

The `bytefield` package*

Scott Pakin
`scott+bf@pakin.org`

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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.

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

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, `\refs` and `\cites` to the surrounding document, and macro calls.

*This document corresponds to `bytefield` v1.3, dated 2010/10/31.

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 importance.

```
\begin{bytefield} {<bit-width>}
<fields>
\end{bytefield}
```

The top-level environment is called, not surprisingly, “`bytefield`”. It takes one (mandatory) argument, which is the number of bits in each word. One can think of a `bytefield` as being analogous to a `tabular`: words are separated by `\\`, and fields within a word are separated by `&`.

```
\wordbox [<sides>] {<height>} {<text>}
\bitbox [<sides>] {<width>} {<text>}
```

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

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 `\wordbox` or `\bitbox`. 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 byte 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 figure 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).

Within a `\wordbox` or `\bitbox`, the `bytefield` package defines `\height`, `\depth`, `\totalheight`, and `\width` to the corresponding dimensions of the box. Section 2.2 gives an example of how these lengths may be utilized.

`\bitheader [<endianness>] {<bit-positions>}`

To make the figure 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} \l
  \bitbox{4}{Four} & \bitbox{8}{Eight} &
  \bitbox{16}{Sixteen} & \bitbox{4}{Four}
\end{bytefield}
```

The resulting figure looks like this:

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Four				Eight								Sixteen																Four			

`\wordgroup* {<text>}`
`\endwordgroup*`

`\wordgroup1 {<text>}`
`\endwordgroup1`

When a set of words functions as a single, logical unit, it helps to group these words together visually. All words defined between `\wordgroup*` and `\endwordgroup*` will be labeled on the right with *<text>*. Similarly, all words defined between `\wordgroup1` and `\endwordgroup1` will be labeled on the left

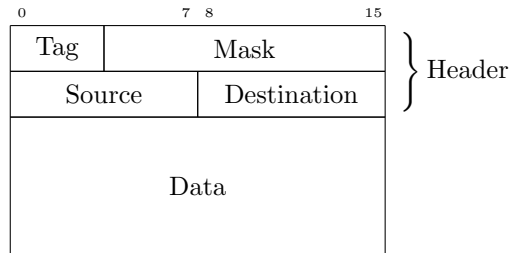
with $\langle text \rangle$. $\backslash wordgroup x$ must lie at the beginning of a row (i.e., right after a $\backslash \backslash$), and $\backslash endwordgroup x$ must lie right *before* the end of the row (i.e., right before a $\backslash \backslash$).

$\backslash wordgroup r \dots \backslash endwordgroup r$ and $\backslash wordgroup l \dots \backslash endwordgroup l$ can overlap each other. However, they cannot overlap themselves. In other words, $\backslash wordgroup r \dots \backslash wordgroup l \dots \backslash endwordgroup r \dots \backslash endwordgroup l$ is a valid sequence, but $\backslash wordgroup r \dots \backslash wordgroup r \dots \backslash endwordgroup r \dots \backslash endwordgroup r$ is not.

The following example shows how to use $\backslash wordgroup r$ and $\backslash endwordgroup r$:

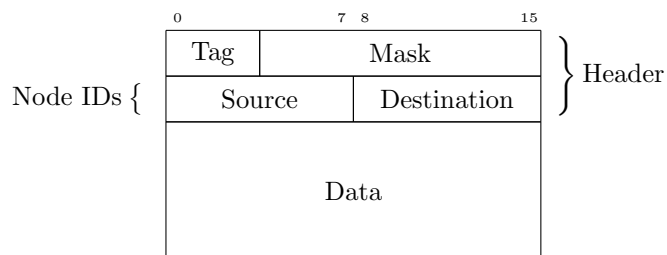
```
\begin{bytefield}{16}
  \bitheader{0,7,8,15} \\\
  \wordgroup r{Header}
    \bitbox{4}{Tag} & \bitbox{12}{Mask} \\\
    \bitbox{8}{Source} & \bitbox{8}{Destination}
  \endwordgroup r \\\
  \wordbox{3}{Data}
\end{bytefield}
```

Note the juxtaposition of $\backslash \backslash$ to $\backslash wordgroup r$ and $\backslash endwordgroup r$ in the above. The resulting figure looks like this:



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

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

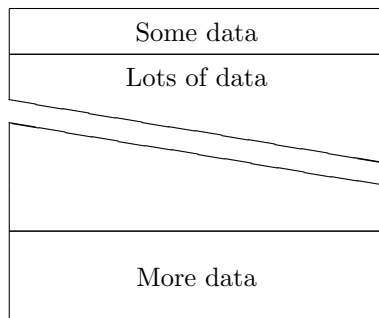


Again, note the justaposition of `\\` to the various word-grouping commands in the above.

`\skippedwords`

Draw a graphic representing a number of words that are not shown. `\skippedwords` is intended to work with the *sides* argument to `\wordbox`. For example:

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



`\bitwidth`
`\byteheight`

The above variables represent the width of each bit and height of each byte in the figure. Change them with `\setlength` to adjust the size of the figure. The default value of `\byteheight` is `2ex`, and 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.

`\curlyspace`
`\labelspace`

`\curlyspace` is the space to insert between the figure and the curly brace preceding a word group (default: `1ex`). `\labelspace` is the space to insert between the curly brace and the label (default: `0.5ex`). Change these with `\setlength` to adjust the spacing.

`\curlyshrinkage`

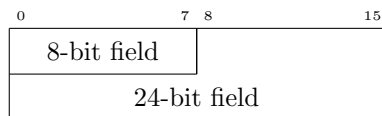
In \TeX/L\TeX , the height of a curly brace does not include the tips. Hence, in a word group label, the tips of the curly brace will extend beyond the height of the word group. `\curlyshrinkage` is an amount by which to reduce the height of curly braces in labels. It is set to `5pt`, and it is extremely unlikely that one would ever need to change it. Nevertheless, it is documented here in case the document is typeset with a math font containing radically different curly braces from the ones that come with \TeX/L\TeX .

2.2 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 from 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} \\
  \wordbox{1}{Node~$N$} \\
\end{bytefield}
```

