# The tikz-timing package

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http://www.ctan.org/indexes/graphics/pgf/contrib/tikz-timing/

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**Note to Advanced Users:** This is a new package which internal macros might still change. Please only rely on the user macros for now.

## 1 Introduction

This package uses the tikz[1] package to produce timing diagrams inside text or {tikzpicture} environments. Also a tabular-like environment is provided to produce a larger timing diagram with multiple labeled signals and the possibility to add own drawing material.

The signal levels of the timing diagram can be given by corresponding characters/letters like 'H' for *Logical High* or 'L' for *Logical Low*. So e.g. '{HLZXD}' gives ''. Lowercase characters only produce a signal with half the width while uppercase characters produce one with the "full" width, called the 'period width' in this document and which is by default identical to there height, called 'signal height', which defaults to 1.6ex (about the height of the uppercase 'X' of the current font). Table 1 shows all by default defined logic characters. Additional functionality is provided by the "modifiers" shown in Table 2.

Table 1: Timing Characters

| Character | Description | Full Width (Uppercase) | Half Width (Lowercase) | Transition Example |
|---|---|---|---|---|
| H | High |  |  |  |
| L | Low |  |  |  |
| Z | High Impedance |  |  |  |
| X | Undefined / Don't Care |  |  |  |
| D | Data / Double |  |  |  |
| U | Unknown Data |  |  |  |
| T | Toggle |  or  |  or  |  |
| C | Clock (no slope) |  or  |  or  |  |
| M | Metastable Condition |  |  |  |
| G | Glitch (zero width) |  |  |  |
| S | Space (nothing) |  |  |  |

[1] Part of the pgf package, CTAN: http://www.ctan.org/pkg/pgf

# 2 Usage

## 2.1 Macro for use in Text Mode

**\texttiming**[⟨*initial character*⟩]{⟨*characters*⟩}

This macro places a single timing diagram line into the current text. The signals have the same height as a uppercase letter (like 'X') of the current font, i.e. they scale with the font size.

The macro argument must contain only valid logic characters which define the logical levels of the diagram line.

An initial character can be given as an optional argument. No logic level will be drawn for this character. Instead it will be used to define the initial position of the signal so that the diagram line will start with a transition from the initial to the first character.

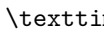
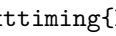
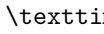
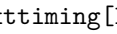
*Examples:*
`\texttiming{HLZDZLH}` gives '  ', with grid: '  '.
`\texttiming[L]{HLZDZLH}` gives '  ', with grid: '  '.

Table 2: Modifiers for Timing Characters

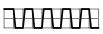
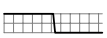
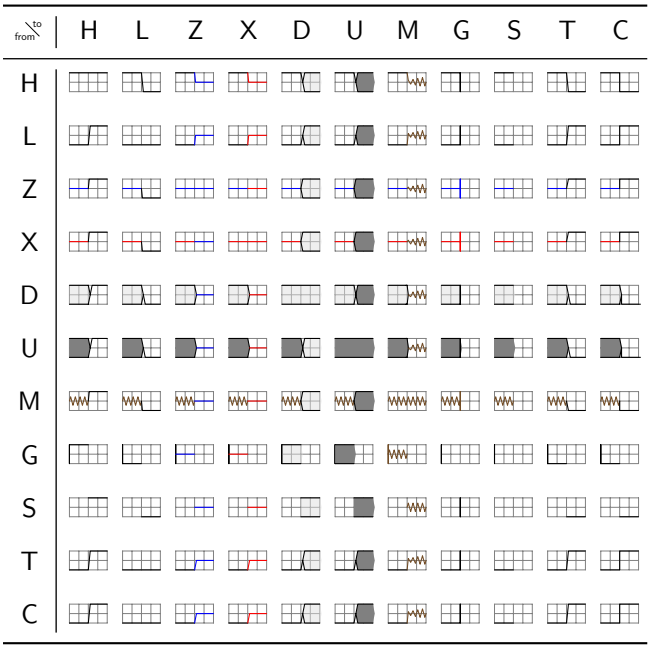
| Modifier Syntax | Description | Example Usage | Example Result |
|---|---|---|---|
| `D{}D` | Produces transition between two data values. | `D{}D` |  |
| `D{`⟨*Text*⟩`}` | Adds text material into a data signal using a node. | `D{A}D{B}` |  |
| `D{[`⟨*TikZ Settings*⟩`]`⟨*Text*⟩`}` | Adds text material into a data signal using the given settings. | `D{[blue]A}` |  |
| ⟨*integer*⟩`{`⟨*characters*⟩`}` | Repeats the given characters by the given number. | `5{hl}` |  |
| ⟨*number*⟩⟨*character*⟩ | Sets width of next signal to given number. Half of it if character is in lower case. | `2.6H5.2l` |  |
| `N[`⟨*Settings*⟩`]`(⟨*Name*⟩)`{`⟨*Content*⟩`}` | Adds node at current position. All three arguments are optional. | `H N(a1) L` |  |
| `[`⟨*TikZ Settings*⟩`]` | Executes given TikZ settings. | `H[blue]LH` |  |
| `;` | Renews the internal drawing path which ends the scope of all options given by `[]`. | `H;[blue]L;H` |  |
| `,` | Same as ';', but timing specific options (atm.: slopes and line width) are restored for the new path. | `H,[lw=1pt]L;H` |  |
| `!{`⟨*code*⟩`}` | Places given code into the internal `{tikzpicture}`. | See Example 1 on page 8. | |

Table 3: Overview over all transitions.




`\texttimingbefore` (*defaults to*: ⟨*empty*⟩)

`\texttimingafter` (*defaults to*: ⟨*empty*⟩)

This two macros are executed before and after every timing diagram line created by `\texttiming` macro inside the same `{tikzpicture}` environment and can be used to add drawing macros. The argument of the `\texttiming` macro is already processed before any of these macros are expanded, therefore this macros can access the width of the diagram.

Example: `\let\texttimingbefore\texttiminggrid` adds a grid into the background of the `\texttiming` diagram. A more LaTeX-stylish way to do this is `\renewcommand*{\textttimingbefore}{\texttiminggrid}`.

`\texttiminggrid`

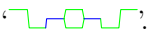
This macro should only be used inside `\texttimingbefore` or `\texttimingafter` and draws a grid of the full size of the `\texttiming` diagram.

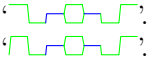
## 2.2 Macro for use inside TikZ-Pictures

`\timing`[⟨*TikZ Settings*⟩] (⟨*TikZ Coordinate*⟩) {[⟨*initial character*⟩]⟨*characters*⟩};

This macro does the same as `\texttiming` but is designed to be used inside a `{tikzpicture}` environment and only there. Like normal TikZ macros (`\path`, `\drawn`, `\node`) it allows an optional argument with TikZ settings and an optional TikZ-coordinate (which may start with `+` or `++`). However, a own argument parser, not the one used by TikZ, is used to detect and read these optional arguments. Therefore the order of the arguments is mandatory and might not be reversed. This small limitation might be overcome in future versions of this package.

Please note that the optional initial character may be given *inside* and at the very start of the mandatory argument, not before it. This is necessary because of several technical reasons.

Example: `\tikz \timing [green] (1,2) {HLZDZLH};` gives '  '.

Example: `\tikz \timing [green] (1,2) {[L]HLZDZLH};` gives '  '.

## 2.3 Table for Timing Diagrams

```
\begin{tikztimingtable}[⟨TikZ settings⟩]
      ⟨Signal Name⟩  &  ⟨Characters⟩ \\
      ...
    \extracode % Optional
      ⟨additional code⟩
\end{tikztimingtable}
```

This environment can be used to typeset multi-line timing diagrams. The syntax is like the one for a `{tabular}` environment with two columns. The first column is for the signal name and the second one ar the logic characters which would be placed inside the argument of a `\texttiming` or `\timing` macro. The whole table will be drawn inside a `{tikzpicture}` environment using multiple `\timing` and `\node` macros for the timing signals and their names, respectively. Additional `tikz` drawing code can be insert at the end of the table using `\extracode`.

`\extracode`

This macro is only defined inside a `{tikztimingtable}` environment and can only be used after the last table line (i.e. after a `\\`). If used all code between it and the `\end{tikztimingtable}` will be placed inside the same `{tikzpicture}`. This allows to add some drawing lines or a grid to the picture. It is also possible to draw something behind the timing diagram by using the PGF background layer: `\begin{pgfonlayer}{background}`...`\end{pgfonlayer}`.

### 2.3.1 Macros for `\extracode` Section

The following macros are only defined inside a `{tikztimingtable}` after the macro `\extracode`. They are useful for drawing additional material.

`\tablegrid[`⟨*TikZ Settings*⟩`]`

`\fulltablegrid[`⟨*TikZ Settings*⟩`]`

After `\extracode` this macros draw a grid in the background of the table. The first one draws a separate grid for each row and the second one a big grid over all rows.

`\rowdist`

`\coldist`

This macros return the row and column distance. There are useful for drawing additional material relative to the rows and columns. This values can be set (e.g. in the optional argument of the table) using the `timing/rowdist` and `timing/coldist` settings which are explained in Section 3.

`\nrows`

Returns the number of rows in the current table. Useful for use in `\horlines`.

`\twidth`

Returns the width (as multiple of the 'period width') of the longest timing diagram line in the table.
Example: If the longest line would be '`H 2.3L z`' than `\twidth` would be $1 + 2.3 + 0.5 = 3.8$.

`\horlines[`⟨*TikZ Settings*⟩`]{`⟨*list*⟩`}`

Draws horizontal lines, optionally with the given ⟨*Settings*⟩, at the base line of the rows given by ⟨*list*⟩. The PGF macro `\foreach`[2] is internally used so the list can include not only row numbers as integer but also fractional numbers and the '`...`' operator to auto-increment the numbers. Please note that all numbers in the list are multiplied by `\rowdist`. If the list is empty the default '`1,2,...,\nrows`' is used which draws lines for all rows.

`\vertlines[`⟨*TikZ Settings*⟩`]{`⟨*list*⟩`}`

Like `\horlines` but draws vertical lines and the listed numbers a relative to the basic width. If the list is empty the default '`0,1,...,\twidth`' is used which draws lines after every period width.

[2] See the `pgf` manual for more details.

`\tablerules`[⟨*TikZ Settings*⟩]

This macro adds top and bottom rules to the table in the same (or at least very similar) way as the `booktabs` package is doing it for normal `tabular`s. The current bounding box is used to calculate the needed rule length, which makes this macro position dependent if further code is changing the bounding box.

