own
\__tl_change_case_output:vwn
\__tl_change_case_output:fwn
\__tl_change_case_end:wn
\__tl_change_case_group:nwnn
\__tl_change_case_group_lower:nnnn
\__tl_change_case_group_upper:nnnn
\__tl_change_case_group_mixed:nnnn
\__tl_change_case_space:wnn
\__tl_change_case_N_type:Nwnn
\__tl_change_case_N_type:NNNnnn
\__tl_change_case_math:NNNnnn
\__tl_change_case_math_loop:wNNnn
\__tl_change_case_math:NwNNnn
\__tl_change_case_math_group:nwNNnn
\__tl_change_case_math_space:wNNnn
\__tl_change_case_N_type:Nnnn
\__tl_change_case_char_lower:Nnn
\__tl_change_case_char_upper:Nnn
\__tl_change_case_char_mixed:Nnn
\__tl_change_case_char:nN
\__tl_change_case_char_UTFviii:nN
\__tl_change_case_char_UTFviii:nNN
\__tl_change_case_char_UTFviii:nNNN
\__tl_change_case_char_UTFviii:nn
\__tl_change_case_cs_letterlike:Nn
\__tl_change_case_cs_letterlike:NnN
\__tl_change_case_cs_accents:NN
\__tl_change_case_cs:N
\__tl_change_case_cs:NN
\__tl_change_case_cs:NNn
\__tl_change_case_protect:wNN
\__tl_change_case_if_expandable:NTF
\__tl_change_case_cs_expand:Nnw
\__tl_change_case_cs_expand:NN
\__tl_change_case_mixed_skip:N
\__tl_change_case_mixed_skip:NN
\__tl_change_case_mixed_skip_tidy:Nwn
\__tl_change_case_mixed_switch:w

```

```

29380 \cs_new:Npn \__tl_change_case:nnn #1#2#3
29381 {
29382   \__kernel_exp_not:w \exp_after:wN
29383   {
29384     \exp:w
29385     \__tl_change_case_aux:nnn {#1} {#2} {#3}
29386   }
29387 }
29388 \cs_new:Npn \__tl_change_case_aux:nnn #1#2#3
29389 {
29390   \group_align_safe_begin:
29391   \__tl_change_case_loop:wnn
29392   #3 \q_recursion_tail \q_recursion_stop {#1} {#2}
29393   \__tl_change_case_result:n { }
29394 }
29395 \cs_new:Npn \__tl_change_case_loop:wnn #1 \q_recursion_stop
29396 {
29397   \tl_if_head_is_N_type:nTF {#1}
29398   { \__tl_change_case_N_type:Nwnn }
29399   {
29400     \tl_if_head_is_group:nTF {#1}
29401     { \__tl_change_case_group:nwnn }
29402     { \__tl_change_case_space:wnn }
29403   }
29404   #1 \q_recursion_stop
29405 }

```

```

29406 \cs_new:Npn \__tl_change_case_output:nwn #1#2 \__tl_change_case_result:n #3
29407 { #2 \__tl_change_case_result:n { #3 #1 } }
29408 \cs_generate_variant:Nn \__tl_change_case_output:nwn { V , o , v , f }
29409 \cs_new:Npn \__tl_change_case_end:wn #1 \__tl_change_case_result:n #2
29410 {
29411   \group_align_safe_end:
29412   \exp_end:
29413   #2
29414 }

```

Earlier versions of the code where only x-type expandable rather than f-type: this causes issues with nesting and so the slight performance hit is taken for a better outcome in usability terms. Setting up for f-type expandability has two requirements: a marker token after the main loop (see above) and a mechanism to “load” and finalise the result. That is handled in the code below, which includes the necessary material to end the `\exp:w` expansion.

Handling for the cases where the current argument is a brace group or a space is relatively easy. For the brace case, the routine works recursively, using the expandability of the mechanism to ensure that the result is finalised before storage. For the space case it is

simply a question of removing the space in the input and storing it in the output. In both cases, and indeed for the N-type grabber, after removing the current item from the input `__tl_change_case_loop:wnn` is inserted in front of the remaining tokens.

```

29415 \cs_new:Npn \__tl_change_case_group:nwnn #1#2 \q_recursion_stop #3#4
29416 {
29417   \use:c { __tl_change_case_group_ #3 : nnnn } {#1} {#2} {#3} {#4}
29418 }
29419 \cs_new:Npn \__tl_change_case_group_lower:nnnn #1#2#3#4
29420 {
29421   \__tl_change_case_output:own
29422   {
29423     \exp_after:wN
29424     {
29425       \exp:w
29426       \__tl_change_case_aux:nnn {#3} {#4} {#1}
29427     }
29428   }
29429   \__tl_change_case_loop:wnn #2 \q_recursion_stop {#3} {#4}
29430 }
29431 \cs_new_eq:NN \__tl_change_case_group_upper:nnnn
29432 \__tl_change_case_group_lower:nnnn

```

For the “mixed” case, a group is taken as forcing a switch to lower casing. That means we need a separate auxiliary. (Tracking whether we have found a first character inside a group and transferring the information out looks pretty horrible.)

```

29433 \cs_new:Npn \__tl_change_case_group_mixed:nnnn #1#2#3#4
29434 {
29435   \__tl_change_case_output:own
29436   {
29437     \exp_after:wN
29438     {
29439       \exp:w
29440       \__tl_change_case_aux:nnn {#3} {#4} {#1}
29441     }
29442   }
29443   \__tl_change_case_loop:wnn #2 \q_recursion_stop { lower } {#4}
29444 }
29445 \exp_last_unbraced:NNo \cs_new:Npn \__tl_change_case_space:wnn \c_space_tl
29446 {
29447   \__tl_change_case_output:nwn { ~ }
29448   \__tl_change_case_loop:wnn
29449 }

```

For N-type arguments there are several stages to the approach. First, a simply check for the end-of-input marker, which if found triggers the final clean up and output step. Assuming that is not the case, the first check is for math-mode escaping: this test can encompass control sequences or other N-type tokens so is handled up front.

```

29450 \cs_new:Npn \__tl_change_case_N_type:Nwnn #1#2 \q_recursion_stop
29451 {
29452   \quark_if_recursion_tail_stop_do:Nn #1
29453   { \__tl_change_case_end:wn }
29454   \exp_after:wN \__tl_change_case_N_type:NNNnnn
29455   \exp_after:wN #1 \l_tl_change_case_math_tl
29456   \q_recursion_tail ? \q_recursion_stop {#2}

```

29457 }

Looking for math mode escape first requires a loop over the possible token pairs to see if the current input (#1) matches an open-math case (#2). If it does then this test loop is ended and a new input-gathering one is begun. The latter simply transfers material from the input to the output without any expansion, testing each N-type token to see if it matches the close-math case required. If that is the situation then the “math loop” stops and resumes the main loop: as that might be either the standard case-changing one or the mixed-case alternative, it is not hard-coded into the math loop but is rather passed as argument #3 to `__tl_change_case_math:NNNnnn`. If no close-math token is found then the final clean-up is forced (*i.e.* there is no assumption of “well-behaved” input in terms of math mode).

```

29458 \cs_new:Npn \__tl_change_case_N_type:NNNnnn #1#2#3
29459 {
29460   \quark_if_recursion_tail_stop_do:Nn #2
29461   { \__tl_change_case_N_type:Nnnn #1 }
29462   \token_if_eq_meaning:NNTF #1 #2
29463   {
29464     \use_i_delimit_by_q_recursion_stop:nw
29465     {
29466       \__tl_change_case_math:NNNnnn
29467       #1 #3 \__tl_change_case_loop:wnn
29468     }
29469   }
29470   { \__tl_change_case_N_type:NNNnnn #1 }
29471 }
29472 \cs_new:Npn \__tl_change_case_math:NNNnnn #1#2#3#4
29473 {
29474   \__tl_change_case_output:nwn {#1}
29475   \__tl_change_case_math_loop:wNNnn #4 \q_recursion_stop #2 #3
29476 }
29477 \cs_new:Npn \__tl_change_case_math_loop:wNNnn #1 \q_recursion_stop
29478 {
29479   \tl_if_head_is_N_type:nTF {#1}
29480   { \__tl_change_case_math:NwNNnn }
29481   {
29482     \tl_if_head_is_group:nTF {#1}
29483     { \__tl_change_case_math_group:nwNNnn }
29484     { \__tl_change_case_math_space:wNNnn }
29485   }
29486   #1 \q_recursion_stop
29487 }
29488 \cs_new:Npn \__tl_change_case_math:NwNNnn #1#2 \q_recursion_stop #3#4
29489 {
29490   \token_if_eq_meaning:NNTF \q_recursion_tail #1
29491   { \__tl_change_case_end:wn }
29492   {
29493     \__tl_change_case_output:nwn {#1}
29494     \token_if_eq_meaning:NNTF #1 #3
29495     { #4 #2 \q_recursion_stop }
29496     { \__tl_change_case_math_loop:wNNnn #2 \q_recursion_stop #3#4 }
29497   }
29498 }
29499 \cs_new:Npn \__tl_change_case_math_group:nwNNnn #1#2 \q_recursion_stop

```

```

29500 {
29501   \_tl_change_case_output:nwn { {#1} }
29502   \_tl_change_case_math_loop:wNNnn #2 \q_recursion_stop
29503 }
29504 \exp_last_unbraced:NNo
29505 \cs_new:Npn \_tl_change_case_math_space:wNNnn \c_space_tl
29506 {
29507   \_tl_change_case_output:nwn { ~ }
29508   \_tl_change_case_math_loop:wNNnn
29509 }

```

Once potential math-mode cases are filtered out the next stage is to test if the token grabbed is a control sequence: they cannot be used in the lookup table and also may require expansion. At this stage the loop code starting `_tl_change_case_loop:wnn` is inserted: all subsequent steps in the code which need a look-ahead are coded to rely on this and thus have w-type arguments if they may do a look-ahead.

```

29510 \cs_new:Npn \_tl_change_case_N_type:Nnnn #1#2#3#4
29511 {
29512   \token_if_cs:NTF #1
29513   { \_tl_change_case_cs_letterlike:Nn #1 {#3} }
29514   { \use:c { \_tl_change_case_char_ #3 :Nnn } #1 {#3} {#4} }
29515   \_tl_change_case_loop:wnn #2 \q_recursion_stop {#3} {#4}
29516 }

```

For character tokens there are some special cases to deal with then the majority of changes are covered by using the T_EX data as a lookup along with expandable character generation. This avoids needing a very large number of macros or (as seen in earlier versions) a somewhat tricky split of the characters into various blocks. Notice that the special case code may do a look-ahead so requires a final w-type argument whereas the core lookup table does not and also guarantees an output so f-type expansion may be used to obtain the case-changed result.

```

29517 \cs_new:Npn \_tl_change_case_char_lower:Nnn #1#2#3
29518 {
29519   \cs_if_exist_use:cF { \_tl_change_case_ #2 _ #3 :Nnw }
29520   { \use_ii:nn }
29521   #1
29522   {
29523     \use:c { \_tl_change_case_ #2 _ sigma:Nnw } #1
29524     { \_tl_change_case_char:nN {#2} #1 }
29525   }
29526 }
29527 \cs_new_eq:NN \_tl_change_case_char_upper:Nnn
29528   \_tl_change_case_char_lower:Nnn

```

For mixed case, the code is somewhat different: there is a need to look up both mixed and upper case chars and we have to cover the situation where there is a character to skip over.

```

29529 \cs_new:Npn \_tl_change_case_char_mixed:Nnn #1#2#3
29530 {
29531   \_tl_change_case_mixed_switch:w
29532   \cs_if_exist_use:cF { \_tl_change_case_mixed_ #3 :Nnw }
29533   {
29534     \cs_if_exist_use:cF { \_tl_change_case_upper_ #3 :Nnw }
29535     { \use_ii:nn }

```

```

29536     }
29537     #1
29538     { \_tl_change_case_mixed_skip:N #1 }
29539 }

```

For Unicode engines we can handle all characters directly. However, for the 8-bit engines the aim is to deal with (a subset of) Unicode (UTF-8) input. They deal with that by making the upper half of the range active, so we look for that and if found work out how many UTF-8 octets there are to deal with. Those can then be grabbed to reconstruct the full Unicode character, which is then used in a lookup. (As will become obvious below, there is no intention here of covering all of Unicode.)

```

29540 \bool_lazy_or:nnTF
29541 { \sys_if_engine luatex_p: }
29542 { \sys_if_engine xetex_p: }
29543 {
29544   \cs_new:Npn \_tl_change_case_char:nN #1#2
29545   {
29546     \_tl_change_case_output:fwn
29547     { \use:c { char_ #1 _case:N } #2 }
29548   }
29549 }
29550 {
29551   \cs_new:Npn \_tl_change_case_char:nN #1#2
29552   {
29553     \int_compare:nNnTF { '#2 } > { "80 }
29554     {
29555       \int_compare:nNnTF { '#2 } < { "E0 }
29556       { \_tl_change_case_char_UTFviii:nNNN {#1} #2 }
29557       {
29558         \int_compare:nNnTF { '#2 } < { "F0 }
29559         { \_tl_change_case_char_UTFviii:nNNNN {#1} #2 }
29560         { \_tl_change_case_char_UTFviii:nNNNNN {#1} #2 }
29561       }
29562     }
29563     {
29564       \_tl_change_case_output:fwn
29565       { \use:c { char_ #1 _case:N } #2 }
29566     }
29567   }
29568 }

```

To allow for the special case of mixed case, we insert here a action-dependent auxiliary.

