PLOTXY: A VERSATILE PLOT PROGRAM

Robert Parker and Loren Shure

INTRODUCTION

Plotxy is a program for generating graphs from data files with a minimum amount of fuss. In the simplest case, data points have been generated as x-y pairs in an ASCII file called xydata perhaps written with a formatted FORTRAN write statement or created with an editor. The program reads the file, and plots y as a function of x, interpolating with straight lines; axes are automatically assigned with reasonable limits and annotations. All this can be done with the three commands

```
        read
        plot
        stop
```

Here a data file with the name xydata has been read format free (that is with * instead of a format in FORTRAN). An output file named myplot has been constructed, it may be plotted on any of the standard devices with a plot filter. As documented in the rest of this writeup, it is possible to add embellishments of considerable complexity: for example many series on one plot, plotting of symbols at the points, cubic spline interpolation of continuous curves, logarithmic scales, error bars, titles, axis labels and all the other common desiderata.

The program operates in a command mode; this means that you are not prompted at the console, but instead you type simple commands instructing the program which options are needed. Almost every option has a default value, so that if nothing is mentioned about a particular parameter the default is taken: for example the default plotting scales are linear in x and y. Once a particular option has been invoked, it remains in force until altered. The advantages of this approach are that great flexibility is available but a minimum of typing is required and no rigid order is demanded of the typist. The last factor makes the program very easy to use in batch mode, in contrast with prompting systems where one must remember the questions and the
branches taken by the program during execution.

BASICS

Upon execution the program prints the single prompt:

```
        Enter read and plot commands
```

Now you must type commands selected from the catalog below; each command begins in the 1st column of a new line; it may be followed by some literal or numerical parameters, which must be separated from the command word by a space. Any command may be abbreviated by its first four characters.

To read data from an external disk file there are a number of commands that define the attributes of the data to be input: an obvious example is the name of the disk file, defined by file, another the format of the numbers defined by format; other input attributes are things like whether this data set is to be connected with a smooth interpolating curve (smooth) or to be plotted as individual points (symbol). Having set up all the necessary specifications of the input, you actually perform the reading with the read command. Another data series may be read fromthe same or a different file, simply by resetting the input attributes as required, and using read again. All the parameters remain in force from the previous read unless they are specifically altered. Each of these data series with its different properties is accumulated in memory ready to be plotted.

Plotting is accomplished with plot. If several data series have been read since the previous call to plot, or this is the first such call, they all appear on one graph. Actually all that is done by this command is to create the file myplot which must be displayed with one of the system routines as we shall discuss in a moment. There are a number of parameters that apply to the whole plot, which may be set before invoking plot. For example, there are the x and y axis labels (xlabel, ylabel) and the plot title (title). The size of the plot will default to 6 inches in x and 8 in y; the limits of the plot will default to values slightly larger than the extremes found in the series. These things can be overridden using xlimit and ylimit. When all the data are strictly positive, logarithmic scales can be set with logxy.

Before typing plot it is sometimes helpful to inspect the series and the way in which the data are going to be interpreted. This is done with status, which provides a synopsis of each data series and the current parameter settings.

Additional graphs may be created by reading in more data and invoking plot again as often as necessary. To terminate the program just type stop. After you have entered stop, the program writes a diskfile called myplot, or something else if you used output, that must be sent to graphics device.

COMMAND CATALOG

The commands are given their full English names here (though only four characters are needed). Commands may be given in upper or lower case letters. The characters following the first blank after the command word itself are termed the 'command field'. A command line may be 120 characters long. Parameters that may be omitted in the command field are enclosed in square brackets. The parameters may be numbers, file names or text; it should be obvious from the context which is appropriate. A list separated by slashes denotes a set of possible alternative items. A command line beginning with a space is ignored and may be used as a comment.

affine a b c d

Transforms the x and y coordinates of the next and subsequent data series to be read according to new(x) = a*x + b, new(y) = c*y + d. This is an affine transformation.
Blank command field a = 1, b = 0, c = 1, d = 0

cancel [n]

