Hewlett-Packard
9825A Desktop Computer
9872A Plotter Programming

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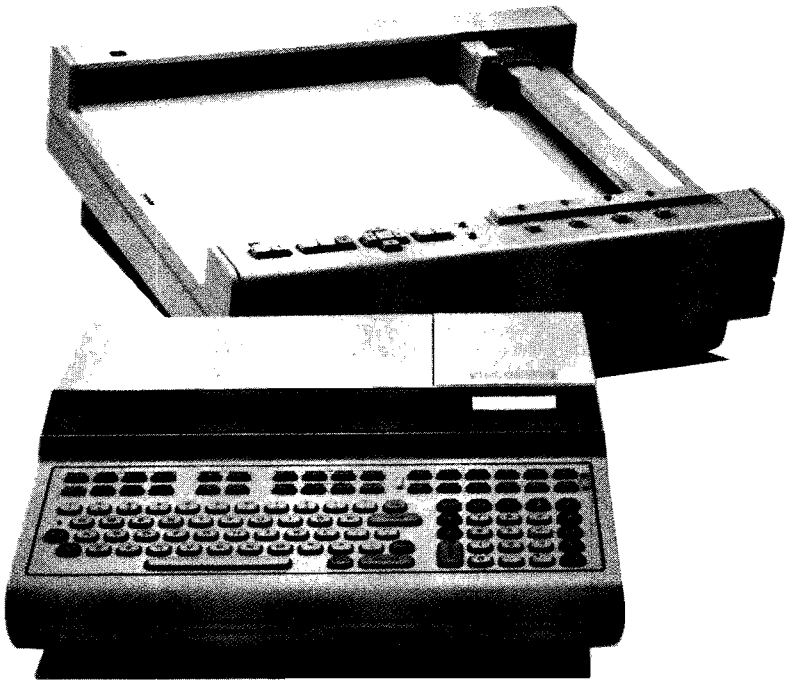
Plotter Programming



HP 9825A Desktop Computer and 9872A Plotter

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(For World-wide Sales and Service Offices see back of manual.)

Table of Contents

Figures

Tables

Chapter 1
General Information

The HP 9872A Plotter ROM (Read Only Memory), provides you with a convenient set of control statements for the HP 9872A Plotter.

The Plotter ROM enables the calculator to control the plotter, providing hard copy graphic solutions to problems solved by the HP 9825A. In addition to plotting, the 9872A can be used to draw axes with or without tic marks and labels, to label alphanumerics and symbols and to provide digitized data to the calculator.

The HP 9872A Plotter ROM uses 104 bytes of user RWM (Read Write Memory) when installed in the HP 9825A.

Equipment Required

The plotter must be connected to the calculator via the HP 98034A HP-IB Interface.

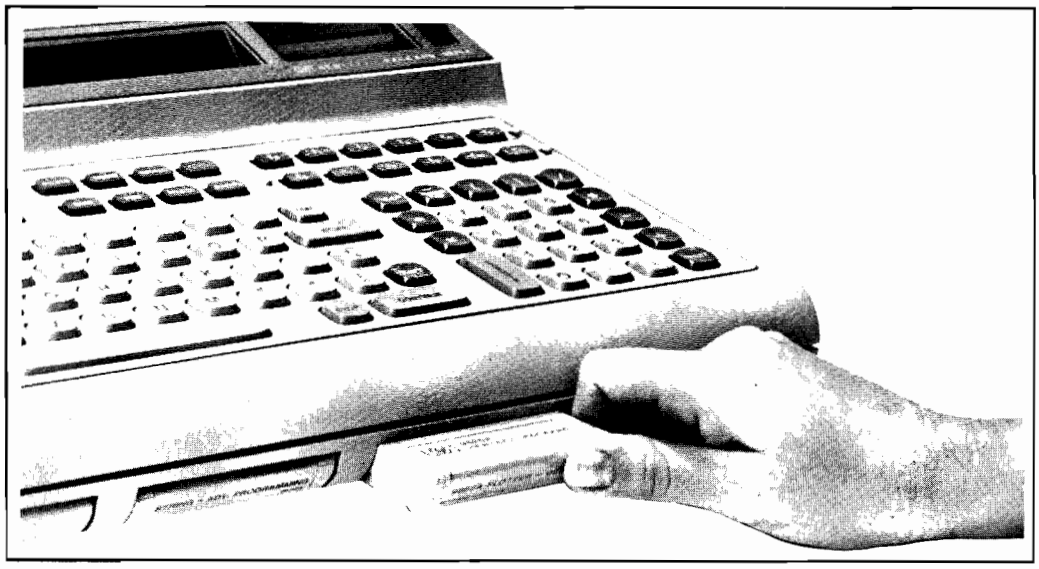
Inspection and Installation

The Plotter ROM is always packaged with other ROMs in a single ROM card. This manual describes plotter operations only.

