

# The `calc` package

## Infix notation arithmetic in $\LaTeX^*$

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2017/05/25

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### Abstract

The `calc` package reimplements the  $\LaTeX$  commands `\setcounter`, `\addtocounter`, `\setlength`, and `\addtolength`. Instead of a simple value, these commands now accept an infix notation expression.

## 1 Introduction

Arithmetic in  $\TeX$  is done using low-level operations such as `\advance` and `\multiply`. This may be acceptable when developing a macro package, but it is not an acceptable interface for the end-user.

This package introduces proper infix notation arithmetic which is much more familiar to most people. The infix notation is more readable and easier to modify than the alternative: a sequence of assignment and arithmetic instructions. One of the arithmetic instructions (`\divide`) does not even have an equivalent in standard  $\LaTeX$ .

The infix expressions can be used in arguments to macros (the `calc` package doesn't employ category code changes to achieve its goals).<sup>1</sup>

## 2 Informal description

Standard  $\LaTeX$  provides the following set of commands to manipulate counters and lengths [2, pages 194 and 216].

`\setcounter{ctr}{num}` sets the value of the counter *ctr* equal to (the value of) *num*. (Fragile)

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\*We thank Frank Mittelbach for his valuable comments and suggestions which have greatly improved this package.

<sup>1</sup>However, it therefore assumes that the category codes of the special characters, such as `(*/)` in its syntax do not change.

`\addtocounter{ctr}{num}` increments the value of the counter *ctr* by (the value of) *num*. (Fragile)

`\setlength{cmd}{len}` sets the value of the length command *cmd* equal to (the value of) *len*. (Robust)

`\addtolength{cmd}{len}` sets the value of the length command *cmd* equal to its current value plus (the value of) *len*. (Robust)

(The `\setcounter` and `\addtocounter` commands have global effect, while the `\setlength` and `\addtolength` commands obey the normal scoping rules.) In standard L<sup>A</sup>T<sub>E</sub>X, the arguments to these commands must be simple values. The `calc` package extends these commands to accept infix notation expressions, denoting values of appropriate types. Using the `calc` package, *num* is replaced by  $\langle$ integer expression $\rangle$ , and *len* is replaced by  $\langle$ glue expression $\rangle$ . The formal syntax of  $\langle$ integer expression $\rangle$  and  $\langle$ glue expression $\rangle$  is given below.

In addition to these commands to explicitly set a length, many L<sup>A</sup>T<sub>E</sub>X commands take a length argument. After loading this package, most of these commands will accept a  $\langle$ glue expression $\rangle$ . This includes the optional width argument of `\makebox`, the width argument of `\parbox`, `minipage`, and a `tabular p`-column, and many similar constructions. (This package does not redefine any of these commands, but they are defined by default to read their arguments by `\setlength` and so automatically benefit from the enhanced `\setlength` command provided by this package.)

In the following, we shall use standard T<sub>E</sub>X terminology. The correspondence between T<sub>E</sub>X and L<sup>A</sup>T<sub>E</sub>X terminology is as follows: L<sup>A</sup>T<sub>E</sub>X counters correspond to T<sub>E</sub>X's count registers; they hold quantities of type  $\langle$ number $\rangle$ . L<sup>A</sup>T<sub>E</sub>X length commands correspond to T<sub>E</sub>X's `dimen` (for rigid lengths) and `skip` (for rubber lengths) registers; they hold quantities of types  $\langle$ dimen $\rangle$  and  $\langle$ glue $\rangle$ , respectively.

T<sub>E</sub>X gives us primitive operations to perform arithmetic on registers as follows:

- addition and subtraction on all types of quantities without restrictions;
- multiplication and division by an *integer* can be performed on a register of any type;
- multiplication by a *real* number (i.e., a number with a fractional part) can be performed on a register of any type, but the stretch and shrink components of a glue quantity are discarded.

The `calc` package uses these T<sub>E</sub>X primitives but provides a more user-friendly notation for expressing the arithmetic.

An expression is formed of numerical quantities (such as explicit constants and L<sup>A</sup>T<sub>E</sub>X counters and length commands) and binary operators (the tokens '+', '-', '\*', and '/' with their usual meaning) using the familiar infix notation; parentheses may be used to override the usual precedences (that multiplication/division have higher precedence than addition/subtraction).

Expressions must be properly typed. This means, e.g., that a `dimen` expression must be a sum of `dimen` terms: i.e., you cannot say '2cm+4' but '2cm+4pt' is valid.

In a `dimen` term, the dimension part must come first; the same holds for glue terms. Also, multiplication and division by non-integer quantities require a special syntax; see below.

Evaluation of subexpressions at the same level of precedence proceeds from left to right. Consider a dimen term such as “4cm\*3\*4”. First, the value of the factor 4cm is assigned to a dimen register, then this register is multiplied by 3 (using `\multiply`), and, finally, the register is multiplied by 4 (again using `\multiply`). This also explains why the dimension part (i.e., the part with the unit designation) must come first;  $\TeX$  simply doesn’t allow untyped constants to be assigned to a dimen register.

The `calc` package also allows multiplication and division by real numbers. However, a special syntax is required: you must use `\real{⟨decimal constant⟩}`<sup>2</sup> or `\ratio{⟨dimen expression⟩}{⟨dimen expression⟩}` to denote a real value to be used for multiplication/division. The first form has the obvious meaning, and the second form denotes the number obtained by dividing the value of the first expression by the value of the second expression.