```

29569 \bool_lazy_or:nnF
29570 { \sys_if_engine luatex_p: }
29571 { \sys_if_engine xetex_p: }
29572 {
29573   \cs_new:Npn \_tl_change_case_char_UTFviii:nNNN #1#2#3#4
29574   { \_tl_change_case_char_UTFviii:nnN {#1} {#2#4} #3 }
29575   \cs_new:Npn \_tl_change_case_char_UTFviii:nNNNN #1#2#3#4#5
29576   { \_tl_change_case_char_UTFviii:nnN {#1} {#2#4#5} #3 }
29577   \cs_new:Npn \_tl_change_case_char_UTFviii:nNNNNN #1#2#3#4#5#6
29578   { \_tl_change_case_char_UTFviii:nnN {#1} {#2#4#5#6} #3 }
29579   \cs_new:Npn \_tl_change_case_char_UTFviii:nnN #1#2#3
29580   {

```



```

29581     \cs_if_exist:cTF { c__tl_ #1 _case_ \tl_to_str:n {#2} _tl }
29582     {
29583         \__tl_change_case_output:wnn
29584         { c__tl_ #1 _case_ \tl_to_str:n {#2} _tl }
29585     }
29586     { \__tl_change_case_output:nwn {#2} }
29587     #3
29588 }
29589 }

```

Before dealing with general control sequences there are the special ones to deal with. Letter-like control sequences are a simple look-up, while for accents the loop is much as done elsewhere. Notice that we have a no-op test to make sure there is no unexpected expansion of letter-like input. The split into two parts here allows us to insert the “switch” code for mixed casing.

```

29590 \cs_new:Npn \__tl_change_case_cs_letterlike:Nn #1#2
29591 {
29592     \str_if_eq:nnTF {#2} { mixed }
29593     {
29594         \__tl_change_case_cs_letterlike:NnN #1 { upper }
29595         \__tl_change_case_mixed_switch:w
29596     }
29597     { \__tl_change_case_cs_letterlike:NnN #1 {#2} \prg_do_nothing: }
29598 }
29599 \cs_new:Npn \__tl_change_case_cs_letterlike:NnN #1#2#3
29600 {
29601     \cs_if_exist:cTF { c__tl_change_case_ #2 _ \token_to_str:N #1 _tl }
29602     {
29603         \__tl_change_case_output:wnn
29604         { c__tl_change_case_ #2 _ \token_to_str:N #1 _tl }
29605         #3
29606     }
29607     {
29608         \cs_if_exist:cTF
29609         {
29610             c__tl_change_case_
29611             \str_if_eq:nnTF {#2} { lower } { upper } { lower }
29612             _ \token_to_str:N #1 _tl
29613         }
29614         {
29615             \__tl_change_case_output:nwn {#1}
29616             #3
29617         }
29618         {
29619             \exp_after:wN \__tl_change_case_cs_accents:NN
29620             \exp_after:wN #1 \l_tl_case_change_accents_tl
29621             \q_recursion_tail \q_recursion_stop
29622         }
29623     }
29624 }
29625 \cs_new:Npn \__tl_change_case_cs_accents:NN #1#2
29626 {
29627     \quark_if_recursion_tail_stop_do:Nn #2
29628     { \__tl_change_case_cs:N #1 }

```

```

29629 \str_if_eq:nnTF {#1} {#2}
29630 {
29631     \use_i_delimit_by_q_recursion_stop:nw
29632     { \_tl_change_case_output:nwn {#1} }
29633 }
29634 { \_tl_change_case_cs_accents:NN #1 }
29635 }

```

To deal with a control sequence there is first a need to test if it is on the list which indicate that case changing should be skipped. That's done using a loop as for the other special cases. If a hit is found then the argument is grabbed: that comes *after* the loop function which is therefore rearranged. In a L^AT_EX 2_ε context, `\protect` needs to be treated specially, to prevent expansion of the next token but output it without braces.

```

29636 \cs_new:Npn \_tl_change_case_cs:N #1
29637 {
29638     (*package)
29639     \str_if_eq:nnTF {#1} { \protect } { \_tl_change_case_protect:wNN }
29640     </package>
29641     \exp_after:wN \_tl_change_case_cs:NN
29642     \exp_after:wN #1 \l_tl_change_case_exclude_tl
29643     \q_recursion_tail \q_recursion_stop
29644 }
29645 \cs_new:Npn \_tl_change_case_cs:NN #1#2
29646 {
29647     \quark_if_recursion_tail_stop_do:Nn #2
29648     {
29649         \_tl_change_case_cs_expand:Nnw #1
29650         { \_tl_change_case_output:nwn {#1} }
29651     }
29652     \str_if_eq:nnTF {#1} {#2}
29653     {
29654         \use_i_delimit_by_q_recursion_stop:nw
29655         { \_tl_change_case_cs:NNn #1 }
29656     }
29657     { \_tl_change_case_cs:NN #1 }
29658 }
29659 \cs_new:Npn \_tl_change_case_cs:NNn #1#2#3
29660 {
29661     \_tl_change_case_output:nwn { #1 {#3} }
29662     #2
29663 }
29664 (*package)
29665 \cs_new:Npn \_tl_change_case_protect:wNN #1 \q_recursion_stop #2 #3
29666 { \_tl_change_case_output:nwn { \protect #3 } #2 }
29667 </package>

```

When a control sequence is not on the exclude list the other test if to see if it is expandable. Once again, if there is a hit then the loop function is grabbed as part of the clean-up and reinserted before the now expanded material. The test for expandability has to check for end-of-recursion as it is needed by the look-ahead code which might hit the end of the input. The test is done in two parts as `\bool_if:nTF` would choke if #1 was (!

```

29668 \cs_new:Npn \_tl_change_case_if_expandable:NTF #1
29669 {
29670     \token_if_expandable:NTF #1

```

```

29671     {
29672         \bool_lazy_any:nTF
29673         {
29674             { \token_if_eq_meaning_p:NN \q_recursion_tail #1 }
29675             { \token_if_protected_macro_p:N      #1 }
29676             { \token_if_protected_long_macro_p:N #1 }
29677         }
29678         { \use_ii:nn }
29679         { \use_i:nn }
29680     }
29681     { \use_ii:nn }
29682 }
29683 \cs_new:Npn \__tl_change_case_cs_expand:Nnw #1#2
29684 {
29685     \__tl_change_case_if_expandable:NTF #1
29686     { \__tl_change_case_cs_expand:NN #1 }
29687     { #2 }
29688 }
29689 \cs_new:Npn \__tl_change_case_cs_expand:NN #1#2
29690 { \exp_after:wN #2 #1 }

```

For mixed case, there is an additional list of exceptions to deal with: once that is sorted, we can move on back to the main loop.

```

29691 \cs_new:Npn \__tl_change_case_mixed_skip:N #1
29692 {
29693     \exp_after:wN \__tl_change_case_mixed_skip:NN
29694     \exp_after:wN #1 \l_tl_mixed_case_ignore_tl
29695     \q_recursion_tail \q_recursion_stop
29696 }
29697 \cs_new:Npn \__tl_change_case_mixed_skip:NN #1#2
29698 {
29699     \quark_if_recursion_tail_stop_do:nn {#2}
29700     { \__tl_change_case_char:nN { mixed } #1 }
29701     \int_compare:nNt { '#1 } = { '#2 }
29702     {
29703         \use_i_delimit_by_q_recursion_stop:nw
29704         {
29705             \__tl_change_case_output:nwn {#1}
29706             \__tl_change_case_mixed_skip_tidy:Nwn
29707         }
29708     }
29709     \__tl_change_case_mixed_skip:NN #1
29710 }
29711 \cs_new:Npn \__tl_change_case_mixed_skip_tidy:Nwn #1#2 \q_recursion_stop #3
29712 {
29713     \__tl_change_case_loop:wnn #2 \q_recursion_stop { mixed }
29714 }

```

Needed to switch from mixed to lower casing when we have found a first character in the former mode.

```

29715 \cs_new:Npn \__tl_change_case_mixed_switch:w
29716 #1 \__tl_change_case_loop:wnn #2 \q_recursion_stop #3
29717 {
29718     #1
29719     \__tl_change_case_loop:wnn #2 \q_recursion_stop { lower }

```

29720 }

(End definition for _tl_change_case:nnn and others.)

_tl_change_case_lower_sigma:Nnw If the current char is an upper case sigma, the a check is made on the next item in the input. If it is N-type and not a control sequence then there is a look-ahead phase.

_tl_change_case_lower_sigma:w 29721 \cs_new:Npn _tl_change_case_lower_sigma:Nnw #1#2#3#4 \q_recursion_stop
_tl_change_case_lower_sigma:Nw 29722 {
29723 \int_compare:nNnTF { '#1 } = { "03A3 }
29724 {
29725 _tl_change_case_output:fwn
29726 { _tl_change_case_lower_sigma:w #4 \q_recursion_stop }
29727 }
29728 {#2}
29729 #3 #4 \q_recursion_stop
29730 }
29731 \cs_new:Npn _tl_change_case_lower_sigma:w #1 \q_recursion_stop
29732 {
29733 \tl_if_head_is_N_type:nTF {#1}
29734 { _tl_change_case_lower_sigma:Nw #1 \q_recursion_stop }
29735 { \c_tl_final_sigma_tl }
29736 }
29737 \cs_new:Npn _tl_change_case_lower_sigma:Nw #1#2 \q_recursion_stop
29738 {
29739 _tl_change_case_if_expandable:NTF #1
29740 {
29741 \exp_after:wN _tl_change_case_lower_sigma:w #1
29742 #2 \q_recursion_stop
29743 }
29744 {
29745 \token_if_letter:NTF #1
29746 { \c_tl_std_sigma_tl }
29747 { \c_tl_final_sigma_tl }
29748 }
29749 }

Simply skip to the final step for upper casing.

29750 \cs_new_eq:NN _tl_change_case_upper_sigma:Nnw \use_ii:nn

(End definition for _tl_change_case_lower_sigma:Nnw and others.)

_tl_change_case_lower_tr:Nnw The Turkic languages need special treatment for dotted-i and dotless-i. The lower casing rule can be expressed in terms of searching first for either a dotless-I or a dotted-I. In the latter case the mapping is easy, but in the former there is a second stage search.

_tl_change_case_lower_tr_auxi:Nw 29751 \bool_lazy_or:nnTF
_tl_change_case_lower_tr_auxii:Nw 29752 { \sys_if_engine luatex_p: }
_tl_change_case_upper_tr:Nnw 29753 { \sys_if_engine xetex_p: }
_tl_change_case_lower_az:Nw 29754 {
_tl_change_case_upper_az:Nw 29755 \cs_new:Npn _tl_change_case_lower_tr:Nnw #1#2
29756 {
29757 \int_compare:nNnTF { '#1 } = { "0049 }
29758 { _tl_change_case_lower_tr_auxi:Nw }
29759 {
29760 \int_compare:nNnTF { '#1 } = { "0130 }
29761 { _tl_change_case_output:nwn { i } }
29762 }

```

29762         {#2}
29763     }
29764 }

```

After a dotless-I there may be a dot-above character. If there is then a dotted-i should be produced, otherwise output a dotless-i. When the combination is found both the dotless-I and the dot-above char have to be removed from the input, which is done by the `\use_i:nn` (it grabs `__tl_change_case_loop:wN` and the dot-above char and discards the latter).

```

29765 \cs_new:Npn \__tl_change_case_lower_tr_auxi:Nw #1#2 \q_recursion_stop
29766 {
29767     \tl_if_head_is_N_type:nTF {#2}
29768     { \__tl_change_case_lower_tr_auxii:Nw #2 \q_recursion_stop }
29769     { \__tl_change_case_output:Vwn \c__tl_dotless_i_tl }
29770     #1 #2 \q_recursion_stop
29771 }
29772 \cs_new:Npn \__tl_change_case_lower_tr_auxii:Nw #1#2 \q_recursion_stop
29773 {
29774     \__tl_change_case_if_expandable:NTF #1
29775     {
29776         \exp_after:wN \__tl_change_case_lower_tr_auxi:Nw #1
29777         #2 \q_recursion_stop
29778     }
29779     {
29780         \bool_lazy_or:nnTF
29781         { \token_if_cs_p:N #1 }
29782         { ! \int_compare_p:nNn { '#1 } = { "0307 } }
29783         { \__tl_change_case_output:Vwn \c__tl_dotless_i_tl }
29784         {
29785             \__tl_change_case_output:nwn { i }
29786             \use_i:nn
29787         }
29788     }
29789 }
29790 }

```

For 8-bit engines, dot-above is not available so there is a simple test for an upper-case I. Then we can look for the UTF-8 representation of an upper case dotted-I without the combining char. If it's not there, preserve the UTF-8 sequence as-is.

```

29791 {
29792     \cs_new:Npn \__tl_change_case_lower_tr:Nnw #1#2
29793     {
29794         \int_compare:nNnTF { '#1 } = { "0049 }
29795         { \__tl_change_case_output:Vwn \c__tl_dotless_i_tl }
29796         {
29797             \int_compare:nNnTF { '#1 } = { 196 }
29798             { \__tl_change_case_lower_tr_auxi:Nw #1 {#2} }
29799             {#2}
29800         }
29801     }
29802     \cs_new:Npn \__tl_change_case_lower_tr_auxi:Nw #1#2#3#4
29803     {
29804         \int_compare:nNnTF { '#4 } = { 176 }
29805         {

```

```

29806         \_tl_change_case_output:nwn { i }
29807         #3
29808     }
29809     {
29810         #2
29811         #3 #4
29812     }
29813 }
29814 }

```

Upper casing is easier: just one exception with no context.