Type	# of nodes
Node 1	
Node 2	
⋮	
Node <i>N</i>	

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):

<i>Default:</i>	<table><tr><td>OK</td><td>Data</td></tr></table>	OK	Data
OK	Data		
<code>\settowidth{\bitwidth}{OK~}</code> :	<table><tr><td>OK</td><td>Data</td></tr></table>	OK	Data
OK	Data		
<code>\tiny OK:</code>	<table><tr><td>OK</td><td>Data</td></tr></table>	OK	Data
OK	Data		
<code>\tiny 0 \ K:</code>	<table><tr><td>OK</td><td>Data</td></tr></table>	OK	Data
OK	Data		
<code>\rotatebox{90}{\small OK}:</code>	<table><tr><td>OK</td><td>Data</td></tr></table>	OK	Data
OK	Data		

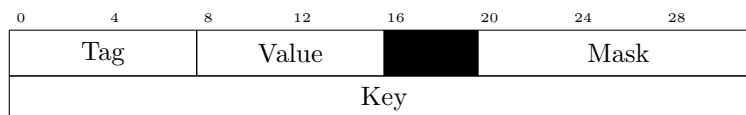
Unused bits Because `\width` and `\height` are defined within `\bitboxes` (also `\wordboxes`), we can represent unused bits by filling a `\bitbox` with a rule of size `\width × \height`:

```
\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}

```

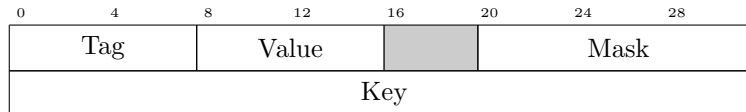


The effect is much better when the `color` package is used to draw the unused bits in color. (Gray looks nice.)

```

\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}

```



2.3 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:

```

\begin{group}
\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}

\settowidth{\byteheight}{~Sign~}
\setlength{\bitwidth}{\baselineskip}
\begin{bytefield}{32}
\bitheader[b]{31,23,0} \\

```

```

\colorbitbox{lightcyan}{1}{\rotatebox{90}{Sign}} &
\colorbitbox{lightgreen}{8}{Exponent} &
\colorbitbox{lightred}{23}{Mantissa} \\
\end{bytefield}
\endgroup

```



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

```

\setlength{\byteheight}{4\baselineskip}
\newcommand{\descbox}[2]{\parbox[c][3.8\baselineskip]{0.95\width}{%
\raggedright #1\vfill #2}}
\begin{bytefield}{32}
\wordgroup{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.}}
\endwordgroup \\
\wordgroup{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.}}
\endwordgroup \\
\wordgroup{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.}}
\endwordgroup \\
\wordgroup{Partition 1}
\bitbox[8]{\texttt{0x03FFFFFF} \\[2\baselineskip]
\texttt{0x00001000}} &
\bitbox{24}{\descbox{4\,MB area for MS-DOS and Windows~3.1
compatibility.}{Read/writable.}} \\
\bitbox[8]{\texttt{0x0000FFF} \\[2\baselineskip]
\texttt{0x00000000}} &
\bitbox{24}{\descbox{4096~byte area for MS-DOS and Windows~3.1
compatibility.}{Protected---catches \textsc{null}
pointers.}}
\endwordgroup \\

```

0xFFFFFFFF	1 GB area for VxDs, memory manager, file system code; shared by all processes.	}	Partition 4
0xC0000000	Read/writable.		
0xBFFFFFFF	1 GB area for memory-mapped files, shared system DLLs, file system code; shared by all processes.	}	Partition 3
0x80000000	Read/writable.		
0x7FFFFFFF	~2 GB area private to process, process code, and data.	}	Partition 2
0x00400000	Read/writable.		
0x003FFFFF	4 MB area for MS-DOS and Windows 3.1 compatibility.	}	Partition 1
0x00001000	Read/writable.		
0x00000FFF	4096 byte area for MS-DOS and Windows 3.1 compatibility.		
0x00000000	Protected—catches NULL pointers.		