Your Plotter ROM may be plugged into any one of the four ROM slots located on the bottom front of the calculator, as shown in the next figure.

Plotter ROM Test

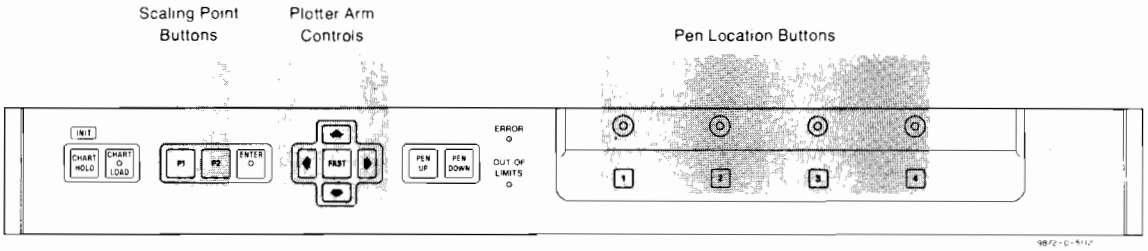
Refer to the HP 9825A System Test Booklet for the procedure used to verify the operation of the plotter ROM.



Installing a ROM Card

Setting Up The Plotter

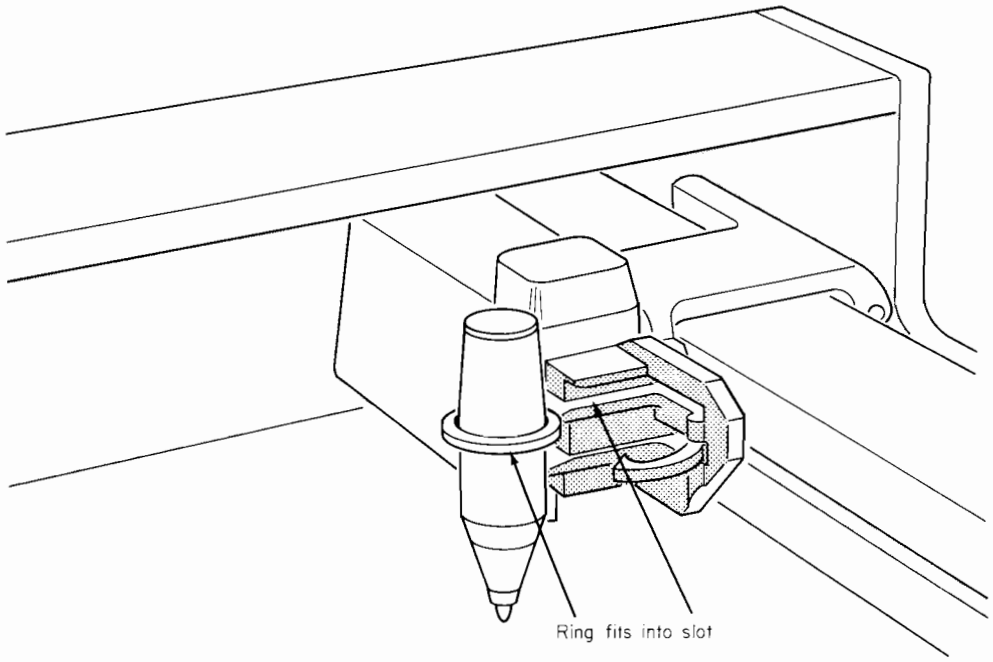
Information concerning power requirements, grounding and plotter maintenance is contained in the HP 9872A Plotter Peripheral Manual supplied with your plotter. The following plotter 'set-up' information is included here for your convenience.



Front Panel Controls

Loading Pens

Switch the plotter power switch on (1). After the plotter's initialization process is complete and the plotter arm has stopped moving, you can install the pens.



Installing The Pens

Select the color of pen that you want in pen storage location 1, remove the cap and place it in the pen holder as shown in the picture above. Note that the thick ring around the middle of the pen fits into the slot in the pen holder. Now press [ENTER] and pen location button [1] . The plotter arm will put the pen in the first storage location. Repeat this procedure with three more pens, substituting the appropiate pen location button for each one.