```

29815 \cs_new:Npn \_tl_change_case_upper_tr:Nnw #1#2
29816 {
29817     \int_compare:nNnTF { '#1 } = { "0069 }
29818     { \_tl_change_case_output:Vwn \c__tl_dotted_I_tl }
29819     {#2}
29820 }

```

Straight copies.

```

29821 \cs_new_eq:NN \_tl_change_case_lower_az:Nnw \_tl_change_case_lower_tr:Nnw
29822 \cs_new_eq:NN \_tl_change_case_upper_az:Nnw \_tl_change_case_upper_tr:Nnw

```

(End definition for _tl_change_case_lower_tr:Nnw and others.)

_tl_change_case_lower_lt:Nnw
_tl_change_case_lower_lt:nNnw
_tl_change_case_lower_lt:nnw
_tl_change_case_lower_lt:Nw
_tl_change_case_lower_lt:NNw
_tl_change_case_upper_lt:Nnw
_tl_change_case_upper_lt:nnw
_tl_change_case_upper_lt:Nw
_tl_change_case_upper_lt:NNw

For Lithuanian, the issue to be dealt with is dots over lower case letters: these should be present if there is another accent. That means that there is some work to do when lower casing I and J. The first step is a simple match attempt: \c__tl_accents_lt_tl contains accented upper case letters which should gain a dot-above char in their lower case form. This is done using f-type expansion so only one pass is needed to find if it works or not. If there was no hit, the second stage is to check for I, J and I-ogonek, and if the current char is a match to look for a following accent.

```

29823 \cs_new:Npn \_tl_change_case_lower_lt:Nnw #1
29824 {
29825     \exp_args:Nf \_tl_change_case_lower_lt:nNnw
29826     { \str_case:nVF #1 \c__tl_accents_lt_tl \exp_stop_f: }
29827     #1
29828 }
29829 \cs_new:Npn \_tl_change_case_lower_lt:nNnw #1#2
29830 {
29831     \tl_if_blank:nTF {#1}
29832     {
29833         \exp_args:Nf \_tl_change_case_lower_lt:nnw
29834         {
29835             \int_case:nnF { '#2 }
29836             {
29837                 { "0049 } i
29838                 { "004A } j
29839                 { "012E } \c__tl_i_ogonek_tl
29840             }
29841             \exp_stop_f:
29842         }
29843     }
29844     {
29845         \_tl_change_case_output:nwn {#1}
29846         \use_none:n

```

```

29847     }
29848   }
29849   \cs_new:Npn \__tl_change_case_lower_lt:nnw #1#2
29850   {
29851     \tl_if_blank:nTF {#1}
29852     {#2}
29853     {
29854       \__tl_change_case_output:wnw {#1}
29855       \__tl_change_case_lower_lt:Nw
29856     }
29857   }

```

Grab the next char and see if it is one of the accents used in Lithuanian: if it is, add the dot-above char into the output.

```

29858   \cs_new:Npn \__tl_change_case_lower_lt:Nw #1#2 \q_recursion_stop
29859   {
29860     \tl_if_head_is_N_type:nT {#2}
29861     { \__tl_change_case_lower_lt:NNw }
29862     #1 #2 \q_recursion_stop
29863   }
29864   \cs_new:Npn \__tl_change_case_lower_lt:NNw #1#2#3 \q_recursion_stop
29865   {
29866     \__tl_change_case_if_expandable:NTF #2
29867     {
29868       \exp_after:wN \__tl_change_case_lower_lt:Nw \exp_after:wN #1 #2
29869       #3 \q_recursion_stop
29870     }
29871     {
29872       \bool_lazy_and:nnT
29873       { ! \token_if_cs_p:N #2 }
29874       {
29875         \bool_lazy_any_p:n
29876         {
29877           { \int_compare_p:nNn { '#2 } = { "0300 } }
29878           { \int_compare_p:nNn { '#2 } = { "0301 } }
29879           { \int_compare_p:nNn { '#2 } = { "0303 } }
29880         }
29881       }
29882       { \__tl_change_case_output:Vwn \c__tl_dot_above_tl }
29883       #1 #2#3 \q_recursion_stop
29884     }
29885   }

```

For upper casing, the test required is for a dot-above char after an I, J or I-ogonek. First a test for the appropriate letter, and if found a look-ahead and potentially one token dropped.

```

29886   \cs_new:Npn \__tl_change_case_upper_lt:Nnw #1
29887   {
29888     \exp_args:Nf \__tl_change_case_upper_lt:nnw
29889     {
29890       \int_case:nnF {'#1}
29891       {
29892         { "0069 } I
29893         { "006A } J
29894         { "012F } \c__tl_I_ogonek_tl

```

```

29895     }
29896     \exp_stop_f:
29897   }
29898 }
29899 \cs_new:Npn \__tl_change_case_upper_lt:nw #1#2
29900 {
29901   \tl_if_blank:nTF {#1}
29902     {#2}
29903     {
29904       \__tl_change_case_output:nwn {#1}
29905       \__tl_change_case_upper_lt:Nw
29906     }
29907 }
29908 \cs_new:Npn \__tl_change_case_upper_lt:Nw #1#2 \q_recursion_stop
29909 {
29910   \tl_if_head_is_N_type:nT {#2}
29911     { \__tl_change_case_upper_lt:NNw }
29912   #1 #2 \q_recursion_stop
29913 }
29914 \cs_new:Npn \__tl_change_case_upper_lt:NNw #1#2#3 \q_recursion_stop
29915 {
29916   \__tl_change_case_if_expandable:NTF #2
29917   {
29918     \exp_after:wN \__tl_change_case_upper_lt:Nw \exp_after:wN #1 #2
29919     #3 \q_recursion_stop
29920   }
29921   {
29922     \bool_lazy_and:nnTF
29923       { ! \token_if_cs_p:N #2 }
29924       { \int_compare_p:nNn { '#2 } = { "0307 } }
29925       { #1 }
29926       { #1 #2 }
29927     #3 \q_recursion_stop
29928   }
29929 }

```

(End definition for __tl_change_case_lower_lt:Nnw and others.)

__tl_change_case_upper_de-alt:Nnw

A simple alternative version for German.

```

29930 \cs_new:cpn { __tl_change_case_upper_de-alt:Nnw } #1#2
29931 {
29932   \int_compare:nNnTF { '#1 } = { 223 }
29933     { \__tl_change_case_output:Vwn \c__tl_upper_Eszett_tl }
29934     {#2}
29935 }

```

(End definition for __tl_change_case_upper_de-alt:Nnw.)

\c__tl_std_sigma_tl
\c__tl_final_sigma_tl
\c__tl_accents_lt_tl
\c__tl_dot_above_tl
\c__tl_upper_Eszett_tl

The above needs various special token lists containing pre-formed characters. This set are only available in Unicode engines, with no-op definitions for 8-bit use.

```

29936 \bool_lazy_or:nnTF
29937   { \sys_if_engine_luatex_p: }
29938   { \sys_if_engine_xetex_p: }
29939   {

```



```

29940 \group_begin:
29941 \cs_set:Npn \__tl_tmp:n #1
29942 { \char_generate:nn {#1} { \char_value_catcode:n {#1} } }
29943 \tl_const:Nx \c__tl_std_sigma_tl { \__tl_tmp:n { "03C3 } }
29944 \tl_const:Nx \c__tl_final_sigma_tl { \__tl_tmp:n { "03C2 } }
29945 \tl_const:Nx \c__tl_accents_lt_tl
29946 {
29947 \__tl_tmp:n { "00CC }
29948 {
29949 \__tl_tmp:n { "0069 }
29950 \__tl_tmp:n { "0307 }
29951 \__tl_tmp:n { "0300 }
29952 }
29953 \__tl_tmp:n { "00CD }
29954 {
29955 \__tl_tmp:n { "0069 }
29956 \__tl_tmp:n { "0307 }
29957 \__tl_tmp:n { "0301 }
29958 }
29959 \__tl_tmp:n { "0128 }
29960 {
29961 \__tl_tmp:n { "0069 }
29962 \__tl_tmp:n { "0307 }
29963 \__tl_tmp:n { "0303 }
29964 }
29965 }
29966 \tl_const:Nx \c__tl_dot_above_tl { \__tl_tmp:n { "0307 } }
29967 \tl_const:Nx \c__tl_upper_Eszett_tl { \__tl_tmp:n { "1E9E } }
29968 \group_end:
29969 }
29970 {
29971 \tl_const:Nn \c__tl_std_sigma_tl { }
29972 \tl_const:Nn \c__tl_final_sigma_tl { }
29973 \tl_const:Nn \c__tl_accents_lt_tl { }
29974 \tl_const:Nn \c__tl_dot_above_tl { }
29975 \tl_const:Nn \c__tl_upper_Eszett_tl { }
29976 }

```

(End definition for `\c__tl_std_sigma_tl` and others.)

`\c__tl_dotless_i_tl` For cases where there is an 8-bit option in the T1 font set up, a variant is provided in both cases.

```

\c__tl_dotted_I_tl
\c__tl_i_ogonek_tl
\c__tl_I_ogonek_tl
29977 \group_begin:
29978 \bool_lazy_or:nnTF
29979 { \sys_if_engine_luatex_p: }
29980 { \sys_if_engine_xetex_p: }
29981 {
29982 \cs_set_protected:Npn \__tl_tmp:w #1#2
29983 {
29984 \tl_const:Nx #1
29985 {
29986 \exp_after:wN \exp_after:wN \exp_after:wN
29987 \exp_not:N \char_generate:nn
29988 {"#2} { \char_value_catcode:n {"#2} }

```

```

29989     }
29990   }
29991 }
29992 {
29993   \cs_set_protected:Npn \__tl_tmp:w #1#2
29994   {
29995     \group_begin:
29996     \cs_set_protected:Npn \__tl_tmp:w ##1##2##3##4
29997     {
29998       \tl_const:Nx #1
29999       {
30000         \exp_after:wN \exp_after:wN \exp_after:wN
30001         \exp_not:N \char_generate:nn {##1} { 13 }
30002         \exp_after:wN \exp_after:wN \exp_after:wN
30003         \exp_not:N \char_generate:nn {##2} { 13 }
30004       }
30005     }
30006     \tl_set:Nx \l__tl_internal_a_tl
30007     { \char_codepoint_to_bytes:n {"#2} }
30008     \exp_after:wN \__tl_tmp:w \l__tl_internal_a_tl
30009   \group_end:
30010 }
30011 }
30012 \__tl_tmp:w \c__tl_dotless_i_tl { 0131 }
30013 \__tl_tmp:w \c__tl_dotted_I_tl { 0130 }
30014 \__tl_tmp:w \c__tl_i_ogonek_tl { 012F }
30015 \__tl_tmp:w \c__tl_I_ogonek_tl { 012E }
30016 \group_end:

```

(End definition for `\c__tl_dotless_i_tl` and others.)

For 8-bit engines we now need to define the case-change data for the multi-octet mappings. These need a list of what code points are doable in T1 so the list is hard coded (there's no saving in loading the mappings dynamically). All of the straight-forward ones have two octets, so that is taken as read.

