

# Manual for Package PGFPLOTS

2D/3D Plots in L<sup>A</sup>T<sub>E</sub>X, Version 1.6.1

<http://sourceforge.net/projects/pgfplots>

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## Abstract

PGFPLOTS draws high-quality function plots in normal or logarithmic scaling with a user-friendly interface directly in T<sub>E</sub>X. The user supplies axis labels, legend entries and the plot coordinates for one or more plots and PGFPLOTS applies axis scaling, computes any logarithms and axis ticks and draws the plots. It supports line plots, scatter plots, piecewise constant plots, bar plots, area plots, mesh- and surface plots, patch plots, contour plots, quiver plots, histogram plots, polar axes, ternary diagrams, smith charts and some more. It is based on Till Tantau's package PGF/TikZ.

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## 1 Introduction

This package provides tools to generate plots and labeled axes easily. It draws normal plots, logplots and semi-logplots, in two and three dimensions. Axis ticks, labels, legends (in case of multiple plots) can be added with key-value options. It can cycle through a set of predefined line/marker/color specifications. In summary, its purpose is to simplify the generation of high-quality function and/or data plots, and solving the problems of

- consistency of document and font type and font size,
- direct use of  $\text{\TeX}$  math mode in axis descriptions,
- consistency of data and figures (no third party tool necessary),
- inter-document consistency using preamble configurations and styles.

Although not necessary, separate `.pdf` or `.eps` graphics can be generated using the [external](#) library developed as part of `TikZ`.

You are invited to use PGFPLOTS for visualization of medium sized data sets in two and three dimensions.

## 2 About PGFPLOTS: Preliminaries

This section contains information about upgrades, the team, the installation (in case you need to do it manually) and troubleshooting. You may skip it completely except for the upgrade remarks.

PGFPLOTS is built completely on `TikZ`/PGF. Knowledge of `TikZ` will simplify the work with PGFPLOTS, although it is not required.

However, note that this library requires at least PGF version 2.10. At the time of this writing, many  $\text{\TeX}$ -distributions still contain the older PGF version 1.18, so it may be necessary to install a recent PGF prior to using PGFPLOTS.

### 2.1 Components

PGFPLOTS comes with two components:

1. the plotting component (which you are currently reading) and
2. the `PGFPLOTS``TABLE` component which simplifies number formatting and postprocessing of numerical tables. It comes as a separate package and has its own manual [pgfplotstable.pdf](#).

### 2.2 Upgrade remarks

This release provides a lot of improvements which can be found in all detail in `ChangeLog` for interested readers. However, some attention is useful with respect to the following changes.

### 2.2.1 New Optional Features

PGFPLOTS has been written with backwards compatibility in mind: old T<sub>E</sub>X files should compile without modifications and without changes in the appearance. However, new features occasionally lead to a different behavior. In such a case, PGFPLOTS will deactivate the new feature<sup>1</sup>.

Any new features or bugfixes which cause backwards compatibility problems need to be activated *manually* and *explicitly*. In order to do so, you should use

```
\usepackage{pgfplots}
\pgfplotsset{compat=1.6}
```

in your preamble. This will configure the compatibility layer.

You should have at least `compat=1.3`. The suggested value is printed to the `.log` file after running T<sub>E</sub>X. Here is a list of changes introduced in recent versions of PGFPLOTS:

1. PGFPLOTS 1.6 added new options for more accurate scaling and more scaling options for `\addplot3` `graphics`. These are enabled with `compat=1.6` or higher.
2. PGFPLOTS 1.5.1 interpretes circle- and ellipse radii as PGFPLOTS coordinates (older versions used PGF unit vectors which have no direct relation to PGFPLOTS). In other words: starting with version 1.5.1, it is possible to write `\draw circle[radius=5]` inside of an axis. This requires `\pgfplotsset{compat=1.5.1}` or higher.

Without this compatibility setting, circles and ellipses use low-level canvas units of PGF as in earlier versions.

3. PGFPLOTS 1.5 uses `log origin=0` as default (which influences logarithmic bar plots or stacked logarithmic plots). Older versions keep `log origin=infty`. This requires `\pgfplotsset{compat=1.5}` or higher.
4. PGFPLOTS 1.4 has fixed several smaller bugs which might produce differences of about 1–2pt compared to earlier releases. This requires `\pgfplotsset{compat=1.4}` or higher.
5. PGFPLOTS 1.3 comes with user interface improvements. The technical distinction between “behavior options” and “style options” of older versions is no longer necessary (although still fully supported). This is always activated.