Removes the last n data series read into memory. If no series has been read in, do nothing. Blank command field n = 1

character h [angle]

Change the height of the lettering in titles, labels and axis numbering to h inches. The new value applies to the next piece of text to be read, so that different height letters can appear in the title, the axis notations etc. The value of h just before plot determines the height of the axis numerals; if this is zero axis numerals and tick marks are suppressed Negative h has the same effect as positive, except that axis numerals are suppressed, without removing the tick marks. The optional parameter angle specifies the angle at which text will be plotted in the next note. Letter height can also be controlled by the a special text phrase (see LETTERING).
Default h = 0.15, angle = 0

color n

On those plotters capable of drawing in color, this command sets the color of subsequent items according to the code: 0 or 1 black, 2 red, 3 blue, 4 green, 5 brown, 6 orange, 7 purple, 8 yellow. For this to work the pens must be in a standard order in the magazine of the penplotter and of course only the first 4 work with four-color plotters The color of a plotted data series is the one set at the time of the associated read command; similarly with labels, notes, etc. Also the axes and the frame are drawn in the color specified at the time plot is called.
Default n = 0

dash [s1 s2]

Plot the next data series to be read in as a dashed line, with visible segments s1 inches long and missing segments s2 inches long. dash is an input attribute applying to the next read command. To return to an unbroken curve, set s1 = 0.
Default s1 = 0, s2 = 0
Blank command field s1 = 0.2, s2 = 0.1

file filename

Defines the file name of the external disk file from which data are to be read; or the symbol * which implies read from the console. The name must consist of 64 or fewer characters. After this command the next read statement will begin at the beginning of the file.
Default = xydata
Blank command field = Rewind existing file

format (format specifier)

Defines a format for reading the next data series from an external disk file. The format specifier may be (1) a normal FORTRAN format specifier enclosed in parentheses (2) the single character * meaning 'format free' reading (3) the character b meaning a binary read. In each case the data are read with a single FORTRAN read statement of the appropriate type. Usually, if the numbers can be unambiguously read by a person without the need to skip certain columns or other tricks, there is no need to use an explicit format - the default * will work. Never use an I format because values are stored as REAL variables; thus a number written with I4 must be read with an F4.0 format. Always remember the space after the word format and the parentheses.
Default = *
Blank command field = *

frame on/grid/off/none

If on causes two more sides to be added to the axes to complete a rectangular frame around the plot: grid includes a lightly dashed grid that corresponds to the axis tick marks as well as a frame; off cancels the surrounding box and returns to the normal situation with two orthogonal axes. Finally, none specifies the total absence of axes and frame.
Default off
Blank command field on

help

Lists the four-letter abbreviation of all the commands. This may remind you of a name you have forgotten.

logxy [n]

Specifies the type of scales for the next plot. The integer n may be 0, 1, 2, 3, meaning: 0 both x and y are linear variables; 1 implies that x is logarithmic; 2 means only y is logarithmic; 3 means both x and y are logarithmic.
Default n = 1
Blank command field n = 3

mode n [x0 dx]

Defines how the input data are grouped in the next and subsequent reads The integer n may be 1, 2, 3, -3, 4· 1 implies data are simply consecutive y values with uniformly increasing x values beginning at x = x0 increment dx; 2 means data are x y pairs; 3 means data are x y z triples in which z is taken to be the uncertainty in y (thus a bar is plotted between y-z and y+z). -3 means use third member of data group as an uncertainty in the x-value. A symbol may be plotted at the actual value of y itself if symbol is set; to guarantee the absence of a symbol put s = 0 in symbol. When mode is 4 the x and y data must be read by separate read commands, the x series being input first. The series length is that of the x series.
Default n = 2
Blank field after n = 1, x0 = 1, dx = 1