```

30017 \group_begin:
30018   \bool_lazy_or:nnT
30019   { \sys_if_engine_pdftex_p: }
30020   { \sys_if_engine_uptex_p: }
30021   {
30022     \cs_set_protected:Npn \__tl_loop:nn #1#2
30023     {
30024       \quark_if_recursion_tail_stop:n {#1}
30025       \tl_set:Nx \l__tl_internal_a_tl
30026       {
30027         \char_codepoint_to_bytes:n {"#1}
30028         \char_codepoint_to_bytes:n {"#2}
30029       }
30030       \exp_after:wN \__tl_tmp:w \l__tl_internal_a_tl
30031       \__tl_loop:nn
30032     }
30033     \cs_set_protected:Npn \__tl_tmp:nnnn #1#2#3#4#5
30034     {
30035       \tl_const:cx
30036       {

```

```

30037         c__tl_ #1 _case_
30038         \char_generate:nn {#2} { 12 }
30039         \char_generate:nn {#3} { 12 }
30040         _tl
30041     }
30042     {
30043         \exp_after:wN \exp_after:wN \exp_after:wN
30044         \exp_not:N \char_generate:nn {#4} { 13 }
30045         \exp_after:wN \exp_after:wN \exp_after:wN
30046         \exp_not:N \char_generate:nn {#5} { 13 }
30047     }
30048 }
30049 \cs_set_protected:Npn \__tl_tmp:w #1#2#3#4#5#6#7#8
30050 {
30051     \tl_const:cx
30052     {
30053         c__tl_lower_case_
30054         \char_generate:nn {#1} { 12 }
30055         \char_generate:nn {#2} { 12 }
30056         _tl
30057     }
30058     {
30059         \exp_after:wN \exp_after:wN \exp_after:wN
30060         \exp_not:N \char_generate:nn {#5} { 13 }
30061         \exp_after:wN \exp_after:wN \exp_after:wN
30062         \exp_not:N \char_generate:nn {#6} { 13 }
30063     }
30064     \__tl_tmp:nnnn { upper } {#5} {#6} {#1} {#2}
30065     \__tl_tmp:nnnn { mixed } {#5} {#6} {#1} {#2}
30066 }
30067 \__tl_loop:nn
30068 { 00C0 } { 00E0 }
30069 { 00C2 } { 00E2 }
30070 { 00C3 } { 00E3 }
30071 { 00C4 } { 00E4 }
30072 { 00C5 } { 00E5 }
30073 { 00C6 } { 00E6 }
30074 { 00C7 } { 00E7 }
30075 { 00C8 } { 00E8 }
30076 { 00C9 } { 00E9 }
30077 { 00CA } { 00EA }
30078 { 00CB } { 00EB }
30079 { 00CC } { 00EC }
30080 { 00CD } { 00ED }
30081 { 00CE } { 00EE }
30082 { 00CF } { 00EF }
30083 { 00D0 } { 00F0 }
30084 { 00D1 } { 00F1 }
30085 { 00D2 } { 00F2 }
30086 { 00D3 } { 00F3 }
30087 { 00D4 } { 00F4 }
30088 { 00D5 } { 00F5 }
30089 { 00D6 } { 00F6 }
30090 { 00D8 } { 00F8 }

```

30091	{ 00D9 }	{ 00F9 }
30092	{ 00DA }	{ 00FA }
30093	{ 00DB }	{ 00FB }
30094	{ 00DC }	{ 00FC }
30095	{ 00DD }	{ 00FD }
30096	{ 00DE }	{ 00FE }
30097	{ 0100 }	{ 0101 }
30098	{ 0102 }	{ 0103 }
30099	{ 0104 }	{ 0105 }
30100	{ 0106 }	{ 0107 }
30101	{ 0108 }	{ 0109 }
30102	{ 010A }	{ 010B }
30103	{ 010C }	{ 010D }
30104	{ 010E }	{ 010F }
30105	{ 0110 }	{ 0111 }
30106	{ 0112 }	{ 0113 }
30107	{ 0114 }	{ 0115 }
30108	{ 0116 }	{ 0117 }
30109	{ 0118 }	{ 0119 }
30110	{ 011A }	{ 011B }
30111	{ 011C }	{ 011D }
30112	{ 011E }	{ 011F }
30113	{ 0120 }	{ 0121 }
30114	{ 0122 }	{ 0123 }
30115	{ 0124 }	{ 0125 }
30116	{ 0128 }	{ 0129 }
30117	{ 012A }	{ 012B }
30118	{ 012C }	{ 012D }
30119	{ 012E }	{ 012F }
30120	{ 0132 }	{ 0133 }
30121	{ 0134 }	{ 0135 }
30122	{ 0136 }	{ 0137 }
30123	{ 0139 }	{ 013A }
30124	{ 013B }	{ 013C }
30125	{ 013E }	{ 013F }
30126	{ 0141 }	{ 0142 }
30127	{ 0143 }	{ 0144 }
30128	{ 0145 }	{ 0146 }
30129	{ 0147 }	{ 0148 }
30130	{ 014A }	{ 014B }
30131	{ 014C }	{ 014D }
30132	{ 014E }	{ 014F }
30133	{ 0150 }	{ 0151 }
30134	{ 0152 }	{ 0153 }
30135	{ 0154 }	{ 0155 }
30136	{ 0156 }	{ 0157 }
30137	{ 0158 }	{ 0159 }
30138	{ 015A }	{ 015B }
30139	{ 015C }	{ 015D }
30140	{ 015E }	{ 015F }
30141	{ 0160 }	{ 0161 }
30142	{ 0162 }	{ 0163 }
30143	{ 0164 }	{ 0165 }
30144	{ 0168 }	{ 0169 }

```

30145     { 016A } { 016B }
30146     { 016C } { 016D }
30147     { 016E } { 016F }
30148     { 0170 } { 0171 }
30149     { 0172 } { 0173 }
30150     { 0174 } { 0175 }
30151     { 0176 } { 0177 }
30152     { 0178 } { 00FF }
30153     { 0179 } { 017A }
30154     { 017B } { 017C }
30155     { 017D } { 017E }
30156     { 01CD } { 01CE }
30157     { 01CF } { 01D0 }
30158     { 01D1 } { 01D2 }
30159     { 01D3 } { 01D4 }
30160     { 01E2 } { 01E3 }
30161     { 01E6 } { 01E7 }
30162     { 01E8 } { 01E9 }
30163     { 01EA } { 01EB }
30164     { 01F4 } { 01F5 }
30165     { 0218 } { 0219 }
30166     { 021A } { 021B }
30167     \q_recursion_tail ?
30168     \q_recursion_stop
30169     \cs_set_protected:Npn \__tl_tmp:w #1#2#3
30170     {
30171         \group_begin:
30172         \cs_set_protected:Npn \__tl_tmp:w ##1##2##3##4
30173         {
30174             \tl_const:cx
30175             {
30176                 c__tl_ #3 _case_
30177                 \char_generate:nn {##1} { 12 }
30178                 \char_generate:nn {##2} { 12 }
30179                 _tl
30180             }
30181             {#2}
30182         }
30183         \tl_set:Nx \l__tl_internal_a_tl
30184         { \char_codepoint_to_bytes:n { "#1 } }
30185         \exp_after:wN \__tl_tmp:w \l__tl_internal_a_tl
30186         \group_end:
30187     }
30188     \__tl_tmp:w { 00DF } { SS } { upper }
30189     \__tl_tmp:w { 00DF } { Ss } { mixed }
30190     \__tl_tmp:w { 0131 } { I } { upper }
30191 }
30192 \group_end:

```

The (fixed) look-up mappings for letter-like control sequences.

```

30193 \group_begin:
30194     \cs_set_protected:Npn \__tl_change_case_setup:NN #1#2
30195     {
30196         \quark_if_recursion_tail_stop:N #1
30197         \tl_const:cn { c__tl_change_case_lower_ \token_to_str:N #1 _tl }

```

```

30198         { #2 }
30199         \tl_const:cn { c__tl_change_case_upper_ \token_to_str:N #2 _tl }
30200         { #1 }
30201         \__tl_change_case_setup:NN
30202     }
30203     \__tl_change_case_setup:NN
30204     \AA \aa
30205     \AE \ae
30206     \DH \dh
30207     \DJ \dj
30208     \IJ \ij
30209     \L \l
30210     \NG \ng
30211     \O \o
30212     \OE \oe
30213     \SS \ss
30214     \TH \th
30215     \q_recursion_tail ?
30216     \q_recursion_stop
30217     \tl_const:cn { c__tl_change_case_upper_ \token_to_str:N \i _tl } { I }
30218     \tl_const:cn { c__tl_change_case_upper_ \token_to_str:N \j _tl } { J }
30219 \group_end:

```

\l_tl_case_change_accents_tl A list of accents to leave alone.

```

30220 \tl_new:N \l_tl_case_change_accents_tl
30221 \tl_set:Nn \l_tl_case_change_accents_tl
30222 { \" \' \. \^ \' \~ \c \H \k \r \t \u \v }

```

(End definition for \l_tl_case_change_accents_tl. This variable is documented on page 263.)

_tl_change_case_mixed_nl:Nnw For Dutch, there is a single look-ahead test for ij when title casing. If the appropriate letters are found, produce IJ and gobble the j/J.

```

\_tl_change_case_mixed_nl:Nw
\_tl_change_case_mixed_nl:Nnw
\_tl_change_case_mixed_nl:Nnw
30223 \cs_new:Npn \__tl_change_case_mixed_nl:Nnw #1
30224 {
30225     \bool_lazy_or:nnTF
30226     { \int_compare_p:nNn { '#1 } = { 'i } }
30227     { \int_compare_p:nNn { '#1 } = { 'I } }
30228     {
30229         \__tl_change_case_output:nwn { I }
30230         \__tl_change_case_mixed_nl:Nw
30231     }
30232 }
30233 \cs_new:Npn \__tl_change_case_mixed_nl:Nw #1#2 \q_recursion_stop
30234 {
30235     \tl_if_head_is_N_type:nT {#2}
30236     { \_tl_change_case_mixed_nl:Nnw }
30237     #1 #2 \q_recursion_stop
30238 }
30239 \cs_new:Npn \__tl_change_case_mixed_nl:NNw #1#2#3 \q_recursion_stop
30240 {
30241     \__tl_change_case_if_expandable:Ntf #2
30242     {
30243         \exp_after:wN \__tl_change_case_mixed_nl:Nw \exp_after:wN #1 #2
30244         #3 \q_recursion_stop

```

```

30245     }
30246     {
30247         \bool_lazy_and:nnTF
30248         { ! ( \token_if_cs_p:N #2 ) }
30249         {
30250             \bool_lazy_or_p:nn
30251             { \int_compare_p:nNn { '#2 } = { 'j } }
30252             { \int_compare_p:nNn { '#2 } = { 'J } }
30253         }
30254         {
30255             \__tl_change_case_output:nwn { J }
30256             #1
30257         }
30258         { #1 #2 }
30259         #3 \q_recursion_stop
30260     }
30261 }

```

(End definition for `__tl_change_case_mixed_n1:Nnw`, `__tl_change_case_mixed_n1:Nw`, and `__tl_change_case_mixed_n1:NNw`.)

`\l_tl_case_change_math_tl` The list of token pairs which are treated as math mode and so not case changed.

```

30262 \tl_new:N \l_tl_case_change_math_tl
30263 \*package
30264 \tl_set:Nn \l_tl_case_change_math_tl
30265 { $ $ \ ( \ ) }
30266 \*package

```

(End definition for `\l_tl_case_change_math_tl`. This variable is documented on page 262.)

`\l_tl_case_change_exclude_tl` The list of commands for which an argument is not case changed.

```

30267 \tl_new:N \l_tl_case_change_exclude_tl
30268 \*package
30269 \tl_set:Nn \l_tl_case_change_exclude_tl
30270 { \cite \ensuremath \label \ref }
30271 \*package

```

(End definition for `\l_tl_case_change_exclude_tl`. This variable is documented on page 262.)

`\l_tl_mixed_case_ignore_tl` Characters to skip over when finding the first letter in a word to be mixed cased.

```

30272 \tl_new:N \l_tl_mixed_case_ignore_tl
30273 \tl_set:Nx \l_tl_mixed_case_ignore_tl
30274 {
30275     ( % )
30276     [ % ]
30277     \cs_to_str:N \{ % \%
30278     '
30279     -
30280 }

```

(End definition for `\l_tl_mixed_case_ignore_tl`. This variable is documented on page 263.)

47.13.2 Building a token list

Between `\tl_build_begin:N <tl var>` and `\tl_build_end:N <tl var>`, the `<tl var>` has the structure

```
\exp_end: ... \exp_end: \__tl_build_last:NNn <assignment> <next tl>
{<left>} <right>
```

where `<right>` is not braced. The “data” it represents is `<left>` followed by the “data” of `<next tl>` followed by `<right>`. The `<next tl>` is a token list variable whose name is that of `<tl var>` followed by `'`. There are between 0 and 4 `\exp_end:` to keep track of when `<left>` and `<right>` should be put into the `<next tl>`. The `<assignment>` is `\cs_set_nopar:Npx` if the variable is local, and `\cs_gset_nopar:Npx` if it is global.

`\tl_build_begin:N` First construct the `<next tl>`: using a prime here conflicts with the usual `expl3` convention
`\tl_build_gbegin:N` but we need a name that can be derived from `#1` without any external data such as a
`__tl_build_begin:NN` counter. Empty that `<next tl>` and setup the structure. The local and global versions
`__tl_build_begin:NNN` only differ by a single function `\cs_(g)set_nopar:Npx` used for all assignments: this is
important because only that function is stored in the `<tl var>` and `<next tl>` for subsequent
assignments. In principle `__tl_build_begin:NNN` could use `\tl_(g)clear_new:N` to
empty `#1` and make sure it is defined, but logging the definition does not seem useful so
we just do `#3 #1 {}` to clear it locally or globally as appropriate.

```
30281 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
30282 \cs_new_protected:Npn \tl_build_begin:N #1
30283 { \__tl_build_begin:NN \cs_set_nopar:Npx #1 }
30284 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
30285 \cs_new_protected:Npn \tl_build_gbegin:N #1
30286 { \__tl_build_begin:NN \cs_gset_nopar:Npx #1 }
30287 \cs_new_protected:Npn \__tl_build_begin:NN #1#2
30288 { \exp_args:Nc \__tl_build_begin:NNN { \cs_to_str:N #2 ' } #2 #1 }
30289 \cs_new_protected:Npn \__tl_build_begin:NNN #1#2#3
30290 {
30291   #3 #1 { }
30292   #3 #2
30293   {
30294     \exp_not:n { \exp_end: \exp_end: \exp_end: \exp_end: }
30295     \exp_not:n { \__tl_build_last:NNn #3 #1 { } }
30296   }
30297 }
```

(End definition for `\tl_build_begin:N` and others. These functions are documented on page 265.)

`\tl_build_clear:N` The `begin` and `gbegin` functions already clear enough to make the token list variable
`\tl_build_gclear:N` effectively empty. Eventually the `begin` and `gbegin` functions should check that `#1'` is
empty or undefined, while the `clear` and `gclear` functions ought to empty `#1'`, `#1''`
and so on, similar to `\tl_build_end:N`. This only affects memory usage.