A later addition to the package (in June 1998) allows an additional method of specifying a factor of type dimen by setting some text (in LR-mode) and measuring its dimensions: these are denoted as follows.

```
\widthof{⟨text⟩} \heightof{⟨text⟩} \depthof{⟨text⟩}
```

These calculate the natural sizes of the `⟨text⟩` in exactly the same way as is done for the commands `\settoheight` etc. on Page 216 of the manual [2]. In August 2005 the package was further extended to provide the command

```
\totalheightof{⟨text⟩}
```

This command does exactly what you’d expect from its name. Additionally the package also provides the command

```
\settototalheight{⟨cmd⟩}{⟨text⟩}
```

Note that there is a small difference in the usage of these two methods of accessing text dimensions. After `\settoheight{⟨cmd⟩}{Some text}` you can use:

```
\setlength{⟨parskip⟩}{0.68\textwd}
```

whereas using the more direct access to the width of the text requires the longer form for multiplication, thus:

```
\setlength{⟨parskip⟩}{\widthof{Some text} * \real{0.68}}
```

$\TeX$  discards the stretch and shrink components of glue when glue is multiplied by a real number. So, for example,

```
\setlength{⟨parskip⟩}{3pt plus 3pt * \real{1.5}}
```

will set the paragraph separation to 4.5pt with no stretch or shrink. Incidentally, note how spaces can be used to enhance readability. When  $\TeX$  is scanning for a `⟨number⟩` etc. it is common to terminate the scanning with a space token or by inserting `\relax`. As of version 4.3 `calc` allows `\relax` tokens to appear in places where they would usually be used for terminating  $\TeX$ ’s scanning. In short this is just before any of `+-*/*`) or at the end of the expression being evaluated.

<sup>2</sup>Actually, instead of `⟨decimal constant⟩`, the more general `⟨optional signs⟩⟨factor⟩` can be used. However, that doesn’t add any extra expressive power to the language of infix expressions.

When  $\TeX$  performs arithmetic on integers, any fractional part of the results are discarded. For example,

```
\setcounter{x}{7/2}
\setcounter{y}{3*\real{1.6}}
\setcounter{z}{3*\real{1.7}}
```

will assign the value 3 to the counter `x`, the value 4 to `y`, and the value 5 to `z`. This truncation also applies to *intermediate* results in the sequential computation of a composite expression; thus, the following command

```
\setcounter{x}{3 * \real{1.6} * \real{1.7}}
```

will assign 6 to `x`.

As an example of the use of `\ratio`, consider the problem of scaling a figure to occupy the full width (i.e., `\textwidth`) of the body of a page. Assume that the original dimensions of the figure are given by the `dimen` (length) variables, `\Xsize` and `\Ysize`. The height of the scaled figure can then be expressed by

```
\setlength{\newYsize}{\Ysize*\ratio{\textwidth}{\Xsize}}
```

Another new feature introduced in August 2005 was `max` and `min` operations with associated macros

```
\maxof{<type expression>}{<type expression>}
\minof{<type expression>}{<type expression>}
```

When *type* is either *glue* or *dimen* these macros are allowed only as part of addition or subtraction but when *type* is *integer* they can also be used when multiplying and dividing. In the latter case they follow the same syntax rules as `\ratio` and `\real` which means they must come after the `*` or the `/`. Thus

```
\setcounter{x}{3*\maxof{4+5}{3*4}+\minof{2*\real{1.6}}{5-1}}
```

will assign  $3 \times \max(9, 12) + \min(3, 4) = 39$  to `x`. Similarly

```
\setlength{\parindent}{%
\minof{3pt}{\parskip}*\real{1.5}*\maxof{2*\real{1.6}}{2-1}}
```

will assign  $\min(13.5\text{pt}, 4.5\text{\parskip})$  to `\parindent`

### 3 Formal syntax

The syntax is described by the following set of rules. Note that the definitions of *number*, *dimen*, *glue*, *decimal constant*, and *plus or minus* are as in Chapter 24 of The  $\TeX$ book [1]; and *text* is LR-mode material, as in the manual [2]. We use *type* as a meta-variable, standing for ‘integer’, ‘dimen’, and ‘glue’.<sup>3</sup>

$$\begin{array}{l} \langle \textit{type} \textit{ expression} \rangle \quad \longrightarrow \quad \langle \textit{type} \textit{ term} \rangle \quad | \quad \langle \textit{type} \textit{ expression} \rangle \\ \quad \quad \quad \langle \textit{plus or minus} \rangle \langle \textit{type} \textit{ term} \rangle \\ \\ \langle \textit{type} \textit{ term} \rangle \quad \longrightarrow \quad \langle \textit{type} \textit{ term} \rangle \langle \textit{type} \textit{ scan stop} \rangle \quad | \quad \langle \textit{type} \textit{ factor} \rangle \\ \quad \quad \quad | \quad \langle \textit{type} \textit{ term} \rangle \langle \textit{multiply or divide} \rangle \langle \textit{integer} \rangle \quad | \quad \langle \textit{type} \textit{ term} \rangle \end{array}$$


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<sup>3</sup>This version of the `calc` package doesn't support evaluation of *mulglue* expressions.

<multiply or divide> <real number> | <type term>  
 <multiply or divide> <max or min integer>  
 <type scan stop> → <empty> | <optional space> | \relax  
 <type factor> → <type> | <text dimen factor>  
 | <max or min type> | ( <sub>12</sub> <type expression> )<sub>12</sub>  
 <integer> → <number>  
 <max or min type> → <max or min command> {  
 <type expression> } { <type expression> }  
 <max or min command> → \maxof | \minof  
 <text dimen factor> → <text dimen command>{ <text> }  
 <text dimen command> → \widthof | \heightof  
 | \depthof | \totalheightof  
 <multiply or divide> → \*<sub>12</sub> | /<sub>12</sub>  
 <real number> → \ratio{ <dimen expression> }{ <dimen expression> }  
 | \real{ <optional signs> <decimal constant> }  
 <plus or minus> → +<sub>12</sub> | -<sub>12</sub>  
 <decimal constant> → .<sub>12</sub> | ,<sub>12</sub> | <digit>  
 <decimal constant> | <decimal constant> <digit>  
 <digit> → 0<sub>12</sub> | 1<sub>12</sub> | 2<sub>12</sub> | 3<sub>12</sub> | 4<sub>12</sub> | 5<sub>12</sub>  
 | 6<sub>12</sub> | 7<sub>12</sub> | 8<sub>12</sub> | 9<sub>12</sub>  
 <optional signs> → <optional spaces> | <optional signs>  
 <plus or minus> <optional spaces>

Relying heavily on  $\text{\TeX}$  to do the underlying assignments, it is only natural for `calc` to simulate  $\text{\TeX}$ 's parsing machinery for these quantities. Therefore it a) imposes the same restrictions on the catcode of syntax characters as  $\text{\TeX}$  and b) tries to expand its argument fully. a) means that implicit characters for the tokens `*12`, `/12`, `(12`, and `)12` will not work<sup>4</sup> but because of b), the expansion should allow you to use macros that expand to explicit syntax characters.