6. PGFPLOTS 1.3 has a new feature which allows to *move axis labels tight to tick labels* automatically. This is strongly recommended. It requires `\pgfplotsset{compat=1.3}` or higher.

Since this affects the spacing, it is not enabled by default.

7. PGFPLOTS 1.3 supports reversed axes. It is no longer necessary to use workarounds with negative units.

Take a look at the `x dir=reverse` key.

Existing workarounds will still function properly. Use `\pgfplotsset{compat=1.3}` or higher together with `x dir=reverse` to switch to the new version.

### 2.2.2 Old Features Which May Need Attention

1. The `scatter/classes` feature produces proper legends as of version 1.3. This may change the appearance of existing legends of plots with `scatter/classes`.
2. Starting with PGFPLOTS 1.1, `\tikzstyle` should *no longer be used* to set PGFPLOTS options.

Although `\tikzstyle` is still supported for some older PGFPLOTS options, you should replace any occurrence of `\tikzstyle` with `\pgfplotsset{<style name>/style={<key-value-list>}}` or the associated `/append style` variant. See Section 4.17 for more detail.

I apologize for any inconvenience caused by these changes.

---

<sup>1</sup>In case of broken backwards compatibility, we apologize – and ask you to submit a bug report. We will take care of it.

/pgfplots/compat=1.6|1.5.1|1.5|1.4|1.3|pre 1.3|default

(initially default)

The preamble configuration

```
\usepackage{pgfplots}
\pgfplotsset{compat=1.6}
```

allows to choose between backwards compatibility and most recent features.

Occasionally, you might want to use different versions in the same document. Then, provide

```
\begin{figure}
  \pgfplotsset{compat=1.4}
  ...
  \caption{...}
\end{figure}
```

in order to restrict the compatibility setting to the actual context (in this case, the `figure` environment).

The the output of your `.log` file to see the suggested value for `compat`.

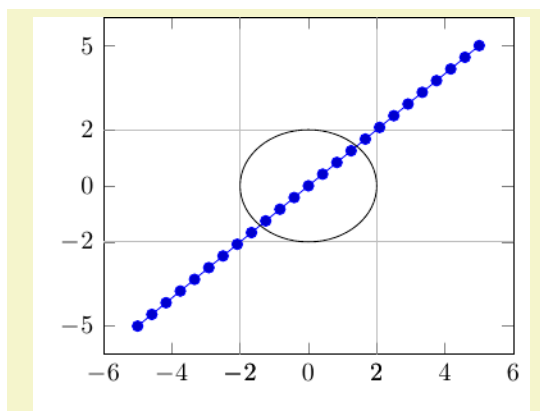
Use `\pgfplotsset{compat=default}` to restore the factory settings.

Although typically unnecessary, it is also possible to activate only selected changes and keep compatibility to older versions in general:

```
/pgfplots/compat/path replacement=<version>
/pgfplots/compat/labels=<version>
/pgfplots/compat/scaling=<version>
/pgfplots/compat/scale mode=<version>
/pgfplots/compat/empty line=<version>
/pgfplots/compat/plot3graphics=<version>
/pgfplots/compat/general=<version>
```

Let us assume that we have a document with `\pgfplotsset{compat=1.3}` and you want to keep it this way.

In addition, you realized that version 1.5.1 supports circles and ellipses. Then, use



```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
% preamble:
\pgfplotsset{compat=1.3,compat/path replacement=1.5.1}
\begin{tikzpicture}
\begin{axis}[
  extra x ticks={-2,2},
  extra y ticks={-2,2},
  extra tick style={grid=major}]
  \addplot {x};
  \draw (axis cs:0,0) circle[radius=2];
\end{axis}
\end{tikzpicture}
```

All of these keys accept the possible values of the `compat` key.

The `compat/path replacement` key controls how radii of circles and ellipses are interpreted.

The `compat/labels` key controls how axis labels are aligned: either uses adjacent to ticks or with an absolute offset.

The `compat/scaling` key controls some bugfixes introduced in version 1.4 and 1.6: they might introduce slight scaling differences in order to improve the accuracy.

The `compat/plot3graphics` controls new features for `\addplot3` graphics.

The `compat/scale mode` allows to enable/disable the warning “The content of your 3d axis has CHANGED compared to previous versions” because the `axis equal` and `unit vector ratio` features were broken for all versions before 1.6 and have been fixed in 1.6.