```
30298 \cs_new_eq:NN \tl_build_clear:N \tl_build_begin:N
30299 \cs_new_eq:NN \tl_build_gclear:N \tl_build_gbegin:N
```

(End definition for `\tl_build_clear:N` and `\tl_build_gclear:N`. These functions are documented on page 265.)

`\tl_build_put_right:Nn` Similar to `\tl_put_right:Nn`, but apply `\exp:w` to #1. Most of the time this just removes one `\exp_end:`. When there are none left, `__tl_build_last:NNn` is expanded instead.
`\tl_build_put_right:Nx` It resets the definition of the $\langle tl\ var \rangle$ by ending the `\exp_not:n` and the definition early.
`\tl_build_gput_right:Nn` Then it makes sure the $\langle next\ tl \rangle$ (its argument #1) is set-up and starts a new definition.
`\tl_build_gput_right:Nx` Then `__tl_build_put:nn` and `__tl_build_put:nw` place the $\langle left \rangle$ part of the original $\langle tl\ var \rangle$ as appropriate for the definition of the $\langle next\ tl \rangle$ (the $\langle right \rangle$ part is left in the right place without ever becoming a macro argument). We use `\exp_after:wN` rather than some `\exp_args:No` to avoid reading arguments that are likely very long token lists. We use `\cs_(g)set_nopar:Npx` rather than `\tl_(g)set:Nx` partly for the same reason and partly because the assignments are interrupted by brace tricks, which implies that the assignment does not simply set the token list to an x-expansion of the second argument.

```

30300 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
30301 \cs_new_protected:Npn \tl_build_put_right:Nn #1#2
30302 {
30303   \cs_set_nopar:Npx #1
30304   { \exp_after:wN \exp_not:n \exp_after:wN { \exp:w #1 #2 } }
30305 }
30306 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
30307 \cs_new_protected:Npn \tl_build_put_right:Nx #1#2
30308 {
30309   \cs_set_nopar:Npx #1
30310   { \exp_after:wN \exp_not:n \exp_after:wN { \exp:w #1 } #2 }
30311 }
30312 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
30313 \cs_new_protected:Npn \tl_build_gput_right:Nn #1#2
30314 {
30315   \cs_gset_nopar:Npx #1
30316   { \exp_after:wN \exp_not:n \exp_after:wN { \exp:w #1 #2 } }
30317 }
30318 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
30319 \cs_new_protected:Npn \tl_build_gput_right:Nx #1#2
30320 {
30321   \cs_gset_nopar:Npx #1
30322   { \exp_after:wN \exp_not:n \exp_after:wN { \exp:w #1 } #2 }
30323 }
30324 \cs_new_protected:Npn \__tl_build_last:NNn #1#2
30325 {
30326   \if_false: { { \fi:
30327     \exp_end: \exp_end: \exp_end: \exp_end: \exp_end:
30328     \__tl_build_last:NNn #1 #2 { }
30329   }
30330 }
30331 \if_meaning:w \c_empty_tl #2
30332   \__tl_build_begin:NN #1 #2
30333 \fi:
30334 #1 #2
30335 {
30336   \exp_after:wN \exp_not:n \exp_after:wN
30337   {
30338     \exp:w \if_false: } } \fi:
30339   \exp_after:wN \__tl_build_put:nn \exp_after:wN {#2}
30340 }
30341 \cs_new_protected:Npn \__tl_build_put:nn #1#2 { \__tl_build_put:nw {#2} #1 }

```

```

30342 \cs_new_protected:Npn \__tl_build_put:nw #1#2 \__tl_build_last:NNn #3#4#5
30343 { #2 \__tl_build_last:NNn #3 #4 { #1 #5 } }

```

(End definition for `\tl_build_put_right:Nn` and others. These functions are documented on page 266.)

```

\tl_build_put_left:Nn See \tl_build_put_right:Nn for all the machinery. We could easily provide \tl_-
\tl_build_put_left:Nx build_put_left_right:NNn, by just add the  $\langle right \rangle$  material after the  $\{ \langle left \rangle \}$  in the
\tl_build_gput_left:Nn x-expanding assignment.
\tl_build_gput_left:Nx
\__tl_build_put_left:NNn
30344 \__kernel_patch:nnNNpn { \__kernel_chk_var_local:N #1 } { }
30345 \cs_new_protected:Npn \tl_build_put_left:Nn #1
30346 { \__tl_build_put_left:NNn \cs_set_nopar:Npx #1 }
30347 \cs_generate_variant:Nn \tl_build_put_left:Nn { Nx }
30348 \__kernel_patch:nnNNpn { \__kernel_chk_var_global:N #1 } { }
30349 \cs_new_protected:Npn \tl_build_gput_left:Nn #1
30350 { \__tl_build_put_left:NNn \cs_gset_nopar:Npx #1 }
30351 \cs_generate_variant:Nn \tl_build_gput_left:Nn { Nx }
30352 \cs_new_protected:Npn \__tl_build_put_left:NNn #1#2#3
30353 {
30354   #1 #2
30355   {
30356     \exp_after:wN \exp_not:n \exp_after:wN
30357     {
30358       \exp:w \exp_after:wN \__tl_build_put:nn
30359       \exp_after:wN {#2} {#3}
30360     }
30361   }
30362 }

```

(End definition for `\tl_build_put_left:Nn`, `\tl_build_gput_left:Nn`, and `__tl_build_put_left:NNn`. These functions are documented on page 266.)

```

\tl_build_get:NN The idea is to expand the  $\langle tl var \rangle$  then the  $\langle next tl \rangle$  and so on, all within an x-expanding
\__tl_build_get:NNN assignment, and wrap as appropriate in \exp_not:n. The various  $\langle left \rangle$  parts are left in
\__tl_build_get:w the assignment as we go, which enables us to expand the  $\langle next tl \rangle$  at the right place. The
\__tl_build_get_end:w various  $\langle right \rangle$  parts are eventually picked up in one last \exp_not:n, with a brace trick
to wrap all the  $\langle right \rangle$  parts together.

```

```

30363 \cs_new_protected:Npn \tl_build_get:NN
30364 { \__tl_build_get:NNN \tl_set:Nx }
30365 \cs_new_protected:Npn \__tl_build_get:NNN #1#2#3
30366 { #1 #3 { \if_false: { \fi: \exp_after:wN \__tl_build_get:w #2 } } }
30367 \cs_new:Npn \__tl_build_get:w #1 \__tl_build_last:NNn #2#3#4
30368 {
30369   \exp_not:n {#4}
30370   \if_meaning:w \c_empty_tl #3
30371   \exp_after:wN \__tl_build_get_end:w
30372   \fi:
30373   \exp_after:wN \__tl_build_get:w #3
30374 }
30375 \cs_new:Npn \__tl_build_get_end:w #1#2#3
30376 { \exp_after:wN \exp_not:n \exp_after:wN { \if_false: } \fi: }

```

(End definition for `\tl_build_get:NN` and others. This function is documented on page 266.)

`\tl_build_end:N` Get the data then clear the *<next tl>* recursively until finding an empty one. It is perhaps
`\tl_build_gend:N` wasteful to repeatedly use `\cs_to_sr:N`. The local/global scope is checked by `\tl_-`
`__tl_build_end_loop:NN` `set:Nx` or `\tl_gset:Nx`.

```

30377 \cs_new_protected:Npn \tl_build_end:N #1
30378 {
30379   \__tl_build_get:NNN \tl_set:Nx #1 #1
30380   \exp_args:Nc \__tl_build_end_loop:NN { \cs_to_str:N #1 ' } \tl_clear:N
30381 }
30382 \cs_new_protected:Npn \tl_build_gend:N #1
30383 {
30384   \__tl_build_get:NNN \tl_gset:Nx #1 #1
30385   \exp_args:Nc \__tl_build_end_loop:NN { \cs_to_str:N #1 ' } \tl_gclear:N
30386 }
30387 \cs_new_protected:Npn \__tl_build_end_loop:NN #1#2
30388 {
30389   \if_meaning:w \c_empty_tl #1
30390     \exp_after:wN \use_none:nnnnnn
30391   \fi:
30392   #2 #1
30393   \exp_args:Nc \__tl_build_end_loop:NN { \cs_to_str:N #1 ' } #2
30394 }

```

(End definition for `\tl_build_end:N`, `\tl_build_gend:N`, and `__tl_build_end_loop:NN`. These functions are documented on page 266.)

47.13.3 Other additions to `\l3tl`

`\tl_range_braced:Nnn` For the braced version `__tl_range_braced:w` sets up `__tl_range_collect_braced:w`
`\tl_range_braced:cnn` which stores items one by one in an argument after the semicolon. The unbraced version
`\tl_range_braced:nnn` is almost identical. The version preserving braces and spaces starts by deleting spaces
`\tl_range_unbraced:Nnn` before the argument to avoid collecting them, and sets up `__tl_range_collect:nn`
`\tl_range_unbraced:cnn` with a first argument of the form `{ {<collected>} <tokens> }`, whose head is the collected
`\tl_range_unbraced:nnn` tokens and whose tail is what remains of the original token list. This form makes it easier
`__tl_range_braced:w` to move tokens to the *<collected>* tokens.

```

\__tl_range_collect_braced:w 30395 \cs_new:Npn \tl_range_braced:Nnn { \exp_args:No \tl_range_braced:nnn }
\__tl_range_unbraced:w       30396 \cs_generate_variant:Nn \tl_range_braced:Nnn { c }
\__tl_range_collect_unbraced:w 30397 \cs_new:Npn \tl_range_braced:nnn { \__tl_range:Nnnn \__tl_range_braced:w }
                             30398 \cs_new:Npn \tl_range_unbraced:Nnn
                             30399 { \exp_args:No \tl_range_unbraced:nnn }
                             30400 \cs_generate_variant:Nn \tl_range_unbraced:Nnn { c }
                             30401 \cs_new:Npn \tl_range_unbraced:nnn
                             30402 { \__tl_range:Nnnn \__tl_range_unbraced:w }
                             30403 \cs_new:Npn \__tl_range_braced:w #1 ; #2
                             30404 { \__tl_range_collect_braced:w #1 ; { } #2 }
                             30405 \cs_new:Npn \__tl_range_unbraced:w #1 ; #2
                             30406 { \__tl_range_collect_unbraced:w #1 ; { } #2 }
                             30407 \cs_new:Npn \__tl_range_collect_braced:w #1 ; #2#3
                             30408 {
                             30409   \if_int_compare:w #1 > 1 \exp_stop_f:
                             30410     \exp_after:wN \__tl_range_collect_braced:w
                             30411     \int_value:w \int_eval:n { #1 - 1 } \exp_after:wN ;
                             30412   \fi:
                             30413   { #2 {#3} }

```

```

30414 }
30415 \cs_new:Npn \__tl_range_collect_unbraced:w #1 ; #2#3
30416 {
30417   \if_int_compare:w #1 > 1 \exp_stop_f:
30418     \exp_after:wN \__tl_range_collect_unbraced:w
30419     \int_value:w \int_eval:n { #1 - 1 } \exp_after:wN ;
30420   \fi:
30421   { #2 #3 }
30422 }

```

(End definition for `\tl_range_braced:Nnn` and others. These functions are documented on page 265.)

47.14 Additions to `l3token`

`\c_catcode_active_space_tl` While `\char_generate:nm` can produce active characters in some engines it cannot in general. It would be possible to simply change the catcode of space but then the code would need to avoid all spaces, making it quite unreadable. Instead we use the primitive `\tex_lowercase:D` trick.

```

30423 \group_begin:
30424   \char_set_catcode_active:N *
30425   \char_set_lccode:nn { ' * } { ' \ }
30426   \tex_lowercase:D { \tl_const:Nn \c_catcode_active_space_tl { * } }
30427 \group_end:

```

(End definition for `\c_catcode_active_space_tl`. This variable is documented on page 266.)

```

30428 <@@=peek>

```

```

\l__peek_collect_tl

```

```

30429 \tl_new:N \l__peek_collect_tl

```

(End definition for `\l__peek_collect_tl`.)

`\peek_catcode_collect_inline:Nn`
`\peek_charcode_collect_inline:Nn`
`\peek_meaning_collect_inline:Nn`
`__peek_collect:NNn`
`__peek_collect_true:w`
`__peek_collect_remove:nw`
`__peek_collect:N`

Most of the work is done by `__peek_execute_branches_...`, which calls either `__peek_true:w` or `__peek_false:w` according to whether the next token `\l__peek_token` matches the search token (stored in `\l__peek_search_token` and `\l__peek_search_tl`). Here, in the true case we run `__peek_collect_true:w`, which generally calls `__peek_collect:N` to store the peeked token into `\l__peek_collect_tl`, except in special non-N-type cases (begin-group, end-group, or space), where a frozen token is stored. The true branch calls `__peek_execute_branches_...` to fetch more matching tokens. Once there are no more, `__peek_false_aux:n` closes the safe-align group and runs the user's inline code.