2.4 Putting it all together

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

```

\setlength{\byteheight}{2.5\baselineskip}
\begin{bytefield}{32}
  \bitheader{0,7,8,15,16,23,24,31} \\\
  \wordgroup{\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}
\endwordgroup \\\
\wordbox[lrt]{1}{Data octets} \\\
\skippedwords \\\
\wordbox[lrb]{1}{} \\\
\wordgroup{\parbox{6em}{\raggedright Note that we can display,
  for example, a misaligned 64-bit value with clever use of the
  optional argument to \texttt{\textbackslash wordbox} and
  \texttt{\textbackslash bitbox}.}}
  \bitbox{8}{Source} & \bitbox{8}{Destination} &

```

```

\bitbox[lrt]{16}{} \\\
\wordbox[lr]{1}{Timestamp} \\\
\wordgroup{\parbox{6em}{\raggedright Why two Length fields?
  No particular reason.}}
\bitbox[lrb]{16}{} & \bitbox{16}{Length}
\endwordgroup1 \\\
\bitbox{6}{Key} & \bitbox{6}{Value} & \bitbox{4}{Unused} &
\bitbox{16}{Length}
\endwordgroup \\\
\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}{\left[ \mbox{A5A5}_{\scriptsize H} \oplus
\left(\sum_{i=1}^N \mbox{Data}_i \right) \bmod 2^{20} \right]} &
\bitbox{12}{Command} \\\
\wordbox{2}{64-bit random number}
\end{bytefield}

```

Figure 1 shows the resulting protocol diagram.

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 the previous section). All other macros are used only internally by `bytefield`.

1 `\package`

3.1 Required packages

Although `\widthof` and `\heightof` were introduced in June 1998, `TeX` 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.

