The bytefield package*

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Abstract

The bytefield package helps the user create illustrations for network protocol specifications and anything else that utilizes fields of data. These illustrations show how the bits and bytes are laid out in a packet or in memory.

WARNING: bytefield version 2.x breaks compatibility with older versions of the package. See Section 2.6 for help porting documents to the new interface.

1 Introduction

Network protocols are usually specified in terms of a sequence of bits and bytes arranged in a field. This is portrayed graphically as a grid of boxes. Each row in the grid represents one word (frequently, 32 bits), and each column represents a bit within a word. The bytefield package makes it easy to typeset these sorts of figures.

bytefield lets one draw protocol diagrams that contain:

- Words of any arbitrary number of bits
- Column headers showing bit positions
- Multiword fields—even non-word-aligned and even if the total number of bits is not a multiple of the word length
- Word labels on either the left or right of the figure
- "Skipped words" within fields

*This document corresponds to bytefield v2.0a, dated 2011/02/09.

Because bytefield draws its figures using only the LaTeX `picture` environment, these figures are not specific to any particular backend, do not require PostScript support, and do not need support from external programs. Furthermore, unlike an imported graphic, bytefield pictures can include arbitrary LaTeX constructs, such as mathematical equations, `\ref`s and `\cite`s to the surrounding document, and macro calls.

2 Usage

2.1 Basic commands

This section explains how to use the bytefield package. It lists all the exported environments, commands, and variables in decreasing order of usefulness.

```
\begin{bytefield} [⟨parameters⟩] {⟨bit-width⟩}
⟨fields⟩
\end{bytefield}
```

The bytefield package's top-level environment is called, not surprisingly, "`bytefield`". It takes one mandatory argument, which is the number of bits in each word, and one optional argument, which is a set of parameters, described in Section 2.2, for formatting the bit-field's layout. One can think of a `bytefield` as being analogous to a `tabular`: words are separated by "`\\`", and fields within a word are separated by "`&`".

```
\bitbox [⟨sides⟩] {⟨width⟩} {⟨text⟩}
\wordbox [⟨sides⟩] {⟨height⟩} {⟨text⟩}
```

The two main commands one uses within a bytefield environment are `\bitbox` and `\wordbox`. The former typesets a field that is one or more bits wide and a single word tall. The latter typesets a field that is one or more words tall and an entire word wide.

The optional argument, ⟨*sides*⟩, is a list of letters specifying which sides of the field box to draw—[`l`]eft, [`r`]ight, [`t`]op, and/or [`b`]ottom. The default is "`lrtb`" (i.e., all sides are drawn). ⟨*text*⟩ is the text to include within the `\bitbox` or `\wordbox`. It is typeset horizontally centered within a vertically centered `\parbox`. Hence, words will wrap, and "`\\`" can be used to break lines manually.

The following example shows how to produce a simple 16-bit-wide field:

```
\begin{bytefield}{16}
  \wordbox{1}{A 16-bit field} \\
  \bitbox{8}{8 bits} & \bitbox{8}{8 more bits} \\
  \wordbox{2}{A 32-bit field.  Note that text wraps within the box.}
\end{bytefield}
```

The resulting bit field looks like this:

A 16-bit field	
8 bits	8 more bits
A 32-bit field. Note that text wraps within the box.	

It is the user's responsibility to ensure that the total number of bits in each row adds up to the number of bits in a single word (the mandatory argument to the `bytefield` environment); bytefield does not currently check for under- or overruns.

Within a `\bitbox` or `\wordbox`, the bytefield package defines `\height`, `\depth`, `\totalheight`, and `\width` to the corresponding dimensions of the box. Section 2.3 gives an example of how these lengths may be utilized.

`\bitheader [`⟨*endianness*⟩`] {`⟨*bit-positions*⟩`}`

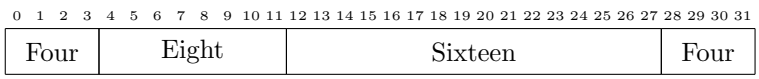
To make the bit field more readable, it helps to label bit positions across the top. The `\bitheader` command provides a flexible way to do that. The optional argument, ⟨*endianness*⟩ is one of "`b`" or "`l`" and specifies whether the bits in each word are numbered in big-endian style (right to left) or little-endian style (left to right). The default is little-endian (`l`).

`\bitheader`'s mandatory argument, ⟨*bit-positions*⟩, is a comma-separated list of bit positions to label. For example, "`0,2,4,6,8,10,12,14`" means to label those bit positions. The numbers must be listed in increasing order. (Use ⟨*endianness*⟩ to display the header in reverse order.) Hyphen-separated ranges are also valid. For example, "`0-15`" means to label all bits from 0 to 15, inclusive. While not particularly useful, ranges and single numbers can be intermixed, as in "`0-3,8,12-15`".

The following example shows how `\bitheader` may be used:

```
\begin{bytefield}{32}
  \bitheader{0-31} \\
  \bitbox{4}{Four} & \bitbox{8}{Eight} &
    \bitbox{16}{Sixteen} & \bitbox{4}{Four}
\end{bytefield}
```

The resulting bit field looks like this:



```
\begin{rightwordgroup} {⟨text⟩}
⟨rows of bit boxes and word boxes⟩
\end{rightwordgroup}

\begin{leftwordgroup} {⟨text⟩}
⟨rows of bit boxes and word boxes⟩
\end{leftwordgroup}
```

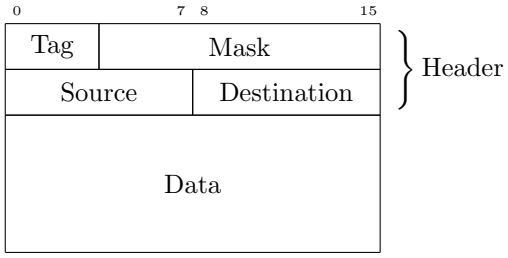
When a set of words functions as a single, logical unit, it helps to group these words together visually. All words defined between `\begin{rightwordgroup}` and `\end{rightwordgroup}` will be labeled on the right with ⟨*text*⟩. Similarly, all words defined between `\begin{leftwordgroup}` and `\end{leftwordgroup}` will be labeled on the left with ⟨*text*⟩. `\begin{`⟨*side*⟩`wordgroup}` must lie at the beginning of a row (i.e., right after a "`\\`"), and `\end{`⟨*side*⟩`wordgroup}` must lie right *before* the end of the row (i.e., right before a "`\\`").

Unlike other LaTeX environments, `rightwordgroup` and `leftwordgroup` do not have to nest properly with each other. However, they cannot overlap themselves. In other words, `\begin{rightwordgroup}`...`\begin{leftwordgroup}`...`\end{rightwordgroup}`...`\end{leftwordgroup}` is a valid sequence, but `\begin{rightwordgroup}`...`\begin{rightwordgroup}`...`\end{rightwordgroup}`...`\end{rightwordgroup}` is not.

The following example presents the basic usage of `\begin{rightwordgroup}` and `\end{rightwordgroup}`:

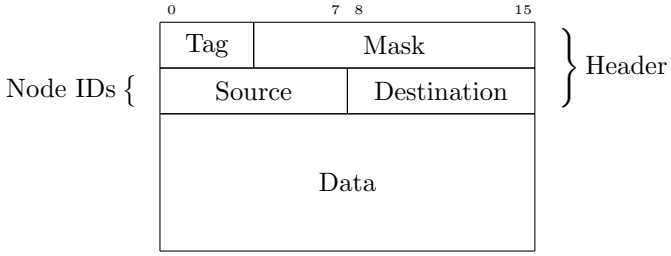
```
\begin{bytefield}{16}
  \bitheader{0,7,8,15} \\
  \begin{rightwordgroup}{Header}
    \bitbox{4}{Tag} & \bitbox{12}{Mask} \\
    \bitbox{8}{Source} & \bitbox{8}{Destination}
  \end{rightwordgroup} \\
  \wordbox{3}{Data}
\end{bytefield}
```

Note the juxtaposition of "`\\`" to the `\begin{rightwordgroup}` and the `\end{rightwordgroup}` in the above. The resulting bit field looks like this:



As a more complex example, the following nests left and right labels:

```
\begin{bytefield}{16}
  \bitheader{0,7,8,15} \\
  \begin{rightwordgroup}{Header}
    \bitbox{4}{Tag} & \bitbox{12}{Mask} \\
    \begin{leftwordgroup}{Node IDs}
      \bitbox{8}{Source} & \bitbox{8}{Destination}
    \end{leftwordgroup}
  \end{rightwordgroup} \\
  \wordbox{3}{Data}
\end{bytefield}
```

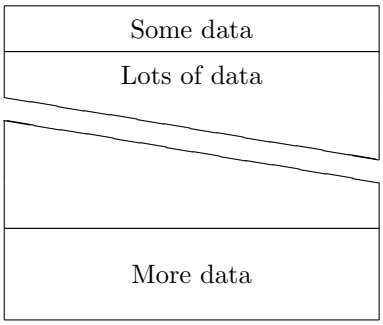


Because `rightwordgroup` and `leftwordgroup` are not required to nest properly, the resulting bit field would look the same if the `\end{leftwordgroup}` and `\end{rightwordgroup}` were swapped. Again, note the justaposition of "\\" to the various word-grouping commands in the above.

`\skippedwords`

Draw a graphic representing a number of words that are not shown. `\skippedwords` is intended to work with the ⟨*sides*⟩ argument to `\wordbox`, as in the following example:

```
\begin{bytefield}{16}
  \wordbox{1}{Some data} \\
  \wordbox[lrt]{1}{Lots of data} \\
  \skippedwords \\
  \wordbox[lrb]{1}{} \\
  \wordbox{2}{More data}
\end{bytefield}
```



`\bytefieldsetup {`⟨*key=value list*⟩`}`

Alter the formatting of all subsequent bit fields. Section 2.2 describes the possible values for each ⟨*key=value*⟩ item in the (comma-separated) list that `\bytefieldsetup` accepts as its argument. Note that changes made with `\bytefieldsetup` are local to their current scope. Hence, if used within an environment (e.g., `figure`), `\bytefieldsetup` does not impact bit fields drawn outside that environment.

2.2 Formatting options

A document author can customize many of the bytefield package's figure-formatting parameters, either globally or on a per-figure basis. The parameters described below can be specified in any of three locations:

- as package options (i.e., in the `\usepackage[`⟨*options*⟩`]{bytefield}` line), which affects all `bytefield` environments in the entire document,
- anywhere in the document using the `\bytefieldsetup` command, which affects all subsequent `bytefield` environments in the current scope, or
- as the optional argument to a `\begin{bytefield}`, which affects only that single bit-field figure.