```

30430 \cs_new_protected:Npn \peek_catcode_collect_inline:Nn
30431   { \__peek_collect:NNn \__peek_execute_branches_catcode: }
30432 \cs_new_protected:Npn \peek_charcode_collect_inline:Nn
30433   { \__peek_collect:NNn \__peek_execute_branches_charcode: }
30434 \cs_new_protected:Npn \peek_meaning_collect_inline:Nn
30435   { \__peek_collect:NNn \__peek_execute_branches_meaning: }
30436 \cs_new_protected:Npn \__peek_collect:NNn #1#2#3
30437   {
30438     \group_align_safe_begin:
30439     \cs_set_eq:NN \l__peek_search_token #2
30440     \tl_set:Nn \l__peek_search_tl {#2}
30441     \tl_clear:N \l__peek_collect_tl

```

```

30442 \cs_set:Npn \__peek_false:w
30443 { \exp_args:No \__peek_false_aux:n \l__peek_collect_tl }
30444 \cs_set:Npn \__peek_false_aux:n ##1
30445 {
30446   \group_align_safe_end:
30447   #3
30448 }
30449 \cs_set_eq:NN \__peek_true:w \__peek_collect_true:w
30450 \cs_set:Npn \__peek_true_aux:w { \peek_after:Nw #1 }
30451 \__peek_true_aux:w
30452 }
30453 \cs_new_protected:Npn \__peek_collect_true:w
30454 {
30455   \if_case:w
30456     \if_catcode:w \exp_not:N \l_peek_token { 1 \exp_stop_f: \fi:
30457     \if_catcode:w \exp_not:N \l_peek_token } 2 \exp_stop_f: \fi:
30458     \if_meaning:w \l_peek_token \c_space_token 3 \exp_stop_f: \fi:
30459     0 \exp_stop_f:
30460     \exp_after:wN \__peek_collect:N
30461   \or: \__peek_collect_remove:nw { \c_group_begin_token }
30462   \or: \__peek_collect_remove:nw { \c_group_end_token }
30463   \or: \__peek_collect_remove:nw { ~ }
30464   \fi:
30465 }
30466 \cs_new_protected:Npn \__peek_collect:N #1
30467 {
30468   \tl_put_right:Nn \l__peek_collect_tl {#1}
30469   \__peek_true_aux:w
30470 }
30471 \cs_new_protected:Npn \__peek_collect_remove:nw #1
30472 {
30473   \tl_put_right:Nn \l__peek_collect_tl {#1}
30474   \exp_after:wN \__peek_true_remove:w
30475 }

```

(End definition for \peek_catcode_collect_inline:Nn and others. These functions are documented on page 267.)

```

30476 </initex | package>

```

48 l3deprecation implementation

```

30477 (*initex | package>
30478 <@@=deprecation>

```

48.1 Helpers and variables

`\l_deprecation_grace_period_bool` This is set to `true` when the deprecated command that is being defined is in its grace period, meaning between the time it becomes an error by default and the time 6 months later where even `undo-recent-deprecations` stops restoring it.

```

30479 \bool_new:N \l__deprecation_grace_period_bool

```

(End definition for \l__deprecation_grace_period_bool.)

`_deprecation_date_compare:nNnTF` Expects #1 and #3 to be dates in the format YYYY-MM-DD (but accepts YYYY or YYYY-MM too, filling in zeros for the missing data). Compares them using #2 (one of <, =, >).

```

30480 \cs_new:Npn \_deprecation_date_compare:nNnTF #1#2#3
30481 { \_deprecation_date_compare_aux:w #1 -0-0- \q_mark #2 #3 -0-0- \q_stop }
30482 \cs_new:Npn \_deprecation_date_compare_aux:w
30483 #1 - #2 - #3 - #4 \q_mark #5 #6 - #7 - #8 - #9 \q_stop
30484 {
30485   \int_compare:nNnTF {#1} = {#6}
30486   {
30487     \int_compare:nNnTF {#2} = {#7}
30488     { \int_compare:nNnTF {#3} #5 {#8} }
30489     { \int_compare:nNnTF {#2} #5 {#7} }
30490   }
30491   { \int_compare:nNnTF {#1} #5 {#6} }
30492 }

```

(End definition for `_deprecation_date_compare:nNnTF` and `_deprecation_date_compare_aux:w`.)

`_deprecation_not_yet_deprecated:nTF` Receives a deprecation $\langle date \rangle$ and runs the `true` (`false`) branch if the `expl3` date is earlier (later) than $\langle date \rangle$. If `undo-recent-deprecations` is used we subtract 6 months to the `expl3` date (equivalently add 6 months to the $\langle date \rangle$). In addition, if the `expl3` date is between $\langle date \rangle$ and $\langle date \rangle$ plus 6 months, `\l__deprecation_grace_period_bool` is set to `true`, otherwise `false`.

```

30493 \cs_new_protected:Npn \_deprecation_not_yet_deprecated:nTF #1
30494 {
30495   \bool_set_false:N \l__deprecation_grace_period_bool
30496   \exp_args:No \_deprecation_date_compare:nNnTF { \ExplLoaderFileDate } < {#1}
30497   { \use_i:nn }
30498   {
30499     \exp_args:Nf \_deprecation_date_compare:nNnTF
30500     {
30501       \exp_after:wN \_deprecation_minus_six_months:w
30502       \ExplLoaderFileDate -0-0- \q_stop
30503     } < {#1}
30504     {
30505       \bool_set_true:N \l__deprecation_grace_period_bool
30506       \bool_if:NTF \l@expl@undo@recent@deprecations@bool
30507     }
30508     { \use_ii:nn }
30509   }
30510 }
30511 \cs_new:Npn \_deprecation_minus_six_months:w #1 - #2 - #3 - #4 \q_stop
30512 {
30513   \int_compare:nNnTF {#2} > 6
30514   { #1 - \int_eval:n { #2 - 6 } - #3 }
30515   { \int_eval:n { #1 - 1 } - \int_eval:n { #2 + 6 } - #3 }
30516 }

```

(End definition for `_deprecation_not_yet_deprecated:nTF` and `_deprecation_minus_six_months:w`.)

48.2 Patching definitions to deprecate

```
\__kernel_patch_deprecation:nnNNpn {<date>} {<replacement>} <definition>
<function> <parameters> {<code>}
```

defines the *<function>* to produce a warning and run its *<code>*, or to produce an error and not run any *<code>*, depending on the `expl3` date.

- If the `expl3` date is less than the *<date>* (plus 6 months in case `undo-recent-deprecations` is used) then we define the *<function>* to produce a warning and run its code. The warning is actually suppressed in two cases:
 - if neither `undo-recent-deprecations` nor `enable-debug` are in effect we may be in an end-user’s document so it is suppressed;
 - if the command is expandable then we cannot produce a warning.
- Otherwise, we define the *<function>* to produce an error.

In both cases we additionally make `\debug_on:n {deprecation}` turn the *<function>* into an `\outer` error, and `\debug_off:n {deprecation}` restore whatever the behaviour was without `\debug_on:n {deprecation}`.

In later sections we use the `l3doc` key `deprecated` with a date equal to that *<date>* plus 6 months, so that `l3doc` will complain if we forget to remove the stale *<parameters>* and *<code>*).

In the explanations below, *<definition>* *<function>* *<parameters>* *<code>* or assignments that only differ in the scope of the *<definition>* will be called “the standard definition”.

```
\__kernel_patch_deprecation:nnNNpn (The parameter text is grabbed using #5#.) The arguments of \__kernel_deprecation_
\__deprecation_patch_aux:nnNNnn code:nn are run upon \debug_on:n {deprecation} and \debug_off:n {deprecation},
\__deprecation_warn_once:nnNnn respectively. In both scenarios we the <function> may be \outer so we undefine it with
\__deprecation_patch_aux:Nn \tex_let:D before redefining it, with \__kernel_deprecation_error:Nnn or with some
\__deprecation_just_error:nnNN code added shortly.
```

Then check the date (taking into account `undo-recent-deprecations`) to see if the command should be deprecated right away (`false` branch of `__deprecation_not_yet_deprecated:nTF`), in which case `__deprecation_just_error:nnNN` makes *<function>* into an error (not `\outer`), ignoring its *<parameters>* and *<code>* completely.

Otherwise distinguish cases where we should give a warning from those where we shouldn’t: warnings can only happen for protected commands, and we only want them if either `undo-recent-deprecations` or `enable-debug` is in force, not for standard users.

```
30517 \cs_new_protected:Npn \__kernel_patch_deprecation:nnNNpn #1#2#3#4#5#
30518 { \__deprecation_patch_aux:nnNNnn {#1} {#2} #3 #4 {#5} }
30519 \cs_new_protected:Npn \__deprecation_patch_aux:nnNNnn #1#2#3#4#5#6
30520 {
30521   \__kernel_deprecation_code:nn
30522   {
30523     \tex_let:D #4 \scan_stop:
30524     \__kernel_deprecation_error:Nnn #4 {#2} {#1}
30525   }
30526   { \tex_let:D #4 \scan_stop: }
30527   \__deprecation_not_yet_deprecated:nTF {#1}
30528   {
30529     \bool_if:nTF
```

```

30530     {
30531         \cs_if_eq_p:NN #3 \cs_new_protected:Npn &&
30532         \__kernel_if_debug:TF
30533         { \c_true_bool } { \l@expl@undo@recent@deprecations@bool }
30534     }
30535     { \__deprecation_warn_once:nnNnn {#1} {#2} #4 {#5} {#6} }
30536     { \__deprecation_patch_aux:Nn #3 { #4 #5 {#6} } }
30537 }
30538 { \__deprecation_just_error:nnNN {#1} {#2} #3 #4 }
30539 }

```

In case we want a warning, the $\langle function \rangle$ is defined to produce such a warning without grabbing any argument, then redefine itself to the standard definition that the $\langle function \rangle$ should have, with arguments, and call that definition. The x -type expansion and $\backslash\exp_not:n$ avoid needing to double the #, which we could not do anyways. We then deal with the code for $\backslash\debug_off:n \{deprecation\}$: presumably someone doing that does not need the warning so we simply do the standard definition.

```

30540 \cs_new_protected:Npn \__deprecation_warn_once:nnNnn #1#2#3#4#5
30541 {
30542     \cs_new_protected:Npx #3
30543     {
30544         \__kernel_if_debug:TF
30545         {
30546             \exp_not:N \__kernel_msg_warning:nnxxx
30547             { kernel } { deprecated-command }
30548             {#1}
30549             { \token_to_str:N #3 }
30550             { \tl_to_str:n {#2} }
30551         }
30552         { }
30553         \exp_not:n { \cs_gset_protected:Npn #3 #4 {#5} }
30554         \exp_not:N #3
30555     }
30556     \__kernel_deprecation_code:nn { }
30557     { \cs_set_protected:Npn #3 #4 {#5} }
30558 }

```

In case we want neither warning nor error, the $\langle function \rangle$ is given its standard definition. Here #1 is $\backslash\cs_new:Npn$ or $\backslash\cs_new_protected:Npn$ and #2 is $\langle function \rangle \langle parameters \rangle \{ \langle code \rangle \}$, so #1#2 performs the assignment. For $\backslash\debug_off:n \{deprecation\}$ we want to use the same assignment but with a different scope, hence the $\backslash\cs_if_eq:NNTF$ test.

```

30559 \cs_new_protected:Npn \__deprecation_patch_aux:Nn #1#2
30560 {
30561     #1 #2
30562     \cs_if_eq:NNTF #1 \cs_new_protected:Npn
30563     { \__kernel_deprecation_code:nn { } { \cs_set_protected:Npn #2 } }
30564     { \__kernel_deprecation_code:nn { } { \cs_set:Npn #2 } }
30565 }

```

Finally, if we want an error we reuse the same $\backslash__deprecation_patch_aux:Nn$ as the previous case. Indeed, we want $\backslash\debug_off:n \{deprecation\}$ to make the $\langle function \rangle$ into an error, just like it is by default. The error is expandable or not, and the last argument of the error message is empty or is `grace` to denote the case where we are in the 6 month grace period, in which case the error message is more detailed.


```

30566 \cs_new_protected:Npn \__deprecation_just_error:nnNN #1#2#3#4
30567 {
30568   \exp_args:NNx \__deprecation_patch_aux:Nn #3
30569   {
30570     \exp_not:N #4
30571     {
30572       \cs_if_eq:NNTF #3 \cs_new_protected:Npn
30573       { \exp_not:N \__kernel_msg_error:nnnnnn }
30574       { \exp_not:N \__kernel_msg_expandable_error:nnnnnn }
30575       { kernel } { deprecated-command }
30576       {#1}
30577       { \token_to_str:N #4 }
30578       { \tl_to_str:n {#2} }
30579       { \bool_if:NT \l_deprecation_grace_period_bool { grace } }
30580     }
30581   }
30582 }

```

(End definition for __kernel_patch_deprecation:nnNNpn and others.)

__kernel_deprecation_error:Nnn The \outer definition here ensures the command cannot appear in an argument. Use this auxiliary on all commands that have been removed since 2015.

```

30583 \cs_new_protected:Npn \__kernel_deprecation_error:Nnn #1#2#3
30584 {
30585   \tex_protected:D \tex_outer:D \tex_edef:D #1
30586   {
30587     \exp_not:N \__kernel_msg_expandable_error:nnnnn
30588     { kernel } { deprecated-command }
30589     { \tl_to_str:n {#3} } { \token_to_str:N #1 } { \tl_to_str:n {#2} }
30590     \exp_not:N \__kernel_msg_error:nnxxx
30591     { kernel } { deprecated-command }
30592     { \tl_to_str:n {#3} } { \token_to_str:N #1 } { \tl_to_str:n {#2} }
30593   }
30594 }

```

(End definition for __kernel_deprecation_error:Nnn.)