### Positions & Scalings inside the Table

The first row starts at $y = 0$ and the next rows are each `-1*\rowdist` lower than the previous one. The vertical unit is 1 signal height and the default row distance is '2' (=2×signal height). This means that a normal table with three rows goes from $y = +1$ (base line at $0 + 1$ signal height) to $y = -4$ (first row: +0, second row: -2, third row: -4). This are relative to the middle of the drawn lines, i.e. the bounding box is $2 \times \frac{\text{line width}}{2} = 1 \cdot$line width higher.

The timing column starts at $x = 0$ and goes into the positive range while scaled using the period width. Example: `HHHh` has a width of 3.5.

The label column starts at $x = -$`\coldist` and the text is right align with the right border at this position.

# 3 Styles

The generated logic signals are drawn using the style mechanism provided by `tikz` (which is based on `pgfkeys`[3]). This styles are defined and can be redefined using `\tikzset{`⟨*style name*⟩`/.style=`⟨*value*⟩`,}`. They can also be used in all places where ⟨*TikZ Settings*⟩ is mentioned. Please note that path/draw specific settings might not survive the transition to characters which have there own color, because these start a new drawing path. For a more detailed explanation why this is necessary see the `tikz` manual. However, timing specific settings are saved and restored between internal paths.

The package follows the directory structures approach used by TikZ/PGF and places all styles and other settings under the "subdirectory" '`timing`' in the main "directory" 'tikz', which is the default when `\tikzset` is used.
Example: The slope of the transitions can be changed using the key '`timing/slope`', which can also written in the absolute form '`/tikz/timing/slope`'.

The Table 4 lists all styles defined by this package.

Table 4: TikZ Styles and Settings provided and used by this Package.

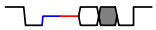
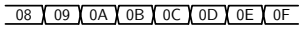
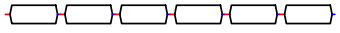
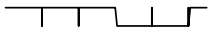
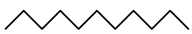
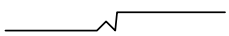
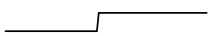
| Style/Setting | Description |
|---|---|
| `timing` | Base settings like signal height & period width. |
| `timing/intext` | Used for `\texttiming`. Depends on `timing`. |
| `timing/grid` | Used for grids. Depends on `help lines` and `timing`. |
| `timing/table` | Used for `{tikztimingtable}`. Depends on `timing`. |
| `timing/table/grid` | Used for table grid. Depends on `timing/grid`. |
| `timing/table/lines` | Used for `\horlines` and `\vertlines`. |
| `timing/table/rules` | Used for `\tablerules`. |
| `timing/inline node` | Used for nodes created by the `N` character. Default to `coordinate`. |
| `timing/`⟨*lowercase char*⟩ | Style for character ⟨*char*⟩. Not used for '`H`' and '`L`'. |
| `timing/`⟨*lc char*⟩`/background` | Background style for characters '`D`' and '`U`'. |
| `timing/`⟨*lc char*⟩`/text` | Text style for character ⟨*char*⟩. Only defined for '`D`'. |
| `timing/slope=`⟨*0.0−1.0*⟩ | Sets slope for logic transitions. This also sets `dslope=2*slope`, `zslope=slope/2`. |
| `timing/lslope=`⟨*0.0−1.0*⟩ | Sets slope for logic transitions only. Default: 0.1 |
| `timing/dslope=`⟨*0.0−1.0*⟩ | Sets slope for data transitions. Default: 0.2 |
| `timing/zslope=`⟨*0.0−1.0*⟩ | Sets slope for Z transitions. Default: 0.05 |
| `timing/rowdist=`⟨*distance*⟩ | Sets (baseline) distance between rows in a tikztimingtable. Default: 2 (=2×signal height) |
| `timing/coldist=`⟨*distance*⟩ | Sets distance between columns in a tikztimingtable. Default: 1 (=1×period width) |

[3]Part of the `pgf` package, CTAN: `http://www.ctan.org/pkg/pgf`

# 4 Examples

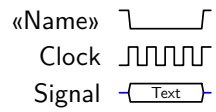
This section shows some examples by putting either the full source code or only the needed characters beside the graphical result. Please note that the displayed syntax is the one of `\timing` where the initial character is declared as optional argument (`[`⟨*char*⟩`]`) *inside/together* with the logic characters. The syntax of `\textttiming` is identical except the initial character is given as a normal optional argument before the characters argument. All examples except Example 1 are attached in compilable form to this PDF.

Example 1: Initial Characters, Modifiers, TikZ Settings

| Characters | Resulting Diagram |
|---|---|
| `HLZXDUTC` |  |
| `cccc` |  |
| `tttt` |  |
| `[c]cccc` |  |
| `4{c}` |  |
| `4c4c` |  |
| `4{1.8c}` |  |
| `[d] 4{5D{Text}} 0.2D` |   |
| `3.4H 0.6L` |  |
| `DDDUUUDDD` |  |
| `DDD{}DUUDD` |  |
| `8{2D{\hexcountmacro }}` |   |
| `3{2{0.25X 2.5D .25Z}}` |  |
| `DDD{} 3{0.2D{}} DDD` |  |
| `DDD{} 3{0.2D{}} 0.4D{} 0.6D{} DDD` |  |
| `HHHLLH SSSS HLLHHL` |  |
| `HHGHHGGHHLLGLLGH` |  |
| `ZZ G ZZ G XX G X` |  |
| `LLL 2{0.1H 0.1L} 0.6H HH` |  |
| `LLL [timing/slope=0.05] 4{.05H .05L} 0.6H HH` |  |
| `LLL 0.4U 0.6H HH` |  |
| `[L][timing/slope=1.0] HL HL HL HL HL` |  |
| `LLLLL !{-- +(.5,.5) -- ++(1,0)} HHHHHH` |  |
| `LLLLL [/utils/exec={\somemacro \code }] HHHHHH` |  |
| `LL [green] HH [brown] XX LL ZZ [orange] HH` |  |
| `[][line width=1pt] HLXZDU [line width=0.1pt] HLXZDU` |  |
| `[][line width=1pt] HLXZDU ;[line width=0.1pt] HLXZDU` |  |

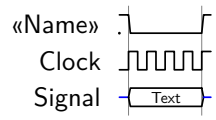
*Note:* Optional argument must be placed before macro argument if `\texttiming` is used.

```
\begin{tikztimingtable}
  <<Name>> & hLLLLh      \\
  Clock    & 10{c}       \\
  Signal   & z4D{Text}z \\
\end{tikztimingtable}
```



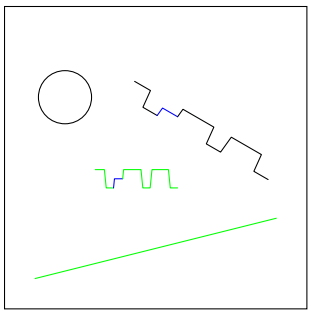

Example 2: {tikztimingtable} without \extracode.

```
\begin{tikztimingtable}
  <<Name>> & hLLLLh      \\
  Clock    & 10{c}       \\
  Signal   & z4D{Text}z \\
 \extracode
  \draw (0,0) circle (0.2pt); % Origin
  \begin{pgfonlayer}{background}
    \vertlines[help lines]{0.5,4.5}
  \end{pgfonlayer}
\end{tikztimingtable}
```



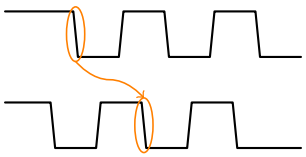

Example 3: {tikztimingtable} with \extracode.

```
\begin{tikzpicture}[x=4cm,y=4cm]
  \draw (0,0) rectangle (1,1);
  \draw (0.2,0.7) circle (10pt);
  \begin{scope}[green]
    \draw (0.1,0.1) -- +(0.8,0.2);
    \timing (0.3,0.4) {hlzhhlhhl};
  \end{scope}
  \timing [rotate=-30]
      (0.4,0.7) {HLZHHLHHL};
\end{tikzpicture}
```



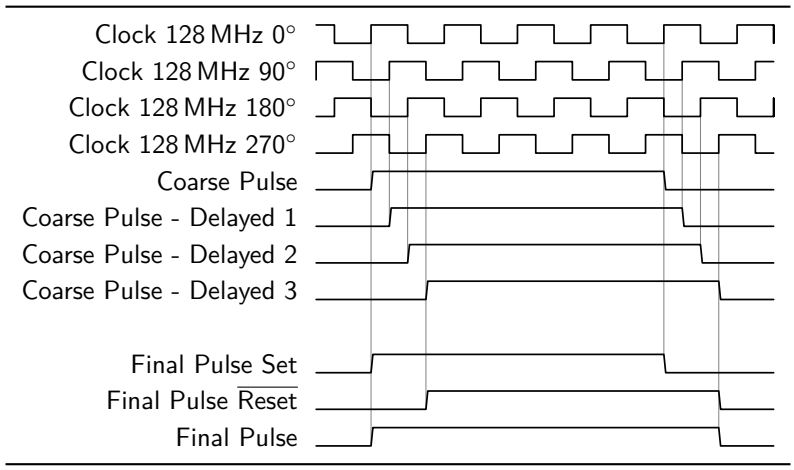
Example 4: \timing inside general {tikzpicture}.

```
\Huge
\begin{tikzpicture}[timing,thick,
  timing/inline node/.style={coordinate,
  shift={(0.05,-.5)}}]
  \timing (0,2) {hH N(A) LHLHL};
  \timing (0,0) {HLH N(B) LHLl};
  \draw [orange,semithick]
    (A) ellipse (.2 and .6) +(0,-0.6) coordinate (Ax)
    (B) ellipse (.2 and .6) +(0,+0.6) coordinate (Bx);
  \draw [orange,semithick,->]
    (Ax) parabola[bend pos=0.5] (Bx);
\end{tikzpicture}
```