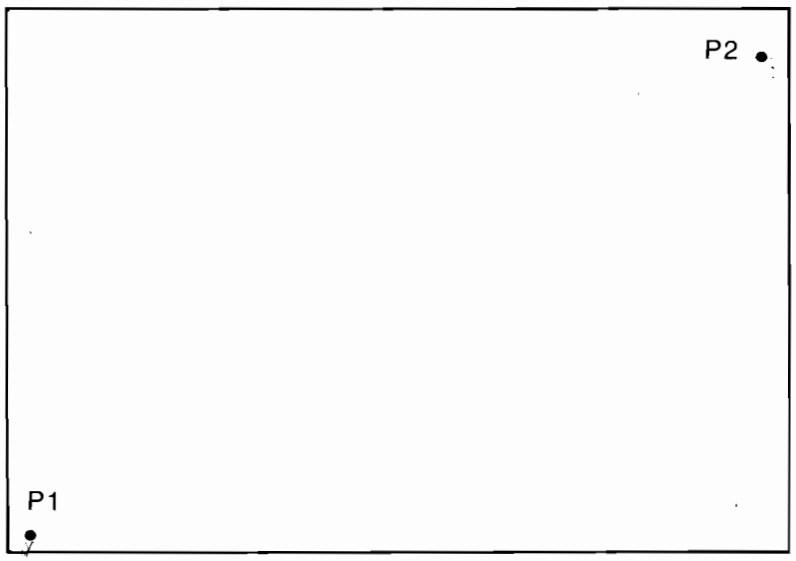
Loading Paper

To load paper, you first press [CHART LOAD] . This releases the paper hold-down mechanism and moves the plotter arm to the upper right corner of the platen. Lay a sheet of paper on the platen surface and smooth it out. Make sure that the paper is positioned squarely against the ridge at the bottom of the platen. Now press [CHART HOLD] . This will activate the paper hold-down mechanism.

Setting The Scaling Points

The scaling points, P1 and P2, do not restrict the plotter arm motion, but are used to establish the scaling area used by the scale statement (see Chapter 2). These points are also referenced by other ROM statements that specify such things as character size and line pattern length.

When the plotter is initialized, it sets P1 and P2 as shown in the next figure.



Initialized Location of PI and P2

To relocate either or both of these points, use the following procedure:

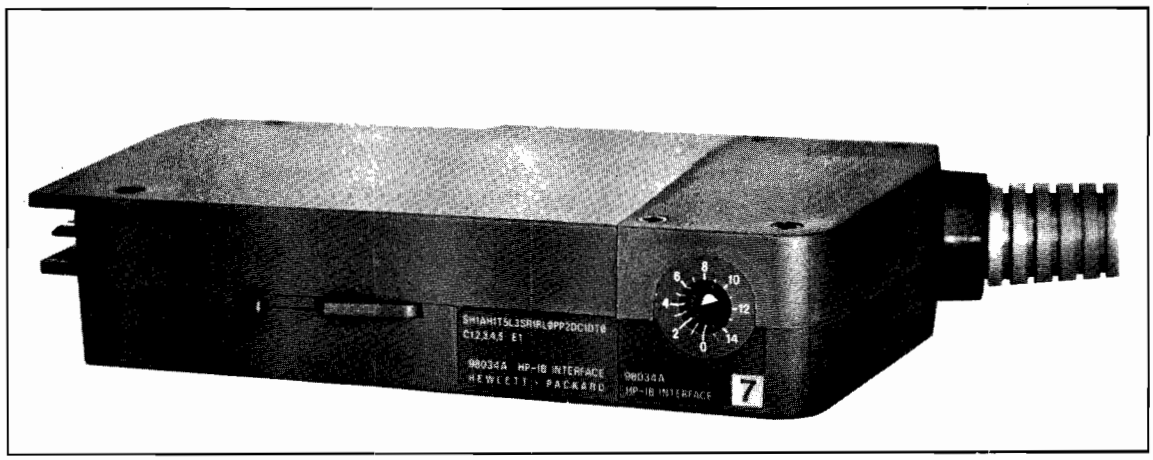
Position the pen at the new location using the plotter arm controls.

When the pen is at the desired location, press [ENTER] and either [P1] or [P2] according to the point that is to be located there.

The Interface Select Code

The plotter is connected to the calculator via an HP 98034A HP-IB Interface. Refer to the HP 98034A HP-IB Interface Installation and Service Manual for complete information about the interface card and cables.

The interface card is preset to a select code of 7 at the factory. To change the setting, rotate the switch (shown below) using a small screwdriver.