```

30595 \__kernel_msg_new:nnn { kernel } { deprecated-command }
30596 {
30597   '#2'~deprecated-on~#1.
30598   \tl_if_empty:nF {#3} { ~Use~'#3'. }
30599   \str_if_eq:nnT {#4} { grace }
30600   {
30601     \c_space_tl
30602     For~6~months~after~that~date~one~can~restore~a~deprecated~
30603     command~by~loading~the~expl3~package~with~the~option~
30604     'undo-recent-deprecations'.
30605   }
30606 }

```

48.3 Removed functions

_deprecation_old_protected:Nnn Short-hands for old commands whose definition does not matter anymore, i.e., commands
 __deprecation_old:Nnn past the grace period.

```

30607 \cs_new_protected:Npn \__deprecation_old_protected:Nnn #1#2#3
30608 {
30609     \__kernel_patch_deprecation:nnNNpn {#3} {#2}
30610     \cs_new_protected:Npn #1 { }
30611 }
30612 \cs_new_protected:Npn \__deprecation_old:Nnn #1#2#3
30613 {
30614     \__kernel_patch_deprecation:nnNNpn {#3} {#2}
30615     \cs_new:Npn #1 { }
30616 }
30617 \__deprecation_old:Nnn \box_resize:Nnn
30618 { \box_resize_to_wd_and_ht_plus_dp:Nnn } { 2019-01-01 }
30619 \__deprecation_old:Nnn \box_use_clear:N
30620 { \box_use_drop:N } { 2019-01-01 }
30621 \__deprecation_old:Nnn \c_job_name_tl
30622 { \c_sys_jobname_str } { 2017-01-01 }
30623 \__deprecation_old:Nnn \c_minus_one
30624 { -1 } { 2019-01-01 }
30625 \__deprecation_old:Nnn \dim_case:nnn
30626 { \dim_case:nnF } { 2015-07-14 }
30627 \__deprecation_old:Nnn \file_add_path:nN
30628 { \file_get_full_name:nN } { 2019-01-01 }
30629 \__deprecation_old_protected:Nnn \file_if_exist_input:nT
30630 { \file_if_exist:nT and~ \file_input:n } { 2018-03-05 }
30631 \__deprecation_old_protected:Nnn \file_if_exist_input:nTF
30632 { \file_if_exist:nT and~ \file_input:n } { 2018-03-05 }
30633 \__deprecation_old:Nnn \file_list:
30634 { \file_log_list: } { 2019-01-01 }
30635 \__deprecation_old:Nnn \file_path_include:n
30636 { \seq_put_right:Nn \l_file_search_path_seq } { 2019-01-01 }
30637 \__deprecation_old:Nnn \file_path_remove:n
30638 { \seq_remove_all:Nn \l_file_search_path_seq } { 2019-01-01 }
30639 \__deprecation_old:Nnn \g_file_current_name_tl
30640 { \g_file_curr_name_str } { 2019-01-01 }
30641 \__deprecation_old:Nnn \int_case:nnn
30642 { \int_case:nnF } { 2015-07-14 }
30643 \__deprecation_old:Nnn \int_from_binary:n
30644 { \int_from_bin:n } { 2016-01-05 }
30645 \__deprecation_old:Nnn \int_from_hexadecimal:n
30646 { \int_from_hex:n } { 2016-01-05 }
30647 \__deprecation_old:Nnn \int_from_octal:n
30648 { \int_from_oct:n } { 2016-01-05 }
30649 \__deprecation_old:Nnn \int_to_binary:n
30650 { \int_to_bin:n } { 2016-01-05 }
30651 \__deprecation_old:Nnn \int_to_hexadecimal:n
30652 { \int_to_hex:n } { 2016-01-05 }
30653 \__deprecation_old:Nnn \int_to_octal:n
30654 { \int_to_oct:n } { 2016-01-05 }
30655 \__deprecation_old_protected:Nnn \ior_get_str:NN
30656 { \ior_str_get:NN } { 2018-03-05 }
30657 \__deprecation_old:Nnn \ior_list_streams:
30658 { \ior_show_list: } { 2019-01-01 }
30659 \__deprecation_old:Nnn \ior_log_streams:
30660 { \ior_log_list: } { 2019-01-01 }

```

```

30661 \_deprecation\_old:Nnn \iow\_list\_streams:
30662   { \iow\_show\_list: } { 2019-01-01 }
30663 \_deprecation\_old:Nnn \iow\_log\_streams:
30664   { \iow\_log\_list: } { 2019-01-01 }
30665 \_deprecation\_old:Nnn \luatex\_if\_engine\_p:
30666   { \sys\_if\_engine\_luatex\_p: } { 2017-01-01 }
30667 \_deprecation\_old:Nnn \luatex\_if\_engine:F
30668   { \sys\_if\_engine\_luatex:F } { 2017-01-01 }
30669 \_deprecation\_old:Nnn \luatex\_if\_engine:T
30670   { \sys\_if\_engine\_luatex:T } { 2017-01-01 }
30671 \_deprecation\_old:Nnn \luatex\_if\_engine:TF
30672   { \sys\_if\_engine\_luatex:TF } { 2017-01-01 }
30673 \_deprecation\_old:Nnn \pdf\_if\_engine\_p:
30674   { \sys\_if\_engine\_pdf\_tex\_p: } { 2017-01-01 }
30675 \_deprecation\_old:Nnn \pdf\_if\_engine:F
30676   { \sys\_if\_engine\_pdf\_tex:F } { 2017-01-01 }
30677 \_deprecation\_old:Nnn \pdf\_if\_engine:T
30678   { \sys\_if\_engine\_pdf\_tex:T } { 2017-01-01 }
30679 \_deprecation\_old:Nnn \pdf\_if\_engine:TF
30680   { \sys\_if\_engine\_pdf\_tex:TF } { 2017-01-01 }
30681 \_deprecation\_old:Nnn \prop\_get:cn
30682   { \prop\_item:cn } { 2016-01-05 }
30683 \_deprecation\_old:Nnn \prop\_get:Nn
30684   { \prop\_item:Nn } { 2016-01-05 }
30685 \_deprecation\_old:Nnn \quark\_if\_recursion\_tail\_break:N
30686   { } { 2015-07-14 }
30687 \_deprecation\_old:Nnn \quark\_if\_recursion\_tail\_break:n
30688   { } { 2015-07-14 }
30689 \_deprecation\_old:Nnn \scan\_align\_safe\_stop:
30690   { protected-commands } { 2017-01-01 }
30691 \_deprecation\_old:Nnn \sort\_ordered:
30692   { \sort\_return\_same: } { 2019-01-01 }
30693 \_deprecation\_old:Nnn \sort\_reversed:
30694   { \sort\_return\_swapped: } { 2019-01-01 }
30695 \_deprecation\_old:Nnn \str\_case:nnn
30696   { \str\_case:nnF } { 2015-07-14 }
30697 \_deprecation\_old:Nnn \str\_case:onnn
30698   { \str\_case:onF } { 2015-07-14 }
30699 \_deprecation\_old:Nnn \str\_case\_x:nnn
30700   { \str\_case\_e:nnF } { 2015-07-14 }
30701 \_deprecation\_old:Nnn \tl\_case:cn
30702   { \tl\_case:cnF } { 2015-07-14 }
30703 \_deprecation\_old:Nnn \tl\_case:Nnn
30704   { \tl\_case:NnF } { 2015-07-14 }
30705 \_deprecation\_old\_protected:Nnn \tl\_to\_lowercase:n
30706   { \tex\_lowercase:D } { 2018-03-05 }
30707 \_deprecation\_old\_protected:Nnn \tl\_to\_uppercase:n
30708   { \tex\_uppercase:D } { 2018-03-05 }
30709 \_deprecation\_old:Nnn \token\_new:Nn
30710   { \cs\_new\_eq:NN } { 2019-01-01 }
30711 \_deprecation\_old:Nnn \xetex\_if\_engine\_p:
30712   { \sys\_if\_engine\_xetex\_p: } { 2017-01-01 }
30713 \_deprecation\_old:Nnn \xetex\_if\_engine:F
30714   { \sys\_if\_engine\_xetex:F } { 2017-01-01 }

```

```

30715 \__deprecation_old:Nnn \xetex_if_engine:T
30716 { \sys_if_engine_xetex:T } { 2017-01-01 }
30717 \__deprecation_old:Nnn \xetex_if_engine:TF
30718 { \sys_if_engine_xetex:TF } { 2017-01-01 }

```

(End definition for __deprecation_old_protected:Nnn and __deprecation_old:Nnn.)

48.4 Deprecated primitives

```

\etex_beginL:D
\__deprecation_primitive:NN
\__deprecation_primitive:w

```

We renamed all primitives to `\tex_...:D` so all others are deprecated. In `l3names`, `__kernel_primitives:` is defined to contain `__kernel_primitive:NN \beginL \etex_beginL:D` and so on, one for each deprecated primitive. We apply `\exp_not:N` to the second argument of `__kernel_primitive:NN` because it may be outer (both when doing and undoing deprecation actually), then `__deprecation_primitive:NN` uses `\tex_let:D` to change the meaning of this potentially outer token. Then, either turn it into an error or make it equal to the primitive `#1`. To be more precise, `#1` may not be defined, so try a `\tex_...:D` command as well.

```

30719 \cs_new_protected:Npn \__deprecation_primitive:NN #1#2 { }
30720 \exp_last_unbraced:NNNNo
30721 \cs_new:Npn \__deprecation_primitive:w #1 { \token_to_str:N _ } { }
30722 \__kernel_deprecation_code:nn
30723 {
30724   \cs_set_protected:Npn \__kernel_primitive:NN #1
30725   {
30726     \exp_after:wN \__deprecation_primitive:NN
30727     \exp_after:wN #1
30728     \exp_not:N
30729   }
30730   \cs_set_protected:Npn \__deprecation_primitive:NN #1#2
30731   {
30732     \tex_let:D #2 \scan_stop:
30733     \exp_args:NNx \__kernel_deprecation_error:Nnn #2
30734     {
30735       \iow_char:N \
30736       \cs_if_exist:NTF #1
30737       { \cs_to_str:N #1 }
30738       {
30739         tex_
30740         \exp_last_unbraced:Nf
30741         \__deprecation_primitive:w { \cs_to_str:N #2 }
30742       }
30743     }
30744     { 2020-01-01 }
30745   }
30746   \__kernel_primitives:
30747 }
30748 {
30749   \cs_set_protected:Npn \__kernel_primitive:NN #1
30750   {
30751     \exp_after:wN \__deprecation_primitive:NN
30752     \exp_after:wN #1
30753     \exp_not:N
30754   }

```

```

30755 \cs_set_protected:Npn \__deprecation_primitive:NN #1#2
30756 {
30757   \tex_let:D #2 #1
30758   \cs_if_exist:cT { tex_ \cs_to_str:N #1 :D }
30759   { \cs_set_eq:Nc #2 { tex_ \cs_to_str:N #1 :D } }
30760 }
30761 \__kernel_primitives:
30762 }

```

(End definition for `\etex_beginL:D`, `__deprecation_primitive:NN`, and `__deprecation_primitive:w.`)

48.5 Deprecated `\box` functions

```

\box_set_eq_clear:NN
\box_set_eq_clear:cN
\box_set_eq_clear:Nc
\box_set_eq_clear:cc
\box_gset_eq_clear:NN
\box_gset_eq_clear:cN
\box_gset_eq_clear:Nc
\box_gset_eq_clear:cc
30763 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \box_set_eq_drop:N }
30764 \cs_new_protected:Npn \box_set_eq_clear:NN #1#2
30765 { \tex_setbox:D #1 \tex_box:D #2 }
30766 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \box_gset_eq_drop:N }
30767 \cs_new_protected:Npn \box_gset_eq_clear:NN #1#2
30768 { \tex_global:D \tex_setbox:D #1 \tex_box:D #2 }
30769 \cs_generate_variant:Nn \box_set_eq_clear:NN { c , Nc , cc }
30770 \cs_generate_variant:Nn \box_gset_eq_clear:NN { c , Nc , cc }

```

(End definition for `\box_set_eq_clear:NN` and `\box_gset_eq_clear:NN.`)

```

\hbox_unpack_clear:N
\hbox_unpack_clear:c
30771 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \hbox_unpack_drop:N }
30772 \cs_new_protected:Npn \hbox_unpack_clear:N
30773 { \hbox_unpack_drop:N }
30774 \cs_generate_variant:Nn \hbox_unpack_clear:N { c }

```

(End definition for `\hbox_unpack_clear:N.`)

```

\vbox_unpack_clear:N
\vbox_unpack_clear:c
30775 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \vbox_unpack_drop:N }
30776 \cs_new_protected:Npn \vbox_unpack_clear:N
30777 { \vbox_unpack_drop:N }
30778 \cs_generate_variant:Nn \vbox_unpack_clear:N { c }

```

(End definition for `\vbox_unpack_clear:N.`)

48.6 Deprecated `\int` functions

30779 `\@@=int`)

`\c_zero` Constants that are now deprecated. By default define them with `\int_const:Nn`.
`\c_one` To deprecate them call for instance `__kernel_deprecation_error:Nnn \c_zero {0}`
`\c_two` `{2020-01-01}`. To redefine them (locally), use `__int_constdef:Nw`, with an `\exp_`
`\c_three` `not:N` construction because the constants themselves are outer at that point.