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

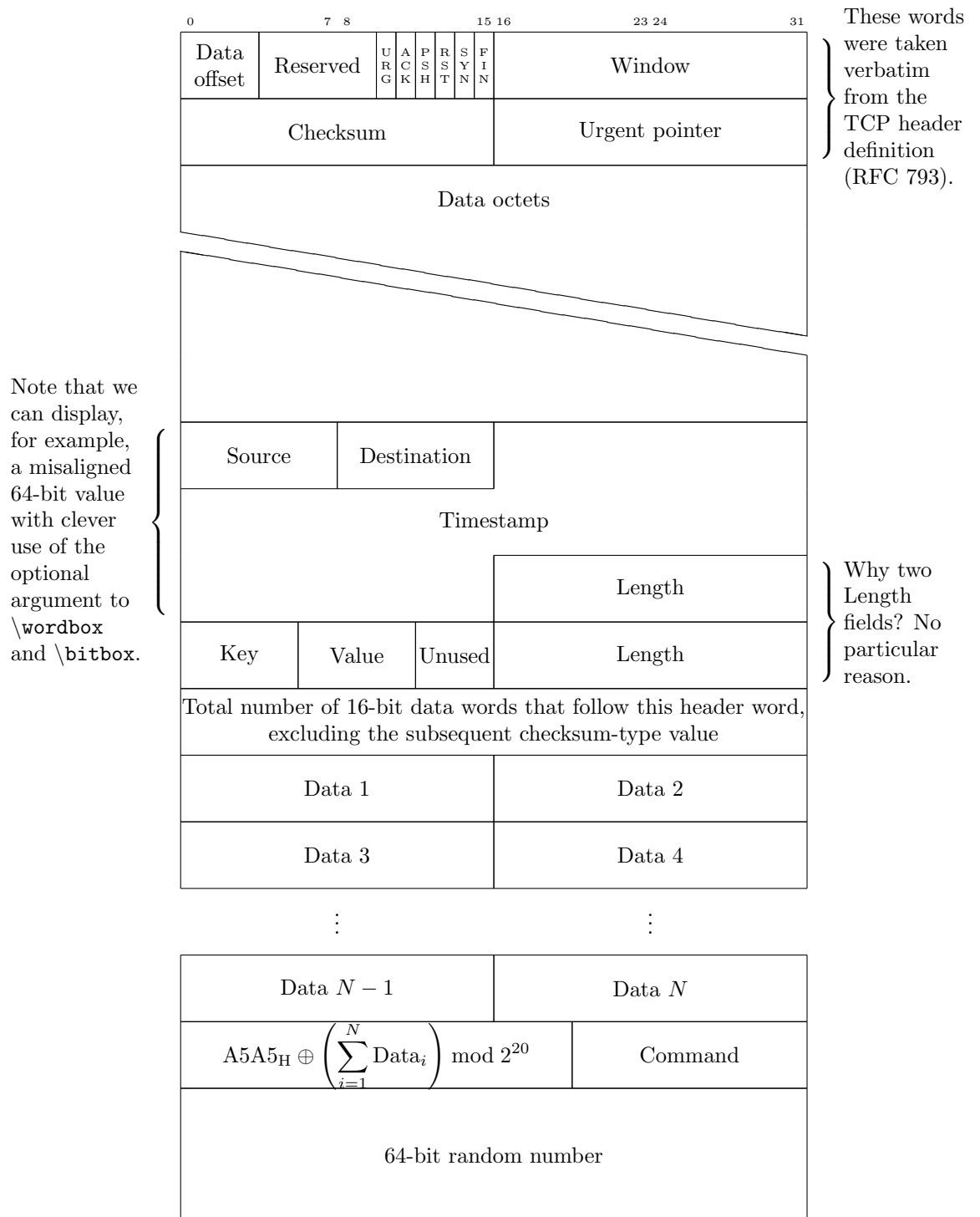


Figure 1: Complex protocol diagram drawn with the `bytefield` package

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` `\newdimen` defines new $\langle dimen \rangle$ s globally. `\bf@newdimen` defines them locally. It simply merges L^AT_EX 2_ε’s `\newdimen` and `\alloc@` macros while omitting `\alloc@`’s “`\global`” declaration.

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

If we’re using ε -T_EX, we have access to many more $\langle dimen \rangle$ s. The `etex` package makes these 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`.

```
8 \AtBeginDocument{%
9   \begingroup\expandafter\expandafter\expandafter\endgroup
10  \expandafter\ifx\csname locdimen\endcsname\relax
11  \else
12    \let\bf@newdimen\locdimen
13  \fi
14 }
```

`\bytefield@height` 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.

```
15 \newlength{\bytefield@height}
16 \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.

```
17 \newlength{\bytefield@height@increment}
18 \DeclareRobustCommand{\inc@bytefield@height}[1]{%
19   \setlength{\bytefield@height@increment}{#1}%
20   \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).

```
21 \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 bytefield, put a box around it, and do other operations on the entire figure.

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

★ `bytefield` 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.)

```
23 \newenvironment{bytefield}[1]{%
24   \setcounter{bits@wide}{#1}%
25   \let\old@nl=\%
26   \let\amp=&%
27   \catcode'\&=10
28   \openup -1pt
29   \setlength{\bytefield@height}{0pt}%
30   \setlength{\unitlength}{1pt}%
31   \counting@wordstrue
32   \begin{lrbox}{\entire@bytefield@picture}%
```

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

```
33   \renewcommand{\}{%
34     \amp\show@wordlabelr\cr%
35     \ignorespaces\counting@wordstrue\make@lspace\amp}%

36   \vbox\bgroup\ialign\bgroup##\amp##\amp##\cr\amp%
37 }{%
38   \amp\show@wordlabelr\cr\egroup\egroup%
39   \end{lrbox}%
40   \usebox{\entire@bytefield@picture}}
```

3.4 Box-drawing macros

3.4.1 Drawing (proper)

★ `\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.

```
41 \newlength{\bitwidth}
42 \AtBeginDocument{\settowidth{\bitwidth}{\tiny 99i}}
```

★ `\byteheight` The height of a single byte.

```
43 \newlength{\byteheight}
44 \AtBeginDocument{\setlength{\byteheight}{4ex}}
```

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

```
45 \newlength{\units@wide}
46 \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).

```
47 \DeclareRobustCommand{\bitbox}[3][lrtb]{%
48   \setlength{\units@wide}{\bitwidth * #2}%
49   \parse@bitbox@arg{#1}%
50   \draw@bit@picture{\strip@pt\units@wide}{\strip@pt\byteheight}{#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).

```
51 \DeclareRobustCommand{\wordbox}[3][lrtb]{%
52   \setlength{\units@wide}{\bitwidth * \value{\bits@wide}}%
53   \setlength{\units@tall}{\byteheight * #2}%
54   \parse@bitbox@arg{#1}%
55   \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).