## 4 The evaluation scheme

In this section, we shall for simplicity consider only expressions containing '+' (addition) and '\*' (multiplication) operators. It is trivial to add subtraction and division.

An expression  $E$  is a sum of terms:  $T_1 + \dots + T_n$ ; a term is a product of factors:  $F_1 * \dots * F_m$ ; a factor is either a simple numeric quantity  $f$  (like <number> as described in the  $\text{\TeX}$ book), or a parenthesized expression ( $E'$ ).

Since the  $\text{\TeX}$  engine can only execute arithmetic operations in a machine-code like manner, we have to find a way to translate the infix notation into this 'instruction set'.

<sup>4</sup>e $\text{\TeX}$  also assumes these catcodes when parsing a `\numexpr`, `\dimexpr`, `\glueexpr`, or `\muglueexpr` and does not allow implicit characters.

Our goal is to design a translation scheme that translates  $X$  (an expression, a term, or a factor) into a sequence of  $\text{\TeX}$  instructions that does the following [Invariance Property]: correctly evaluates  $X$ , leaves the result in a global register  $A$  (using a global assignment), and does not perform global assignments to the scratch register  $B$ ; moreover, the code sequence must be balanced with respect to  $\text{\TeX}$  groups. We shall denote the code sequence corresponding to  $X$  by  $\llbracket X \rrbracket$ .

In the replacement code specified below, we use the following conventions:

- $A$  and  $B$  denote registers; all assignments to  $A$  will be global, and all assignments to  $B$  will be local.
- “ $\Leftarrow$ ” means global assignment to the register on the lhs.
- “ $\leftarrow$ ” means local assignment to the register on the lhs.
- “ $\hookrightarrow[C]$ ” means “save the code  $C$  until the current group (scope) ends, then execute it.” This corresponds to the  $\text{\TeX}$ -primitive `\aftergroup`.
- “{” denotes the start of a new group, and “}” denotes the end of a group.

Let us consider an expression  $T_1 + T_2 + \dots + T_n$ . Assuming that  $\llbracket T_k \rrbracket$  ( $1 \leq k \leq n$ ) attains the stated goal, the following code clearly attains the stated goal for their sum:

$$\begin{aligned} \llbracket T_1 + T_2 + \dots + T_n \rrbracket \implies & \{ \llbracket T_1 \rrbracket \} B \leftarrow A \quad \{ \llbracket T_2 \rrbracket \} B \leftarrow B + A \\ & \dots \quad \{ \llbracket T_n \rrbracket \} B \leftarrow B + A \quad A \Leftarrow B \end{aligned}$$

Note the extra level of grouping enclosing each of  $\llbracket T_1 \rrbracket$ ,  $\llbracket T_2 \rrbracket$ ,  $\dots$ ,  $\llbracket T_n \rrbracket$ . This will ensure that register  $B$ , used to compute the sum of the terms, is not clobbered by the intermediate computations of the individual terms. Actually, the group enclosing  $\llbracket T_1 \rrbracket$  is unnecessary, but it turns out to be simpler if all terms are treated the same way.

The code sequence “ $\{ \llbracket T_2 \rrbracket \} B \leftarrow B + A$ ” can be translated into the following equivalent code sequence: “ $\{ \hookrightarrow_{[B \leftarrow B + A]} \llbracket T_2 \rrbracket \}$ ”. This observation turns out to be the key to the implementation: The “ $\hookrightarrow_{[B \leftarrow B + A]}$ ” is generated *before*  $T_2$  is translated, at the same time as the ‘+’ operator between  $T_1$  and  $T_2$  is seen.

Now, the specification of the translation scheme is straightforward:

$$\begin{aligned} \llbracket f \rrbracket & \implies A \Leftarrow f \\ \llbracket (E') \rrbracket & \implies \llbracket E' \rrbracket \\ \llbracket T_1 + T_2 + \dots + T_n \rrbracket & \implies \{ \hookrightarrow_{[B \leftarrow A]} \llbracket T_1 \rrbracket \} \quad \{ \hookrightarrow_{[B \leftarrow B + A]} \llbracket T_2 \rrbracket \} \\ & \quad \dots \quad \{ \hookrightarrow_{[B \leftarrow B + A]} \llbracket T_n \rrbracket \} \quad A \Leftarrow B \\ \llbracket F_1 * F_2 * \dots * F_m \rrbracket & \implies \{ \hookrightarrow_{[B \leftarrow A]} \llbracket F_1 \rrbracket \} \quad \{ \hookrightarrow_{[B \leftarrow B * A]} \llbracket F_2 \rrbracket \} \\ & \quad \dots \quad \{ \hookrightarrow_{[B \leftarrow B * A]} \llbracket F_m \rrbracket \} \quad A \Leftarrow B \end{aligned}$$

By structural induction, it is easily seen that the stated property is attained.

By inspection of this translation scheme, we see that we have to generate the following code:

- we must generate “ $\{ \hookrightarrow_{[B \leftarrow A]} \{ \hookrightarrow_{[B \leftarrow A]} \}$ ” at the left border of an expression (i.e., for each left parenthesis and the implicit left parenthesis at the beginning of the whole expression);

- we must generate “ $\}A \leftarrow B\}A \leftarrow B$ ” at the right border of an expression (i.e., each right parenthesis and the implicit right parenthesis at the end of the full expression);
- ‘\*’ is replaced by “ $\}\{\hookrightarrow[B\leftarrow B*A]$ ”;
- ‘+’ is replaced by “ $\}A \leftarrow B\}\{\hookrightarrow[B\leftarrow B+A]\{\hookrightarrow[B\leftarrow A]$ ”;
- when we see (expect) a numeric quantity, we insert the assignment code “ $A \leftarrow$ ” in front of the quantity and let  $\TeX$  parse it.