note (x y [in]) text
note (p q x y [in]) text

Reads the characters of text to be plotted on the graph at the coordinates x,y. The text may be up to 80 characters in length. If the optional in appears the coordinates refer to the bottom left corner of the first text character, measured in inches from the intersection of the axes; otherwise x,y are in the units of the graph. Notice that the parentheses surrounding the coordinates are mandatory. The height of the plotted characters is the value h in the most recent character command. Similarly the angle the text makes with horizontal is the one previously set in character. Up to 20 separate notes may be input. To clear the notes enter note and a blank command field and this must be done explicitly for new graphs with a fresh set of notes. If four coordinates instead of two appear in the parentheses, an arrow is drawn with its tip at p,q and its tail tastefully near the text, which is plotted as before with x, y at the bottom left of the first character. The text is always horizontal with this option.
Blank field = delete old notes

offset [dx dy]

When several similar data series are to be displayed together it is often convenient to introduce a displacement between them to clarify the picture. Thus if dy is nonzero at plotting time, the nth series will be plotted with values of y + (n-1)*dy, where y is the input value. Similarly with dx. When a logarithmic scale is used, the data are plotted as y*10**((n-1)*dy) to preserve equal apparent displacement on the graph. Notice all the series are displaced whenever offset is invoked; for a more flexible method of offsetting data see affine.
Default dx = 0, dy = 0
Blank command field dx = 0, dy = 0

output filename

Defines the name of the plot file to be filename, which must be composed of 64 or fewer characters. Every time output is issued, the currently opened plot file is closed and a new one opened ready to receive further plots.
Default = myplot

plot [x0 y0]

Creates the next complete graph containing all the data series that are currently in memory. Unless a save command has been used, the plotted series are the ones read in since the last plot command or, if this is the first such command, all the series. A plot file is generated named myplot, unless you have set a different name with output. Usually plot is invoked with a blank command field but, if x0 and y0 are specified, the new graph is plotted with its origin at those coordinates in inches relative to the previous plot origin. The plot origin for these purposes is the place where the annotated axes cross, not the point (0,0).

read [n]

Performs the reading of the external disk file according to the specifications in force at this point. Each read instruction is performed with a single FORTRAN READ statement with an implied DO; this means many data may appear on a single line in formatted files. With binary files only one binary record is read with every read command. The integer n is the number of points to be read from the file, but if n is absent the file is read to the end of file (eof). When the eof is not reached, the file remains open and ready for further reading beginning at the next unread record (i.e. the next line in formatted files); if the eof was reached, another read on this file will begin at the beginning.
Up to 100 separate data series may be present at any one time. Note n must be explicit if file = *

save

After a plot command, the series in memory are normally erased ready for new data. To prevent this, the command save must be entered before the next read statement. If no additional data are to be read in, there is no need to use save because the previous data are available for plotting in this case.

smooth [on/off]

Decides whether continuous curves of y against x are interpolated with straight lines, smooth off, or natural cubic splines, smooth on. When splines are used, the series is taken to be a single-valued function of x and the actual x values will be reordered to be increasing by

the program if necessary. This command is an input attribute, applying to subsequent read commands, not to the whole plot. smooth on cancels a symbol command and vice versa. smooth off reverts to symbol mode if that was the previous style of plotting, with the same symbol number and height as before. Note that the automatic plot limits use the original data series, not the smoothed values, so that sometimes pieces of a smoothed curve may be lost off the top or bottom of a graph even when you have let the program find its own limits.
Default = off
Blank command field = on

skip [n]

Skips the next n records in the current data file. With formatted files this means skipping n lines. The command examines the current read format to determine whether the current file is binary or formatted. Although skipping can be performed by including slashes in a format specification it is often more convenient to use skip.
Blank command field n = 1

stack

Causes the next complete graph, including axes, titles etc, to be drawn above the previous one with enough space to give a pleasing appearance. To stack several curves on one graph see affine or offset. This command is turned off internally after plot to prevent accidental plotting off the top of the paper. A more flexible way of organizing the relative positions of several complete graphs is by means of plot with origin parameters.