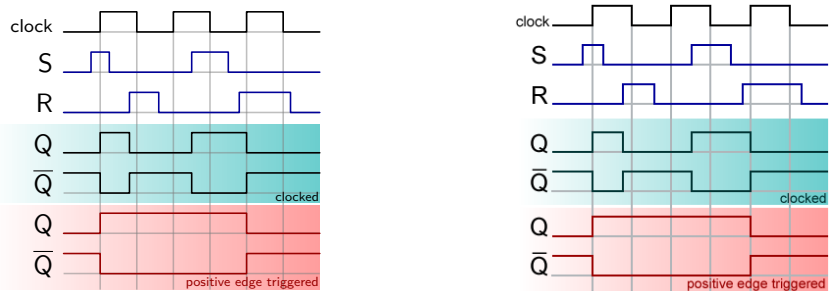
Example 5: Using In-Line Nodes to draw Relationships.

```
\def\degr{${}^\circ$}
\begin{tikztimingtable}
  Clock 128\,MHz 0\degr     & H 2C N(A1) 8{2C} N(A5) 3{2C} G\\
  Clock 128\,MHz 90\degr    & [C] 2{2C} N(A2) 8{2C} N(A6) 2{2C} C\\
  Clock 128\,MHz 180\degr   & C 2{2C} N(A3) 8{2C} N(A7) 2{2C} G\\
  Clock 128\,MHz 270\degr   & 3{2C} N(A4) 8{2C} N(A8) 2C C\\
  Coarse Pulse              & 3L 16H 6L \\
  Coarse Pulse - Delayed 1 & 4L N(B2) 16H N(B6) 5L \\
  Coarse Pulse - Delayed 2 & 5L N(B3) 16H N(B7) 4L \\
  Coarse Pulse - Delayed 3 & 6L 16H 3L \\
  \\
  Final Pulse Set           & 3L 16H N(B5) 6L \\
  Final Pulse $\overline{\text{Reset}}$ & 6L N(B4) 16H 3L \\
  Final Pulse               & 3L N(B1) 19H N(B8) 3L \\
\extracode
  \tablerules
  \begin{pgfonlayer}{background}
    \foreach \n in {1,...,8}
      \draw [help lines] (A\n) -- (B\n);
  \end{pgfonlayer}
\end{tikztimingtable}
```



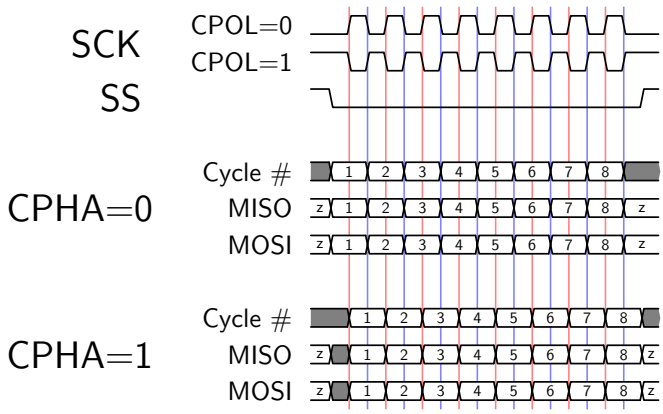

Example 6: Using In-Line Nodes to draw Marker Lines.

```
\definecolor{bgblue}{rgb}{0.41961,0.80784,0.80784}
\definecolor{bgred}{rgb}{1,0.61569,0.61569}
\definecolor{fgblue}{rgb}{0,0,0.6}
\definecolor{fgred}{rgb}{0.6,0,0}
\begin{tikztimingtable}[timing/slope=0,
  timing/coldist=2pt,xscale=2,yscale=1.1,semithick]
  \scriptsize clock & 7{C}\\
  S & .75L h 2.25L H LLl [fgblue]\\
  R & 1.8L .8H 2.2L 1.4H 0.8L [fgblue]\\
  Q & L .8H 1.7L 1.5H LL\\
  $\overline{\mbox{Q}}$ & H .8L 1.7H 1.5L HH\\
  Q & LHHHHLL[fgred]\\
  $\overline{\mbox{Q}}$ & HLLLLHH[fgred]\\
\extracode
 \begin{pgfonlayer}{background}
  \shade [right color=bgblue,left color=white]
     (7,-8.45) rectangle (-2,-4.6);
  \shade [right color=bgred,left color=white]
     (7,-12.8) rectangle (-2,-8.6);
  \begin{scope}[gray,semitransparent,semithick]
    \horlines{}
    \foreach \x in {1,...,6}
      \draw (\x,1) -- (\x,-12.8);
    % similar: \vertlines{1,...,6}
  \end{scope}
  \node [anchor=south east,inner sep=0pt]
    at (7,-8.45) {\tiny clocked};
  \node [anchor=south east,inner sep=0pt,fgred]
    at (7,-12.8) {\tiny positive edge triggered};
 \end{pgfonlayer}
\end{tikztimingtable}
\insertoriginalimageforcomparisionifpresent
```




Example 7: SR flip-flop timing diagram (left). Redrawn from image (right)
http://commons.wikimedia.org/wiki/File:SR_FF_timing_diagram.png

```
\newcounter{countup}
\newcommand*{\countup}{\addtocounter{countup}{1}\thecountup}
\newcommand*{\crst}{\setcounter{countup}{0}}
\begin{tikztimingtable}
  [timing/d/background/.style={fill=white},
   timing/lslope=0.2]
          CPOL=0 & LL 15{T} LL \\
          CPOL=1 & HH 15{T} HH \\
                 & H 17L H     \\
  \\
  \crst Cycle \# & U     8{2D{\countup}} 2U    \\
  \crst      MISO & D{z}  8{2D{\countup}} 2D{z} \\
  \crst      MOSI & D{z}  8{2D{\countup}} 2D{z} \\
  \\
  \crst Cycle \# & UU    8{2D{\countup}}  U    \\
  \crst      MISO & D{z}U 8{2D{\countup}}  D{z} \\
  \crst      MOSI & D{z}U 8{2D{\countup}}  D{z} \\
\extracode
  \begin{pgfonlayer}{background}
    \begin{scope}[semitransparent,semithick]
      \vertlines[red]{2.1,4.1,...,17.1}
      \vertlines[blue]{3.1,5.1,...,17.1}
    \end{scope}
  \end{pgfonlayer}
  \begin{scope}
    [font=\sffamily\Large,shift={(-6em,-0.5)},anchor=east]
    \node at (  0, 0) {SCK};    \node at (  0,-3 ) {SS};
    \node at (1ex,-9) {CPHA=0}; \node at (1ex,-17) {CPHA=1};
  \end{scope}
\end{tikztimingtable}%
```




Example 8: SPI Interface Timing. Redrawn from image
http://en.wikipedia.org/wiki/File:SPI_timing_diagram.svg

# 5 Implementation

## 5.1 Package Header

```
⟨*package⟩
\RequirePackage{tikz}
\usetikzlibrary{calc}
\usetikzlibrary{backgrounds}
\RequirePackage{environ}

\def\tikztimingwidth{0.0}
\newcount\tikztiming@numint
\newcount\tikztiming@numfrac
\def\tikztiming@num{1.0}%
%%\def\tikztiming@num{\the\tikztiming@numint.\the\tikztiming@numfrac}

\newcounter{tikztiming@nrows}%
\def\tikztiming@rowdist{2}%
\def\tikztiming@coldist{1}%
\def\tikztiminglabel#1{#1}%

\def\tikztiming@prefix{tikztiming@trans@}
```

## 5.2 TikZ Style Settings

```
\tikzset{timing/.style={%
    x=1.6ex, y=1.6ex,
    line cap=round, line join=round,
  }%
}
\tikzset{%
  timing/.cd,
  grid/.style={timing,help lines},
  intext/.style={timing,line width=0.15ex},
  inline node/.style={shape=coordinate},
  table/.style={timing,line width=0.15ex,font=\sffamily},
  coord/.style={inner sep=0pt,outer sep=0pt},
  save/.style={inner sep=0pt,outer sep=0pt,/utils/exec=\tikztiming@savesettings},
  restore/.style={/utils/exec=\tikztiming@restoresettings},
  name/.style={inner sep=0pt,outer sep=0pt},
  d/text/.style={timing,scale=0.6,font=\sffamily},
  d/background/.style={},
  h/.style={},
  l/.style={},
  d/.style={},
  m/.style={black!40!brown},
  u/background/.style={fill=gray},
  u/.style={},
  o/background/.style={},
  o/.style={timing/d,line width=0.10ex,dotted},
  z/.style={blue},
```

```
  t/.style={},
  c/.style={timing/slope=0.0},
  x/.style={red},
  table/grid/.style={timing/grid},
  table/lines/.style={},
  table/rules/.style={line width=0.08em,line cap=butt},
  slope/.code={%
    \tikztimingsetslope{#1}%
    \tikztimingsetdslope{2*#1}%
    \tikztimingsetzslope{#1/2}%
  },
  lslope/.code={\tikztimingsetslope{#1}},
  dslope/.code={\tikztimingsetdslope{#1}},
  zslope/.code={\tikztimingsetzslope{#1}},
  coldist/.store in=\tikztiming@coldist,
  rowdist/.store in=\tikztiming@rowdist,
}
```

## 5.3 Macros

**\texttimingbefore**

This macro is executed inside the tikzpicture environment of \texttiming before the timing diagram is drawn.

```
\def\texttimingbefore{}
```

**\texttimingafter**

This macro is executed inside the tikzpicture environment of \texttiming after the timing diagram is drawn.

```
\def\texttimingafter{}
```

**\texttiminggrid**

Draws a background grid with the 'timing/grid' setting. Should be used inside \texttimingbefore.

```
\def\texttiminggrid{%
  \draw[xstep={\timingwidth/2.},ystep={\timingheight/2.},timing/grid] (0,0) grid
  (\timingwidth*\tikztimingwidth,\timingheight);
}
```

**\texttiming**

`#1`: Optional initial character
`#2`: Timing characters

```
\DeclareRobustCommand*\texttiming[2][]{%
  \begingroup
    \tikztiming@init
    \uppercase{\def\lastchar{#1}}%
    \@ifundefined{tikztiming@initcode@\lastchar}%
      {}%
```

```
      {\@nameuse{tikztiming@initcode@\lastchar}}%
    \ifx\lastchar\empty\else
    \@ifundefined{\tikztiming@prefix\lastchar @start}%
      {\PackageWarning{tikz-timing}{Start value for timing character '\lastchar'
      is not defined and will be ignored!}{}{}{}}%
      {\tikztiming@nameaddtostr{\lastchar @start}{}}%
    \fi
    \tikztiming@#2\relax
    %\message{^^J\meaning\tikztiming@str^^J}%
    \begin{tikzpicture}[timing/intext]%
      \path[use as bounding box] (0,0) rectangle
      (\timingwidth*\tikztimingwidth,\timingheight);%
      \texttimingbefore
      \tikztiming@str;%
      \texttimingafter
    \end{tikzpicture}%
  \endgroup
}
```

### \tikztiming@init

```
\def\tikztiming@init{%
    \def\lastchar{}%
    \let\currentchar\empty
    \def\tikztimingwidth{0.0}%
    \setcounter{tikztimingtrans}{-1}%
    \def\tikztiming@str{\draw (0,0) coordinate (timing/start base) }%
}
```