## 5 Implementation

For brevity define

$\langle \text{numeric} \rangle \longrightarrow \langle \text{number} \rangle \mid \langle \text{dimen} \rangle \mid \langle \text{glue} \rangle \mid \langle \text{muglue} \rangle$

So far we have ignored the question of how to determine the type of register to be used in the code. However, it is easy to see that (1) ‘\*’ always initiates an  $\langle \text{integer factor} \rangle$ , (2) all  $\langle \text{numeric} \rangle$ s in an expression, except those which are part of an  $\langle \text{integer factor} \rangle$ , are of the same type as the whole expression, and all  $\langle \text{numeric} \rangle$ s in an  $\langle \text{integer factor} \rangle$  are  $\langle \text{number} \rangle$ s.

We have to ensure that  $A$  and  $B$  always have an appropriate type for the  $\langle \text{numeric} \rangle$ s they manipulate. We can achieve this by having an instance of  $A$  and  $B$  for each type. Initially,  $A$  and  $B$  refer to registers of the proper type for the whole expression. When an  $\langle \text{integer factor} \rangle$  is expected, we must change  $A$  and  $B$  to refer to integer type registers. We can accomplish this by including instructions to change the type of  $A$  and  $B$  to integer type as part of the replacement code for ‘\*’; if we append such instructions to the replacement code described above, we also ensure that the type-change is local (provided that the type-changing instructions only have local effect). However, note that the instance of  $A$  referred to in  $\hookrightarrow[B\leftarrow B*A]$  is the integer instance of  $A$ .

We shall use  $\backslash \text{begingroup}$  and  $\backslash \text{endgroup}$  for the open-group and close-group characters. This avoids problems with spacing in math (as pointed out to us by Frank Mittelbach).

### 5.1 Getting started

Now we have enough insight to do the actual implementation in  $\TeX$ . First, we announce the macro package.<sup>5</sup>

```

1  $\backslash \text{*package}$ 
2  $\% \backslash \text{NeedsTeXFormat}\{LaTeX2e\}$ 
3  $\% \backslash \text{ProvidesPackage}\{calc\}[\filedate\space\fileversion]$ 

```

### 5.2 Assignment macros

$\backslash \text{calc@assign@generic}$  The  $\backslash \text{calc@assign@generic}$  macro takes four arguments: (1 and 2) the registers to be used for global and local manipulations, respectively; (3) the lvalue part; (4) the expression to be evaluated.

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<sup>5</sup>Code moved to top of file

The third argument (the lvalue) will be used as a prefix to a register that contains the value of the specified expression (the fourth argument).

In general, an lvalue is anything that may be followed by a variable of the appropriate type. As an example, `\linepenalty` and `\global\advance\linepenalty` may both be followed by an  $\langle$ integer variable $\rangle$ .

The macros described below refer to the registers by the names `\calc@A` and `\calc@B`; this is accomplished by `\let`-assignments.

As discovered in Section 4, we have to generate code as if the expression is parenthesized. As described below, `\calc@open` is the macro that replaces a left parenthesis by its corresponding TeX code sequence. When the scanning process sees the exclamation point, it generates an `\endgroup` and stops. As we recall from Section 4, the correct expansion of a right parenthesis is “ $\}A \leftarrow B\}A \leftarrow B$ ”. The remaining tokens of this expansion are inserted explicitly, except that the last assignment has been replaced by the lvalue part (i.e., argument #3 of `\calc@assign@generic`) followed by `\calc@B`.

```
4 \def\calc@assign@generic#1#2#3#4{\let\calc@A#1\let\calc@B#2%
5   \calc@open(#4!%
6   \global\calc@A\calc@B\endgroup#3\calc@B}
```

`\calc@assign@count` We need three instances of the `\calc@assign@generic` macro, corresponding to `\calc@assign@dimen` the types  $\langle$ integer $\rangle$ ,  $\langle$ dimen $\rangle$ , and  $\langle$ glue $\rangle$ .

```
\calc@assign@skip 7 \def\calc@assign@count{\calc@assign@generic\calc@Acount\calc@Bcount}
8 \def\calc@assign@dimen{\calc@assign@generic\calc@Adimen\calc@Bdimen}
9 \def\calc@assign@skip{\calc@assign@generic\calc@Askip\calc@Bskip}
```

These macros each refer to two registers, one to be used globally and one to be used locally. We must allocate these registers.

```
10 \newcount\calc@Acount   \newcount\calc@Bcount
11 \newdimen\calc@Adimen   \newdimen\calc@Bdimen
12 \newskip\calc@Askip     \newskip\calc@Bskip
```

### 5.3 The L<sup>A</sup>T<sub>E</sub>X interface

`\setcounter` As promised, we redefine the following standard L<sup>A</sup>T<sub>E</sub>X commands: `\setcounter`, `\addtocounter` `\addtocounter`, `\setlength`, and `\addtolength`.

```
\steptocounter 13 \def\setcounter#1#2{\@ifundefined{c@#1}{\@nocounterr{#1}}%
\setlength      14   {\calc@assign@count{\global\csname c@#1\endcsname}{#2}}
\addtolength    15 \def\addtocounter#1#2{\@ifundefined{c@#1}{\@nocounterr{#1}}%
                  16   {\calc@assign@count{\global\advance\csname c@#1\endcsname}{#2}}}%
```

We also fix `\steptocounter` to not go through the whole calc process.

```
17 \def\steptocounter#1{\@ifundefined {c@#1}%
18   {\@nocounterr {#1}}%
19   {\global\advance\csname c@#1\endcsname \@ne
20   \beginingroup
21     \let\@elt\@stpelt \csname cl@#1\endcsname
22   \endgroup}}%
```

If the `amstext` package is loaded we must add the `\iffirstchoice@` switch as well. We patch the commands this way since it’s good practice when we know how many arguments they take.



```

23 \@ifpackageloaded{amstext}{%
24   \expandafter\def\expandafter\stepcounter
25     \expandafter#\expandafter1\expandafter{%
26     \expandafter\iffirstchoice@\stepcounter{#1}\fi
27   }
28   \expandafter\def\expandafter\addtocounter
29     \expandafter#\expandafter1\expandafter#\expandafter2\expandafter{%
30     \expandafter\iffirstchoice@\addtocounter{#1}{#2}\fi
31   }
32 }{}

33 \DeclareRobustCommand\setlength{\calc@assign@skip}
34 \DeclareRobustCommand\addtolength[1]{\calc@assign@skip{\advance#1}}

```

(\setlength and \addtolength are robust according to [2].)