status

Lists a synopsis of the current data series (their lengths, extreme values and other attributes), the plot and reading parameters, and the number of words available for further data series.

stop

Closes the output file and brings program to an orderly halt. This must always be the last command of any run, otherwise part of your plot will be lost.

symbol n s

Defines the next input series to be a set of discrete points with symbols rather"than a curve. The height of symbol is s inches, the type of symbol defined by the integer n:

0 square
1 triangle
2 octagon
3 diamond
4 plus
5 asterisk
6 cross
7 slashed square
8 upward arrow
9 hourglass
10 campstool
11 hexagon
12 Y
13 vertical bar
14 star of David
15 dot
16 small circle
17 circle
18 large circle
19 small filled disk
20 small filled square
21 small filled triangle

To cause one of these symbols to be drawn in a text string (a note for example) just enclose the symbol number plus 2000 in backslashes, for example, \2019\. The value of n may be used to reset the input of continuous data: n = -1 means next data read will be continuous with straight line interpolation; n = -2 means go to cubic-splined curves.
Default n = -1, s = 0

title text

Specifies a title for the plot. This may be up to 115 characters in length. A blank command field cancels the previous title and leaves the next plot untitled. The character font of the title is assumed by all the lettering of the graph unless explicitly reset. If the title consists only of a font-setting phrase, the font is set and the graph is untitled.
Default text = blanks

xlabel text

Specifies a label to be written under the x axis. See title for other details.
Default text = blanks

xlimit xlength [x1 x2]

Defines the length of the x axis, xlength, in inches and the lower and upper limits of x: x1, x2. All plotted points will have values inside (x1, x2); those outside are omitted from the plot. If x1 = x2 = 0, or if these values are omitted in the command, the x extremes will be chosen to encompass the values in the data series. If x2 is less than x1 the data and axes are plotted reversed, that is with x decreasing to the right, between the given limits. Reversed logarithmic axes are not permitted.
This is a plot attribute, governing the behavior when plot is invoked.
Default xlength = 6, x1 = x2 = 0

ylabel text

Same as xlabel but for the y axis.
Default text = blanks

ylimit ylength [y1 y2]

Same as xlimit but for the y axis.
Default ylength = 8, y1 = y2 = 0

DEFAULT VALUES

affine	1, 0, 1, 0	output	myplot
character	0.15 0	smooth	off
dash	0, 0	symbol	-1, 0
file	xydata	title	blanks
format	*	xlabel	blanks
frame	off	xlimit	6, 0, 0
logxy	0	ylabel	blanks
mode	2	ylimit	8, 0, 0
offset	0, 0		

LETTERING

Plotxy provides a variety of fonts in which the titles, labels, notes may be written as well as the ability to include mathematical material and Greek letters. The names of the fonts are simplex, complex, italic, duplex; the default is the austere simplex. To get any of the others in a text string enclose the first three letters of the font name in backslashes (e.g. \ita\ or \dup\) ahead of the text. The font remains in force until explicitly changed. To obtain a uniform font throughout the graph and its labels include a font-setting phrase (e.g.\ita\) at the beginning of the title. If you want to vary the fonts within one plot you must specify the desired font for each character string plotted. Font changes may appear at any point in a piece of text.

You may also get Greek letters by enclosing their names in backslashes, as \GAMMA\ or \lambda\; upper case Greek appears when the English name is upper case. The name of a Greek letter can be abbreviated to its fewest unambiguous leading letters: thus \s\ specifies sigma, but you need \ome\ for omega. Super-scripts are possible with the construct \sup(...), so that x-squared is rendered x\sup(2). Similarly with subscripts one writes, for example, g\sub(ij). As mentioned in symbol you may plot a special graphics symbol by enclosing the symbol integer plus 2000 in backslashes. The code \bs\ suppresses the character advance so that characters may be superimposed.