### \timing

```
\def\timing{%
  \@ifnextchar{[}%
    {\timing@}%
    {\timing@[]}%
}
```

### \timing@

`#1`: Optional TikZ Settings

```
\def\timing@[#1]{%
  \@ifnextchar{+}%
    {\timing@@{#1}}%
    {\@ifnextchar(%)
      {\timing@@{#1}}%
      {\timing@@{#1}+(0,0)}%
    }%
}
```

### \timing@@

`#1`: Optional TikZ Settings

#2: Potential '+' or empty
#3: Coordinate

```
\def\timing@@#1#2(#3){%
  \timing@@@{#1}{#2(#3)}%
}
```

### \timing@@@

#1: Optional TikZ Settings
#2: Coordinate
#3: Timing Characters

```
\def\timing@@@#1#2#3{%
  \begingroup
    \tikztiming@init
    \@ifnextchar{[}%
      {\timing@@@init}%
      {\timing@@@init[]}%
    #3\relax
    %\message{^^J\meaning\tikztiming@str^^J}%
    \begin{scope}[shift={#2},timing,#1]%
      \tikztiming@str;%
    \end{scope}%
  \endgroup
  \timing@@@end
}
```

### \timing@@@end

#1: Token behind \timing macro.

```
\def\timing@@@end#1;{%
  \ifx;#1;\else
    \PackageError{tikz-package}{Can not parse timing path}{}{}{}%
  \fi
}
%
```

### \timing@@@init

#1: Initial character.

```
\def\timing@@@init[#1]{%
  \uppercase{\def\lastchar{#1}}%
  \@ifundefined{tikztiming@initcode@\lastchar}%
    {}%
    {\@nameuse{tikztiming@initcode@\lastchar}}%
  \ifx\lastchar\empty\else
  \@ifundefined{\tikztiming@prefix\lastchar @start}%
    {\PackageWarning{tikz-timing}{Start value for timing character '\lastchar'
    is not defined and will be ignored!}{}{}{}}%
    {\tikztiming@nameaddtostr{\lastchar @start}{}}%
  \fi
```

```
  \tikztiming@
}
```

### \tikztiming@trans@

The empty transition gets defined to avoid errors if it is used by the generic code, e.g. if a non-combinable character like 'C' is the last one.

```
\let\tikztiming@trans@\@gobble
```

### \tikztiming@aftercode@T

```
\def\tikztiming@aftercode@T{%
  \tikztiming@output@flush
}
```

### \tikztiming@aftercode@t

```
\def\tikztiming@aftercode@t{%
  \tikztiming@aftercode@T
}
```

### \tikztiming@aftercode@C

```
\def\tikztiming@aftercode@C{%
  %\tikztiming@output@flush
}
```

### \tikztiming@aftercode@c

```
\def\tikztiming@aftercode@c{%
  \tikztiming@aftercode@C
}
```

### \tikztiming@aftercode@G

```
\def\tikztiming@aftercode@G{%
  \let\lastchar\secondlastchar
  \let\tikztimingwidth\lasttikztimingwidth
}
```

### \tikztiming@aftercode@g

```
\def\tikztiming@aftercode@g{%
  \let\lastchar\secondlastchar
  \let\tikztimingwidth\lasttikztimingwidth
}
```

### \tikztiming@aftercode@S

```
\def\tikztiming@aftercode@S{%
  \let\lastchar\secondlastchar
}
```

### \tikztiming@aftercode@s

```
\def\tikztiming@aftercode@s{%
  \let\lastchar\secondlastchar
}
```

### \tikztiming@beforenextcode@D@edge@

```
\def\tikztiming@beforenextcode@D@edge@{%
  \if D\currentchar\else
    \if d\currentchar\else
      \def\lastchar{D}%
    \fi
  \fi
}
```

### \tikztiming@beforecode@d@edge@

```
\def\tikztiming@beforenextcode@d@edge@{%
  \if D\currentchar\else
    \if d\currentchar\else
      \def\lastchar{D}%
    \fi
  \fi
}
```

### \tikztiming@initcode@D

```
\def\tikztiming@initcode@D{%
  \def\lastchar{D@edge@}%
}
```

### \tikztiming@initcode@d

```
\def\tikztiming@initcode@d{%
  \def\lastchar{d@edge@}%
}
```

### \tikztiming@

The `\@ifnextchar\bgroup` is a trick to remove following spaces which would break the number test.

```
\def\tikztiming@{%
  \@ifnextchar\bgroup
    {\tikztiming@testfornum}%
    {\tikztiming@testfornum}%
}
```

### \tikztiming@eaddtostr

`#1`: Tokens to add to string.

```
\def\tikztiming@eaddtostr#1{%
  \begingroup
    \tikztiming@internaldefs{}%
```

```
    \@temptokena\expandafter{\tikztiming@str}%
    \xdef\tikztiming@str{%
      \the\@temptokena
      #1%
    }%
  \endgroup
}
```

### \tikztiming@addtostr

```
\def\tikztiming@addtostr{%
  \g@addto@macro\tikztiming@str
}
```

### \tikztiming@output

#1: Character 1
#2: Character 2

```
\def\tikztiming@output#1#2{%
  \ifx\relax#2\relax
    \tikztiming@nameaddtostr{#1}%
  \else
    \ifcase0%
      \ifx\tikztiming@output@bufchara\empty
        \ifx\tikztiming@output@bufcharb\empty
          1%
        \fi
      \fi\relax
      % not empty
      \edef\tikztiming@output@currentchar{#2}%
      \ifcase0%
      \expandafter\ifx\csname tikztiming@nocombine@#2\endcsname\relax
      \ifx\tikztiming@output@currentchar\tikztiming@output@bufcharb
        1%
      \fi\fi
      \relax
        \tikztiming@output@flush
        \edef\tikztiming@output@bufchara{#1}%
        \edef\tikztiming@output@bufcharb{#2}%
      \or
        \pgfmathparse{\tikztiming@output@bufnum + \tikztiming@num}%
        \let\tikztiming@output@bufnum\pgfmathresult
        \def\tikztiming@num{1.0}%
      \fi
    \else % empty
      \edef\tikztiming@output@bufchara{#1}%
      \edef\tikztiming@output@bufcharb{#2}%
      \let\tikztiming@output@bufnum\tikztiming@num
      \def\tikztiming@num{1.0}%
    \fi
  \fi
```

```
}
```

Init buffer macros:

```
\def\tikztiming@output@bufchara{}%
\def\tikztiming@output@bufcharb{}%
\def\tikztiming@output@bufnum{0}%
```

### \tikztiming@output@flush

```
\def\tikztiming@output@flush{%
  \begingroup
    \let\tikztiming@num\tikztiming@output@bufnum
    \tikztiming@nameaddtostr{%
      \tikztiming@output@bufchara
      \tikztiming@output@bufcharb
    }%
  \endgroup%
  \gdef\tikztiming@output@bufchara{}%
  \gdef\tikztiming@output@bufcharb{}%
  \global\let\tikztiming@output@bufnum\tikztiming@num
  \gdef\tikztiming@num{1.0}%
}
```

### \tikztiming@nameaddtostr

`#1`: Name of macro without prefix to add

```
\def\tikztiming@nameaddtostr#1{%
  \begingroup
    \edef\@tempa{\tikztiming@num}%
    \expandafter\g@addto@macro
    \expandafter\tikztiming@str
    \expandafter{\csname\tikztiming@prefix#1\expandafter\endcsname
    \expandafter{\@tempa} }%
  \endgroup
  \def\tikztiming@num{1.0}%
}
```

### \tikztiming@nameedef

`#1`: Optional character to indicate character case
`#2`: Macro name to be defined (without prefix)
`#3`: Content of macro

Defines internal tikztiming macro with name \⟨*prefix*⟩⟨*name (#2)*⟩. The macro definition (#3) is expanded while the internal drawing definitions are active.

```
\newcommand\tikztiming@nameedef[3][A]{%
  \def\@gtempa##1{#3}%
  \expandafter\let\csname\tikztiming@prefix#2@general\endcsname\@gtempa
  \begingroup
    \tikztiming@internaldefs{#1}%
    \xdef\@gtempa##1{\@gtempa{\width}}%
  \endgroup
```

```
  \expandafter\let\csname\tikztiming@prefix#2\endcsname\@gtempa
  \let\@gtempa\empty
}
```

### \tikztiming@namelet

#1: Original Characters
#2: New Characters

Only execute \let if the original macro is defined or the destination macro is defined and would now set to undefined.

```
\newcommand\tikztiming@namelet[2]{%
  \ifcase0%
    \@ifundefined{\tikztiming@prefix#2}%
      {\@ifundefined{\tikztiming@prefix#1}%
        {0}{1}%
      }%
      {1}%
    \relax
  \else
    \expandafter\let
    \csname\tikztiming@prefix#1\expandafter\endcsname
    \csname\tikztiming@prefix#2\endcsname
  \fi
}
```

### \tikztiming@@end

```
\def\tikztiming@@end{%
  \tikztiming@output@flush
  \global\let\tikztimingwidth\tikztimingwidth
  \tikztiming@addtostr{ coordinate (timing/end)
    let \p1 = (timing/start base), \p2 = (timing/end) in
      coordinate (timing/end base) at (\x2,\y1)
      coordinate (timing/end top)  at (\x2,1+\y1)
  }%
}
```

### \tikztiming@@

#1: Next Character

```
\def\tikztiming@@#1{%
  \ifx\relax#1\empty
    \expandafter\tikztiming@@end
  \else
    \let\lasttikztimingwidth\tikztimingwidth
    \tikztiming@iflower{#1}%
      {\pgfmathparse{\tikztiming@num/2.0}\let\tikztiming@num\pgfmathresult}%
      {}%
    \pgfmathparse{\tikztimingwidth + \tikztiming@num}%
    \let\tikztimingwidth\pgfmathresult
    \def\currentchar{#1}%
```

```
    \uppercase{\def\currentcharuc{#1}}%
    \@ifundefined{tikztiming@beforenextcode@\lastchar}%
      {}%
      {\@nameuse{tikztiming@beforenextcode@\lastchar}}%
    \@ifundefined{tikztiming@beforecode@\currentchar}%
      {}%
      {\@nameuse{tikztiming@beforecode@\currentchar}}%
    \@ifundefined{\tikztiming@prefix\lastchar\currentchar}%
      {\@ifundefined{\tikztiming@prefix\lastchar\currentcharuc}%
        {\PackageWarning{tikz-timing}{Timing transition '\lastchar\currentchar'
        is not defined and will be ignored!}{}{}{}}%
        {\tikztiming@output{\lastchar}{\currentcharuc}}%
      }%
      {\tikztiming@output{\lastchar}{\currentchar}}%
    \let\secondlastchar\lastchar
    \let\lastchar\currentcharuc
    \@ifundefined{tikztiming@aftercode@\currentcharuc}%
      {}%
      {\@nameuse{tikztiming@aftercode@\currentcharuc}}%
    \expandafter
    \tikztiming@testfortext
  \fi
}
```