## 5.4 The scanner

We evaluate expressions by explicit scanning of characters. We do not rely on active characters for this.

The scanner consists of two parts, `\calc@pre@scan` and `\calc@post@scan`; `\calc@pre@scan` consumes left parentheses, and `\calc@post@scan` consumes binary operator, `\real`, `\ratio`, and right parenthesis tokens.

`\calc@pre@scan` Note that this is called at least once on every use of calc processing, even when  
`\@calc@pre@scan` none of the extended syntax is present; it therefore needs to be made very efficient.

It reads the initial part of expressions, until some `<text dimen factor>` or `<numeric>` is seen; in fact, anything not explicitly recognized here is taken to be a `<numeric>` of some sort as this allows unary `+` and unary `-` to be treated easily and correctly<sup>6</sup> but means that anything illegal will simply generate a T<sub>E</sub>X-level error, often a reasonably comprehensible one!

The `\romannumeral-‘\a` part is a little trick which forces expansion in case `#1` is a normal macro, something that occurs from time to time. A conditional test inside will possibly leave a trailing `\fi` but this remnant is removed later when `\calc@post@scan` performs the same trick.

The many `\expandafters` are needed to efficiently end the nested conditionals so that `\calc@textsize` and `\calc@maxmin@addsub` can process their argument.

```

35 \def\calc@pre@scan#1{%
36   \expandafter\@calc@pre@scan\romannumeral-‘\a#1}
37 \def\@calc@pre@scan#1{%
38   \ifx(#1%
39     \expandafter\calc@open
40   \else
41     \ifx\widthof#1%
42       \expandafter\expandafter\expandafter\calc@textsize
43     \else
44       \ifx\maxof#1%
45         \expandafter\expandafter\expandafter\expandafter
46         \expandafter\expandafter\expandafter\calc@maxmin@addsub
47       \else
48         \calc@numeric% no \expandafter needed for this one.

```

<sup>6</sup>In the few contexts where signs are allowed: this could, I think, be extended (CAR).

```

49     \fi
50     \fi
51     \fi
52     #1}

```

`\calc@open` `\calc@open` is used when there is a left parenthesis right ahead. This parenthesis is replaced by T<sub>E</sub>X code corresponding to the code sequence “ $\{\leftrightarrow[B\leftarrow A]\{\leftrightarrow[B\leftarrow A]\}$ ” derived in Section 4. Finally, `\calc@pre@scan` is called again.

```

53 \def\calc@open{\begingroup\aftergroup\calc@initB
54   \begingroup\aftergroup\calc@initB
55   \calc@pre@scan}
56 \def\calc@initB{\calc@B\calc@A}

```

`\calc@numeric` `\calc@numeric` assigns the following value to `\calc@A` and then transfers control to `\calc@post@scan`.

```

57 \def\calc@numeric{\afterassignment\calc@post@scan \global\calc@A}

```

`\widthof` These do not need any particular definition when they are scanned so, for efficiency and robustness, we make them all equivalent to the same harmless (I hope) `\heightof` unexpandable command.<sup>7</sup> Thus the test in `\@calc@pre@scan` finds any of them.  
`\depthof`  
`\totalheightof` As we have to check for these commands explicitly we must ensure that our definition wins. Using `\newcommand` gives an error when loading `calc` and may be mildly surprising. This should be a little more informative.

```

58 \@for\reserved@a:=widthof,heightof,depthof,totalheightof,maxof,minof\do
59 {\@ifundefined{\reserved@a}\{}{
60   \PackageError{calc}{
61     The\space calc\space package\space reserves\space the\space
62     command\space name\space ‘\@backslashchar\reserved@a’\MessageBreak
63     but\space it\space has\space already\space been\space defined\space
64     with\space the\space meaning\MessageBreak
65     ‘\expandafter\meaning\csname\reserved@a\endcsname’.\MessageBreak
66     This\space original\space definition\space will\space be\space lost}%
67     {If\space you\space need\space a\space command\space with\space
68     this\space definition,\space you\space must\space use\space a\space
69     different\space name.}}%
70 }
71 \let\widthof\ignorespaces
72 \let\heightof\ignorespaces
73 \let\depthof\ignorespaces
74 \let\totalheightof\ignorespaces

```

`\calc@textsize` The presence of the above four commands invokes this code, where we must distinguish them from each other. This implementation is somewhat optimized by using low-level code from the commands `\settowidth`, etc.<sup>8</sup>

Within the text argument we must restore the normal meanings of the four user-level commands since arbitrary material can appear in here, including further uses of `calc`.

```

75 \def\calc@textsize #1#2{%
76   \begingroup
77   \let\widthof\wd

```

<sup>7</sup>If this level of safety is not needed then the code can be sped up: CAR.

<sup>8</sup>It is based on suggestions by Donald Arseneau and David Carlisle.

```

78 \let\heightof\ht
79 \let\depthof\dp
80 \def\totalheightof{\ht\dp}%

```

We must expand the argument one level if it's `\totalheightof` and it doesn't hurt the other three.

```

81 \expandafter\@settodim\expandafter{#1}%
82 {\global\calc@A}%
83 {%
84 \let\widthof\ignorespaces
85 \let\heightof\ignorespaces
86 \let\depthof\ignorespaces
87 \let\totalheightof\ignorespaces
88 #2}%
89 \endgroup
90 \calc@post@scan}

```

`\calc@post@scan` The macro `\calc@post@scan` is called right after a value has been read. At this point, a binary operator, a sequence of right parentheses, an optional `\relax`, and the end-of-expression mark (`'!`) is allowed.<sup>9</sup> Depending on our findings, we call a suitable macro to generate the corresponding  $\TeX$  code (except when we detect the end-of-expression marker: then scanning ends, and control is returned to `\calc@assign@generic`).