The `compat/empty line` allows to write empty lines into input files in order to generate a jump. This requires `compat=1.4` or newer. See `empty line` for details.

The `compat/general` key currently only activates `log origin`.

The detailed effects can be seen on the beginning of this section.

The value  $\langle version \rangle$  can be `default`, `pre 1.3`, `1.3`, `1.4`, `1.5`, `1.5.1`, `1.6`, and `newest`. The value `default` is the same as `pre 1.3` (up to insignificant changes). The use of `newest` is strongly *discouraged*: it might cause changes in your document, depending on the current version of PGFPLOTS. Please inspect your `.log` file to see suggestions for the best possible version.

## 2.3 The Team

PGFPLOTS has been written mainly by Christian Feuersänger with many improvements of Pascal Wolkotte and Nick Papior Andersen as a spare time project. We hope it is useful and provides valuable plots.

If you are interested in writing something but don't know how, consider reading the auxiliary manual [TeX-programming-notes.pdf](#) which comes with PGFPLOTS. It is far from complete, but maybe it is a good starting point (at least for more literature).

## 2.4 Acknowledgements

I thank God for all hours of enjoyed programming. I thank Pascal Wolkotte and Nick Papior Andersen for their programming efforts and contributions as part of the development team. I thank Jürnjakob Dugge for his contribution of `hist/density`, matlab scripts for `\addplot3 graphics`, excellent user forum help and helpful bug reports. I thank Stefan Tibus, who contributed the `plot shell` feature. I thank Tom Cashman for the contribution of the `reverse legend` feature. Special thanks go to Stefan Pinnow whose tests of PGFPLOTS lead to numerous quality improvements. Furthermore, I thank Dr. Schweitzer for many fruitful discussions and Dr. Meine for his ideas and suggestions. Special thanks go to Markus Böhning for proof-reading all the manuals of PGF, PGFPLOTS, and `PGFPLOTS`TABLE. Thanks as well to the many international contributors who provided feature requests or identified bugs or simply improvements of the manual!

Last but not least, I thank Till Tantau and Mark Wibrow for their excellent graphics (and more) package PGF and TikZ, which is the base of PGFPLOTS.



### 3 User’s Guide: Drawing Axes and Plots

The user interface of PGFPLOTS consists of three components: a `tikzpicture` environment, an `axis` and the `\addplot` command.

Each axis is generated as part of a picture environment (which can be used to annotate plots afterwards, for example). The axis environment encapsulates one or more `\addplot` commands and controls axis-wide settings (like limits, legends, and descriptions). The `\addplot` command supports several coordinate input methods (like table input or mathematical expressions) and allows various sorts of visualization options with straight lines as initial configuration.

The rest of PGFPLOTS is a huge set of key–value options to modify the initial configuration or to select plot types. The reference manual has been optimized for electronical display: a lot of examples illustrate the features, and reference documentation can be found by clicking into the sourcecode text fields. Note that most pdf viewers also support to jump back from a hyperlink: for Acrobat Reader, open the menu View»Toolbars»More Tools and activate the “Previous View” and “Next View” buttons (which are under “Page Navigation Toolbar”). Thus, knowledge of all keys is unnecessary; you can learn them when it is necessary.

To learn PGFPLOTS, you should learn about the `\addplot` command and its coordinate input methods. The most important input methods are `\addplot table` and `\addplot expression`.

The following sections explain the basics of PGFPLOTS, namely how to work with the `\addplot` commands and `axis` environments and how line styles are assigned automatically.

#### 3.1 T<sub>E</sub>X-dialects: L<sup>A</sup>T<sub>E</sub>X, ConT<sub>E</sub>Xt, plain T<sub>E</sub>X

The starting point for PGFPLOTS is an `axis` environment like `axis` or the logarithmic variants `semilogxaxis`, `semilogyaxis` or `loglogaxis`.