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

```

\height First, we plot the user's text, with all sorts of useful lengths predefined.
\depth 58   \put(0,0){\makebox(#1,#2){\parbox[c]{#1\unitlength}{%
\totalheight 59     \bf@newdimen\height
\width 60     \bf@newdimen\depth
\widthunits 61     \bf@newdimen\totalheight
\heightunits 62     \bf@newdimen\width
63     \height=#2\unitlength
64     \depth=0pt%
65     \totalheight=#2\unitlength
66     \width=#1\unitlength
67     \def\widthunits{#1}%
68     \def\heightunits{#2}%
69     \centering #3}}}%
```

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.

```

70 \ifbitbox@top
71 \put(0,#2){\line(1,0){#1}}
72 \fi
73 \ifbitbox@bottom
74 \put(0,0){\line(1,0){#1}}
75 \fi
76 \ifbitbox@left
77 \put(0,0){\line(0,1){#2}}
78 \fi
79 \ifbitbox@right
80 \put(#1,0){\line(0,1){#2}}
81 \fi
82 \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.

```

83 \ifcounting@words
84 \inc@bytefield@height{\unitlength * \real{#2}}%
85 \counting@wordsfalse
86 \fi
87 \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}`.

<pre> \ifbitbox@top \ifbitbox@bottom \ifbitbox@left \ifbitbox@right </pre>	<p>These macros are set to TRUE if we’re to draw the corresponding edge on the subsequent <code>\bitbox</code> or <code>\wordbox</code>.</p> <pre> 88 \newif\ifbitbox@top 89 \newif\ifbitbox@bottom 90 \newif\ifbitbox@left 91 \newif\ifbitbox@right </pre>
--	---

<pre> \parse@bitbox@arg </pre>	<p>This main parsing macro merely resets the above conditionals and calls a helper function, <code>\parse@bitbox@sides</code>.</p>
--------------------------------	--

```

92 \def\parse@bitbox@arg#1{%
93 \bitbox@topfalse
94 \bitbox@bottomfalse
95 \bitbox@leftfalse
96 \bitbox@rightfalse
97 \parse@bitbox@sides#1X}

```

<pre> \parse@bitbox@sides </pre>	<p>The helper function for <code>\parse@bitbox@arg</code> parses a single letter, sets the appropriate conditional to TRUE, and calls itself tail-recursively until it sees an “X”.</p>
----------------------------------	---

```

98 \def\parse@bitbox@sides#1{%
99 \ifx#1X%

```

```

100 \else
101   \ifx#1t%
102     \bitbox@toptrue
103   \else
104     \ifx#1b%
105       \bitbox@bottomtrue
106     \else
107       \ifx#1l%
108         \bitbox@lefttrue
109       \else
110         \ifx#1r%
111           \bitbox@righttrue
112         \fi
113       \fi
114     \fi
115   \fi
116   \expandafter\parse@bitbox@sides
117 \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`.

```
118 \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).

```

119 \DeclareRobustCommand{\skippedwords}[1][2ex]{%
120   \setlength{\units@wide}{\bitwidth * \value{bits@wide}}%
121   \setlength{\units@high}{1pt * \ratio{\units@wide}{6.0pt}}%
122   \setlength{\units@tall}{#1 + \units@high}%
123   \edef\num@wide{\strip@pt\units@wide}%
124   \edef\num@tall{\strip@pt\units@tall}%
125   \edef\num@high{\strip@pt\units@high}%
126   \begin{picture}(\num@wide,\num@tall)
127     \put(0,\num@tall){\line(6,-1){\num@wide}}
128     \put(\num@wide,0){\line(-6,1){\num@wide}}
129     \put(0,0){\line(0,1){\num@high}}
130     \put(\num@wide,\num@tall){\line(0,-1){\num@high}}
131   \end{picture}%
132   \ifcounting@words
133     \inc@bytefield@height{\unitlength * \real{\num@tall}}%
134   \counting@wordsfalse
135 \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.

```

136 \DeclareRobustCommand{\bitheader}[2][1]{%
137   \parse@bitbox@arg{lr}tb}%
138   \setlength{\units@wide}{\bitwidth * \value{bits@wide}}%
139   \setlength{\units@tall}{\heightof{\tiny 9}}%
140   \setlength{\units@high}{\units@tall * -1}%
141   \def\bit@endianness{#1}%
142   \begin{picture}(\strip@pt\units@wide,\strip@pt\units@tall)%
143     (0,\strip@pt\units@high)
144     \parse@range@list#2,X,
145   \end{picture}%
146   \ifcounting@words
147     \inc@bytefield@height{\unitlength * \real{\strip@pt\units@tall}}%
148   \counting@wordsfalse
149   \fi
150   \ignorespaces}

```

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

```

151 \def\parse@range@list#1,{%
152   \ifx X#1
153   \else
154     \parse@range#1-#1-#1\relax
155     \expandafter\parse@range@list
156   \fi}

```

`\header@xpos` Miscellaneous variables used internally by `\parse@range`— x position of header,
`header@val` current label to output, and maximum label to output (+1).
`max@header@val` 157 `\newlength{\header@xpos}`
158 `\newcounter{header@val}`
159 `\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.