This macro may be optimized by selecting a different order of `\ifx`-tests. The test for `'!` (end-of-expression) is placed first as it will always be performed: this is the only test to be performed if the expression consists of a single  $\langle$ numeric $\rangle$ . This ensures that documents that do not use the extra expressive power provided by the `calc` package only suffer a minimum slowdown in processing time.

```

91 \def\calc@post@scan#1{%
92 \expandafter\@calc@post@scan\romannumeral-'\a#1}
93 \def\@calc@post@scan#1{%
94 \ifx#1!\let\calc@next\endgroup \else
95 \ifx#1+\let\calc@next\calc@add \else
96 \ifx#1-\let\calc@next\calc@subtract \else
97 \ifx#1*\let\calc@next\calc@multiply \else
98 \ifx#1/\let\calc@next\calc@dividex \else
99 \ifx#1)\let\calc@next\calc@close \else
100 \ifx#1\relax\let\calc@next\calc@post@scan \else
101 \def\calc@next{\calc@error#1}%
102 \fi
103 \fi
104 \fi
105 \fi
106 \fi
107 \fi
108 \fi
109 \calc@next}

```

`\calc@add` The replacement code for the binary operators `'+` and `'-` follow a common pattern; the only difference is the token that is stored away by `\aftergroup`. After this replacement code, control is transferred to `\calc@pre@scan`.

`\calc@addAtoB`

`\calc@subtractAfromB` <sup>9</sup>Is ! a good choice, CAR?

```

110 \def\calc@add{\calc@generic@add\calc@addAtoB}
111 \def\calc@subtract{\calc@generic@add\calc@subtractAfromB}
112 \def\calc@generic@add#1{\endgroup\global\calc@A\calc@B\endgroup
113   \begingroup\aftergroup#1\begingroup\aftergroup\calc@initB
114   \calc@pre@scan}
115 \def\calc@addAtoB{\advance\calc@B\calc@A}
116 \def\calc@subtractAfromB{\advance\calc@B-\calc@A}

```

`\real` The multiplicative operators, ‘\*’ and ‘/’, may be followed by a `\real`, `\ratio`, `\ratio` `\minof`, or `\maxof` token. The last two of these control sequences are defined by `calc` as they are needed by the scanner for addition or subtraction while the `\calc@ratio@x` first two are not defined (at least not by the `calc` package); this, unfortunately, leaves them highly non-robust. We therefore equate them to `\relax` but only if they have not already been defined<sup>10</sup> (by some other package: dangerous but possible!); this will also make them appear to be undefined to a L<sup>A</sup>T<sub>E</sub>X user (also possibly dangerous).

```

117 \ifx\real@undefined\let\real\relax\fi
118 \ifx\ratio@undefined\let\ratio\relax\fi

```

In order to test for `\real` or `\ratio`, we define these two.<sup>11</sup>

```

119 \def\calc@ratio@x{\ratio}
120 \def\calc@real@x{\real}

```

`\calc@multiplyx` Test which operator followed \* or /. If none followed it’s just a standard multiplication or division.

```

121 \def\calc@multiplyx#1{\def\calc@tmp{#1}%
122   \ifx\calc@tmp\calc@ratio@x \let\calc@next\calc@ratio@multiply \else
123   \ifx\calc@tmp\calc@real@x \let\calc@next\calc@real@multiply \else
124   \ifx\maxof#1\let\calc@next\calc@maxmin@multiply \else
125   \let\calc@next\calc@multiply
126   \fi
127   \fi
128   \fi
129   \calc@next#1}
130 \def\calc@dividex#1{\def\calc@tmp{#1}%
131   \ifx\calc@tmp\calc@ratio@x \let\calc@next\calc@ratio@divide \else
132   \ifx\calc@tmp\calc@real@x \let\calc@next\calc@real@divide \else
133   \ifx\maxof#1\let\calc@next\calc@maxmin@divide \else
134   \let\calc@next\calc@divide
135   \fi
136   \fi
137   \fi
138   \calc@next#1}

```

`\calc@multiply` The binary operators ‘\*’ and ‘/’ also insert code as determined above. Moreover, the meaning of `\calc@A` and `\calc@B` is changed as factors following a multiplication and division operator always have integer type; the original meaning of these macros will be restored when the factor has been read and evaluated.

```

\calc@generic@multiply \calc@multiplyBbyA
\calc@multiplyBbyA \calc@divideBbyA
\calc@divideBbyA 139 \def\calc@multiply{\calc@generic@multiply\calc@multiplyBbyA}
140 \def\calc@divide{\calc@generic@multiply\calc@divideBbyA}
141 \def\calc@generic@multiply#1{\endgroup\begingroup

```

<sup>10</sup>Suggested code from David Carlisle.

<sup>11</sup>May not need the extra names, CAR?

```

142 \let\calc@A\calc@Acount \let\calc@B\calc@Bcount
143 \aftergroup#1\calc@pre@scan}
144 \def\calc@multiplyBbyA{\multiply\calc@B\calc@Acount}
145 \def\calc@divideBbyA{\divide\calc@B\calc@Acount}

```

Since the value to use in the multiplication/division operation is stored in the `\calc@Acount` register, the `\calc@multiplyBbyA` and `\calc@divideBbyA` macros use this register.

`\calc@close` `\calc@close` generates code for a right parenthesis (which was derived to be “ $\}A \leftarrow B\}A \leftarrow B$ ” in Section 4). After this code, the control is returned to `\calc@post@scan` in order to look for another right parenthesis or a binary operator.

```

146 \def\calc@close
147   {\endgroup\global\calc@A\calc@B
148   \endgroup\global\calc@A\calc@B
149   \calc@post@scan}

```

## 5.5 Calculating a ratio

`\calc@ratio@multiply` When `\calc@post@scan` encounters a `\ratio` control sequence, it hands control to one of the macros `\calc@ratio@multiply` or `\calc@ratio@divide`, depending on the preceding character. Those macros both forward the control to the macro `\calc@ratio@evaluate`, which performs two steps: (1) it calculates the ratio, which is saved in the global macro token `\calc@the@ratio`; (2) it makes sure that the value of `\calc@B` will be multiplied by the ratio as soon as the current group ends.