Each environment is available for L<sup>A</sup>T<sub>E</sub>X, ConT<sub>E</sub>Xt and plain T<sub>E</sub>X:

L<sup>A</sup>T<sub>E</sub>X: `\usepackage{pgfplots}` and

```
\begin{tikzpicture}
\begin{axis}
...
\end{axis}
\end{tikzpicture}
```

```
\begin{tikzpicture}
\begin{semilogxaxis}
...
\end{semilogxaxis}
\end{tikzpicture}
```

```

\documentclass[a4paper]{article}

% for dvipdfm:
% \def\pgfsysdriver{pgfsys-dvipdfm.def}
\usepackage{pgfplots}
\pgfplotsset{compat=1.6}% <-- moves axis labels near ticklabels (respects tick label widths)

\begin{document}
\begin{figure}
\centering
\begin{tikzpicture}
\begin{loglogaxis}[xlabel=Cost,ylabel=Error]
\addplot coordinates {
(5,      8.31160034e-02)
(17,     2.54685628e-02)
(49,     7.40715288e-03)
(129,    2.10192154e-03)
(321,    5.87352989e-04)
(769,    1.62269942e-04)
(1793,   4.44248889e-05)
(4097,   1.20714122e-05)
(9217,   3.26101452e-06)
};
\addplot coordinates {
(7,      8.47178381e-02)
(31,     3.04409349e-02)
(111,    1.02214539e-02)
(351,    3.30346265e-03)
(1023,   1.03886535e-03)
(2815,   3.19646457e-04)
(7423,   9.65789766e-05)
(18943,  2.87339125e-05)
(47103,  8.43749881e-06)
};
\legend{Case 1,Case 2}
\end{loglogaxis}
\end{tikzpicture}
\caption{A larger example}
\end{figure}
\end{document}

```

**ConT<sub>E</sub>Xt:** `\usemodule[pgfplots]` and

<code>\starttikzpicture</code>	<code>\starttikzpicture</code>
<code>\startaxis</code>	<code>\startsemilogxaxis</code>
<code>...</code>	<code>...</code>
<code>\stopaxis</code>	<code>\stopsemilogxaxis</code>
<code>\stoptikzpicture</code>	<code>\stoptikzpicture</code>

A complete ConT<sub>E</sub>Xt-example file can be found in

`doc/context/pgfplots/pgfplotsexample.tex`.

**plain T<sub>E</sub>X:** `\input pgfplots.tex` and

<code>\tikzpicture</code>	<code>\tikzpicture</code>
<code>\axis</code>	<code>\semilogxaxis</code>
<code>...</code>	<code>...</code>
<code>\endaxis</code>	<code>\endsemilogxaxis</code>
<code>\endtikzpicture</code>	<code>\endtikzpicture</code>

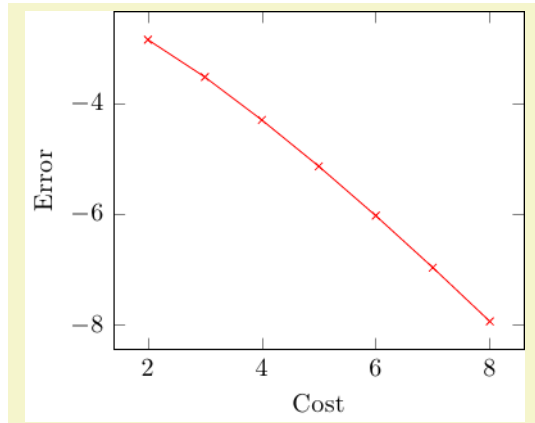
A complete plain-T<sub>E</sub>X-example file can be found in

`doc/plain/pgfplots/pgfplotsexample.tex`.

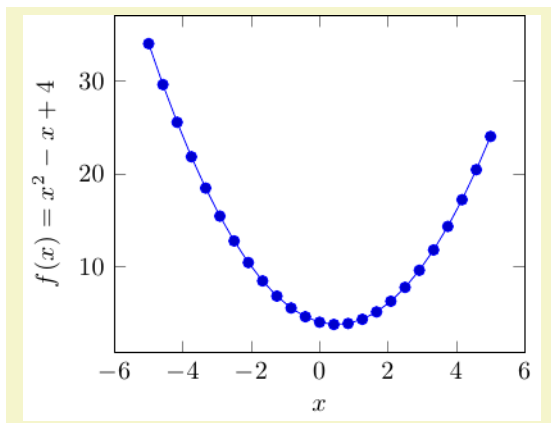
If you use `latex` / `dvips` or `pdflatex`, no further modifications are necessary. For `dvipdfm`, you should use the `\def\pgfsysdriver` line as indicated above in the examples (see also Section 2.6.3).