### \tikztiming@testfortext

```
\def\tikztiming@testfortext{%
  \@ifnextchar\bgroup
    {\tikztiming@handletext}%
    {\tikztiming@}%
}
```

### \tikztiming@handletext

`#1`: Text

```
\def\tikztiming@handletext#1{%
  \@ifnextchar[]%
    {\tikztiming@handletext@}%
    {\tikztiming@handletext@[]}%
  #1\relax
}
```

### \tikztiming@handletext@

`#1`: Optional Settings
`#2`: Text

```
\def\tikztiming@handletext@[#1]#2\relax{%
  \begingroup
  \expandafter\lowercase\expandafter{%
    \expandafter\def\expandafter\currentcharlc
    \expandafter{\currentchar}%
```

```
  }%
  \pgfkeysifdefined{/tikz/timing/\currentcharlc/text/.@cmd}%
  {%
  \tikztiming@output@flush
  \tikztiming@eaddtostr{%
    node (timing@dend) at +(\dslope/2.0,\height/2.0) {}
    node [%]
      shift={($ (timing@dstart)!0.5!(timing@dend) $)},%
      timing/\currentcharlc/text,%
  }%
  \endgroup
  \tikztiming@addtostr{%[
      #1%
      ] {#2}%
  }%
  \def\lastchar{D@edge@}%
  }{%
    \endgroup
    \PackageWarning{tikz-timing}{Ignoring text for character
    '\currentchar'!}{}{}{}%
  }%
  \tikztiming@
}
```

### \tikztiming@stoppath

`#1`: Character to gobble

```
\def\tikztiming@stoppath#1{%
  \tikztiming@output@flush
  \tikztiming@eaddtostr{%
    \newdraw
  }%
  \tikztiming@
}
```

### \tikztiming@stoppath@nosave

`#1`: Character to gobble

```
\def\tikztiming@stoppath@nosave#1{%
  \tikztiming@output@flush
  \tikztiming@eaddtostr{%
    \newdrawns
  }%
  \tikztiming@
}
```

### \tikztiming@addnode

`#1`: Character to gobble

```
\def\tikztiming@addnode#1{%
  \@ifnextchar{[}%]
```

```
    {\tikztiming@addnode@getoptions}%
    {\tikztiming@addnode@getoptions[]}%
}
```

### \tikztiming@addnode

#1: Options

```
\def\tikztiming@addnode@getoptions[#1]{%
  \@ifnextchar{(}%)}
    {\tikztiming@addnode@getname{#1}}%
    {\tikztiming@addnode@getname{#1}()}%
}
```

### \tikztiming@addnode@getname

#1: Previous read options
#2: Node name

```
\def\tikztiming@addnode@getname#1(#2){%
  \@ifnextchar\bgroup
    {\tikztiming@addnode@{#1}{#2}}%
    {\tikztiming@addnode@{#1}{#2}{}}%
}
```

### \tikztiming@addnode@

#1: Options
#2: Node name
#3: Node text

```
\def\tikztiming@addnode@#1#2#3{%
  \tikztiming@output@flush
  \begingroup
    \def\@tempa{#2}%
    \ifx\@tempa\empty
      \def\@tempa{ node [timing/inline node,#1] }%
    \else
      \def\@tempa{ node [timing/inline node,#1] (#2) }%
    \fi
    \expandafter\tikztiming@addtostr\expandafter{\@tempa {#3} }%
  \endgroup
  \tikztiming@
}
```

### \tikztiming@testforcode

```
\def\tikztiming@testforcode{%
  \@ifnextchar{!}%
    {\tikztiming@testforcode@}%
    {\@ifnextchar{[}%
      {\tikztiming@handleoption}%
      {\@ifnextchar{;}%
        {\tikztiming@stoppath@nosave}%
```

```
        {\@ifnextchar{,}%
          {\tikztiming@stoppath}%
          {\@ifnextchar{N}%
            {\tikztiming@addnode}%
            {\tikztiming@@}%
          }%
        }%
      }%
    }%
}
```

### \tikztiming@testforcode@

`#1`: Character to gobble

```
\def\tikztiming@testforcode@#1{%
  \@ifnextchar\bgroup
    {\tikztiming@handlecode}%
    {%
      \PackageWarning{tikz-timing}{Missing braces after '!' character. Ignoring
      this character}{}{}{}%
      \tikztiming@
    }%
}
```

### \tikztiming@handlecode

`#1`: Code to add to string

```
\def\tikztiming@handlecode#1{%
  \tikztiming@output@flush
  \tikztiming@addtostr{ #1 }%
  \tikztiming@
}
```

### \tikztiming@handleoption

`#1`: Options to add to string

```
\def\tikztiming@handleoption[#1]{%
  \tikztiming@addtostr{ [#1] }%
  \tikztiming@
}
```

### \tikztiming@testfornum

```
\def\tikztiming@testfornum{%
  \let\tikztiming@numchars\empty
  \tikztiming@numfrac0\relax
  \afterassignment
  \tikztiming@testfornum@
  \tikztiming@numint0%
}
```

### \tikztiming@testfornumfrac

```
\def\tikztiming@testfornumfrac{%
  \afterassignment
  \tikztiming@testfornum@@@
  \tikztiming@numfrac1%
}
```

### \tikztiming@numloop

```
\def\tikztiming@numloop{%
  \ifnum\tikztiming@numint>0%
    \toks@\expandafter{\tikztiming@numchars}%
    \xdef\tikztiming@numchars{%
      \the\toks@
      \the\@temptokena
    }%
    \advance\tikztiming@numint by -1\relax
    \expandafter\tikztiming@numloop
  \fi
}
```

### \tikztiming@testfornum@

```
\def\tikztiming@testfornum@{%
  \ifnum0<\tikztiming@numint
    \let\tikztiming@next\tikztiming@testfornum@@
  \else
    \def\tikztiming@next{%
      \@ifnextchar{.}%
        {\expandafter\tikztiming@testfornumfrac\@gobble}%
        {%
          \tikztiming@numint1\relax
          \tikztiming@numfrac0\relax
          \def\tikztiming@num{1.0}%
          \expandafter\tikztiming@testforcode
        }%
    }%
  \fi
  \tikztiming@next
}
```

### \tikztiming@testfornum@@

```
\def\tikztiming@testfornum@@{%
  \@ifnextchar{.}%
    {\expandafter\tikztiming@testfornumfrac\@gobble}%
    {\tikztiming@testfornum@@@}%
}
```

### \tikztiming@testfornum@@@

```
\def\tikztiming@testfornum@@@{%
```

```
  \xdef\tikztiming@num{\the\tikztiming@numint.\expandafter\@gobble\the\tikztiming@numfrac}%
  \@ifnextchar\bgroup
    {%
      \expandafter\tikztiming@numfrac\expandafter0\expandafter
      \@gobble\the\tikztiming@numfrac\relax
      \ifnum0=\tikztiming@numfrac\else
        \pgfmathparse{round(\tikztiming@num)}%
        \PackageWarning{tikz-timing}%
          {Can not repeat group by a non-integer factor!^^J%
           Rounding '\tikztiming@num' to '\pgfmathresult'.}{}{}{}%
        \let\tikztiming@num\pgfmathresult
      \fi
      \tikztiming@testfornum@@@@
    }%
    {%
      \tikztiming@testforcode
    }%
}
```

**\tikztiming@testfornum@@@@**

`#1`: Characters and other tokens to repeat

```
\def\tikztiming@testfornum@@@@#1{%
  \begingroup
    \@temptokena{#1}%
    \tikztiming@numloop%
  \endgroup
  \tikztiming@numint1\relax
  \tikztiming@numfrac0\relax
  \expandafter\tikztiming@\tikztiming@numchars
}
```

## 5.4 Table environment

```
%\usetikzlibrary{backgrounds}
\newcounter{tikztimingrows}
```

**\tikztiming@extracode**

```
\def\tikztiming@extracode{\@gobble{EXTRACODE}}%
```

**tikztimingtable**

`#1`: Optional settings

```
\NewEnviron{tikztimingtable}[1][]{%
  \begingroup
  \setcounter{tikztiming@nrows}{0}%
  \def\tikztiming@maxwidth{0.0}%
  \let\extracode\tikztiming@extracode
  \let\tablegrid\tikztiming@tablegrid
  \let\fulltablegrid\tikztiming@fulltablegrid
```

```
  \let\horlines\tikztiming@horlines
  \let\vertlines\tikztiming@vertlines
  \let\tablerules\tikztiming@tablerules
  \def\rowdist{\tikztiming@rowdist}%
  \def\coldist{\tikztiming@coldist}%
  \def\nrows{\the\c@tikztiming@nrows}%
  \def\twidth{\tikztiming@maxwidth}%
  \begin{tikzpicture}[timing/table,#1]%
    \coordinate (last row)  at (0,\rowdist);
    \coordinate (label pos) at (-1*\coldist,0);
    \coordinate (timing/table/top left) at (0,1);
    \coordinate (timing/table/bottom right) at (0,0);
    \expandafter\tikztimingtable@row\BODY\endtikztimingtable@
  \end{tikzpicture}
  \endgroup
}

\def\endtikztimingtable@{\@gobble{ENDTIKSTIMING}}
```

### \tikztimingextracode

`#1`: Token to gobble
`#2`: Extra drawing code

```
\long\def\tikztimingextracode#1#2\endtikztimingtable@{%
  \path let
     \p1 = (timing/table/top left),
     \p2 = (timing/table/bottom right)
   in
     coordinate (timing/table/bottom left) at (\x1,\y2)
     coordinate (timing/table/top right) at (\x2,\y1)
     coordinate (timing/table/size) at (\x2-\x1,\y1-\y2)
   ;
  #2%
}
```

### \tikztiming@emptycell

Just used as marker. Needs unique definition.

```
\def\tikztiming@emptycell{%
  \@gobble{tikztiming@emptycell}%
}
```

### \tikztimingtable@row

`#1`: Row content

```
\def\tikztimingtable@row#1\\{%
  \tikztimingtable@row@#1&\tikztiming@emptycell&\\
}
```