Unfortunately, LaTeX 2ε tends to abort with a "`TeX capacity exceeded`" or "`Missing \endcsname inserted`" error when a control sequence (i.e., `\`⟨*name*⟩) or `\`⟨*symbol*⟩) is encountered within the optional argument to `\usepackage`. Hence, parameters that typically expect a control sequence in their argument—in particular, `bitformatting`, `boxformatting`, `leftcurly`, and `rightcurly`—should best be avoided within the `\usepackage[`⟨*options*⟩`]{bytefield}` line.

`bitwidth` = ⟨*length*⟩
`bitheight` = ⟨*length*⟩

The above parameters represent the width and height of each bit in a bit field. The default value of `bitwidth` is the width of "`{\tiny 99i}`", i.e., the width of a

two-digit number plus a small amount of extra space. This enables `\bitheader` to show two-digit numbers without overlap. The default value of `bitheight` is `2ex`, which should allow a normal piece of text to appear within a `\bitbox` or `\wordbox` without abutting the box's top or bottom edge.

As a special case, if `bitwidth` is set to the word "`auto`", it will be set to the width of "`99i`" in the current bit-number formatting (cf. `bitformatting` below). This feature provides a convenient way to adjust the bit width after a formatting change.

`bitformatting` = ⟨*command*⟩ *or* `{`⟨*commands*⟩`}`

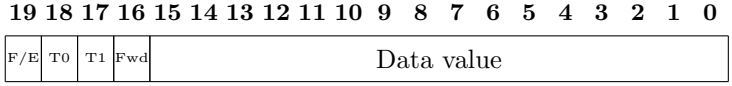
The numbers that appear in a bit header are typeset in the `bitformatting` style, which defaults to `\tiny`. To alter the style of bit numbers in the bit header, set `bitformatting` to a macro that takes a single argument (like `\textbf`) or no arguments (like `\small`). Groups of commands (e.g., `{\large\itshape}`) are also acceptable.

When `bitformatting` is set, `bitwidth` usually needs to be recalculated as well to ensure that a correct amount of spacing surrounds each number in the bit header. As described above, setting `bitwidth=auto` is a convenient shortcut for recalculating the bit-width in the common case of bit fields containing no more than 99 bits per line and no particularly wide labels in bit boxes that contain only a few bits.

The following example shows how to use `bitformatting` and `bitwidth` to format a bit header with small, boldface text:

```
\begin{bytefield}[bitformatting={\small\bfseries},bitwidth=auto]{20}
  \bitheader[b]{0-19} \\
  \bitbox{1}{\tiny F/E} & \bitbox{1}{\tiny T0} & \bitbox{1}{\tiny T1}
  & \bitbox{1}{\tiny Fwd} & \bitbox{16}{Data value} \\
\end{bytefield}
```

The resulting bit field looks like this:



`boxformatting` = ⟨*command*⟩ *or* `{`⟨*commands*⟩`}`

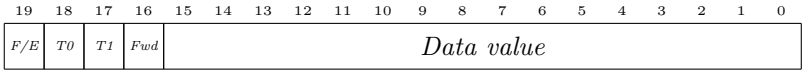
The text that appears in a `\bitbox` or `\wordbox` is formatted in the `boxformatting` style, which defaults to `\centering`. To alter the style of bit numbers in the bit header, set `boxformatting` to a macro that takes a single argument (like `\textbf` but not `\textbf`—see below) or no arguments (like `\small`). Groups of commands (e.g., `{\large\itshape}`) are also acceptable.

If `boxformatting` is set to a macro that takes an argument, the macro must be defined as a "long" macro, which means it can accept more than one paragraph as an argument. Commands defined with `\newcommand` are automatically made long, but commands defined with `\newcommand*` are not. LaTeX's `\text...` formatting commands (e.g., `\textbf`) are not long and therefore cannot be used directly in `boxformatting`; use the zero-argument versions (e.g., `\bfseries`) instead.

The following example shows how to use `boxformatting` to format the text within each box horizontally centered and italicized:

```
\begin{bytefield}[boxformatting={\centering\itshape},
                  bitwidth=1.5em]{20}
  \bitheader[b]{0-19} \\
  \bitbox{1}{\tiny F/E} & \bitbox{1}{\tiny T0} & \bitbox{1}{\tiny T1}
  & \bitbox{1}{\tiny Fwd} & \bitbox{16}{Data value} \\
\end{bytefield}
```

The resulting bit field looks like this:

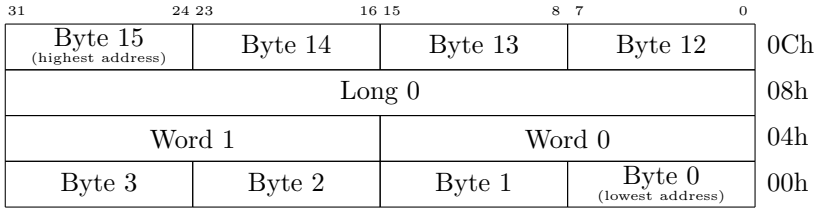


`leftcurly` = ⟨*delimiter*⟩
`rightcurly` = ⟨*delimiter*⟩

Word groups are normally indicated by a curly brace spanning all of its rows. However, the curly brace can be replaced by any other extensible math delimiter (i.e., a symbol that can meaningfully follow `\left` or `\right` in math mode) via a suitable redefinition of `leftcurly` or `rightcurly`. As in math mode, "`.`" means "no symbol", as in the following example (courtesy of Steven R. King):

```
\begin{bytefield}[rightcurly=., rightcurlyspace=0pt]{32}
  \bitheader[b]{0,7,8,15,16,23,24,31} \\
  \begin{rightwordgroup}{0Ch}
    \bitbox{8}{Byte 15 \\ \tiny (highest address)}
    & \bitbox{8}{Byte 14}
    & \bitbox{8}{Byte 13}
    & \bitbox{8}{Byte 12}
  \end{rightwordgroup} \\
  \begin{rightwordgroup}{08h}
    \bitbox{32}{Long 0}
  \end{rightwordgroup} \\
  \begin{rightwordgroup}{04h}
    \bitbox{16}{Word 1} & \bitbox{16}{Word 0}
  \end{rightwordgroup} \\
  \begin{rightwordgroup}{00h}
```

```
    \bitbox{8}{Byte 3}
    & \bitbox{8}{Byte 2}
    & \bitbox{8}{Byte 1}
    & \bitbox{8}{Byte 0 \\ \tiny (lowest address)}
  \end{rightwordgroup} \\
\end{bytefield}
```



`leftcurlyspace` = ⟨*length*⟩
`rightcurlyspace` = ⟨*length*⟩
`curlyspace` = ⟨*length*⟩

`leftcurlyspace` and `rightcurlyspace` specify the space to insert between the bit field and the curly brace in a left or right word group (default: `1ex`). Setting `curlyspace` is a shortcut for setting both `leftcurlyspace` and `rightcurlyspace` to the same value.

`leftlabelspace` = ⟨*length*⟩
`rightlabelspace` = ⟨*length*⟩
`labelspace` = ⟨*length*⟩

`leftlabelspace` and `rightlabelspace` specify the space to insert between the curly brace and the text label in a left or right word group (default: `0.5ex`). Setting `labelspace` is a shortcut for setting both `leftlabelbrace` and `rightlabelspace` to the same value.

Figure 1 illustrates the juxtaposition of `rightcurlyspace` and `rightlabelspace` to a word group and its label. The `leftcurlyspace` and `leftlabelspace` parameters are symmetric.

`leftcurlyshrinkage` = ⟨*length*⟩
`rightcurlyshrinkage` = ⟨*length*⟩
`curlyshrinkage` = ⟨*length*⟩

In TEX/LATEX, the height of a curly brace does not include the tips. Hence, in a word group label, the tips of the curly brace will extend beyond the height of

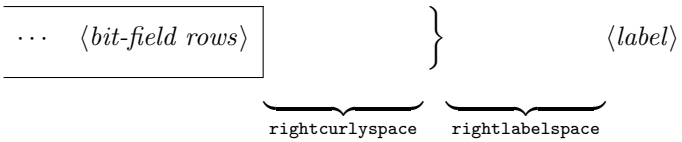


Figure 1: Role of `rightcurlyspace` and `rightlabelspace`

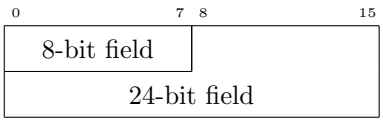
the word group. `leftcurlyshrinkage`/`rightcurlyshrinkage` is an amount by which to reduce the height of the curly brace in a left/right word group's label. Setting `curlyshrinkage` is a shortcut for setting both `leftcurlyshrinkage` and `rightcurlyshrinkage` to the same value. Shrinkages default to `5pt`, and it is extremely unlikely that one would ever need to change them. Nevertheless, these parameters are included here in case a document is typeset with a math font containing radically different curly braces from the ones that come with TEX/LATEX or that replaces the curly braces (using `leftcurly`/`rightcurly`, described above) with symbols of substantially different heights.

2.3 Common tricks

This section shows some clever ways to use bytefield's commands to produce some useful effects.

Odd-sized fields To produce a field that is, say, $1\frac{1}{2}$ words long, use a `\bitbox` for the fractional part and specify appropriate values for the various ⟨*sides*⟩ parameters. For instance:

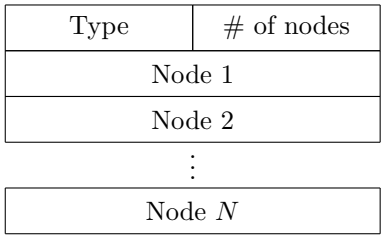
```
\begin{bytefield}{16}
  \bitheader{0,7,8,15} \\
  \bitbox{8}{8-bit field} & \bitbox[lrt]{8}{} \\
  \wordbox[lrb]{1}{24-bit field}
\end{bytefield}
```



Ellipses To skip words that appear the middle of enumerated data, put some `\vdots` in a `\wordbox` with empty ⟨*sides*⟩:

```
\begin{bytefield}{16}
  \bitbox{8}{Type} & \bitbox{8}{\# of nodes} \\
```

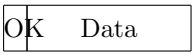
```
  \wordbox{1}{Node~1} \\
  \wordbox{1}{Node~2} \\
  \wordbox[]{1}{$\vdots$ \\[1ex]} \\
  \wordbox{1}{Node~$N$} \\
\end{bytefield}
```



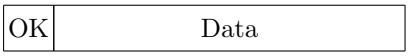
The extra `1ex` of vertical space helps center the `\vdots` a bit better.