## 3.2 A First Plot

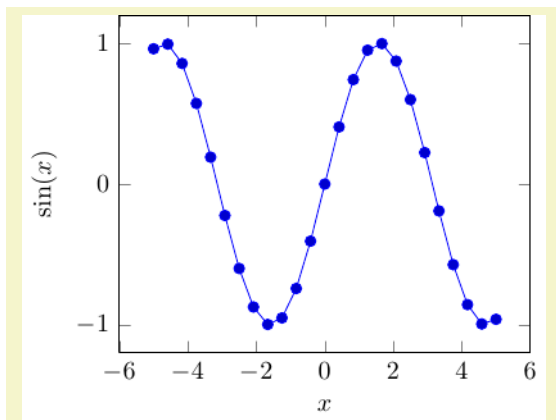
Plotting is done using `\begin{axis} ... \addplot ...; \end{axis}`, where `\addplot` is the main interface to perform plotting operations.



```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
  \begin{axis}[
    xlabel=Cost,
    ylabel=Error]
    \addplot[color=red,mark=x] coordinates {
      (2,-2.8559703)
      (3,-3.5301677)
      (4,-4.3050655)
      (5,-5.1413136)
      (6,-6.0322865)
      (7,-6.9675052)
      (8,-7.9377747)
    };
  \end{axis}
\end{tikzpicture}
```



```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
  \begin{axis}[
    xlabel=$x$,
    ylabel={$f(x) = x^2 - x + 4$}]
  ]
  % use TeX as calculator:
  \addplot {x^2 - x + 4};
  \end{axis}
\end{tikzpicture}
```



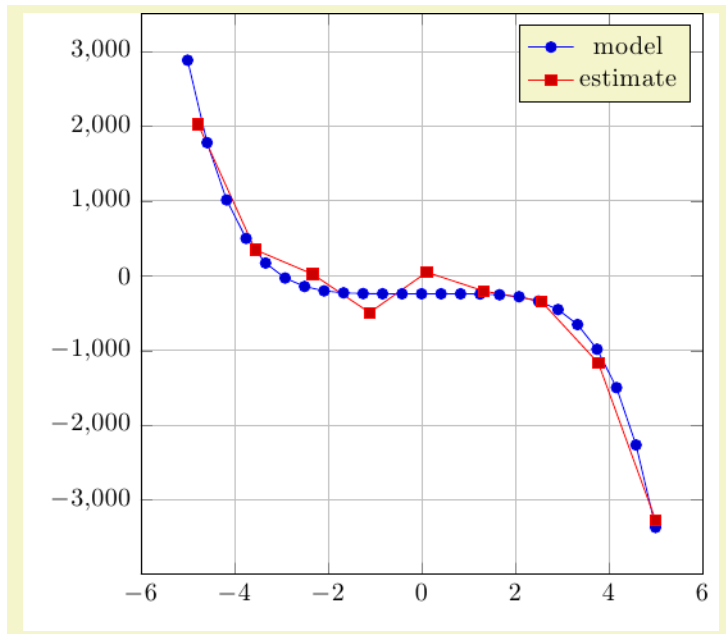
```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
  \begin{axis}[
    xlabel=$x$,
    ylabel=$\sin(x)$]
  ]
  % invoke external gnuplot as
  % calculator:
  \addplot gnuplot[id=sin]{sin(x)};
  \end{axis}
\end{tikzpicture}
```

The `plot coordinates`, `plot expression` and `plot gnuplot` commands are three of the several supported ways to create plots, see Section 4.2 for more details<sup>2</sup> and the remaining ones (`plot file`, `plot shell`, `plot table` and `plot graphics`). The options ‘`xlabel`’ and ‘`ylabel`’ define axis descriptions.

## 3.3 Two Plots in the Same Axis

Multiple `\addplot`-commands can be placed into the same axis, and a `cycle list` is used to automatically select different line styles:

<sup>2</sup>Please note that you need `gnuplot` installed to use `plot gnuplot`.



```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
  \begin{axis}[
    height=9cm,
    width=9cm,
    grid=major,
  ]

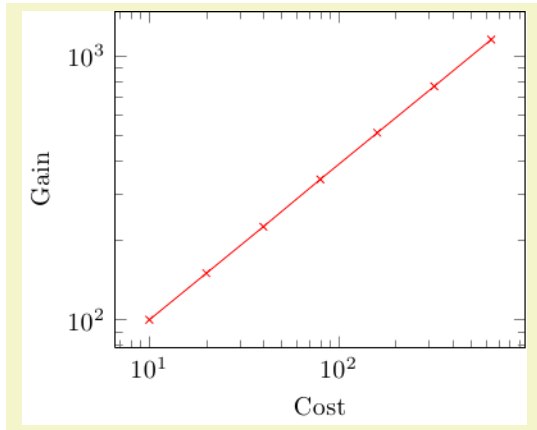
    \addplot {-x^5 - 242};
    \addlegendentry{model}

    \addplot coordinates {
      (-4.77778,2027.60977)
      (-3.55556,347.84069)
      (-2.33333,22.58953)
      (-1.11111,-493.50066)
      (0.11111,46.66082)
      (1.33333,-205.56286)
      (2.55556,-341.40638)
      (3.77778,-1169.24780)
      (5.00000,-3269.56775)
    };
    \addlegendentry{estimate}
  \end{axis}
\end{tikzpicture}
```

A legend entry is generated if there are `\addlegendentry` commands (or one `\legend` command).

### 3.4 Logarithmic Plots

Logarithmic plots show  $\log x$  versus  $\log y$  (or just one logarithmic axis). PGFPLOTS normally uses the natural logarithm, i.e. basis  $e \approx 2.718$  (see the key `log basis x`). Now, the axis description also contains minor ticks and the labels are placed at  $10^i$ .

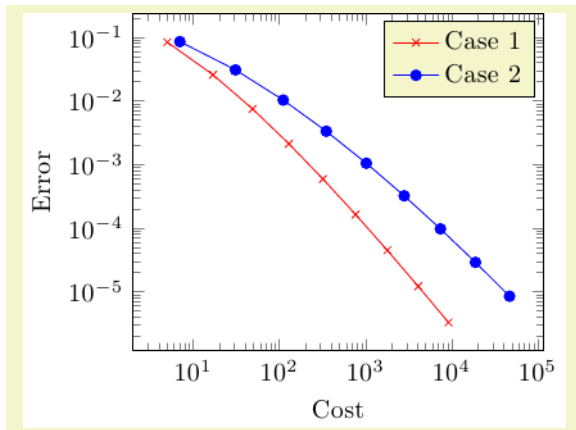


```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
\begin{loglogaxis}[xlabel=Cost,ylabel=Gain]
\addplot[color=red,mark=x] coordinates {
(10,100)
(20,150)
(40,225)
(80,340)
(160,510)
(320,765)
(640,1150)
};
\end{loglogaxis}
\end{tikzpicture}
```

A common application is to visualise scientific data. This is often provided in the format  $1.42 \cdot 10^4$ , usually written as 1.42e+04. Suppose we have a numeric table named `pgfplots.testtable`, containing

Level	Cost	Error
1	7	8.471e-02
2	31	3.044e-02
3	111	1.022e-02
4	351	3.303e-03
5	1023	1.038e-03
6	2815	3.196e-04
7	7423	9.657e-05
8	18943	2.873e-05
9	47103	8.437e-06

then we can plot `Cost` versus `Error` using



```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
\begin{loglogaxis}[
xlabel=Cost,
ylabel=Error]
\addplot[color=red,mark=x] coordinates {
(5, 8.31160034e-02)
(17, 2.54685628e-02)
(49, 7.40715288e-03)
(129, 2.10192154e-03)
(321, 5.87352989e-04)
(769, 1.62269942e-04)
(1793, 4.44248889e-05)
(4097, 1.20714122e-05)
(9217, 3.26101452e-06)
};
\addplot[color=blue,mark=*]
table[x=Cost,y=Error] {pgfplots.testtable};
\legend{Case 1,Case 2}
\end{loglogaxis}
\end{tikzpicture}
```

The first plot employs inline coordinates; the second one reads numerical data from file and plots column 'Cost' versus 'Error'.

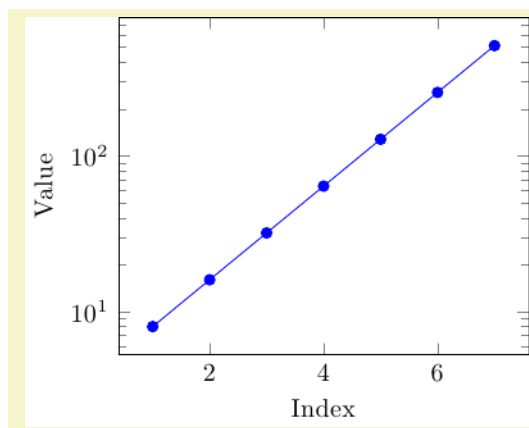
Besides the environment "loglogaxis" you can use

- `\begin{axis}...\end{axis}` for normal plots,
- `\begin{semilogxaxis}...\end{semilogxaxis}` for plots which have a normal  $y$  axis and a logarithmic  $x$  axis,
- `\begin{semilogyaxis}...\end{semilogyaxis}` the same with  $x$  and  $y$  switched,
- `\begin{loglogaxis}...\end{loglogaxis}` for double-logarithmic plots.