There are certain special characters that have no keyboard equivalent. To get them you must use a special code: a 4-digit key number enclosed in backslashes. The code acts just like an ordinary character so that, for example, the space of infinitely differentiable functions would be written C\sup(\1395\) since \1395\ is the code for infinity. Here is a table of the codes for the special symbols; every symbol in the graphics character set has such a code but only those without keyboard equivalents are given here.

1387 curly d	1403 summation
1388 del	1404 regular theta
1389 member of	1405 {
1390 less or equal	1406 }
1391 greater or equal	1407 #
1392 proportional	1408 hat
1393 integral	1409 [
1394 circuit int	1410]
1395 infinity	1411 #
1396 + or -	1412 paragraph
1397 - or +	1413 dagger
1398 times	1425 tall <
1399 division	1426 tall >
1400 product	1429 degree
1401 times dot	1430 tends to
1402 radical	1431 regular phi

Finally, another use for the four-digit code is to specify text size. The height of the text following the phrase \0025\ is changed from its current value to 0.25 inches; any number less than 500 is interpreted as the letter height in hundreths of an inch, but remember there must be four digits between the backslashes

NOTES

Plotxy is reasonably graceful with error conditions; explanatory messages are issued in most circumstances. A common problem is with formats not matching the data; the program will usually detect this type of error, reject the whole series and then issue a warning. Misread data can result in incorrect values being stored; this may perhaps be detected before plotting by looking at the extreme values of each input series, something given by status Strange pictures result if you forget that affine parameters are still in force. Also be sure to understand the FORTRAN convention for rescanning FORMAT statements if you are using an explicit format and your input file is longer than the number of items in your format statement. Attempting to plot negative data on a log scale will not cause a crash - an error message is printed and the offending scale is made linear instead of a logarithmic.

If you have explicitly set plot extremes with xlimit and ylimit and a data value falls outside the window, when smooth is on the program draws a piece of curve between the last captured point(s) and the edge of the graph in the direction of the invisible point. When smooth is off the pen is simply lifted until onscale data are encountered. This allows you to insert breaks in your data records by using large values; remember to set limits explicitly at plot time.

A useful idea for creating elaborate graphs that overcomes the apparent restrictions on the number of notes and the kinds of axes available is the superposition of several graphs on top of each other: plot 0 0 draws the next graph right over the old one. Thus if you only want an x axis, plot the data with frame none then cancel the data, set the length of the *y* axis to zero and plot a new *x* axis with plot 0 0

Artistic users seem to want to vary the font and size of every notation and label This is straightforward: any piece of text may be preceded by a font phrase; the height may be defined in the text as described in the previous section or by the character command immediately before the text is entered (and similarly with color). The only writing that can not be specified in this way is the numerical annotation of the axes. To control its size and color set these parameters immediately before plot; to arrange a special font put the font phrase you desire at the end of the title text. If you want the two axes in different colors with different numeral sizes and fonts, this can be done too, but discovering how is left as an exercise.

EXAMPLES

Here are two examples of quite presentable plots made with relatively little effort. The first is a reproduction of some graphs of Bessel functions found in Abramovitz & Stegun's Handbook of Mathematical Functions. A rather sparse table has been entered equally spaced directly into the input file and the values are spline smoothed to add authority. All modern operating systems allow you to prepare an input file and submit it to a program as if it were entered interactively; it is very handy then to put the data in the file together with the plot commands. Notice that comments have inserted by beginning a command line with a blank.

```
     A diagram from Chapter 9 of Handbook of Mathematical Functions

  file *
  smooth
  mode 1 0 1

     First 16 values of J0 for x=0, 1, 2, .. 15
  read 16
  1.000  .762  .224 - 260 -.397 -.178  .151  .300  .172 -.090  -.246
-.171  .048  .207  .171 -.014

     Now 16 values of J1
  read 16
  0.000  .440  .577  .339 -.066 -.328 -.277 -.005  .235  .245  .043
-.177 - 233 -.070  .133  .205

     Next 15 values of Y0 for x=1, 2, .. 15  dashed
  mode 1 1 1
  dash .05 .07
  read 15      -
   .088  .510  .377 -.017 -.309 -.288 -.026  .224  .250  .056  -.169
-.225 -.078  .127  .205

     Finally values of Y1
  read 15
  -.781 -.107  .325  .398  .148 -.175 -.303 -.158 - .104  .2:2  .164
-.057 -.210 -.167  .021

  xlim 3.5 0 16
  ylim 3 0 0

  title \dup\
  xlab \com\FIGURE 9.1: \ita\J\sub(0)(x), Y\sub(0)(x),
  note (1,0.8)J\sub(0)
  note (1.8,-.5)Y\sub(1)
  note (2,.577,3,.8)J\sub(1)
  note (3,.377,5,.6)Y\sub(0)

  plot 1 7
```