```

160 \def\parse@range#1-#2-#3\relax{%
161   \setcounter{header@val}{#1}
162   \setcounter{max@header@val}{#2 + 1}
163   \loop
164     \ifnum\value{header@val}<\value{max@header@val}%
165       \if\bit@endianness b%
166         \setlength{\header@xpos}{%
167           \bitwidth * (\value{bits@wide}-\value{header@val}-1)}
168       \else
169         \setlength{\header@xpos}{\bitwidth * \value{header@val}}
170       \fi
171     \put(\strip@pt\header@xpos,0){%

```

```

172         \makebox(\strip@pt\bitwidth,\strip@pt\units@tall){%
173             \tiny \theheader@val}}
174         \addtocounter{header@val}{1}
175     \repeat}

```

3.7 Word labels

3.7.1 Curly-brace manipulation

★ `\curlyshrinkage` Reduce the height of a curly brace by `\curlyshrinkage` 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, `\curlyshrinkage` can be modified.

```

176 \newlength{\curlyshrinkage}
177 \setlength{\curlyshrinkage}{5pt}

```

★ `\curlyspace` Space to insert before a curly brace and before a word label (i.e., after a curly
★ `\labelspace` brace). Because the default values are specified in terms of x heights, we wait until the `\begin{document}` to set them, after the default font has been selected.

```

178 \newlength{\curlyspace}
179 \AtBeginDocument{\setlength{\curlyspace}{1ex}}
180 \newlength{\labelspace}
181 \AtBeginDocument{\setlength{\labelspace}{0.5ex}}

```

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

```

182 \newbox{\curly@box}

```

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

```

183 \def\store@rcurly#1#2{%
184     \begingroup
185     \bf@newdimen\curly@height%
186     \setlength{\curly@height}{#2 - \curlyshrinkage}%
187     \bf@newdimen\half@curly@height%
188     \setlength{\half@curly@height}{0.5\curly@height}%
189     \bf@newdimen\curly@shift%
190     \setlength{\curly@shift}{\half@curly@height + 0.5\curlyshrinkage}%
191     \global\sbox{#1}{\raisebox{\curly@shift}{%
192         $\xdef\old@axis{\the\fontdimen22\textfont2}$%
193         $\fontdimen22\textfont2=0pt%
194         \left.\vrule height\half@curly@height
195             width 0pt
196             depth\half@curly@height\right\}$%
197         $\fontdimen22\textfont2=\old@axis$}}%
198     \endgroup
199 }

```

`\store@lcurly` Same as `\store@rcurly`, but using a “{” instead of a “}”.

`\curly@height` 200 `\def\store@lcurly#1#2{%`

`\half@curly@height` 201 `\begingroup`

`\curly@shift` 202 `\bf@newdimen\curly@height%`

203 `\setlength{\curly@height}{#2 - \curlyshrinkage}%`

204 `\bf@newdimen\half@curly@height%`

205 `\setlength{\half@curly@height}{0.5\curly@height}%`

206 `\bf@newdimen\curly@shift%`

207 `\setlength{\curly@shift}{\half@curly@height + 0.5\curlyshrinkage}%`

208 `\global\sbox{#1}{\raisebox{\curly@shift}{%`

209 `\xdef\old@axis{\the\fontdimen22\textfont2}$%`

210 `\fontdimen22\textfont2=0pt%`

211 `\left\{\vrule height\half@curly@height`

212 `width 0pt`

213 `depth\half@curly@height\right.$%`

214 `\fontdimen22\textfont2=\old@axis$}}%`

215 `\endgroup`

216 `}`

3.7.2 Right-side labels

`\show@wordlabelr` This macro is output in the third column of every row of the `\ialigned` bytefield table. It’s normally a no-op, but `\endwordgroup` defines it to output the word label and then reset itself to a no-op.

217 `\def\show@wordlabelr{}`

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

`\wordlabelr@end`

218 `\newlength{\wordlabelr@start}`

219 `\newlength{\wordlabelr@end}`

★ `\wordgroup` Label the words defined between `\wordgroup` and `\endwordgroup` on the right

★ `\endwordgroup` side of the figure. 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.

220 `\newenvironment{wordgroup}[1]{%`

`\wordlabelr@start` `\wordgroup` merely stores the starting height in `\wordlabelr@start` and the

`\wordlabelr@text` user-supplied text in `\wordlabelr@text`. `\endwordgroup` does most of the work.

`\wordlabelr@end`

221 `\global\wordlabelr@start=\bytefield@height`

222 `\gdef\wordlabelr@text{#1}%`

223 `\ignorespaces%`

224 `}{%`

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

`\show@wordlabelr` Redefine `\show@wordlabelr` to output `\curlyspace` space, followed by a large curly brace (in `\curlybox`), followed by `\labelspace` space, followed by the user’s text (previously recorded in `\wordlabelr@text`). We typeset `\wordlabelr@text` within a `tabular` environment, so L^AT_EX will calculate its width automatically.