Narrow fields There are a number of options for labeling a narrow field (e.g., one occupying a single bit):

Default:




```
\bytefieldsetup{%
  bitwidth=\widthof{OK~}}:
```



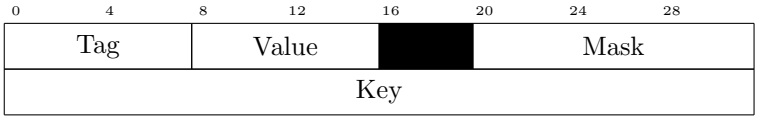
`\tiny OK`:

`\tiny O \\ K`:

`\rotatebox{90}{\small OK}`:

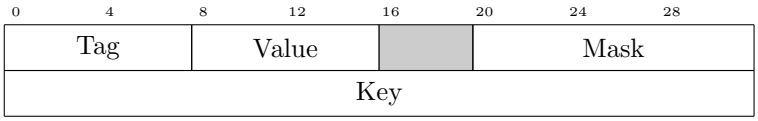
Unused bits Because `\width` and `\height` are defined within bit boxes (also word boxes), we can represent unused bits by filling a `\bitbox` with a rule of size `\width` × `\height`:

```
\begin{bytefield}{32}
  \bitheader{0,4,8,12,16,20,24,28} \\
  \bitbox{8}{Tag} & \bitbox{8}{Value} &
  \bitbox{4}{\rule{\width}{\height}} &
  \bitbox{12}{Mask} \\
  \wordbox{1}{Key}
\end{bytefield}
```



The effect is much better when the color package is used to draw the unused bits in color. (Gray looks nice.)

```
\definecolor{lightgray}{gray}{0.8}
\begin{bytefield}{32}
  \bitheader{0,4,8,12,16,20,24,28} \\
  \bitbox{8}{Tag} & \bitbox{8}{Value} &
  \bitbox{4}{\color{lightgray}\rule{\width}{\height}} &
  \bitbox{12}{Mask} \\
  \wordbox{1}{Key}
\end{bytefield}
```



Aligning text on the baseline Because bytefield internally uses LaTeX's `picture` environment and that environment's `\makebox` command to draw bit boxes and word boxes, the text within a box is centered vertically with no attention paid to the text's baseline. As a result, some bit fields appear somewhat askew:

```
\begin{bytefield}[bitwidth=1.5em]{2}
  \bitbox{1}{M} & \bitbox{1}{y} \\
\end{bytefield}
```

A solution is to use the `boxformatting` option to trick `\makebox` into thinking that all text has the same height and depth. Here we use `\raisebox` to indicate that all text is as tall as a "`W`" and does not descend at all below the baseline:

```
\newlength{\maxheight}
\setlength{\maxheight}{\heightof{W}}

\newcommand{\baselinealign}[1]{%
  \centering
```

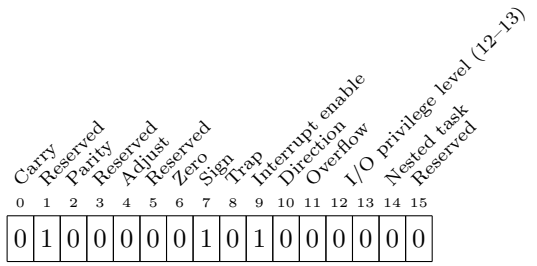
```
  \raisebox{0pt}[\maxheight][0pt]{#1}%
}

\begin{bytefield}[boxformatting=\baselinealign,
                  bitwidth=1.5em]{2}
  \bitbox{1}{M} & \bitbox{1}{y} \\
\end{bytefield}
```

Register contents Sometimes, rather than listing the *meaning* of each bit field within each `\bitbox` or `\wordbox`, it may be desirable to list the *contents*, with the meaning described in an additional label above each bit number in the bit header. Although the register package is more suited to this form of layout, bytefield can serve in a pinch with the help of the `\turnbox` macro from the rotating package:

```
\newcommand{\bitlabel}[2]{%
  \bitbox[]{#1}{%
    \raisebox{0pt}[4ex][0pt]{%
      \turnbox{45}{\fontsize{7}{7}\selectfont#2}%
    }%
  }%
}

\begin{bytefield}[bitwidth=1em]{16}
   \bitlabel{1}{Carry} & \bitlabel{1}{Reserved} &
   \bitlabel{1}{Parity} & \bitlabel{1}{Reserved} &
   \bitlabel{1}{Adjust} & \bitlabel{1}{Reserved} &
   \bitlabel{1}{Zero} & \bitlabel{1}{Sign} &
   \bitlabel{1}{Trap} & \bitlabel{1}{Interrupt enable} &
   \bitlabel{1}{Direction} & \bitlabel{1}{Overflow} &
   \bitlabel{2}{I/O privilege level (12--13)} &
   \bitlabel{1}{Nested task} & \bitlabel{1}{Reserved} \\
   \bitheader{0-15} \\
   \bitbox{1}{0} & \bitbox{1}{1} & \bitbox{1}{0} & \bitbox{1}{0} &
   \bitbox{1}{0} & \bitbox{1}{0} & \bitbox{1}{0} & \bitbox{1}{1} &
   \bitbox{1}{0} & \bitbox{1}{1} & \bitbox{1}{0} & \bitbox{1}{0} &
   \bitbox{1}{0} & \bitbox{1}{0} & \bitbox{1}{0} & \bitbox{1}{0} \\
 \end{bytefield}
```



2.4 Not-so-common tricks

Colored fields A similar approach to that utilized to indicate unused bits can be applied to coloring an individual bit field. The trick is to use the TEX `\rlap` primitive to draw a colored box that overlaps whatever follows it to the right:

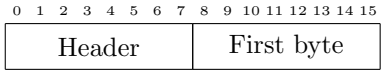
```
\begingroup
  \small
  \newcommand{\colorbitbox}[3]{%
    \rlap{\bitbox{#2}{\color{#1}\rule{\width}{\height}}}%
    \bitbox{#2}{#3}}
  \definecolor{lightcyan}{rgb}{0.84,1,1}
  \definecolor{lightgreen}{rgb}{0.64,1,0.71}
  \definecolor{lightred}{rgb}{1,0.7,0.71}

  \begin{bytefield}[bitheight=\widthof{~Sign~}]{32}
    \bitheader[b]{31,23,0} \\
    \colorbitbox{lightcyan}{1}{\rotatebox{90}{Sign}} &
    \colorbitbox{lightgreen}{8}{Exponent} &
    \colorbitbox{lightred}{23}{Mantissa} \\
  \end{bytefield}
\endgroup
```

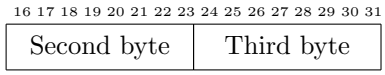
Renumbered bit headers The `\bitheader` macro always numbers bits starting from 0. However, one may occasionally want to begin numbering from a different value. (This was in fact a feature request from Chris L'Esperance.) The way to accomplish this is to define a macro that adds a value to its argument and specify this macro to the `bitformatting` parameter. This works because the argument passed to a macro named by `bitformatting` is always numeric except when called from `bitwidth=auto`. (Caveat: This happens automatically at the `\begin{document}`.) However, bytefield sometimes passes a `bitformatting`-named macro the value `1234567890` to measure the height of a formatted bit number. The examples below include a case in which this value needs to be

checked explicitly to ensure that the height is correct even when the formatted number is rotated by 90°.

```
\begin{bytefield}{16}
  \bitheader{0-15} \\
  \bitbox{8}{Header} & \bitbox{8}{First byte} \\
\end{bytefield}
```

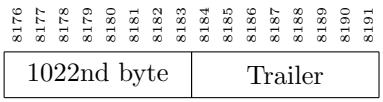



```
\newcommand{\formatplusXVI}[1]{%
  \tiny
  \count10=#1
  \advance\count10 by 16
  \the\count10
}
\begin{bytefield}[bitformatting=\formatplusXVI]{16}
  \bitheader{0-15} \\
  \bitbox{8}{Second byte} & \bitbox{8}{Third byte} \\
\end{bytefield}
```




```
\newcommand{\formatplusMMMMMMMMCLXXVI}[1]{%
  \tiny
  \count10=#1
  \ifnum\count10=1234567890
    \rotatebox[origin=B]{90}{8191}%
  \else
    \advance\count10 by 8176
    \rotatebox[origin=B]{90}{\the\count10}%
  \fi
}

\begin{bytefield}[bitformatting=\formatplusMMMMMMMMCLXXVI]{16}
  \bitheader{0-15} \\
  \bitbox{8}{1022nd byte} & \bitbox{8}{Trailer} \\
\end{bytefield}
```

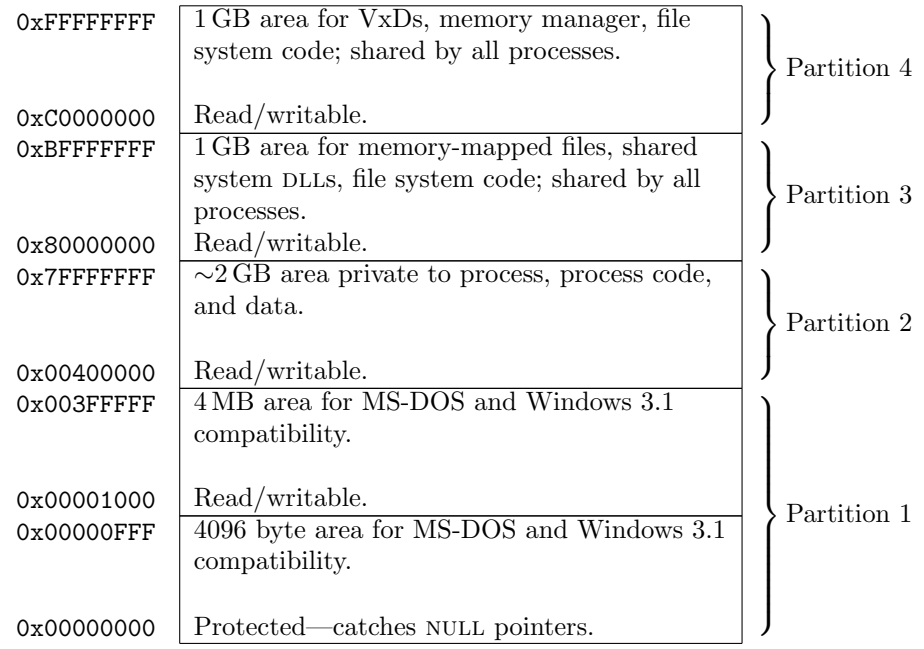


As an even trickier example of modifying bit numbers, the following shows how to *conditionally* modify the bit number: If the number is `1234567890` (for bytefield's bit-height calculation, the number is used as is; numbers greater than 9 are increased by 48; numbers less than 4 are unmodified; the number 6 is replaced by an ellipsis; and all other numbers are discarded.

```
\newcommand{\fakesixtyfourbits}[1]{%
  \tiny
  \ifnum#1=1234567890
    #1
  \else
    \ifnum#1>9
      \count32=#1
      \advance\count32 by 48
      \the\count32%
    \else
      \ifnum#1<4
        #1%
      \else
        \ifnum#1=6
          $\cdots$%
        \fi
      \fi
    \fi
  \fi
}
\begin{bytefield}[%
    bitwidth=\widthof{\tiny Fwd~},
    bitformatting=\fakesixtyfourbits]{16}
  \bitheader[b]{0-15} \\
  \bitbox{1}{\tiny F/E} & \bitbox{1}{\tiny T0} & \bitbox{1}{\tiny T1}
  & \bitbox{1}{\tiny Fwd} & \bitbox{12}{Data value} \\
\end{bytefield}
```