### \tikztimingtable@row@

`#1`: Cell 1

#2: Cell 2 or empty
#3: Potential further cells

```
\def\tikztimingtable@row@#1&#2&#3\\{%
  \ifx\\#3\\\else
    \begingroup
      \def\@tempa{\tikztiming@emptycell&}%
      \def\@tempb{#3}%
      \ifx\@tempa\@tempb\else
        \PackageWarning{tikz-timing}{%
          To many columns in tikztimingtable row! Only two are allowed%
        }{}{}{}%
      \fi
    \endgroup
  \fi
  \ifx\tikztiming@emptycell#2%
    \def\next{\tikztimingtable@row@@{#1}{}}%
  \else
    \def\next{\tikztimingtable@row@@{#1}{#2}}%
  \fi
  \next
}%
```

### \tikztimingtable@row@@

#1: Name/Label
#2: Timing characters

```
\def\tikztimingtable@row@@#1#2{%
  \addtocounter{tikztiming@nrows}{1}%
  \path ($ (last row) + (0,-1*\rowdist) $) coordinate (last row);
  \path ($ (last row) + (-1*\coldist,0) $) node [anchor=base east,timing/name]
    {\tikztiminglabel{#1}};
  \timing (last row) {#2};
  \path let \p1 = (timing/table/bottom right), \p2 = (timing/end base) in
    coordinate (timing/table/bottom right) at ({max(\x1,\x2)},\y2);
  %
  \pgfmathparse{max(\tikztiming@maxwidth,\tikztimingwidth)}%
  \let\tikztiming@maxwidth\pgfmathresult
  \@ifnextchar\extracode
    {%
      \let\extracode\relax
      \tikztimingextracode
    }%
    {%
      \@ifnextchar\endtikztimingtable@
        {\@gobble}{\tikztimingtable@row}%
    }%
}
```

### \tikztiming@fulltablegrid

#1: Optional settings

```
\newcommand*\tikztiming@fulltablegrid[1][]{%
  \begin{pgfonlayer}{background}
    \scope[xstep={\timingwidth/2.},ystep={\timingheight/2.},
    shift={(timing/table/bottom left)},timing/table/grid,#1]
      \draw (0,0) grid
        ($ (timing/table/top right) - (timing/table/bottom left) $);
   \endscope
  \end{pgfonlayer}
}
```

### \tikztiming@tablegrid

#1: Optional settings

```
\newcommand*\tikztiming@tablegrid[1][]{%
  \begin{pgfonlayer}{background}
    \scope[xstep={\timingwidth/2.},ystep={\timingheight/2.},timing/table/grid,#1]
      \foreach \y in {1,...,\nrows} {%
        \draw {[shift={($ (timing/table/bottom left) + (0,\y*\rowdist) -
        (0,\rowdist) $)}] let \p1 = (timing/table/bottom right) in (0,0) grid
        (\x1,1)};
      }%
    \endscope
  \end{pgfonlayer}
}
```

### \tikztiming@tablerules

#1: Optional Settings

```
\newcommand*\tikztiming@tablerules[1][]{%
    \draw [timing/table/rules,#1] let
      \p1 = (current bounding box.north west),
      \p2 = (current bounding box.south east),
      \p3 = (last row)
    in
      (\x1-\tabcolsep,\rowdist) -- (\x2+\tabcolsep,\rowdist)
      ($ (\x1-\tabcolsep,\y3) - (0,\rowdist-1) $) --
      ($ (\x2+\tabcolsep,\y3) - (0,\rowdist-1) $)
    ;
}
```

### \tikztiming@horlines

#1: Optional Settings
#2: Row numbers

```
\newcommand*\tikztiming@horlines[2][]{%
  \begingroup
    \def\list{#2}%
    \ifx\list\empty
      \def\list{1,2,...,\nrows}%
    \fi
    \foreach \row in \list%
```

```
      \draw [timing/table/lines,#1] let
        \p1 = (timing/table/bottom right)
      in
        (0,\rowdist-\row*\rowdist) -- +(\x1,0);
  \endgroup
}
```

**\tikztiming@vertlines**

#1: Optional Settings
#2: Column numbers

```
\newcommand*\tikztiming@vertlines[2][]{%
  \begingroup
    \def\list{#2}%
    \ifx\list\empty
      \def\list{0,1,...,\twidth}%
    \fi
    \draw [timing/table/lines,#1] let
        \p1 = ($ (timing/table/bottom right) - (0,2) $)
      in
        \foreach \clk in \list {
          (\clk,+1.5) -- +(0,\y1)
        }
    ;
  \endgroup
}
```

## 5.5 Other Macros

**\tikztiming@iflower**

#1: Character

```
\def\tikztiming@iflower#1{%
  \begingroup
  \edef\@tempa{`#1}%
  \ifnum\@tempa=\lccode\@tempa
    \endgroup
    \expandafter
    \@firstoftwo
  \else
    \endgroup
    \expandafter
    \@secondoftwo
  \fi
}
```

**\timingwidth**

**\timingheight**

```
\def\timingwidth{1}%
\def\timingheight{1}%
```

### \tikztiming@internaldefs

#1: Character

```
\def\tikztiming@internaldefs#1{%
  \def\draw{\noexpand\draw}%
  \def\path{\noexpand\path}%
  \def\fill{\noexpand\fill}%
  \def\width{####1*\noexpand\timingwidth}%
  \def\fwidth{\noexpand\timingwidth}%
  \def\height{\noexpand\timingheight}%
  \def\slope{\noexpand\timingslope}%
  \def\zslope{\noexpand\timingzslope}%
  \def\dslope{\noexpand\timingdslope}%
  \def\gslope{0}%
  \lowercase{%
  \def\style{timing/#1}%
  \def\bgstyle{timing/#1/background}%
  }%
  \def\newdraw{\tikztiming@newdraw}%
  \def\newdrawns{\tikztiming@newdraw@nosave}%
  \def\code##1{ [/utils/exec={\unexpanded{##1}}] }%
}
```

### \tikztimingsetslope

#1: Slope value

```
\def\tikztimingsetslope#1{%
  \pgfmathparse{min(1.0,{max(0.0,#1)})}%
  \let\tikztiming@slope\pgfmathresult
  \edef\timingslope{\tikztiming@slope*\noexpand\timingwidth}%
}
```

### \tikztimingsetdslope

#1: Slope value

```
\def\tikztimingsetdslope#1{%
  \pgfmathparse{min(1.0,{max(0.0,#1)})}%
  \let\tikztiming@dslope\pgfmathresult
  \edef\timingdslope{\tikztiming@dslope*\noexpand\timingwidth}%
}
```

### \tikztimingsetzslope

#1: Slope value

```
\def\tikztimingsetzslope#1{%
  \pgfmathparse{min(1.0,{max(0.0,#1)})}%
  \let\tikztiming@zslope\pgfmathresult
  \edef\timingzslope{\tikztiming@zslope*\noexpand\timingwidth}%
}
```

```
\tikztimingsetslope{0.10}%
```

```
\tikztimingsetdslope{0.20}%
\tikztimingsetzslope{0.05}%
```

### \tikztiminguse

`#1`: Character(s)

```
\def\tikztiminguse#1{%
  \@ifundefined{\tikztiming@prefix#1@general}%
    {\PackageWarning{Can not use transition macro for '#1'.}{}{}{}}%
    {\@nameuse{\tikztiming@prefix#1@general}}%
}
```

### \tikztimingdef

`#1`: One or two characters

```
\def\tikztimingdef#1{%
  \tikztimingdef@#1\relax%
}
```

### \tikztimingdef@

`#1`: First character
`#2`: Second character or empty
`#3`: Definition code

```
\def\tikztimingdef@#1#2\relax#3{%
  \ifx\relax#2\relax
    \tikztiming@nameedef[#1]{#1}{#3}%
  \else
    \tikztiming@nameedef[#2]{#1#2}{#3}%
  \fi
}
```

### \tikztiminglet

`#1`: Original characters
`#2`: New characters

```
\def\tikztiminglet#1#2{%
  \tikztiminglet@#1\relax#2\relax
}
```

### \tikztiminglet@

`#1`: First original character
`#2`: Second original character
`#3`: First new character
`#4`: Second new character

```
\def\tikztiminglet@#1#2\relax#3#4\relax{%
  \tikztiming@namelet{#1#2}{#3#4}%
  \tikztiming@namelet{#1#2@general}{#3#4@general}%
  \tikztiming@iflower{#1}{}%
    {\tikztiming@iflower{#2}%
```

```
      {%
        \lowercase{\tikztiminglet@{#1}{#2}\relax{#3}{#4}}\relax
      }%
      {%
        \uppercase{\lowercase{%
        \uppercase{\lowercase{\tikztiminglet@{#1}}{#2}}\relax{#3}}{#4}}\relax
        \lowercase{\uppercase{%
        \lowercase{\uppercase{\tikztiminglet@{#1}}{#2}}\relax{#3}}{#4}}\relax
      }%
    }%
}
```

### \tikztiming@chars

`#1`: Comma to gobble

Initial definition of character list. Will gobble the separation comma in front of the first character which is added to the list.

```
\def\tikztiming@chars#1{}
```

### \tikztiming@ifcharexists

`#1`: Character to check if in list

```
\def\tikztiming@ifcharexists#1{%
  \def\tikztiming@ifcharexists@##1,#1,##2\relax{%
    \ifx\relax##2\relax%
      \expandafter\@firstoftwo
    \else
      \expandafter\@secondoftwo
    \fi
  }%
  \expandafter\tikztiming@ifcharexists@
  \expandafter,\tikztiming@chars,#1,\relax%
}
```

### \tikztiming@addchar

`#1`: Character

```
\def\tikztiming@addchar#1{%
  \tikztiming@ifcharexists{#1}{%
    \edef\tikztiming@chars{\tikztiming@chars,#1}%
  }{}%
}
```

### \tikztimingchar

`#1`: New character

```
\def\tikztimingchar#1{%
  \uppercase{%
  \tikztiming@addchar{#1}%
  \tikztimingchar@{#1}}%
}
```

```
\expandafter\def\csname\tikztiming@prefix @start\endcsname#1{}%
```

### \tikztimingchar@

#1: Character
#2: Start position
#3: Character drawing code

```
\def\tikztimingchar@#1#2#3{%
  \tikztiming@nameedef[#1]{#1@start}{#2 coordinate (timing/start) }%
  \tikztiming@nameedef[#1]{#1}{#2 coordinate (timing/start) #3}%
  \tikztimingdef{#1#1}{#3}%
}
```

### \tikztimingalias

#1: Original character
#2: New character

```
\def\tikztimingalias#1#2{%
  \uppercase{\tikztimingalias@{#1}{#2}}%
}
```