```

226 \gdef\show@wordlabelr{%
227   \sbox{\word@label@box}{%
228     \begin{tabular}[b]{@{}l@{}}\wordlabelr@text\end{tabular}}%
229   \settowidth{\label@box@width}{\usebox{\word@label@box}}%
230   \setlength{\label@box@height}{\wordlabelr@end-\wordlabelr@start}%
231   \store@rcurly{\curly@box}{\label@box@height}%
232   \bf@newdimen\total@box@width%
233   \setlength{\total@box@width}{%
234     \curlyspace +
235     \widthof{\usebox{\curly@box}} +
236     \label@box@width}%
237   \begin{picture}(\strip@pt\total@box@width,0)
238     \put(0,0){%
239       \hspace*{\curlyspace}%
240       \usebox{\curly@box}%
241       \hspace*{\label@box@width}%
242       \makebox(\strip@pt\label@box@width,\strip@pt\label@box@height){%
243         \usebox{\word@label@box}}
244     }
245   \end{picture}%

```

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

```

246   \gdef\show@wordlabelr{}%
247   \ignorespaces}

```

3.7.3 Left-side labels

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

```

248 \newlength{\wordlabell@start}
249 \newlength{\wordlabell@end}

```

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

```

250 \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 `\wordgroup1` defines it to output enough space for the next word label and then reset itself to a no-op.

```

251 \gdef\make@lspace{}

```

★ `\wordgroup1` Same as `\wordgroup` and `\endwordgroup`, but put the label on the left.

★ `\endwordgroup1` However, the following code is not symmetric to that of `\wordgroup` and `\endwordgroup`. The problem is that we encounter `\wordgroup1` 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 `\endwordgroup1`, 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. `\endwordgroup1` outputs the label immediately. Even though `\endwordgroup1` 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 figure or extend beyond the figure boundaries.

```
252 \newenvironment{wordgroup1}[1]{%
```

```
\wordlabel1@start First, we store the starting height and label text, which are needed by
\wordlabel1@text \endwordgroup1.
```

```
253 \global\wordlabel1@start=\bytefield@height
254 \gdef\wordlabel1@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 `\endwordgroup1`, 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.

```
255 \sbox{\word@label@box}{%
256   \begin{tabular}[b]{@{}l@{}}\wordlabel1@text\end{tabular}}%
257 \settowidth{\label@box@width}{\usebox{\word@label@box}}%
258 \store@lcurly{\curly@box}{5cm}%
259 \setlength{\total@lbox@width}{%
260   \curlyspace +
261   \widthof{\usebox{\curly@box}} +
262   \label@space +
263   \label@box@width}%
264 \global\total@lbox@width=\total@lbox@width
```

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.

```
265 \gdef\make@lspace{%
266   \hspace*{\total@lbox@width}%
267   \gdef\make@lspace{}}%
268 \ignorespaces%
269 }%
```

`\endwordgroup1` is comparatively straightforward. We calculate the final height of the word group, and then output the label text, followed by `\label@space` space,

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

followed by a curly brace (now that we know how tall it's supposed to be), followed by `\curlyspace` 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.