Memory-map diagrams While certainly not the intended purpose of the bytefield package, one can utilize word boxes with empty ⟨*sides*⟩ and word labels to produce memory-map diagrams:

```
\newcommand{\descbox}[2]{\parbox[c][3.8\baselineskip]{0.95\width}{%
  \raggedright #1\vfill #2}}
\begin{bytefield}[bitheight=4\baselineskip]{32}
  \begin{rightwordgroup}{Partition 4}
    \bitbox[]{8}{\texttt{0xFFFFFFFF} \\[2\baselineskip]
      \texttt{0xC0000000}} &
    \bitbox{24}{\descbox{1\,GB area for VxDs, memory manager,
      file system code; shared by all processes.}{Read/writable.}}
  \end{rightwordgroup} \\
  \begin{rightwordgroup}{Partition 3}
    \bitbox[]{8}{\texttt{0xBFFFFFFF} \\[2\baselineskip]
      \texttt{0x80000000}} &
    \bitbox{24}{\descbox{1\,GB area for memory-mapped files,
      shared system \textsc{dll}s, file system code; shared by all
      processes.}{Read/writable.}}
  \end{rightwordgroup} \\
  \begin{rightwordgroup}{Partition 2}
    \bitbox[]{8}{\texttt{0x7FFFFFFF} \\[2\baselineskip]
      \texttt{0x00400000}} &
    \bitbox{24}{\descbox{$\sim$2\,GB area private to process,
       process code, and data.}{Read/writable.}}
  \end{rightwordgroup} \\
  \begin{rightwordgroup}{Partition 1}
    \bitbox[]{8}{\texttt{0x003FFFFF} \\[2\baselineskip]
      \texttt{0x00001000}} &
    \bitbox{24}{\descbox{4\,MB area for MS-DOS and Windows~3.1
      compatibility.}{Read/writable.}} \\
    \bitbox[]{8}{\texttt{0x00000FFF} \\[2\baselineskip]
      \texttt{0x00000000}} &
    \bitbox{24}{\descbox{4096~byte area for MS-DOS and Windows~3.1
      compatibility.}{Protected---catches \textsc{null}
      pointers.}}
  \end{rightwordgroup} \\
```



2.5 Putting it all together

The following code showcases most of bytefield's features in a single figure.

```
\begin{bytefield}[bitheight=2.5\baselineskip]{32}
  \bitheader{0,7,8,15,16,23,24,31} \\
  \begin{rightwordgroup}{\parbox{6em}{\raggedright These words were taken
    verbatim from the TCP header definition (RFC~793).}}
    \bitbox{4}{Data offset} & \bitbox{6}{Reserved} &
      \bitbox{1}{\tiny U\\R\\G} & \bitbox{1}{\tiny A\\C\\K} &
      \bitbox{1}{\tiny P\\S\\H} & \bitbox{1}{\tiny R\\S\\T} &
      \bitbox{1}{\tiny S\\Y\\N} & \bitbox{1}{\tiny F\\I\\N} &
      \bitbox{16}{Window} \\
    \bitbox{16}{Checksum} & \bitbox{16}{Urgent pointer}
  \end{rightwordgroup} \\
  \wordbox[lrt]{1}{Data octets} \\
  \skippedwords \\
  \wordbox[lrb]{1}{} \\
  \begin{leftwordgroup}{\parbox{6em}{\raggedright Note that we can display,
    for example, a misaligned 64-bit value with clever use of the
    optional argument to \texttt{\string\wordbox} and
    \texttt{\string\bitbox}.}}
    \bitbox{8}{Source} & \bitbox{8}{Destination} &
      \bitbox[lrt]{16}{} \\
```

```
    \wordbox[lr]{1}{Timestamp} \\
    \begin{rightwordgroup}{\parbox{6em}{\raggedright Why two Length fields?
      No particular reason.}}
      \bitbox[lrb]{16}{} & \bitbox{16}{Length}
  \end{leftwordgroup} \\
      \bitbox{6}{Key} & \bitbox{6}{Value} & \bitbox{4}{Unused} &
        \bitbox{16}{Length}
    \end{rightwordgroup} \\
  \wordbox{1}{Total number of 16-bit data words that follow this
    header word, excluding the subsequent checksum-type value} \\
  \bitbox{16}{Data~1} & \bitbox{16}{Data~2} \\
  \bitbox{16}{Data~3} & \bitbox{16}{Data~4} \\
  \bitbox[]{16}{$\vdots$ \\[1ex]} &
    \bitbox[]{16}{$\vdots$ \\[1ex]} \\
  \bitbox{16}{Data~$N-1$} & \bitbox{16}{Data~$N$} \\
  \bitbox{20}{\[ \mbox{A5A5}_{\mbox{\scriptsize H}} \oplus
    \left(\sum_{i=1}^N \mbox{Data}_i \right) \bmod 2^{20} \]} &
    \bitbox{12}{Command} \\
  \wordbox{2}{64-bit random number}
\end{bytefield}
```

Figure 2 shows the resulting protocol diagram.

2.6 Upgrading from older versions

bytefield's user interface changed substantially with the introduction of version 2.0. Because documents written for bytefield v1.x will not build properly under later versions of the package, this section shows how to convert documents to the new interface.

```
\wordgroupr
\endwordgroupr
```

These have been replaced with the `rightwordgroup` environment to make their invocation more LaTeX-like. Use `\begin{rightwordgroup}` instead of `\wordgroupr` and `\end{rightwordgroup}` instead of `\endwordgroupr`.

```
\wordgroupl
\endwordgroupl
```

These have been replaced with the `leftwordgroup` environment to make their invocation more LaTeX-like. Use `\begin{leftwordgroup}` instead of `\wordgroupl` and `\end{leftwordgroup}` instead of `\endwordgroupl`.

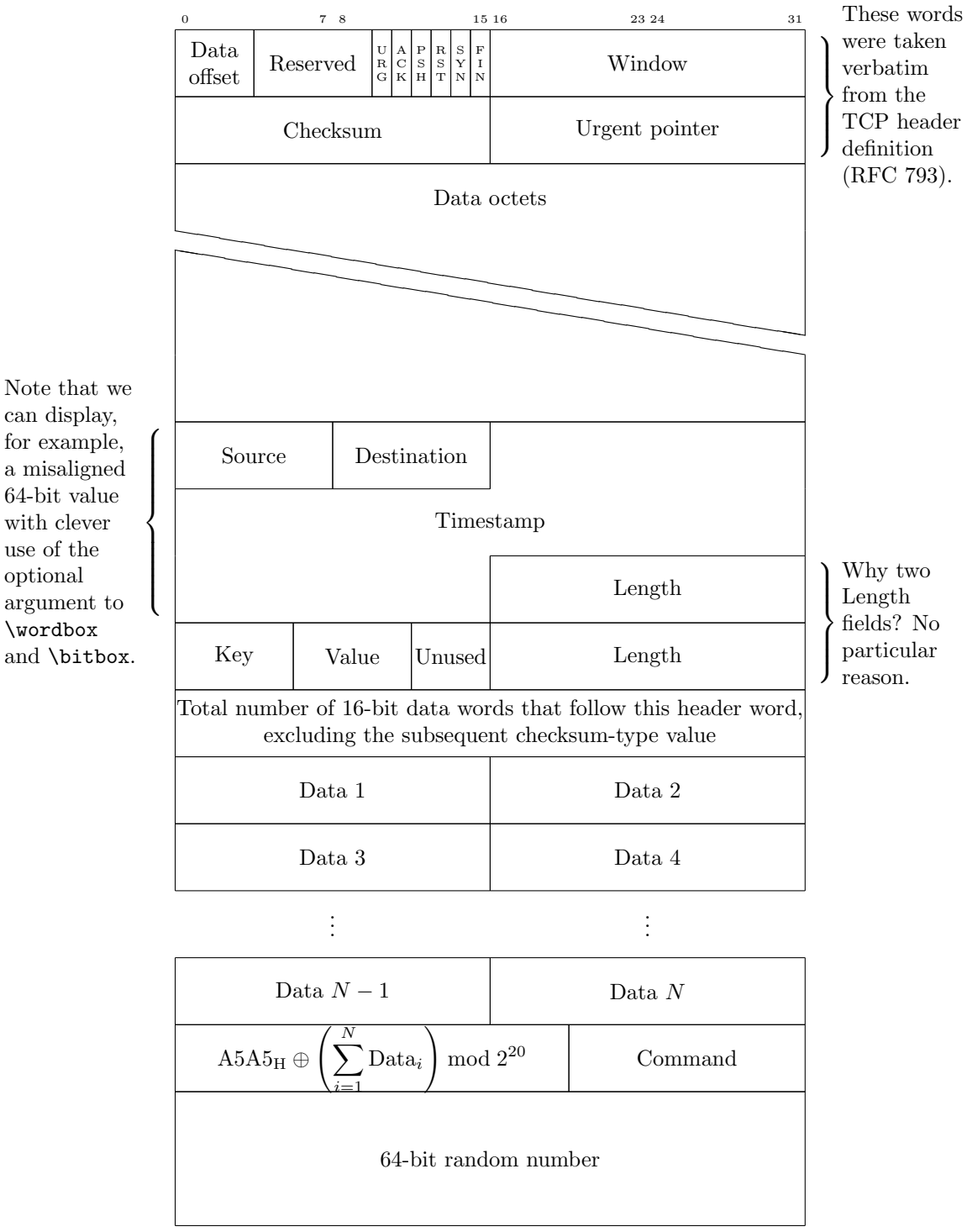


Figure 2: Complex protocol diagram drawn with the bytefield package

`\bitwidth`

Instead of changing bit widths with `\setlength{\bitwidth}{`⟨*width*⟩`}`, use `\bytefieldsetup{bitwidth=`⟨*width*⟩`}`.