### \tikztimingalias@

#1: New character
#2: Original character

```
\def\tikztimingalias@#1#2{%
  \tikztiming@namelet{#1}{#2}%
  \tikztiming@namelet{#1@start}{#2@start}%
  \lowercase{%
  \tikztiming@namelet{#1}{#2}%
  \tikztiming@namelet{#1@start}{#2@start}%
  }%
  \tikztiminglet{#1#1}{#2#2}%
  \@for\@tempa:=\tikztiming@chars\do{%
    \expandafter\tikztiminglet@@
    \expandafter{\@tempa}{#1}{#2}%
  }%
}
```

### \tikztimingecopy

#1: New character
#2: Original character

```
\def\tikztimingecopy#1#2{%
  \uppercase{\tikztimingecopy@{#1}{#2}}%
}
```

### \tikztimingecopy@

#1: New character
#2: Original character

```
\def\tikztimingecopy@#1#2{%
  \tikztimingchar{#1}{}{}%
  \tikztimingdef{#1}{\tikztiminguse{#2}{##1}}%
  \tikztiming@nameedef[#1]{#1@start}{\tikztiminguse{#2@start}{##1}}%
  \lowercase{%
    \@ifundefined{\tikztiming@prefix#2}{}{%
      \tikztimingdef{#1}{\tikztiminguse{#2}{##1}}%
      \tikztiming@nameedef[#1]{#1@start}{\tikztiminguse{#2@start}{##1}}%
    }%
  }%
  \tikztimingdef{#1#1}{\tikztiminguse{#2#2}{##1}}%
  \@for\@tempa:=\tikztiming@chars\do{%
    \expandafter\tikztimingdef@@
    \expandafter{\@tempa}{#1}{#2}%
```

Handle lowercase macros:

```
    \expandafter\lowercase\expandafter{\expandafter\def\expandafter\@tempb
    \expandafter{\@tempa}}%
    \@ifundefined{\tikztiming@prefix#2\@tempb}{}{%
      \expandafter\tikztimingdef@@
      \expandafter{\@tempb}{#1}{#2}%
    }%
  }%
}
```

### \tikztiminglet@@

`#1`: Character from list
`#2`: New character
`#3`: Original character

```
\def\tikztiminglet@@#1#2#3{%
  \tikztiminglet@@@#1#2#3%
  % Should stay, cause no harm:
  \lowercase{\tikztiminglet@@@#1}#2#3%
  \lowercase{\tikztiminglet@@@#1#2#3}%
  \lowercase{\uppercase{\tikztiminglet@@@#1}#2#3}%
}
```

### \tikztiminglet@@@

`#1`: Character from list
`#2`: New character
`#3`: Original character

```
\def\tikztiminglet@@@#1#2#3{%
  \tikztiminglet{#1#2}{#1#3}%
  \tikztiminglet{#2#1}{#3#1}%
}
```

### \tikztimingdef@@

`#1`: Character from list

#2: New character
#3: Original character

```
\def\tikztimingdef@@#1#2#3{%
  \tikztimingdef{#1#2}{\tikztiminguse{#1#3}{##1}}%
  \tikztimingdef{#2#1}{\tikztiminguse{#3#1}{##1}}%
}
```

### \tikztiming@savesettings

```
\def\tikztiming@savesettings{%
  \xdef\tikztiming@saved@settings{%
    {\tikztiming@slope}%
    {\tikztiming@dslope}%
    {\tikztiming@zslope}%
    {\the\pgflinewidth}%
  }%
}
```

### \tikztiming@restoresettings

```
\def\tikztiming@restoresettings{%
  \expandafter\tikztiming@restoresettings@
  \tikztiming@saved@settings\relax
}
```

### \tikztiming@restoresettings@

#1: Slope
#2: D-Slope
#3: Z-Slope
#4: Line width

```
\def\tikztiming@restoresettings@#1#2#3#4\relax{%
  \tikztimingsetslope{#1}%
  \tikztimingsetdslope{#2}%
  \tikztimingsetzslope{#3}%
  \pgfsetlinewidth{#4}%
}
```

### \tikztiming@newdraw

```
\def\tikztiming@newdraw{%
  node [timing/save] (timing@save) {};%
  \draw [timing/restore] (timing@save) ++(0,0)
}
```

### \tikztiming@newdraw

```
\def\tikztiming@newdraw@nosave{%
  node [timing/coord] (timing@save) {};%
  \draw (timing@save) ++(0,0)
}
```

## 5.6 Definition of Timing Characters

```
\tikztimingchar{H}{++(0,\height)}{-- ++(#1,0)}

\tikztimingchar{L}{++(0,0)}{-- ++(#1,0)}

\tikztimingchar{Z}{++(0,\height/2.)}{%
  \newdraw [\style]
  -- ++(#1,0)
}

\tikztimingchar{X}{}{}%
\tikztimingchar{D}{}{}%
\tikztimingchar{U}{}{}%
%\tikztimingchar{O}{}{}%
\tikztimingchar{M}{}{}%

\tikztimingchar{G}{++(0,0)}{-- ++(\gslope,\height) -- ++(\gslope,-\height)}
\tikztimingchar{S}{++(0,0)}{++(#1,0)}

\tikztimingdef{DD}{
  node [timing/save] (timing@save) {}; \path [\bgstyle] (timing@save) ++(0,0)
     +(0.5*\dslope,0.5*\height) -- +(\dslope,0)
  -- +(#1,0)
  -- +($ (#1,0) + 0.5*(\dslope,\height) $)
  -- +(#1,\height)
  -- +(\dslope,\height) -- cycle;
  \draw [timing/restore,\style] (timing@save) ++(0,0)
  node [timing/save] (timing@dstart) at +(\dslope/2.,\height/2.) {}
  --  +(\dslope,+\height) --  +(#1,+\height) ++(0,+\height)
  --  +(\dslope,-\height) -- ++(#1,-\height)
}
\tikztiming@namelet{D@edge@D}{DD}
\tikztiming@namelet{D@edge@D@general}{DD@general}

\tikztimingchar{D}{++(0,0)}{
  node [timing/save] (timing@save) {}; \path [\bgstyle] (timing@save) ++(0,0)
  -- +(#1,0)
  -- +($ (#1,0) + 0.5*(\dslope,\height) $)
  -- +(#1,\height)
  -- +(0,\height)
  -- cycle;
  \draw [timing/restore,\style] (timing@save) ++(0,0)
  node [timing/save] (timing@dstart) at +(-\dslope/2.,\height/2.0) {}
  --  +(#1,0) ++(0,+\height)
  -- ++(#1,0) ++(0,-\height)
}

\tikztimingdef{DD}{
  node [timing/save] (timing@save) {}; \path [\bgstyle] (timing@save) ++(0,0)
```

```
  -- +(#1,0)
  -- +($ (#1,0) + 0.5*(\dslope,\height) $)
  -- +(#1,\height)
  -- +(0,\height)
  -- cycle;
  \newdraw [\style]
  --  +(#1,0) ++(0,+\height)
  -- ++(#1,0) ++(0,-\height)
}

\tikztiming@namelet{D@edge@@start}{D@start}
\tikztiming@namelet{d@edge@@start}{d@start}

```

### \tikztiming@trans@D@fill

#1: Original width
#2: Width to subtract

```
\def\tikztiming@trans@D@fill#1#2{%
  node [timing/save] (timing@save) {}; \path [\bgstyle] (timing@save) ++(0,0)
  -- +(0.5*\dslope,-0.5*\height)
  -- ++($ (#1,-0.5*\height) - (#2,0) $)
  -- +(0.5*\dslope,0.5*\height)
  -- +(0,\height)
  -- ++($ (#2,\height) - (#1,0) + (0.5*\dslope,0) $)
  -- cycle;
  \draw [timing/restore,\style] (timing@save) ++(0,0)
  node [timing/save] (timing@dstart) {}
}
\tikztimingdef{HH}{-- ++(#1,0)}
\tikztimingdef{LL}{-- ++(#1,0)}
\tikztimingdef{HL}{-- ++(\slope,-\height) \tikztiminguse{HH}{#1-\slope}}
\tikztimingdef{LH}{-- ++(\slope, \height) \tikztiminguse{LL}{#1-\slope}}

\tikztimingdef{HG}{-- ++(\gslope,-\height) -- ++(\gslope,+\height)}
\tikztimingdef{LG}{-- ++(\gslope,+\height) -- ++(\gslope,-\height)}
\tikztimingdef{ZG}{
  -- ++(\gslope,-\height/2.0)
  -- ++(\gslope,+\height)
  -- ++(\gslope,-\height/2.0)
}
\tikztiminglet{DG}{LG}
\tikztiminglet{MG}{ZG}

\tikztiminglet{HS}{S}
\tikztiminglet{LS}{S}
\tikztiminglet{ZS}{S}
\tikztiminglet{DS}{S}
\tikztiminglet{TS}{S}

```

```
\tikztimingdef{LZ}{
  \newdraw [\style]
  -- ++(\zslope,+\height/2.) -- ++($ (#1,0) - (\zslope,0) $)
}
\tikztimingdef{HZ}{%
  \newdraw [\style]
  -- ++(\zslope,-\height/2.) -- ++($ (#1,0) - (\zslope,0) $)
}
  \tikztimingdef{ZH}{
    \newdraw
  -- ++(\zslope,+\height/2.) -- ++($ (#1,0) - (\zslope,0) $)
}
\tikztimingdef{ZL}{%
  \newdraw
  -- ++(\zslope,-\height/2.) -- ++($ (#1,0) - (\zslope,0) $)
}

\tikztimingdef{DZ}{
  -- ++( \dslope/2.,+\height/2.)
     ++(-\dslope/2.,+\height/2.)
  -- ++( \dslope/2.,-\height/2.)
  \newdraw [\style]
  -- ++($ (#1,0) - (\dslope/2.,0) $)
}

\tikztimingdef{ZD}{
  \tikztiming@trans@D@fill{#1}{0}%
  -- ++(\dslope/2.,\height/2.)  -- ++($ (#1,0) - (\dslope/2.,0) $)
     ++($ -1*(#1,0) + (0,-\height/2.) $)
  -- ++(\dslope/2.,-\height/2.) -- ++($ (#1,0) - (\dslope/2.,0) $)
}

\tikztimingdef{LD}{
  -- ++(0.5*\dslope,0.5*\height)
  \tikztiming@trans@D@fill{#1}{0.5*\dslope}%
  -- ++(0.5*\dslope,0.5*\height)
  -- ++($ (#1,0) - (\dslope,0) $)
     ++($ -1*(#1,0) + (0,-\height) $)          ++(\dslope/2.,+\height/2.)
  -- ++(\dslope/2.,-\height/2.) -- ++($ (#1,0) - (\dslope,0) $)
}

\tikztimingdef{DL}{
  -- ++( \dslope/2.,+\height/2.)
     ++(-\dslope/2.,+\height/2.)
  -- ++(\dslope/2.,-\height/2.)
  \newdraw [\style]
  -- ++(\dslope/2.,-\height/2.)
  -- ++($ (#1,0) - (\dslope,0) $)
}