```

270 \global\wordlabell@end=\bytefield@height
271 \bf@newdimen\starting@point
272 \setlength{\starting@point}{%
273   -\total@lbox@width - \bitwidth*\value{bits@wide}}%
274 \sbox{\word@label@box}{%
275   \begin{tabular}[b]{@{}l@{}}\wordlabell@text\end{tabular}}%
276 \settowidth{\label@box@width}{\usebox{\word@label@box}}%
277 \setlength{\label@box@height}{\wordlabell@end-\wordlabell@start}%
278 \store@lcurly{\curly@box}{\label@box@height}%
279 \begin{picture}(0,0)
280   \put(\strip@pt\starting@point,0){%
281     \makebox(\strip@pt\label@box@width,\strip@pt\label@box@height){%
282       \usebox{\word@label@box}}%
283     \hspace*{\labelspace}%
284     \usebox{\curly@box}%
285     \hspace*{\curlyspace}}
286 \end{picture}%
287 \ignorespaces}

```

3.7.4 Scratch space

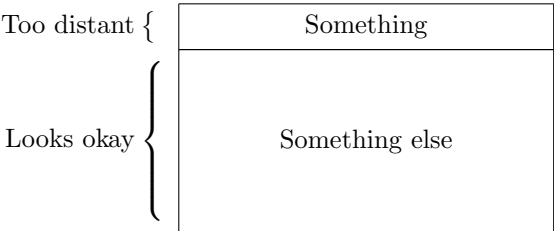
<pre> \label@box@width \label@box@height \word@label@box </pre>	<p>Scratch storage for the width, height, and contents of the word label we're about to output.</p> <pre> 288 \newlength{\label@box@width} 289 \newlength{\label@box@height} 290 \newsavebox{\word@label@box} </pre> <p>291 <code></package></code></p>
---	---

4 Future work

`bytefield` is my first L^AT_EX package, and, as such, there are a number of macros that could probably have been implemented a lot better. The package should really get a major rewrite. If I were to do it all over again, I would probably not use an `\ialign` for the main `bytefield` environment. The problem—as I discovered too late—is that `\begin... \end` blocks are unable to cross cells of an `\ialign` (or `tabular` environment, for that matter).

That said, I'd like the next major release of `bytefield` to let the user use `\begin{wordgroup}[r]... \end{wordgroup}` instead of `\wordgroup r... \endwordgroup` and `\begin{wordgroup}[l]... \end{wordgroup}` instead of `\wordgroup l... \endwordgroup l`. That would make the word-grouping commands a little more L^AT_EX-ish.

Finally, a minor improvement I'd like to make in the package is to move left, small curly braces closer to the figure. In the following figure, notice how distant the small curly appears from the figure body:



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

Change History

v1.0		by Stefan Ulrich)	19
General: Initial version	1	v1.2a	
v1.1		General: Specified an explicit pack-	
General: Restructured the .dtx file	1	age date when loading the <code>calc</code>	
<code>\bf@newdimen</code> : Bug fix: Added		package to avoid loading an out-	
<code>\bf@newdimen</code> to eliminate “No		dated version. Thanks to Kevin	
room for a new <code>\dimen</code> ” er-		Quick for discovering that out-	
rors (reported by Vitaly A. Re-		dated versions of <code>calc</code> are still	
pin)	13	being included in T _E X distribu-	
<code>\parse@range@list</code> : Bug fix:		tions.	11
Swapped order of arguments to			
<code>\ifx</code> test (suggested by Hans-		v1.3	
Joachim Widmaier)	18	<code>\bf@newdimen</code> : Added support for	
v1.2		ε -T _E X’s larger local $\langle dimen \rangle$	
<code>\curly@box</code> : Bug fix: Defined		pool (code provided by Heiko	
<code>\curly@box</code> globally (suggested		Oberdiek)	13

Index

Numbers written in *italic* refer to the page where the corresponding entry is described; numbers underlined refer to the code line of the definition; numbers in *roman* refer to the code lines where the entry is used.

Symbols		<code>\bitbox</code>	<u>47</u>
<code>\</code>	<u>33</u>	<code>\bitheader</code>	<u>136</u>
B		<code>\bits@wide</code>	<u>21</u>
<code>\bf@newdimen</code>	<u>3</u>	<code>\bitwidth</code>	<u>41</u>
		<code>bytefield</code> (environment)	<u>23</u>

\bytefield@height	15		
\byteheight	43		
		C	
\curly@box	182		
\curly@height	183, 200		
\curly@shift	183, 200		
\curlyshrinkage	176		
\curlyspace	178		
		D	
\depth	58		
\draw@bit@picture	56		
		E	
\endwordgroup1	252		
\endwordgroup2	220		
\entire@bytefield@picture	22		
environments:			
bytefield	23		
		H	
\half@curly@height	183, 200		
\header@val	157		
\header@xpos	157		
\height	58		
\heightunits	58		
		I	
\ifbitbox@bottom	88		
\ifbitbox@left	88		
\ifbitbox@right	88		
\ifbitbox@top	88		
\ifcounting@words	15		
\inc@bytefield@height	17		
		L	
\label@box@height	288		
\label@box@width	288		
\labelspace	178		
		M	
\make@lspace	251		
\max@header@val	157		
		P	
\parse@bitbox@arg	92		
\parse@bitbox@sides	98		
\parse@range	160		
\parse@range@list	151		
		S	
\show@wordlabelr	217, 226		
\skippedwords	119		
\store@lcurly	200		
\store@rcurly	183		
		T	
\total@box@width	250		
\totalheight	58		
		U	
\units@high	118		
\units@tall	45		
\units@wide	45		
		W	
\width	58		
\widthunits	58		
\word@label@box	288		
\wordbox	51		
\wordgroup1	252		
\wordgroup2	220		
\wordlabell@end	248		
\wordlabell@start	248, 253		
\wordlabell@text	253		
\wordlabelr@end	218, 221		
\wordlabelr@start	218, 221		
\wordlabelr@text	221		