`\byteheight`

Instead of changing bit heights with `\setlength{\byteheight}{`⟨*height*⟩`}`, use `\bytefieldsetup{bitheight=`⟨*height*⟩`}` (and note the change from "`byte`" to "`bit`" for consistency with `bitwidth`).

`\curlyspace`
`\labelspace`

Instead of using `\setlength{\curlyspace}{`⟨*dist*⟩`}` and `\setlength{\labelspace}{`⟨*dist*⟩`}` to alter the horizontal space that appears before and after a curly brace, use `\bytefieldsetup{curlyspace=`⟨*dist*⟩`}` and `\bytefieldsetup{labelspace=`⟨*dist*⟩`}`. Note that, as described in Section 2.1, left and right spacing can be set independently if desired.

`\curlyshrinkage`

Instead of using `\setlength{\curlyshrinkage}{`⟨*dist*⟩`}` to reduce the vertical space occupied by a curly brace, use `\bytefieldsetup{curlyshrinkage=`⟨*dist*⟩`}`. Note that, as described in Section 2.1, left and right curly-brace height can be reduced independently if desired.

As a crutch to help build older documents with minimal modification, bytefield provides a `compat1` package option that restores the old interface. This option, invoked with `\usepackage[compat1]{bytefield}`, may disappear in a future version of the package and should therefore not be relied upon as a long-term approach to using bytefield.

3 Implementation

This section contains the complete source code for bytefield. Most users will not get much out of it, but it should be of use to those who need more precise documentation and those who want to extend (or debug ☺) the bytefield package.

In this section, macros marked in the margin with a "★" are intended to be called by the user (and were described in Section 2). All other macros are used only internally by bytefield.

3.1 Required packages

Although `\widthof` and `\heightof` were introduced in June 1998, teTeX 2.0—still in widespread use at the time of this writing (2005)—ships with an earlier `calc.sty` in the `source` directory. Because a misconfigured system may find the `source` version of `calc.sty` we explicitly specify a later date when loading the `calc` package.

```
\RequirePackage{calc}[1998/07/07]
\RequirePackage{keyval}
```

3.2 Utility macros

The following macros in this section are used by the box-drawing macros and the "skipped words"-drawing macros.

`\bf@newdimen` `\allocationnumber`

`\newdimen` defines new ⟨*dimen*⟩s globally. `\bf@newdimen` defines them locally. It simply merges LaTeX 2ε's `\newdimen` and `\alloc@` macros while omitting `\alloc@`'s "`\global`" declaration.

```
\def\bf@newdimen#1{\advance\count11 by 1
  \ch@ck1\insc@unt\dimen
  \allocationnumber=\count11
  \dimendef#1=\allocationnumber
  \wlog{\string#1=\string\dimen\the\allocationnumber\space (locally)}%
}
```

`\bf@newdimen`

If we're using ε-TeX then we have access to many more ⟨*dimen*⟩s than in original TeX. The etex package makes these extra ⟨*dimen*⟩s available via the `\locdimen` macro. At the start of the document we check if `\locdimen` is defined and, if so, replace the preceding definition of `\bf@newdimen` with etex's `\locdimen`.

```
\AtBeginDocument{%
  \begingroup\expandafter\expandafter\expandafter\endgroup
  \expandafter\ifx\csname locdimen\endcsname\relax
  \else
    \let\bf@newdimen\locdimen
  \fi
}
```

`\bytefield@height` `\ifcounting@words`

When `\ifcounting@words` is True, add the height of the next `picture` environment to `\bytefield@height`. We set `\counting@wordstrue` at the beginning of each word, and `\counting@wordsfalse` after each `\bitbox`, `\wordbox`, or `\skippedwords` picture.

```
\newlength{\bytefield@height}
\newif\ifcounting@words
```

`\inc@bytefield@height`

We have to define a special macro to increment `\bytefield@height` because the calc package's `\addtolength` macro doesn't seem to see the global value. So we `\setlength` a temporary (to get calc's nice infix features) and `\advance` `\bytefield@height` by that amount.

```
\newlength{\bytefield@height@increment}
\DeclareRobustCommand{\inc@bytefield@height}[1]{%
  \setlength{\bytefield@height@increment}{#1}%
  \global\advance\bytefield@height by \bytefield@height@increment}
```

3.3 Top-level environment

`bits@wide` The number of bits in each word (i.e., the argument to the `\bytefield` environment).

```
\newcounter{bits@wide}
```

`\entire@bytefield@picture` A box containing the entire bytefield. By storing everything in a box and then typesetting it later (at the `\end{bytefield}`), we can center the bit field, put a box around it, and do other operations on the entire figure.

```
\newsavebox{\entire@bytefield@picture}
```

★ `bytefield` `\old@nl` `\amp` Environment containing the layout of bits in a sequence of bytes. This is the main environment defined by the bytefield package. The argument is the number of bits wide the bytefield should be. We turn `&` into a space character so the user can think of a bytefield as being analogous to a `tabular` environment, even though we're really setting the bulk of the picture in a single column. (Row labels go in separate columns, however.)

```
\newenvironment{bytefield}[2][]{%
  \bf@bytefieldsetup{#1}%
  \setcounter{bits@wide}{#2}%
  \let\old@nl=\\%
  \let\amp=&%
  \catcode`\&=10
  \openup -1pt
  \setlength{\bytefield@height}{0pt}%
  \setlength{\unitlength}{1pt}%
  \global\counting@wordstrue
  \begin{lrbox}{\entire@bytefield@picture}%
```

`\\` We redefine `\\` within the `bytefield` environment to make it aware of curly braces that surround the protocol diagram.

```
  \renewcommand{\\}{%
    \unskip
    \amp\show@wordlabelr\cr
    \ignorespaces\global\counting@wordstrue\make@lspace\amp}%

  \vbox\bgroup\ialign\bgroup##\amp##\amp##\cr\amp
}{%
  \amp\show@wordlabelr\cr\egroup\egroup
  \end{lrbox}%
  \usebox{\entire@bytefield@picture}}
```

3.4 Box-drawing macros

3.4.1 Drawing (proper)

`\bf@bitformatting` Formats a bit number in the bit header. `\bf@bitformatting` may be redefined to take either a single argument (à la `\textbf`) or no argument (à la `\small`).

```
\newcommand*{\bf@bitformatting}{\tiny}
```

`\bf@boxformatting` Formats the text within a bit box or word box. `\bf@boxformatting` takes either a single argument (à la `\textbf`) or no argument (à la `\small`). The text that follows `\bf@boxformatting` is guaranteed to be a group that ends in `\par`, so if `\bf@boxformatting` accepts an argument, the macro should be defined with `\long` (e.g., with `\newcommand` but not with `\newcommand*`).

```
\newcommand*{\bf@boxformatting}{\centering}
```

`\bf@bitwidth` The width of a single bit. Note that this is wide enough to display a two-digit number without it running into adjacent numbers. For larger words, be sure to `\setlength` this larger.

```
\newlength{\bf@bitwidth}
\settowidth{\bf@bitwidth}{\bf@bitformatting{99i}}
```

`\bf@bitheight` The height of a single bit within the bit field.

```
\newlength{\bf@bitheight}
\setlength{\bf@bitheight}{4ex}
```

`\units@wide` `\units@tall` Scratch variables for storing the width and height (in points) of the box we're about to draw.

```
\newlength{\units@wide}
\newlength{\units@tall}
```

★ `\bitbox` Put some text (`#3`) in a box that's a given number of bits (`#2`) wide and one byte tall. An optional argument (`#1`) specifies which lines to draw—`[l]`eft, `[r]`ight, `[t]`op, and/or `[b]`ottom (default: `lrtb`).

```
\DeclareRobustCommand{\bitbox}[3][lrtb]{%
  \setlength{\units@wide}{\bf@bitwidth * #2}%
  \parse@bitbox@arg{#1}%
  \draw@bit@picture{\strip@pt\units@wide}{\strip@pt\bf@bitheight}{#3}}
```

★ `\wordbox` Put some text (`#3`) in a box that's a given number of bytes (`#2`) tall and one word (`bits@wide` bits) wide. An optional argument (`#1`) specifies which lines to draw—`[l]`eft, `[r]`ight, `[t]`op, and/or `[b]`ottom (default: `lrtb`).

```
\DeclareRobustCommand{\wordbox}[3][lrtb]{%
  \setlength{\units@wide}{\bf@bitwidth * \value{bits@wide}}%
  \setlength{\units@tall}{\bf@bitheight * #2}%
  \parse@bitbox@arg{#1}%
  \draw@bit@picture{\strip@pt\units@wide}{\strip@pt\units@tall}{#3}}
```

\draw@bit@picture Put some text (#3) in a box that's a given number of units (#1) wide and a given number of units (#2) tall. We format the text with a \parbox to enable word-wrapping and explicit line breaks. In addition, we define \height, \depth, \totalheight, and \width (à la \makebox and friends), so the user can utilize those for special effects (e.g., a \rule that fills the entire box). As an added bonus, we define \widthunits and \heightunits, which are the width and height of the box in multiples of \unitlength (i.e., #1 and #2, respectively).

```
\DeclareRobustCommand{\draw@bit@picture}[3]{%
  \begin{picture}(#1,#2)%
```

\height \depth \totalheight \width \widthunits \heightunits First, we plot the user's text, with all sorts of useful lengths predefined.

```
    \put(0,0){\makebox(#1,#2){\parbox{#1\unitlength}{%
      \bf@newdimen\height
      \bf@newdimen\depth
      \bf@newdimen\totalheight
      \bf@newdimen\width
      \height=#2\unitlength
      \depth=0pt%
      \totalheight=#2\unitlength
      \width=#1\unitlength
      \def\widthunits{#1}%
      \def\heightunits{#2}%
      \bf@boxformatting{#3\par}}}}%
```

Next, we draw each line individually. I suppose we could make a special case for "all lines" and use a \framebox above, but the following works just fine.

```
    \ifbitbox@top
      \put(0,#2){\line(1,0){#1}}
    \fi
    \ifbitbox@bottom
      \put(0,0){\line(1,0){#1}}
    \fi
    \ifbitbox@left
      \put(0,0){\line(0,1){#2}}
    \fi
    \ifbitbox@right
      \put(#1,0){\line(0,1){#2}}
    \fi
  \end{picture}%
```

Finally, we indicate that we're no longer at the beginning of a word. The following code structure (albeit with different arguments to \inc@bytefield@height) is repeated in various places throughout this package. We document it only here, however.

```
  \ifcounting@words
    \inc@bytefield@height{\unitlength * \real{#2}}%
    \global\counting@wordsfalse
  \fi
  \ignorespaces}
```

3.4.2 Parsing arguments

The macros in this section are used to parse the optional argument to `\bitbox` or `\wordbox`, which is some subset of {`l`, `r`, `t`, `b`}.