The following macros call `\calc@ratio@evaluate` which multiplies `\calc@B` by the ratio, but `\calc@ratio@divide` flips the arguments so that the ‘opposite’ fraction is actually evaluated.

```

150 \def\calc@ratio@multiply\ratio{\calc@ratio@evaluate}
151 \def\calc@ratio@divide\ratio#1#2{\calc@ratio@evaluate{#2}{#1}}

```

`\calc@Ccount` We shall need two registers for temporary usage in the calculations. We can save `\calc@numerator` one register since we can reuse `\calc@Bcount`.

```

\calc@denominator 152 \newcount\calc@Ccount
153 \let\calc@numerator=\calc@Bcount
154 \let\calc@denominator=\calc@Ccount

```

`\calc@ratio@evaluate` Here is the macro that handles the actual evaluation of ratios. The procedure is this: First, the two expressions are evaluated and coerced to integers. The whole procedure is enclosed in a group to be able to use the registers `\calc@numerator` and `\calc@denominator` for temporary manipulations.

```

155 \def\calc@ratio@evaluate#1#2{%
156   \endgroup\begin{group}
157     \calc@assign@dimen\calc@numerator{#1}%
158     \calc@assign@dimen\calc@denominator{#2}%

```

Here we calculate the ratio. First, we check for negative numerator and/or denominator; note that `TEX` interprets two minus signs the same as a plus sign. Then, we calculate the integer part. The minus sign(s), the integer part, and a decimal point, form the initial expansion of the `\calc@the@ratio` macro.

```

159 \gdef\calc@the@ratio{}%
160 \ifnum\calc@numerator<0 \calc@numerator-\calc@numerator
161 \gdef\calc@the@ratio{-}%
162 \fi
163 \ifnum\calc@denominator<0 \calc@denominator-\calc@denominator
164 \xdef\calc@the@ratio{\calc@the@ratio}%
165 \fi
166 \calc@Acount\calc@numerator
167 \divide\calc@Acount\calc@denominator
168 \xdef\calc@the@ratio{\calc@the@ratio\number\calc@Acount.}%

```

Now we generate the digits after the decimal point, one at a time. When  $\TeX$  scans these digits (in the actual multiplication operation), it forms a fixed-point number with 16 bits for the fractional part. We hope that six digits is sufficient, even though the last digit may not be rounded correctly.

```

169 \calc@next@digit \calc@next@digit \calc@next@digit
170 \calc@next@digit \calc@next@digit \calc@next@digit
171 \endgroup

```

Now we have the ratio represented (as the expansion of the global macro `\calc@the@ratio`) in the syntax `\langle decimal constant \rangle` [1, page 270]. This is fed to `\calc@multiply@by@real` that will perform the actual multiplication. It is important that the multiplication takes place at the correct grouping level so that the correct instance of the  $B$  register will be used. Also note that we do not need the `\aftergroup` mechanism in this case.

```

172 \calc@multiply@by@real\calc@the@ratio
173 \begingroup
174 \calc@post@scan}

```

The `\begingroup` inserted before the `\calc@post@scan` will be matched by the `\endgroup` generated as part of the replacement of a subsequent binary operator or right parenthesis.

`\calc@next@digit`

```

175 \def\calc@next@digit{%
176 \multiply\calc@Acount\calc@denominator
177 \advance\calc@numerator -\calc@Acount
178 \multiply\calc@numerator 10
179 \calc@Acount\calc@numerator
180 \divide\calc@Acount\calc@denominator
181 \xdef\calc@the@ratio{\calc@the@ratio\number\calc@Acount}}

```

`\calc@multiply@by@real` In the following code, it is important that we first assign the result to a `dimen` register. Otherwise,  $\TeX$  won't allow us to multiply with a real number.

```

182 \def\calc@multiply@by@real#1{\calc@Bdimen #1\calc@B \calc@B\calc@Bdimen}

```

(Note that this code wouldn't work if `\calc@B` were a `muglue` register. This is the real reason why the `calc` package doesn't support `muglue` expressions. To support `muglue` expressions in full, the `\calc@multiply@by@real` macro must use a `muglue` register instead of `\calc@Bdimen` when `\calc@B` is a `muglue` register; otherwise, a `dimen` register should be used. Since integer expressions can appear as part of a `muglue` expression, it would be necessary to determine the correct register to use each time a multiplication is made.)

## 5.6 Multiplication by real numbers

`\calc@real@multiply` This is similar to the `\calc@ratio@evaluate` macro above, except that it is considerably simplified since we don't need to calculate the factor explicitly.

```

183 \def\calc@real@multiply\real#1{\endgroup
184   \calc@multiply@by@real{#1}\begingroup
185   \calc@post@scan}
186 \def\calc@real@divide\real#1{\calc@ratio@evaluate{1pt}{#1pt}}
```

## 5.7 max and min operations

`\maxof` With version 4.2, the max and min operators were added to `calc`. The user functions for them are `\maxof` and `\minof` respectively. These macros are internally similar to `\widthof` etc. in that they are unexpandable and easily recognizable by the scanner.

```

187 \let\maxof\@@italiccorr
188 \let\minof\@@italiccorr
```

`\calc@Cskip` The max and min operations take two arguments so we need an extra `<skip>` register. We also add a switch for determining when to perform a `<skip>` or a `<count>` assignment.

```

189 \newskip\calc@Cskip
190 \newif\ifcalc@count@
```

`\calc@maxmin@addsub` When doing addition or subtraction with a max or min operator, we first check if `\calc@A` is a `<count>` register or not and then set the switch. Then call the real function which sets `\calc@A` to the desired value and continue as usual with `\calc@post@scan`.