```

```
\tikztimingdef{HD}{
  -- ++(0.5*\dslope,-0.5*\height)
  \tikztiming@trans@D@fill{#1}{0.5*\dslope}%
  -- ++(0.5*\dslope,-0.5*\height)
  -- ++($ (#1,0) - (\dslope,0) $)
     ++($ -1*(#1,0) + (0,+\height) $)          ++(\dslope/2.,-\height/2.)
  -- ++(\dslope/2.,+\height/2.) -- ++($ (#1,0) - (\dslope,0) $)
     ++(0,-\height)
}

\tikztimingdef{DH}{
     ++(0,+\height)
  -- ++(+\dslope/2.,-\height/2.)
     ++(-\dslope/2.,-\height/2.)
  -- ++(\dslope/2.,+\height/2.)
  \newdraw [\style]
  -- ++(\dslope/2.,+\height/2.)
  -- ++($ (#1,0) - (\dslope,0) $)
}


\tikztimingalias{M}{Z}
\tikztimingchar{M}{++(0,\height/2.)}{
  [\style]
  -- ++($ 1/16.*(#1,0) + (0,+\height*.225) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/16.*(#1,0) + (0,+\height*.225) $)
}

\tikztimingdef{MZ}{
  \newdraw [\style]
  -- ++(#1,0)
}

\tikztimingdef{m}{
  [\style]
     ++(0,+\height/2.)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.225) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/4.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.225) $)
}

```

```
\tikztimingdef{ZM}{
  \newdraw [\style]
  -- ++($ 1/16.*(#1,0) + (0,+\height*.075) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.35) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.40) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/16.*(#1,0) + (0,+\height*.225) $)
}

\tikztimingdef{Zm}{
  \newdraw [\style]
  -- ++($ 1/8.*(#1,0) + (0,+\height*.075) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/4.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.175) $)
}

\tikztimingdef{Mm}{
  -- ++($ 1/8.*(#1,0) + (0,+\height*.225) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/4.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.225) $)
}

\tikztimingdef{LM}{
  \newdraw [\style]
  -- ++($ 1/16.*(#1,0) + (0,+\height*.60) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.35) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.40) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/16.*(#1,0) + (0,+\height*.20) $)
}
\tikztimingdef{HM}{
  \newdraw [\style]
  -- ++($ 1/16.*(#1,0) + (0,-\height*.40) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.35) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.40) $)
```

```
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/16.*(#1,0) + (0,+\height*.20) $)
}
\tikztimingdef{DM}{
     ++($ -1/16.*(#1,0) + (0,0) $)
  -- ++($  1/16.*(#1,0) + (0,0) $)
  -- ++($  1/16.*(#1,0) + (0,+\height*.50) $)
     ++($ -1/8.*(#1,0) + (0,+\height*.50) $)
  -- ++($  1/16.*(#1,0) + (0,0) $)
  -- ++($  1/16.*(#1,0) + (0,-\height*.50) $)
  \newdraw [\style]
  -- ++($  1/8.*(#1,0) + (0,-\height*.10) $)
  -- ++($  1/8.*(#1,0) + (0,+\height*.25) $)
  -- ++($  1/8.*(#1,0) + (0,-\height*.30) $)
  -- ++($  1/8.*(#1,0) + (0,+\height*.35) $)
  -- ++($  1/8.*(#1,0) + (0,-\height*.40) $)
  -- ++($  1/8.*(#1,0) + (0,+\height*.45) $)
  -- ++($  1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($  1/16.*(#1,0) + (0,+\height*.20) $)
}

\tikztimingdef{Lm}{
  \newdraw [\style]
  -- ++($ 1/8.*(#1,0) + (0,+\height*.575) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/4.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.175) $)
}
\tikztimingdef{Hm}{
  \newdraw [\style]
  -- ++($ 1/8.*(#1,0) + (0,-\height*.425) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/4.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.175) $)
}
\tikztimingdef{Dm}{
     ++($ -1/8.*(#1,0) + (0,0) $)
  -- ++($  1/8.*(#1,0) + (0,0) $)
  -- ++($  1/8.*(#1,0) + (0,+\height*.50) $)
     ++($ -1/4.*(#1,0) + (0,+\height*.50) $)
  -- ++($  1/8.*(#1,0) + (0,0) $)
  -- ++($  1/8.*(#1,0) + (0,-\height*.50) $)
  \newdraw [\style]
  -- ++($  1/4.*(#1,0) + (0,-\height*.10) $)
  -- ++($  1/4.*(#1,0) + (0,+\height*.25) $)
  -- ++($  1/4.*(#1,0) + (0,-\height*.30) $)
  -- ++($  1/8.*(#1,0) + (0,+\height*.15) $)
```

```
}

\newcounter{tikztimingtrans}
\newcounter{tikztimingtranspos}

\tikztimingchar{T}{++(0,0)}{
  -- ++(#1,0)
}

\tikztimingdef{HT}{%
  {[\style]
  \code{\setcounter{tikztimingtrans}{-1}}
  -- ++(\slope,\value{tikztimingtrans}*\height) -- ++($ (#1,0) - (\slope,0) $)
  }
}

\tikztimingdef{LT}{%
  {[\style]
  \code{\setcounter{tikztimingtrans}{+1}}
  -- ++(\slope,\value{tikztimingtrans}*\height) -- ++($ (#1,0) - (\slope,0) $)
  }
}

\tikztimingdef{TL}{%
  \code{\setcounter{tikztimingtranspos}{\value{tikztimingtrans}}%
  \addtocounter{tikztimingtranspos}{+1}}
  -- ++(\slope, -0.5*\value{tikztimingtranspos}*\height) -- ++($ (#1,0) - (\slope,0) $)
}

\tikztimingdef{TH}{%
  \code{\setcounter{tikztimingtranspos}{\value{tikztimingtrans}}%
  \addtocounter{tikztimingtranspos}{-1}}
  -- ++(\slope, -0.5*\value{tikztimingtranspos}*\height) -- ++($ (#1,0) - (\slope,0) $)
}

\tikztimingdef{TZ}{%
  \newdraw [\style]
  \code{\setcounter{tikztimingtrans}{-\value{tikztimingtrans}}}
  -- ++(\slope,\value{tikztimingtrans}*\height/2.)
  -- ++($ (#1,0) - (\slope,0) $)
}

\tikztimingdef{TG}{%
  -- +(\gslope,-1*\value{tikztimingtrans}*\height)
  -- +(\gslope,0)
}

\tikztimingdef{ZT}{%
  \newdraw
  {[\style]
```

```
  node [timing/save] {\setcounter{tikztimingtrans}{-\value{tikztimingtrans}}}
  -- ++(\slope,\value{tikztimingtrans}*\height/2.)
  -- ++($ (#1,0) - (\slope,0) $)
  }
}

\tikztimingdef{TT}{%
  {[\style]
  \code{\setcounter{tikztimingtrans}{-\value{tikztimingtrans}}}
  -- ++(\slope,\value{tikztimingtrans}*\height) -- ++($ (#1,0) - (\slope,0) $)
  }
}

\tikztimingdef{TD}{
  \code{\setcounter{tikztimingtrans}{-\value{tikztimingtrans}}}
  \code{\setcounter{tikztimingtranspos}{\value{tikztimingtrans}}%
  \addtocounter{tikztimingtranspos}{-1}}
  -- ++(0.5*\dslope,+0.5*\value{tikztimingtrans} * \height)
  \tikztiming@trans@D@fill{#1}{0.5*\dslope}%
  -- ++(0.5*\dslope,+0.5*\value{tikztimingtrans} * \height)
  -- ++($ (#1,0) - (\dslope,0) $)
     ++($ -1*(#1,\value{tikztimingtrans}*\height) $)
     ++(\dslope/2.,+1*\value{tikztimingtrans}*\height/2.)
  -- ++(\dslope/2.,-1*\value{tikztimingtrans}*\height/2.)
  -- ++($ (#1,0) - (\dslope,0) $)
     ++(0,\value{tikztimingtranspos}*\height/2.)
}

\tikztimingdef{DT}{
  \code{\setcounter{tikztimingtrans}{-1}}
  \tikztiminguse{DL}{#1}%
}

\tikztimingdef{MT}{%
  \newdraw
  {[\style]
  -- ++(\slope,\value{tikztimingtrans}*\height/2.) -- ++($ (#1,0) - (\slope,0) $)
  }
}

\tikztimingdef{TM}{%
  \newdraw [\style]
  \code{\setcounter{tikztimingtrans}{-\value{tikztimingtrans}}}
  -- ++($ 1/16.*(#1,0) + (0,\value{tikztimingtrans}*\height*.50+\height*.10) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.35) $)
  -- ++($ 1/8.*(#1,0) + (0,-\height*.40) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.45) $)
```

```
  -- ++($ 1/8.*(#1,0) + (0,-\height*.45) $)
  -- ++($ 1/16.*(#1,0) + (0,+\height*.20) $)
}

\tikztimingdef{Tm}{%
  \newdraw [\style]
  \code{\setcounter{tikztimingtrans}{-\value{tikztimingtrans}}}
  -- ++($ 1/8.*(#1,0) + (0,\value{tikztimingtrans}*\height*.50+\height*.075) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.20) $)
  -- ++($ 1/4.*(#1,0) + (0,+\height*.25) $)
  -- ++($ 1/4.*(#1,0) + (0,-\height*.30) $)
  -- ++($ 1/8.*(#1,0) + (0,+\height*.175) $)
}

\tikztimingecopy{C}{T}
\def\tikztiming@nocombine@T{}%
\def\tikztiming@nocombine@C{}%
\def\tikztiming@nocombine@t{}%
\def\tikztiming@nocombine@c{}%
\def\tikztiming@nocombine@M{}%
\def\tikztiming@nocombine@m{}%


\tikztimingecopy{U}{D}
\tikztimingdef{UD}{\tikztiminguse{D@edge@D}{#1}}
\tikztimingdef{DU}{\tikztiminguse{D@edge@D}{#1}}

%\tikztimingecopy{O}{D}
\tikztimingecopy{X}{Z}
```

# Change History