`\ifbitbox@top` `\ifbitbox@bottom` `\ifbitbox@left` `\ifbitbox@right`

These macros are set to TRUE if we're to draw the corresponding edge on the subsequent `\bitbox` or `\wordbox`.

```
\newif\ifbitbox@top
\newif\ifbitbox@bottom
\newif\ifbitbox@left
\newif\ifbitbox@right
```

`\parse@bitbox@arg`

This main parsing macro merely resets the above conditionals and calls a helper function, `\parse@bitbox@sides`.

```
\def\parse@bitbox@arg#1{%
  \bitbox@topfalse
  \bitbox@bottomfalse
  \bitbox@leftfalse
  \bitbox@rightfalse
  \parse@bitbox@sides#1X}
```

`\parse@bitbox@sides`

The helper function for `\parse@bitbox@arg` parses a single letter, sets the appropriate conditional to TRUE, and calls itself tail-recursively until it sees an "`X`".

```
\def\parse@bitbox@sides#1{%
  \ifx#1X%
  \else
    \ifx#1t%
      \bitbox@toptrue
    \else
      \ifx#1b%
        \bitbox@bottomtrue
      \else
        \ifx#1l%
          \bitbox@lefttrue
        \else
          \ifx#1r%
            \bitbox@righttrue
          \fi
        \fi
      \fi
    \fi
    \expandafter\parse@bitbox@sides
  \fi}
```

3.5 Skipped words

`\units@high`

The height of each diagonal line in the `\skippedwords` graphic. Note that `\units@high` = `\units@tall` − *optional argument to* `\skippedwords`.

```
\newlength{\units@high}
```

★ `\skippedwords` Output a fancy graphic representing skipped words. The optional argument is the vertical space between the two diagonal lines (default: `2ex`).

```
\DeclareRobustCommand{\skippedwords}[1][2ex]{%
  \setlength{\units@wide}{\bf@bitwidth * \value{bits@wide}}%
  \setlength{\units@high}{1pt * \ratio{\units@wide}{6.0pt}}%
  \setlength{\units@tall}{#1 + \units@high}%
  \edef\num@wide{\strip@pt\units@wide}%
  \edef\num@tall{\strip@pt\units@tall}%
  \edef\num@high{\strip@pt\units@high}%
  \begin{picture}(\num@wide,\num@tall)
    \put(0,\num@tall){\line(6,-1){\num@wide}}
    \put(\num@wide,0){\line(-6,1){\num@wide}}
    \put(0,0){\line(0,1){\num@high}}
    \put(\num@wide,\num@tall){\line(0,-1){\num@high}}
  \end{picture}%
  \ifcounting@words
    \inc@bytefield@height{\unitlength * \real{\num@tall}}%
    \global\counting@wordsfalse
  \fi}
```

3.6 Bit-position labels

★ `\bitheader` Output a header of numbered bit positions. The optional argument (`#1`) is "`l`" for little-endian (default) or "`b`" for big-endian. The required argument (`#2`) is a list of bit positions to label. It is composed of comma-separated ranges of numbers, for example, "`0-31`", "`0,7-8,15-16,23-24,31`", or even something odd like "`0-7,15-23`". Ranges must be specified in increasing order; use the optional argument to `\bitheader` to reverse the labels' direction.

```
\DeclareRobustCommand{\bitheader}[2][l]{%
  \parse@bitbox@arg{lrtb}%
  \setlength{\units@wide}{\bf@bitwidth * \value{bits@wide}}%
  \setlength{\units@tall}{\heightof{\bf@bitformatting{1234567890}}}%
  \setlength{\units@high}{\units@tall * -1}%
  \def\bit@endianness{#1}%
  \begin{picture}(\strip@pt\units@wide,\strip@pt\units@tall)%
                 (0,\strip@pt\units@high)
    \parse@range@list#2,X,
  \end{picture}%
  \ifcounting@words
    \inc@bytefield@height{\unitlength * \real{\strip@pt\units@tall}}%
    \global\counting@wordsfalse
  \fi
  \ignorespaces}
```

`\parse@range@list` Helper function #1 for `\bitheader`—parse a comma-separated list of ranges, calling `\parse@range` on each range.

```
\def\parse@range@list#1,{%
```

```
\ifx X#1
\else
  \parse@range#1-#1-#1\relax
  \expandafter\parse@range@list
\fi}
```

\header@xpos
header@val
max@header@val

Miscellaneous variables used internally by \parse@range—x position of header, current label to output, and maximum label to output (+1).

```
\newlength{\header@xpos}
\newcounter{header@val}
\newcounter{max@header@val}
```

\parse@range

Helper function #2 for \bitheader—parse a hyphen-separated pair of numbers (or a single number) and display the number at the correct bit position.

```
\def\parse@range#1-#2-#3\relax{%
  \setcounter{header@val}{#1}
  \setcounter{max@header@val}{#2 + 1}
  \loop
    \ifnum\value{header@val}<\value{max@header@val}%
      \if\bit@endianness b%
        \setlength{\header@xpos}{%
          \bf@bitwidth * (\value{bits@wide}-\value{header@val}-1)}
      \else
        \setlength{\header@xpos}{\bf@bitwidth * \value{header@val}}
      \fi
      \put(\strip@pt\header@xpos,0){%
        \makebox(\strip@pt\bf@bitwidth,\strip@pt\units@tall){%
          \bf@bitformatting{\theheader@val}}}
      \addtocounter{header@val}{1}
  \repeat}
```

3.7 Word labels

3.7.1 Curly-brace manipulation

\bf@leftcurlyshrinkage
\bf@rightcurlyshrinkage

Reduce the height of a left (right) curly brace by \bf@leftcurlyshrinkage (\bf@rightcurlyshrinkage) so its ends don't overlap whatever is above or below it. The default value (5 pt.) was determined empirically and shouldn't need to be changed. However, on the off-chance the user employs a math font with very different curly braces from Computer Modern's, \bf@leftcurlyshrinkage and \bf@rightcurlyshrinkage can be modified.

```
\def\bf@leftcurlyshrinkage{5pt}
\def\bf@rightcurlyshrinkage{5pt}
```

\bf@leftcurlyspace
\bf@rightcurlyspace
\bf@leftlabelspace
\bf@rightlabelspace

Space to insert before a curly brace and before a word label (i.e., after a curly brace).

```
\def\bf@leftcurlyspace{0pt}
\def\bf@rightcurlyspace{0pt}
```

```
\def\bf@leftlabelspace{0pt}
\def\bf@rightlabelspace{0pt}

\gdef\bf@leftcurlyspace{1ex}
\gdef\bf@rightcurlyspace{1ex}
\gdef\bf@leftlabelspace{0.5ex}
\gdef\bf@rightlabelspace{0.5ex}
```

`\bf@leftcurly` `\bf@rightcurly` Symbols to use as left and right curly braces. These symbols must be extensible math symbols (i.e., they will immediately follow `\left` or `\right` in math mode).

```
\let\bf@leftcurly=\{
\let\bf@rightcurly=\}
```

`\curly@box` Define a box in which to temporarily store formatted curly braces.

```
\newbox{\curly@box}
```

`\store@rcurly` `\curly@height` `\half@curly@height` `\curly@shift` `\old@axis` Store a "}" that's `#2` tall in box `#1`. The only unintuitive thing here is that we have to redefine `\fontdimen22`—axis height—to 0 pt. before typesetting the curly brace. Otherwise, the brace would be vertically off-center by a few points. When we're finished, we reset it back to its old value.

```
\def\store@rcurly#1#2{%
  \begingroup
    \bf@newdimen\curly@height
    \setlength{\curly@height}{#2 - \bf@rightcurlyshrinkage}%
    \bf@newdimen\half@curly@height
    \setlength{\half@curly@height}{0.5\curly@height}%
    \bf@newdimen\curly@shift
    \setlength{\curly@shift}{\bf@rightcurlyshrinkage}%
    \setlength{\curly@shift}{\half@curly@height + 0.5\curly@shift}%
    \global\sbox{#1}{\raisebox{\curly@shift}{%
      $\xdef\old@axis{\the\fontdimen22\textfont2}$%
      $\fontdimen22\textfont2=0pt%
       \left.
       \vrule height\half@curly@height
              width 0pt
              depth\half@curly@height\right\bf@rightcurly$%
      $\fontdimen22\textfont2=\old@axis$}}%
  \endgroup
}
```

`\store@lcurly` `\curly@height` `\half@curly@height` `\curly@shift` Same as `\store@rcurly`, but using a "{" instead of a "}".

```
\def\store@lcurly#1#2{%
  \begingroup
    \bf@newdimen\curly@height
    \setlength{\curly@height}{#2 - \bf@leftcurlyshrinkage}%
    \bf@newdimen\half@curly@height
    \setlength{\half@curly@height}{0.5\curly@height}%
    \bf@newdimen\curly@shift
    \setlength{\curly@shift}{\bf@leftcurlyshrinkage}%
```

```
    \setlength{\curly@shift}{\half@curly@height + 0.5\curly@shift}%
    \global\sbox{#1}{\raisebox{\curly@shift}{%
      $\xdef\old@axis{\the\fontdimen22\textfont2}$%
      $\fontdimen22\textfont2=0pt%
       \left\bf@leftcurly
       \vrule height\half@curly@height
              width 0pt
              depth\half@curly@height\right.$%
      $\fontdimen22\textfont2=\old@axis$}}%
  \endgroup
}
```