You can also use

```
\begin{axis}[xmode=normal,ymode=log]
...
\end{axis}
```

which is the same as `\begin{semilogyaxis}...\end{semilogyaxis}`.

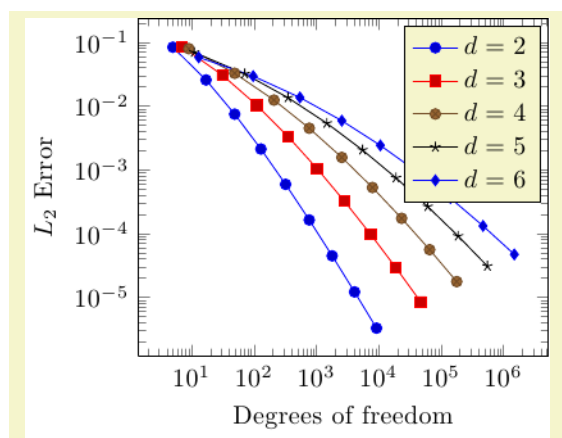


```
% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
\begin{semilogyaxis}[
  xlabel=Index,ylabel=Value]

\addplot[color=blue,mark=*] coordinates {
  (1,8)
  (2,16)
  (3,32)
  (4,64)
  (5,128)
  (6,256)
  (7,512)
};
\end{semilogyaxis}%
\end{tikzpicture}%
```

### 3.5 Cycling Line Styles

You can skip the style arguments for `\addplot[...]` to determine plot specifications from a predefined list:



```

% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
\begin{loglogaxis}[
  xlabel={Degrees of freedom},
  ylabel={$L_2$ Error}
]
\addplot coordinates {
  (5,8.312e-02) (17,2.547e-02) (49,7.407e-03)
  (129,2.102e-03) (321,5.874e-04) (769,1.623e-04)
  (1793,4.442e-05) (4097,1.207e-05) (9217,3.261e-06)
};

\addplot coordinates{
  (7,8.472e-02) (31,3.044e-02) (111,1.022e-02)
  (351,3.303e-03) (1023,1.039e-03) (2815,3.196e-04)
  (7423,9.658e-05) (18943,2.873e-05) (47103,8.437e-06)
};

\addplot coordinates{
  (9,7.881e-02) (49,3.243e-02) (209,1.232e-02)
  (769,4.454e-03) (2561,1.551e-03) (7937,5.236e-04)
  (23297,1.723e-04) (65537,5.545e-05) (178177,1.751e-05)
};

\addplot coordinates{
  (11,6.887e-02) (71,3.177e-02) (351,1.341e-02)
  (1471,5.334e-03) (5503,2.027e-03) (18943,7.415e-04)
  (61183,2.628e-04) (187903,9.063e-05) (553983,3.053e-05)
};

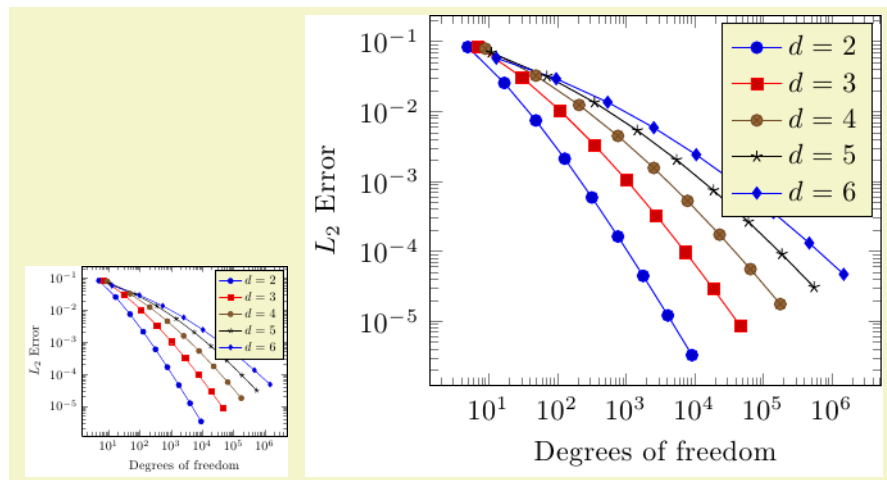
\addplot coordinates{
  (13,5.755e-02) (97,2.925e-02) (545,1.351e-02)
  (2561,5.842e-03) (10625,2.397e-03) (40193,9.414e-04)
  (141569,3.564e-04) (471041,1.308e-04) (1496065,4.670e-05)
};
};
\legend{$d=2$, $d=3$, $d=4$, $d=5$, $d=6$}
\end{loglogaxis}
\end{tikzpicture}