`\calc@maxmin@generic`

```

191 \def\calc@maxmin@addsub#1#2#3{\begingroup
192   \ifx\calc@A\calc@Acount%
193     \calc@count@true
194   \else
195     \calc@count@false
196   \fi
197   \calc@maxmin@generic#1{#2}{#3}%
198   \endgroup
199   \calc@post@scan
200 }
```

Check the switch and do either `<count>` or `<skip>` assignments. Note that `\maxof` and `\minof` are not set to `>` and `<` until after the assignments, which ensures we can nest them without problems. Then set `\calc@A` to the correct one.

```

201 \def\calc@maxmin@generic#1#2#3{%
202   \begingroup
203   \ifcalc@count@
204     \calc@assign@count\calc@Ccount{#2}%
205     \calc@assign@count\calc@Bcount{#3}%
206     \def\minof{<}\def\maxof{>}%
207     \global\calc@A\ifnum\calc@Ccount#1\calc@Bcount
208       \calc@Ccount\else\calc@Bcount\fi
209   \else
210     \calc@assign@skip\calc@Cskip{#2}%
211     \calc@assign@skip\calc@Bskip{#3}%
```

```

212     \def\minof{<}\def\maxof{>}%
213     \global\calc@A\ifdim\calc@Cskip#1\calc@Bskip
214         \calc@Cskip\else\calc@Bskip\fi
215     \fi
216 \endgroup
217 }

```

`\calc@maxmin@divmul` When doing division or multiplication we must be using `<count>` registers so we  
`\calc@maxmin@multiply` set the switch. Other than that it is almost business as usual when multiplying or  
`\calc@maxmin@divide` dividing. #1 is the instruction to either multiply or divide `\calc@B` by `\calc@A`,  
#2 is either `\maxof` or `\minof` which is waiting in the input stream and #3 and #4  
are the calc expressions. We end it all as usual by calling `\calc@post@scan`.

```

218 \def\calc@maxmin@divmul#1#2#3#4{%
219     \endgroup\begingroup
220     \calc@count@true
221     \aftergroup#1%
222     \calc@maxmin@generic#2{#3}{#4}%
223     \endgroup\begingroup
224     \calc@post@scan
225 }

```

The two functions called when seeing a `*` or a `/`.

```

226 \def\calc@maxmin@multiply{\calc@maxmin@divmul\calc@multiplyBbyA}
227 \def\calc@maxmin@divide  {\calc@maxmin@divmul\calc@divideBbyA}

```

## 6 Reporting errors

`\calc@error` If `\calc@post@scan` reads a character that is not one of `'+', '-', '*', '/', or ')'` , an  
error has occurred, and this is reported to the user. Violations in the syntax of  
`<numeric>`s will be detected and reported by `TEX`.

```

228 \def\calc@error#1{%
229     \PackageError{calc}%
230     {'#1' invalid at this point}%
231     {I expected to see one of: + - * / )}}

```

## 7 Other additions

`\@settodim` The kernel macro `\@settodim` is changed so that it runs through a list containing  
`\setttotalheight` `\ht`, `\wd`, and `\dp` and then advance the length one step at a time. We just have  
to use a scratch register in case the user decides to put in a `\global` prefix on the  
length register. A search on the internet confirmed that some people do that kind  
of thing.

```

232 \def\@settodim#1#2#3{%
233     \setbox\@tempboxa\hbox{#3}%
234     \dimen@ii=\z@
235     \@tf@r\reserved@a #1\do{%
236     \advance\dimen@ii\reserved@a\@tempboxa}%
237     #2=\dimen@ii
238     \setbox\@tempboxa\box\voidb@x}

```

Now the user level macro is straightforward.

```

239 \def\setttotalheight{\@settodim{\ht\dp}}

```



That's the end of the package.

240 `\package`

## References

- [1] D. E. KNUTH. *The T<sub>E</sub>Xbook* (Computers & Typesetting Volume A). Addison-Wesley, Reading, Massachusetts, 1986.
- [2] L. LAMPORT. *LaTeX, A Document Preparation System*. Addison-Wesley, Reading, Massachusetts, Second edition 1994/1985.

## Change History

|  |      |  |    |
|--|------|--|----|
| v4.0d  |      |  |    |
| General: Contributed to tools distribution   | 1    |  |    |
| <code>\calc@error</code> : Use <code>\PackageError</code> for error messages (DPC)         | 16   |  |    |
| v4.0e  |      |  |    |
| <code>\calc@error</code> : typo fixed  | 16   |  |    |
| v4.1a  |      |  |    |
| General: Added text sizes: CAR   | 1    |  |    |
| Attempt to make user-syntax robust: CAR  | 1    |  |    |
| <code>\calc@pre@scan</code> : Added code for text sizes: CAR                               | 9    |  |    |
| <code>\calc@error</code> : Improved, I hope, error message: CAR                            | 16   |  |    |
| <code>\calc@real@x</code> : Added macro set-ups to make them robust but undefined: CAR     | 12   |  |    |
| <code>\calc@textsize</code> : Added macro: CAR   | 10   |  |    |
| <code>\depthof</code> : Added macros: CAR  | 10   |  |    |
| v4.1b  |      |  |    |
| <code>\calc@pre@scan</code> : Correction to ifx true case                                  | 9    |  |    |
| v4.2   |      |  |    |
| <code>\calc@post@scan</code> : Added macro and force expansion                             | 11   |  |    |
| <code>\calc@pre@scan</code> : Added <code>\maxof</code> and <code>\minof</code> operations | 9    |  |    |
| Added macro and force expansion  | 9    |  |    |
|  |      |  |    |
|  |      | <code>\@settodim</code> : Changed kernel macro   | 16 |
|  |      | <code>\addtocounter</code> : Fix to make <code>\addtocounter</code> work with <code>amstext</code>                                       | 8  |
|  |      | <code>\calc@assign@generic</code> : Removed a few redundant <code>\expandafters</code>   | 7  |
|  |      | <code>\calc@dividex</code> : Added max and min operations  | 12 |
|  |      | <code>\calc@maxmin@divide</code> : Macros added  | 16 |
|  |      | <code>\calc@maxmin@generic</code> : Macros added   | 15 |
|  |      | <code>\calc@multiplyx</code> : Added max and min operations  | 12 |
|  |      | <code>\calc@textsize</code> : Extended macro with <code>\totalheightof</code>  | 10 |
|  |      | <code>\minof</code> : Added macros   | 15 |
|  |      | <code>\settototalheight</code> : Added macro   | 16 |
|  |      | <code>\steptocounter</code> : Avoid redundant processing. PR/3795  | 8  |
|  |      | <code>\totalheightof</code> : Added informative message for reserved macros  | 10 |
|  |      | Added macro  | 10 |
|  | v4.3 |  |    |
|  |      | <code>\calc@post@scan</code> : Discard terminating <code>\relax</code> tokens and avoid extra error message from <code>\calc@next</code> | 11 |