3.7.2 Right-side labels

`\show@wordlabelr` This macro is output in the third column of every row of the `\ialign`ed bytefield table. It's normally a no-op, but `\end{rightwordgroup}` defines it to output the word label and then reset itself to a no-op.

```
\def\show@wordlabelr{}
```

`\wordlabelr@start` `\wordlabelr@end` The starting and ending height (in points) of the set of rows to be labeled on the right.

```
\newlength{\wordlabelr@start}
\newlength{\wordlabelr@end}
```

★ `rightwordgroup` Label the words defined between `\begin{rightwordgroup}` and `\end{rightwordgroup}` on the right side of the bit field. The argument is the text of the label. The label is typeset to the right of a large curly brace, which groups the words together.

```
\newenvironment{rightwordgroup}[1]{%
```

We begin by ending the group that `\begin{rightwordgroup}` created. This lets the `rightwordgroup` environment span rows (because we're technically no longer within the environment).

```
  \endgroup
```

`\wordlabelr@start` `\wordlabelr@text` `\begin{rightwordgroup}` merely stores the starting height in `\wordlabelr@start` and the user-supplied text in `\wordlabelr@text`. `\end{rightwordgroup}` does most of the work.

```
  \global\wordlabelr@start=\bytefield@height
  \gdef\wordlabelr@text{#1}%
  \ignorespaces
}{%
```

`\wordlabelr@end` Because we already ended the group that `\begin{rightwordgroup}` created we now have to begin a group for `\end{rightwordgroup}` to end.

```
  \begingroup
  \global\wordlabelr@end=\bytefield@height
```

`\show@wordlabelr` Redefine `\show@wordlabelr` to output `\bf@rightcurlyspace` space, followed by a large curly brace (in `\curlybox`), followed by `\bf@rightlabelspace` space, followed by the user's text (previously recorded in `\wordlabelr@text`). We typeset `\wordlabelr@text` within a `tabular` environment, so LaTeX will calculate its width automatically.

```
\gdef\show@wordlabelr{%
  \sbox{\word@label@box}{%
    \begin{tabular}[b]{@{}l@{}}\wordlabelr@text\end{tabular}}%
  \settowidth{\label@box@width}{\usebox{\word@label@box}}%
  \setlength{\label@box@height}{\wordlabelr@end-\wordlabelr@start}%
  \store@rcurly{\curly@box}{\label@box@height}%
  \bf@newdimen\total@box@width
  \setlength{\total@box@width}{%
    \bf@rightcurlyspace +
    \widthof{\usebox{\curly@box}} +
    \bf@rightlabelspace +
    \label@box@width}%
  \begin{picture}(\strip@pt\total@box@width,0)
    \put(0,0){%
      \hspace*{\bf@rightcurlyspace}%
      \usebox{\curly@box}%
      \hspace*{\bf@rightlabelspace}%
      \makebox(\strip@pt\label@box@width,\strip@pt\label@box@height){%
        \usebox{\word@label@box}}}
  \end{picture}%
```

The last thing `\show@wordlabelr` does is redefine itself back to a no-op.

```
  \gdef\show@wordlabelr{}}%
```

`\@currenvir` Because of our meddling with `\begingroup` and `\endgroup`, the current environment is all messed up. We therefore force the `\end{rightwordgroup}` to succeed, even if it doesn't match the preceding `\begin`.

```
  \def\@currenvir{rightwordgroup}%
  \ignorespaces
}
```

3.7.3 Left-side labels

`\wordlabell@start` `\wordlabell@end` The starting and ending height (in points) of the set of rows to be labeled on the left.

```
\newlength{\wordlabell@start}
\newlength{\wordlabell@end}
```

`\total@box@width` The total width of the next label to typeset on the left of the bit field, that is, the aggregate width of the text box, curly brace, and spaces on either side of the curly brace.

```
\newlength{\total@lbox@width}
```

\make@lspace

This macro is output in the first column of every row of the \ialigned bytefield table. It's normally a no-op, but \begin{leftwordgroup} defines it to output enough space for the next word label and then reset itself to a no-op.

```
\gdef\make@lspace{}
```

★ leftwordgroup

This environment is essentially the same as the rightwordgroup environment but puts the label on the left. However, the following code is not symmetric to that of rightwordgroup. The problem is that we encounter \begin{leftwordgroup} after entering the second (i.e., figure) column, which doesn't give us a chance to reserve space in the first (i.e., left label) column. When we reach the \end{leftwordgroup}, we know the height of the group of words we wish to label. However, if we try to label the words in the subsequent first column, we won't know the vertical offset from the "cursor" at which to start drawing the label, because we can't know the height of the subsequent row until we reach the second column.[1]

Our solution is to allocate space for the box the next time we enter a first column. As long as space is eventually allocated, the column will expand to fit that space. \end{leftwordgroup} outputs the label immediately. Even though \end{leftwordgroup} is called at the end of the *second* column, it \puts the label at a sufficiently negative x location for it to overlap the first column. Because there will eventually be enough space to accomodate the label, we know that the label won't overlap the bit field or extend beyond the bit-field boundaries.

```
\newenvironment{leftwordgroup}[1]{%
```

We begin by ending the group that \begin{rightwordgroup} created. This lets the leftwordgroup environment span rows (because we're technically no longer within the environment).

```
  \endgroup
```

\wordlabell@start
\wordlabell@text

We store the starting height and label text, which are needed by the \end{leftwordgroup}.

```
  \global\wordlabell@start=\bytefield@height
  \gdef\wordlabell@text{#1}%
```

Next, we typeset a draft version of the label into \word@label@box, which we measure (into \total@lbox@width) and then discard. We can't typeset the final version of the label until we reach the \end{leftwordgroup}, because that's when we learn the height of the word group. Without knowing the height of the word group, we don't how how big to make the curly brace. In the scratch version, we make the curly brace 5 cm. tall. This should be more than large enough to reach the maximum curly-brace width, which is all we really care about at this point.

```
  \sbox{\word@label@box}{%
    \begin{tabular}[b]{@{}l@{}}\wordlabell@text\end{tabular}}%
  \settowidth{\label@box@width}{\usebox{\word@label@box}}%
  \store@lcurly{\curly@box}{5cm}%
```

[1] Question: Is there a way to push the label up to the *top* of the subsequent row, perhaps with \vfill?

```
  \setlength{\total@lbox@width}{%
    \bf@leftcurlyspace +
    \widthof{\usebox{\curly@box}} +
    \bf@leftlabelspace +
    \label@box@width}%
  \global\total@lbox@width=\total@lbox@width
```

`\make@lspace` Now we know how wide the box is going to be (unless, of course, the user is using some weird math font that scales the width of a curly brace proportionally to its height). So we redefine `\make@lspace` to output `\total@lbox@width`'s worth of space and then redefine itself back to a no-op.

```
  \gdef\make@lspace{%
    \hspace*{\total@lbox@width}%
    \gdef\make@lspace{}}%
  \ignorespaces
}{%
```

Because we already ended the group that `\begin{leftwordgroup}` created we have to start the `\end{leftwordgroup}` by beginning a group for `\end{leftwordgroup}` to end.

```
  \begingroup
```

The `\end{leftwordgroup}` code is comparatively straightforward. We calculate the final height of the word group, and then output the label text, followed by `\bf@leftlabelspace` space, followed by a curly brace (now that we know how tall it's supposed to be), followed by `\bf@leftcurlyspace` space. The trick, as described earlier, is that we typeset the entire label in the second column, but in a 0×0 `picture` environment and with a negative horizontal offset (`\starting@point`), thereby making it overlap the first column.

```
  \global\wordlabell@end=\bytefield@height
  \bf@newdimen\starting@point
  \setlength{\starting@point}{%
    -\total@lbox@width - \bf@bitwidth*\value{bits@wide}}%
  \sbox{\word@label@box}{%
    \begin{tabular}[b]{@{}l@{}}\wordlabell@text\end{tabular}}%
  \settowidth{\label@box@width}{\usebox{\word@label@box}}%
  \setlength{\label@box@height}{\wordlabell@end-\wordlabell@start}%
  \store@lcurly{\curly@box}{\label@box@height}%
  \begin{picture}(0,0)
    \put(\strip@pt\starting@point,0){%
      \makebox(\strip@pt\label@box@width,\strip@pt\label@box@height){%
        \usebox{\word@label@box}}%
      \hspace*{\bf@leftlabelspace}%
      \usebox{\curly@box}%
      \hspace*{\bf@leftcurlyspace}}
  \end{picture}%
```

`\@currenvir`

```
% Because of our meddling with |\begingroup| and |\endgroup|, the
```

```
% current environment is all messed up.  We therefore force the
% |\end{leftwordgroup}| to succeed, even if it doesn't match the preceding
% |\begin|.
  \def\@currenvir{leftwordgroup}%
  \ignorespaces}
```

3.7.4 Scratch space

\label@box@width
\label@box@height
\word@label@box

Scratch storage for the width, height, and contents of the word label we're about to output.

```
\newlength{\label@box@width}
\newlength{\label@box@height}
\newsavebox{\word@label@box}
```

3.8 Compatibility mode

\bf@enter@compatibility@mode@i

bytefield's interface changed substantially with the move to version 2.0. To give version 1.x users a quick way to build their old documents, we provide a version 1.x compatibility mode. We don't enable this by default because it exposes a number of extra length registers (a precious resource) and we therefore want to encourage users to migrate to the new interface.

```
\newcommand{\bf@enter@compatibility@mode@i}{%
```

\bitwidth
\byteheight
\curlyspace
\labelspace
\curlyshrinkage

Define a handful of lengths that the user was allowed to `\setlength` explicitly in bytefield 1.x.

```
  \PackageInfo{bytefield}{Entering version 1 compatibility mode}%
  \newlength{\bitwidth}%
  \newlength{\byteheight}%
  \newlength{\curlyspace}%
  \newlength{\labelspace}%
  \newlength{\curlyshrinkage}%

  \settowidth{\bitwidth}{\tiny 99i}%
  \setlength{\byteheight}{4ex}%
  \setlength{\curlyspace}{1ex}%
  \setlength{\labelspace}{0.5ex}%
  \setlength{\curlyshrinkage}{5pt}%
```