In the above listing the xlab command line has been trucated to fit on the page. Several different fonts have been used; notice that the axis numerals are in the font of the title, which is in fact blank. The picture has been placed at the top of the page leaving room for the second example below it.

Next we illustrate how a disk file may be rescanned with a format to pick out different columns for various purposes. The data file rhodata contains a table of Wenner array apparent resistivity data at various electrode spacings, together with an estimated uncertainty (column 3) and the fit of a one-dimensional theoretical model (column 4). The file is read in mode 3 to get error bars, then reread and smoothed to put the theory on the graph. Log axes are appropriate here for obvious reasons.

```
  title \ita\
  logxy 3
  frame

  xlim 4 1.0 1000
  ylim 3.6 10 2000
  ylabel Apparent resistivity  \rho\\sub(a) (\OME\m)
  xlabel Electrode separation  r  (meters)

     1st read uses the format to pick __asurements and errors in
     mode 3
  file rhodata
  symbol 19 0.1
  mode 3
  format (3f11.0)
  read

     2nd read picks up 1st and 4th column
  mode 2
  dash 0 0
  smooth
  format (f11.0, 22x, f11.0)
  read

  notes
```

```
 plot 0 -5.5
 stop
```

Here is the data file rhodata

```
   1.52      69.6      10.0      67.9
   4.57      126.3     21.1      126.3
   7.62      207.6     33.6      199.8
   12.1      304.3     47.0      304.2
   18.2      421.2     40.2      431.0
   24.3      508.7     69.2      541.8
   30 4      587.6     52.0      636.4
   42 6      769.9     83.0      778.2
   79 2      987.7     122.0     913.2
   106.7     902.3     150.1     848.7
   137.2     891.2     114.1     715 2
   167.6     543.3     86.16     571.0
   228.6     366.7     101.2     333.1
```

NEW FEATURES

The following are new features of Plotxy added recently.