```

\c_four 30780 \cs_new_protected:Npn \__int_deprecated_constants:nn #1#2
\c_five 30781 {
\c_six 30782 #1 \c_zero { 0 } #2
\c_seven 30783 #1 \c_one { 1 } #2
\c_eight 30784 #1 \c_two { 2 } #2
\c_nine 30785 #1 \c_three { 3 } #2
\c_ten
\c_eleven
\c_twelve
\c_thirteen
\c_fourteen
\c_fifteen
\c_sixteen
\c_thirty_two
\c_one_hundred
\c_two_hundred_fifty_five

```

```

30786      #1 \c_four           { 4 } #2
30787      #1 \c_five          { 5 } #2
30788      #1 \c_six           { 6 } #2
30789      #1 \c_seven         { 7 } #2
30790      #1 \c_eight         { 8 } #2
30791      #1 \c_nine          { 9 } #2
30792      #1 \c_ten           { 10 } #2
30793      #1 \c_eleven         { 11 } #2
30794      #1 \c_twelve        { 12 } #2
30795      #1 \c_thirteen      { 13 } #2
30796      #1 \c_fourteen      { 14 } #2
30797      #1 \c_fifteen       { 15 } #2
30798      #1 \c_sixteen       { 16 } #2
30799      #1 \c_thirty_two    { 32 } #2
30800      #1 \c_one_hundred    { 100 } #2
30801      #1 \c_two_hundred_fifty_five { 255 } #2
30802      #1 \c_two_hundred_fifty_six { 256 } #2
30803      #1 \c_one_thousand   { 1000 } #2
30804      #1 \c_ten_thousand   { 10000 } #2
30805    }
30806    \__int_deprecated_constants:nn { \int_const:Nn } { }
30807    \__kernel_deprecation_code:nn
30808    {
30809      \__int_deprecated_constants:nn
30810      { \exp_after:wN \__kernel_deprecation_error:Nnn \exp_not:N }
30811      { { 2020-01-01 } }
30812    }
30813    {
30814      \__int_deprecated_constants:nn
30815      {
30816        \exp_after:wN \use:nnn
30817        \exp_after:wN \__int_constdef:Nw \exp_not:N
30818      }
30819      { \exp_stop_f: }
30820    }

```

(End definition for \c_zero and others.)

__int_value:w Made public.

```

30821 \cs_new_eq:NN \__int_value:w \int_value:w

```

(End definition for __int_value:w.)

48.7 Deprecated l3luatex functions

```

30822 <@@=lua>

```

```

\lua_now_x:n
\lua_escape_x:n 30823 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \lua_now:e }
\lua_shipout_x:n 30824 \cs_new:Npn \lua_now_x:n #1 { \__lua_now:n {#1} }
30825 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \lua_escape:e }
30826 \cs_new:Npn \lua_escape_x:n #1 { \__lua_escape:n {#1} }
30827 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \lua_shipout_e:n }
30828 \cs_new_protected:Npn \lua_shipout_x:n #1 { \__lua_shipout:n {#1} }

```

(End definition for \lua_now_x:n, \lua_escape_x:n, and \lua_shipout_x:n.)

48.8 Deprecated l3msg functions

```

30829 <@@=msg>

\msg_log:n
\msg_term:n
30830 \__kernel_patch_deprecation:nnN\Npn { 2020-01-01 } { \iow_log:n }
30831 \cs_new_protected:Npn \msg_log:n #1
30832 {
30833   \iow_log:n { ..... }
30834   \iow_wrap:nnnN { . ~ #1 } { . ~ } { } \iow_log:n
30835   \iow_log:n { ..... }
30836 }
30837 \__kernel_patch_deprecation:nnN\Npn { 2020-01-01 } { \iow_term:n }
30838 \cs_new_protected:Npn \msg_term:n #1
30839 {
30840   \iow_term:n { ***** }
30841   \iow_wrap:nnnN { * ~ #1 } { * ~ } { } \iow_term:n
30842   \iow_term:n { ***** }
30843 }

```

(End definition for \msg_log:n and \msg_term:n.)

```

\msg_interrupt:nnn
30844 \__kernel_patch_deprecation:nnN\Npn { 2020-01-01 } { [Defined-error-message] }
30845 \cs_new_protected:Npn \msg_interrupt:nnn #1#2#3
30846 {
30847   \tl_if_empty:nTF {#3}
30848   {
30849     \__msg_old_interrupt_wrap:nn { \ \c__msg_no_info_text_tl }
30850     {#1 \ \ \ #2 \ \ \ \c__msg_continue_text_tl }
30851   }
30852   {
30853     \__msg_old_interrupt_wrap:nn { \ \ #3 }
30854     {#1 \ \ \ #2 \ \ \ \c__msg_help_text_tl }
30855   }
30856 }
30857 \cs_new_protected:Npn \__msg_old_interrupt_wrap:nn #1#2
30858 {
30859   \iow_wrap:nnnN {#1} { | ~ } { } \__msg_old_interrupt_more_text:n
30860   \iow_wrap:nnnN {#2} { ! ~ } { } \__msg_old_interrupt_text:n
30861 }
30862 \cs_new_protected:Npn \__msg_old_interrupt_more_text:n #1
30863 {
30864   \exp_args:Nx \tex_errhelp:D
30865   {
30866     |,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
30867     #1 \iow_newline:
30868     |.....
30869   }
30870 }
30871 \group_begin:
30872 \char_set_lccode:nn {'\} {'\ }
30873 \char_set_lccode:nn {'\} {'\ }
30874 \char_set_lccode:nn {'\& {'\!}
30875 \char_set_catcode_active:N \&

```

```

30876 \tex_lowercase:D
30877 {
30878   \group_end:
30879   \cs_new_protected:Npn \__msg_old_interrupt_text:n #1
30880   {
30881     \iow_term:x
30882     {
30883       \iow_newline:
30884       !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
30885       \iow_newline:
30886       !
30887     }
30888     \__kernel_iow_with:Nnn \tex_newlinechar:D { ‘^^J }
30889     {
30890       \__kernel_iow_with:Nnn \tex_errorcontextlines:D { -1 }
30891       {
30892         \group_begin:
30893         \cs_set_protected:Npn &
30894         {
30895           \tex_errmessage:D
30896           {
30897             #1
30898             \use_none:n
30899             { ..... }
30900           }
30901         }
30902         \exp_after:wN
30903         \group_end:
30904         &
30905       }
30906     }
30907   }
30908 }

```

(End definition for `\msg_interrupt:nnn`.)

48.9 Deprecated `l3prg` functions

30909 `<@@=prg>`

`__prg_break_point:Nn` Made public, but used by a few third-parties. It’s not possible to perfectly support a mixture of `__prg_map_break:Nn` and `\prg_map_break:Nn` because they use different delimiters. The following code only breaks if someone tries to break from two “old-style” `__prg_map_break:Nn` ... `__prg_break_point:Nn` mappings in one go. Basically, the `__prg_map_break:Nn` converts a single `__prg_break_point:Nn` to `\prg_break_point:Nn`, and that delimiter had better be the right one. Then we call `\prg_map_break:Nn` which may end up breaking intermediate looks in the (unbraced) argument #1. It is essential to define the `break_point` functions before the corresponding `break` functions: otherwise `\debug_on:n {deprecation}` `\debug_off:n {deprecation}` would break when trying to restore the definitions because they would involve deprecated commands whose definition has not yet been restored.

```

30910 \__kernel_patch_deprecation:nnNn { 2020-01-01 } { \prg_break_point:Nn }
30911 \cs_new:Npn \__prg_break_point:Nn { \prg_break_point:Nn }
30912 \__kernel_patch_deprecation:nnNn { 2020-01-01 } { \prg_break_point: }

```



```

30913 \cs_new:Npn \__prg_break_point: { \prg_break_point: }
30914 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \prg_map_break:Nn }
30915 \cs_new:Npn \__prg_map_break:Nn #1 \__prg_break_point:Nn
30916 { \prg_map_break:Nn #1 \prg_break_point:Nn }
30917 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \prg_break: }
30918 \cs_new:Npn \__prg_break: #1 \__prg_break_point: { }
30919 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \prg_break:n }
30920 \cs_new:Npn \__prg_break:n #1#2 \__prg_break_point: {#1}

```

(End definition for __prg_break_point:Nn and others.)

48.10 Deprecated l3str functions

```

\str_case_x:nn
\str_case_x:nnTF
\str_if_eq_x_p:nn
\str_if_eq_x:nnTF
30921 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_case_e:nn }
30922 \cs_new:Npn \str_case_x:nn { \str_case_e:nn }
30923 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_case_e:nnT }
30924 \cs_new:Npn \str_case_x:nnT { \str_case_e:nnT }
30925 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_case_e:nnF }
30926 \cs_new:Npn \str_case_x:nnF { \str_case_e:nnF }
30927 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_case_e:nnTF }
30928 \cs_new:Npn \str_case_x:nnTF { \str_case_e:nnTF }
30929 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_if_eq_p:ee }
30930 \cs_new:Npn \str_if_eq_x_p:nn { \str_if_eq_p:ee }
30931 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_if_eq:eeT }
30932 \cs_new:Npn \str_if_eq_x:nnT { \str_if_eq:eeT }
30933 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_if_eq:eeF }
30934 \cs_new:Npn \str_if_eq_x:nnF { \str_if_eq:eeF }
30935 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \str_if_eq:eeTF }
30936 \cs_new:Npn \str_if_eq_x:nnTF { \str_if_eq:eeTF }

```

(End definition for \str_case_x:nnTF and \str_if_eq_x:nnTF.)

48.10.1 Deprecated l3tl functions

```

30937 (@@=tl)

\tl_set_from_file:Nnn
\tl_set_from_file:cnn
30938 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \file_get:nnN }
\tl_gset_from_file:Nnn
30939 \cs_new_protected:Npn \tl_set_from_file:Nnn #1#2#3
\tl_gset_from_file:cnn
30940 { \file_get:nnN {#3} {#2} #1 }
\tl_set_from_file_x:Nnn
30941 \cs_generate_variant:Nn \tl_set_from_file:Nnn { c }
\tl_set_from_file_x:cnn
30942 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \file_get:nnN }
\tl_gset_from_file_x:Nnn
30943 \cs_new_protected:Npn \tl_gset_from_file:Nnn #1#2#3
\tl_gset_from_file_x:cnn
30944 {
30945   \group_begin:
30946     \file_get:nnN {#3} {#2} \l__tl_internal_a_tl
30947     \tl_gset_eq:NN #1 \l__tl_internal_a_tl
30948   \group_end:
30949 }
30950 \cs_generate_variant:Nn \tl_gset_from_file:Nnn { c }
30951 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \file_get:nnN }
30952 \cs_new_protected:Npn \tl_set_from_file_x:Nnn #1#2#3
30953 {
30954   \group_begin:

```

```

30955     \file_get:nnN {#3} {#2} \l__tl_internal_a_tl
30956     #2 \scan_stop:
30957     \tl_set:Nx \l__tl_internal_a_tl { \l__tl_internal_a_tl }
30958     \exp_args:NNNo \group_end:
30959     \tl_set:Nn #1 \l__tl_internal_a_tl
30960   }
30961   \cs_generate_variant:Nn \tl_set_from_file_x:Nnn { c }
30962   \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \file_get:nnN }
30963   \cs_new_protected:Npn \tl_gset_from_file_x:Nnn #1#2#3
30964   {
30965     \group_begin:
30966     \file_get:nnN {#3} {#2} \l__tl_internal_a_tl
30967     #2 \scan_stop:
30968     \tl_gset:Nx #1 { \l__tl_internal_a_tl }
30969     \group_end:
30970   }
30971   \cs_generate_variant:Nn \tl_gset_from_file_x:Nnn { c }

```

(End definition for `\tl_set_from_file:Nnn` and others.)

48.11 Deprecated `l3tl-analysis` functions

```

\tl_show_analysis:N Simple renames.
\tl_show_analysis:n
30972 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \tl_analysis_show:N }
30973 \cs_new_protected:Npn \tl_show_analysis:N { \tl_analysis_show:N }
30974 \__kernel_patch_deprecation:nnNNpn { 2020-01-01 } { \tl_analysis_show:n }
30975 \cs_new_protected:Npn \tl_show_analysis:n { \tl_analysis_show:n }

```

(End definition for `\tl_show_analysis:N` and `\tl_show_analysis:n`.)

48.12 Deprecated `l3token` functions

```

\token_get_prefix_spec:N
\token_get_arg_spec:N
\token_get_replacement_spec:N
30976 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \cs_prefix_spec:N }
30977 \cs_new:Npn \token_get_prefix_spec:N { \cs_prefix_spec:N }
30978 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \cs_argument_spec:N }
30979 \cs_new:Npn \token_get_arg_spec:N { \cs_argument_spec:N }
30980 \__kernel_patch_deprecation:nnNNpn { 2021-01-01 } { \cs_replacement_spec:N }
30981 \cs_new:Npn \token_get_replacement_spec:N { \cs_replacement_spec:N }

```

(End definition for `\token_get_prefix_spec:N`, `\token_get_arg_spec:N`, and `\token_get_replacement_spec:N`.)

```

30982 </initex | package>

```

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<code>\XeTeXuseglyphmetrics</code>	873, 1734	Y	
<code>\XeTeXvariation</code>	874, 1735	<code>\ybaselineshift</code>	1252, 2060
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<code>\XeTeXvariationmax</code>	876, 1737	<code>\yoko</code>	1253, 2061