```

The `cycle list` can be modified, see the reference below.

### 3.6 Scaling Plots

You can use any of the TikZ options to modify the appearance. For example, the “`scale`” transformation takes the picture as such and scales it (just like `\includegraphics`):



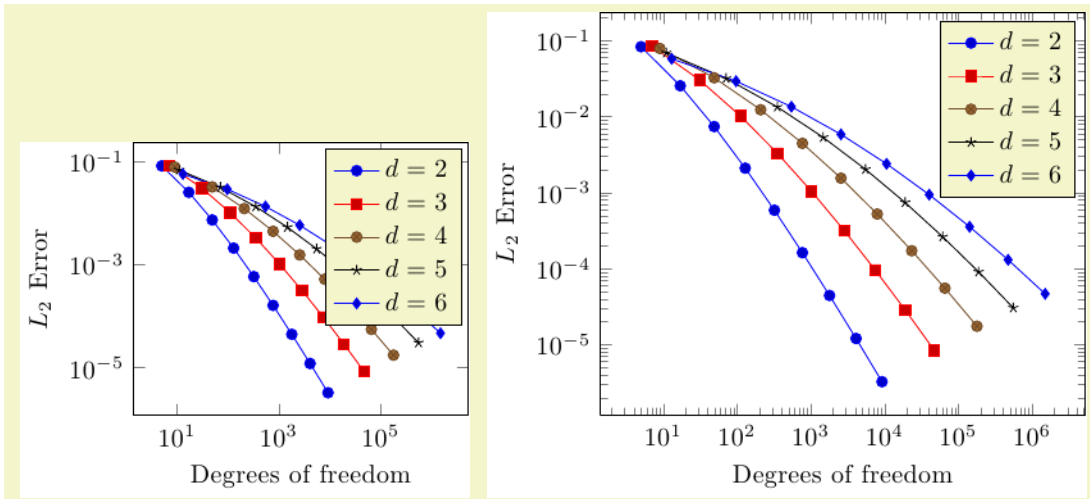
```

% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}[scale=0.5]
  \begin{loglogaxis}[
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error}
  ]
    \plotcoords
    \legend{$d=2$, $d=3$, $d=4$, $d=5$, $d=6$}
  \end{loglogaxis}
\end{tikzpicture}

\begin{tikzpicture}[scale=1.1]
  \begin{loglogaxis}[
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error}
  ]
    \plotcoords
    \legend{$d=2$, $d=3$, $d=4$, $d=5$, $d=6$}
  \end{loglogaxis}
\end{tikzpicture}

```

However, you can also scale plots by assigning a `width=5cm` and/or `height=3cm` argument. This only affects the distance of point coordinates, no font sizes or axis descriptions:



```

% Preamble: \pgfplotsset{width=7cm,compat=1.7}
\begin{tikzpicture}
  \begin{loglogaxis}[
    width=6cm,
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error}
  ]
    \plotcoords
    \legend{$d=2$, $d=3$, $d=4$, $d=5$, $d=6$}
  \end{loglogaxis}
\end{tikzpicture}

\begin{tikzpicture}
  \begin{loglogaxis}[
    width=8cm,
    xlabel={Degrees of freedom},
    ylabel={$L_2$ Error}
  ]
    \plotcoords
    \legend{$d=2$, $d=3$, $d=4$, $d=5$, $d=6$}
  \end{loglogaxis}
\end{tikzpicture}

```

Use the predefined styles `normalsize`, `small`, `footnotesize` to adopt font sizes and ticks automatically. Use the `/pgfplots/scale` key to rescale the axis without affecting fonts.



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