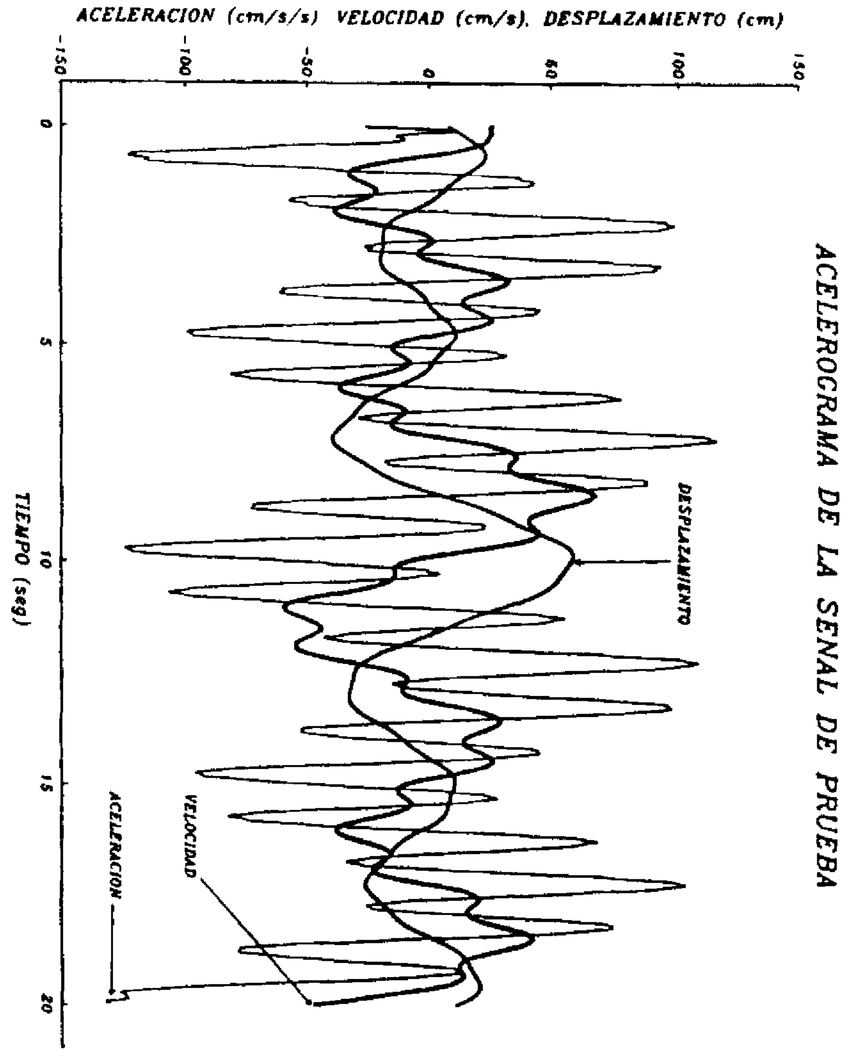
frame grid
This new option to frame causes a lightly dotted network of grid lines to be drawn in addition to the regular box.

char -0.15
A negative character size is allowed The absolute character size is used everywhere but now the axis numerals are suppressed, WITHOUT removing the corresponding tick marks. Recall to remove ticks and numerals you can set char 0 just before the plot command.

xlim 6 1.0 0.0
Setting the plot limits in reverse now causes the axis to be labeled backwards (with 1 on the left and 0 on the right in this example) and the figure to be plotted accordingly. Similarly with ylim. Note this option does not work with log axes.

title \0025\P\0015\ater Noster
In any text the current letter size may be over-ridden with a new size measured in 0.01 inches given as a 4-digit number (therefore usually preceded with 2 zeros) and enclosed in backslashes. Thus letters may vary in height in a single line of text. The revised size holds only in the line and does NOT affect other text strings (unlike font changes which persist throughout).

```
OUTPUT HPA
FILE TAVD
FORMAT (2(F16.7))
MODE 2
LOGXY 0
XLIMIT 8
CHARACTER 0.15
TITLE \ITA\ACELEROGRAMA DE LA SENAL DE PRUEBA
READ 2000
FILE TAVD
FORMAT (F16.7,16X,F16.7)
MODE 2
SYMBOL 1 0.03
READ 2000
LOGXY 0
FILE TAVD
FORMAT (F16.7,32X,F16.7)
SYMBOL 6 0.02
MODE 2
READ 2000
LOGXY 0
CHARACTER 0.1
XLABEL \ITA\TIEMPO (seg)
YLABEL \ITA\ACELERACION (cm/s/s), VELOCIDAD (cm/s), DESPLAZAMIENTO (cm)
CHARACTER 0.08
NOTE (19.8 -130 15 -130) ACELERACION
NOTE (20 -49 15 -100) VELOCIDAD
NOTE (10 59 8 100) DESPLAZAMIENTO
YLIMIT 6 -150 150
PLOT
STOP
```


ACELEROGRAMA DE LA SENAL DE PRUEBA
ACELERACION (cm/s/s) VELOCIDAD (cm/s), DESPLAZAMIENTO (cm)
TIEMPO (seg)
DESPLAZAMIENTO
VELOCIDAD
ACELERACION