\newbytefield
\endnewbytefield
bytefield

Redefine the `bytefield` environment in terms of the existing (new-interface) `bytefield` environment. The difference is that the redefinition utilizes all of the preceding lengths.

```
  \let\newbytefield=\bytefield
  \let\endnewbytefield=\endbytefield
  \renewenvironment{bytefield}[1]{%
    \begin{newbytefield}[%
      bitwidth=\bitwidth,
      bitheight=\byteheight,
      curlyspace=\curlyspace,
```

```
      labelspace=\labelspace,
      curlyshrinkage=\curlyshrinkage]{##1}%
  }{%
    \end{newbytefield}%
  }
```

`\wordgroupr` `\endwordgroupr` `\wordgroupl` `\endwordgroupl`

Define `\wordgroupr`, `\endwordgroupr`, `\wordgroupl`, and `\endwordgroupl` in terms of the new `rightwordgroup` and `leftwordgroup` environments.

```
  \def\wordgroupr{\begin{rightwordgroup}}
  \def\endwordgroupr{\end{rightwordgroup}}
  \def\wordgroupl{\begin{leftwordgroup}}
  \def\endwordgroupl{\end{leftwordgroup}}
```

`\bytefieldsetup`

Disable `\bytefieldsetup` in compatibility mode because it doesn't work as expected. (Every use of the compatibility-mode `bytefield` environment overwrites all of the figure-formatting values.)

```
  \renewcommand{\bytefieldsetup}[1]{%
    \PackageError{bytefield}{%
      The \protect\bytefieldsetup\space macro is not available in\MessageBreak
      version 1 compatibility mode%
    }{%
      Remove [compat1] from the \protect\usepackage{bytefield} line to
      make \protect\bytefieldsetup\MessageBreak
      available to this document.\space\space (The document may also need
      to be modified to use\MessageBreak
      the new bytefield interface.)
    }%
  }%
}
```

`\wordgroupr` `\endwordgroupr` `\wordgroupl` `\endwordgroupl`

Issue a helpful error message for the commands that were removed in bytefield v2.0. While this won't help users who first invalid action is to modify a no-longer-extant length register such as `\bitwidth` or `\byteheight`, it may benefit at least a few users who didn't realize that the bytefield interface has changed substantially with version 2.0.

```
\newcommand{\wordgroupr}{%
  \PackageError{bytefield}{%
    Macros \protect\wordgroupr, \protect\wordgroupl, \protect\endwordgroupr,
    \MessageBreak
    and \protect\endwordgroupl\space no longer exist%
  }{%
    Starting with version 2.0, bytefield uses \protect\begin{wordgroupr}...
    \MessageBreak
    \protect\end{wordgroupr} and \protect\begin{wordgroupl}...%
    \protect\end{wordgroupl}\MessageBreak
    to specify word groups and a new \protect\bytefieldsetup\space macro to
    \MessageBreak
    change bytefield's various formatting parameters.%
  }%
```

```
}
\let\endwordgroupr=\wordgroupr
\let\wordgroupl=\wordgroupr
\let\endwordgroupl=\wordgroupr
```

3.9 Option processing

We use the keyval package to handle option processing. Because all of bytefield's options have local impact, options can be specified either as package arguments or through the use of the `\bytefieldsetup` macro.

`\KV@bytefield@bitwidth` `\bf@bw@arg` `\bf@auto`

Specify the width of a bit number in the bit header. If the special value "`auto`" is given, set the width to the width of a formatted "`99i`".

```
\define@key{bytefield}{bitwidth}{%
  \def\bf@bw@arg{#1}%
  \def\bf@auto{auto}%
  \ifx\bf@bw@arg\bf@auto
    \settowidth{\bf@bitwidth}{\bf@bitformatting{99i}}%
  \else
    \setlength{\bf@bitwidth}{#1}%
  \fi
}
```

`\KV@bytefield@bf@bitheight`

Specify the height of a bit in a `\bitbox` or `\wordbox`.

```
\define@key{bytefield}{bitheight}{\setlength{\bf@bitheight}{#1}}
```

`\KV@bytefield@bitformatting`

Specify the style of a bit number in the bit header. This should be passed an expression that takes either one argument (e.g., `\textit`) or no arguments (e.g., `{\small\bfseries}`).

```
\define@key{bytefield}{bitformatting}{\def\bf@bitformatting{#1}}
```

`\KV@bytefield@boxformatting`

Specify a style to be applied to the contents of every bit box and word box. This should be passed an expression that takes either one argument (e.g., `\textit`) or no arguments (e.g., `{\small\bfseries}`).

```
\define@key{bytefield}{boxformatting}{\def\bf@boxformatting{#1}}
```

`\KV@bytefield@leftcurly` `\KV@bytefield@rightcurly`

Specify the symbol to use for bracketing a left or right word group. This must be an extensible math delimiter (i.e., something that can immediately follow `\left` or `\right` in math mode).

```
\define@key{bytefield}{leftcurly}{\def\bf@leftcurly{#1}}
\define@key{bytefield}{rightcurly}{\def\bf@rightcurly{#1}}
```

`\KV@bytefield@leftcurlyspace` `\KV@bytefield@rightcurlyspace` `\KV@bytefield@curlyspace`

Specify the amount of space between the bit fields in a word group and the adjacent left or right curly brace. The `curlyspace` option is a shortcut that puts the same space before both left and right curly braces.

```
\define@key{bytefield}{leftcurlyspace}{\def\bf@leftcurlyspace{#1}}
\define@key{bytefield}{rightcurlyspace}{\def\bf@rightcurlyspace{#1}}
```

```
\define@key{bytefield}{curlyspace}{%
  \def\bf@leftcurlyspace{#1}%
  \def\bf@rightcurlyspace{#1}%
}
```

\KV@bytefield@leftlabelspace
\KV@bytefield@rightlabelspace
\KV@bytefield@labelspace

Specify the amount of space between a left or right word group's curly brace and the associated label text. The `labelspace` option is a shortcut that puts the same space after both left and right curly braces.

```
\define@key{bytefield}{leftlabelspace}{\def\bf@leftlabelspace{#1}}
\define@key{bytefield}{rightlabelspace}{\def\bf@rightlabelspace{#1}}
\define@key{bytefield}{labelspace}{%
  \def\bf@leftlabelspace{#1}%
  \def\bf@rightlabelspace{#1}%
}
```

\KV@bytefield@leftcurlyshrinkage
\KV@bytefield@rightcurlyshrinkage
\KV@bytefield@curlyshrinkage

Specify the number of points by which to reduce the height of a curly brace (left, right, or both) so its ends don't overlap whatever's above or below it.

```
\define@key{bytefield}{leftcurlyshrinkage}{\def\bf@leftcurlyshrinkage{#1}}
\define@key{bytefield}{rightcurlyshrinkage}{\def\bf@rightcurlyshrinkage{#1}}
\define@key{bytefield}{curlyshrinkage}{%
  \def\bf@leftcurlyshrinkage{#1}%
  \def\bf@rightcurlyshrinkage{#1}%
}
```

★ \bytefieldsetup
\bf@bytefieldsetup

Reconfigure values for various bytefield parameters. Internally to the package we use the `\bf@bytefieldsetup` macro instead of `\bytefieldsetup`. This enables us to redefine `\bytefieldsetup` when entering version 1 compatibility mode without impacting the rest of bytefield.

```
\newcommand{\bf@bytefieldsetup}{\setkeys{bytefield}}
\let\bytefieldsetup=\bf@bytefieldsetup
```

We define only a single option that can be used only as a package option, not as an argument to `\bytefieldsetup`: `compat1` instructs bytefield to enter version 1 compatibility mode—at the cost of a number of additional length registers and the inability to specify parameters in the argument to the `bytefield` environment.

```
\DeclareOption{compat1}{\bf@enter@compatibility@mode@i}
```

\bf@package@options
\next

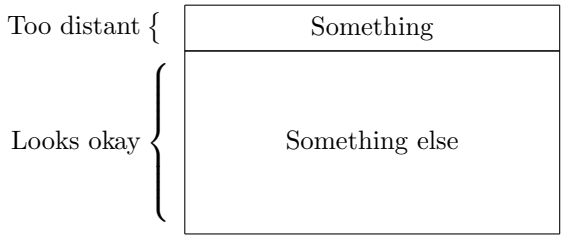
We want to use `\bf@bytefieldsetup` to process bytefield package options. Unfortunately, `\DeclareOption` doesn't handle ⟨*key*⟩=⟨*value*⟩ arguments. Hence, we use `\DeclareOption*` to catch *all* options, each of which it appends to `\bf@package@options`. `\bf@package@options` is passed to `\bf@bytefieldsetup` only at the beginning of the document so that the options it specifies (a) can refer to ex-heights and (b) override the default values, which are also set at the beginning of the document.

```
\def\bf@package@options{}
\DeclareOption*{%
  \edef\next{%
    \noexpand\g@addto@macro\noexpand\bf@package@options{,\CurrentOption}%
```

```
  }%
  \next
}
\ProcessOptions\relax
\expandafter\bf@bytefieldsetup\expandafter{\bf@package@options}
```

4 Future work

bytefield is my first LaTeX package, and, as such, there are a number of macros that could probably have been implemented a lot better. For example, bytefield is somewhat wasteful of ⟨*dimen*⟩ registers (although it did get a lot better with version 1.1 and again with version 1.3). The package should really get a major overhaul now that I've gotten better at TeX/LaTeX programming. One minor improvement I'd like to make in the package is to move left, small curly braces closer to the bit field. In the following figure, notice how distant the small curly appears from the bit-field body:



The problem is that the curly braces are left-aligned relative to each other, while they should be right-aligned.

Change History

v1.3

\bf@newdimen: Added support for ε-TEX's larger local ⟨*dimen*⟩ pool (code provided by Heiko Oberdiek) 22

v1.4

General: Made assignments to \counting@words global to prevent vertical-spacing problems with back-to-back word groups (bug fix due to Steven R. King) 1

Split \curlyspace, \labelspace, and \curlyshrinkage into left and right versions 1

\bf@bitformatting: Introduced this macro at Steven R. King's request to enable users to alter the bit header's font size 24

v2.0

General: Made a number of non-backwards-compatible changes, including replacing \wordgroupr and \endwordgroupr with a rightwordgroup environment and \wordgroupl and \endwordgroupl with a leftwordgroup environment and also replacing a slew of user-visible lengths and macros with a single \bytefieldsetup macro 1

\bytefieldsetup: Introduced this macro to provide a more convenient way of configuring bytefield's parameters 37

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