Select Code Switch

NOTE

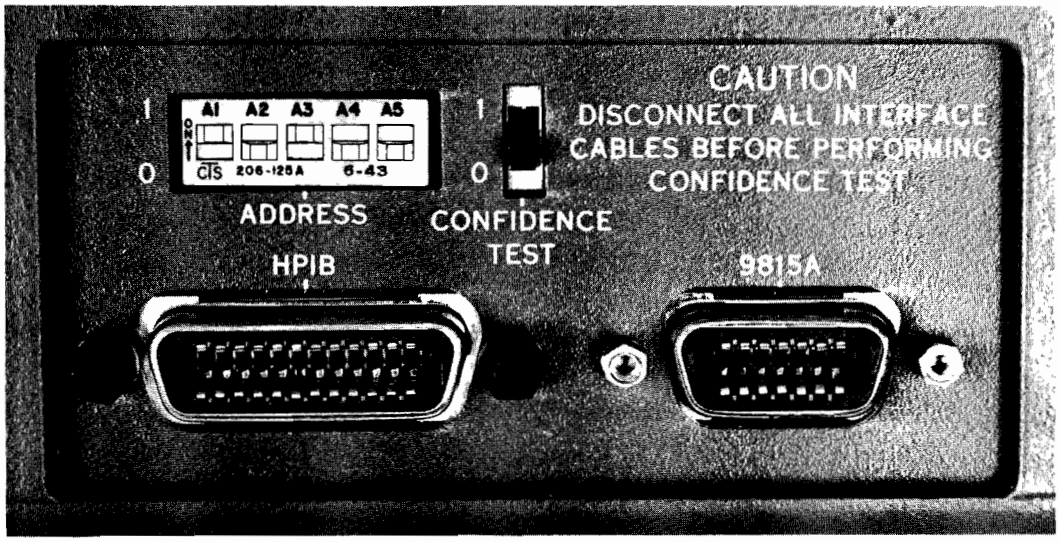
The interface should not be set to select code 0 or 1. Those codes are reserved for internal calculator peripherals (display, keyboard, etc.). Also, do not use the same select code for more than one interface.

The Plotter Address Code

Since each HP-IB interface can have as many as 14 devices connected to it, each device must be set to a specific address code.

The plotter can be set to any one of 31 HP-IB addresses ranging from 0 thru 30. Each address can be selected by setting the switches on the plotter back panel (shown next) to the appropriate binary bit positions for the particular address value desired.

The plotter is set to an address code of 05 at the factory. Check your plotter for the proper switch positions shown below.



Plotter Address Switches

The following table lists the switch positions for each address value.

Address Switch Positions

Address Characters		Address Switch Settings					Address Codes	
Listen	Talk	(5)	(4)	(3)	(2)	(1)	decimal	octal
SP	@	0	0	0	0	0	0	0
!	A	0	0	0	0	1	1	1
"	B	0	0	0	1	0	2	2
#	C	0	0	0	1	1	3	3
$	D	0	0	1	0	0	4	4
&	F	0	0	1	1	0	6	6
'	G	0	0	1	1	1	7	7
(	H	0	1	0	0	0	8	10
)	I	0	1	0	0	1	9	11
*	J	0	1	0	1	0	10	12
+	K	0	1	0	1	1	11	13
,	L	0	1	1	0	0	12	14
-	M	0	1	1	0	1	13	15
.	N	0	1	1	1	0	14	16
/	O	0	1	1	1	1	15	17
0	P	1	0	0	0	0	16	20
1	Q	1	0	0	0	1	17	21
2	R	1	0	0	1	0	18	22
3	S	1	0	0	1	1	19	23
4	T	1	0	1	0	0	20	24
5	U	1	0	1	0	1	21	25
6	V	1	0	1	1	0	22	26
7	W	1	0	1	1	1	23	27
8	X	1	1	0	0	0	24	30
9	Y	1	1	0	0	1	25	31
:	Z	1	1	0	1	0	26	32
;	[	1	1	0	1	1	27	33
<	\	1	1	1	0	0	28	34
=	]	1	1	1	0	1	29	35
>	^	1	1	1	1	0	30	36

The ROM statement that specifies both the interface select code and the plotter address code is the plotter select statement (PSC), which is explained in Chapter 2.

Operating and Programming Requirements

Before using this manual, you should be familiar with the calculator and the HPL programming language described in the HP 9825A Operating and Programming Manual.

Syntax

The following conventions apply to the statement syntax found in this manual.

`dot matrix`	All items in dot matrix are required exactly as shown.
[ ]	All items in brackets are optional.

All other items are required but can be numbers, variables or expressions.

All plotter statements can be executed from the keyboard, in the live keyboard mode or within a program.

See the Appendix for a complete summary of the formal syntax of each statement.

Error Messages

The Plotter ROM adds error messages P1 thru P8 and p0 thru p6 to the calculator error list. Explanations of the error conditions that these messages represent are given in the Appendix.

Chapter 2
Plotting

The Plotter Select Code Statement

A select code is a number that is used to specify which peripheral device is being addressed by the calculator. As explained in Chapter 1, the HP 98034A HP-IB Interface and the 9872A Plotter can be set to respond to various select codes and addresses. The plotter select code statement specifies the particular interface and plotter to which the calculator will address the various Plotter ROM statements.

Syntax:

PSC select code value

The select code value consists of either three digits or four digits that combine the two addresses as follows:

cdd	c or cc = one or two-digit interface select code of 0 or within the range of 2 thru 15.
or	
ccdd	dd = two digit plotter address code ranging from 0 thru 30.

The interface select code can be one or two digits depending upon the setting (e.g., 7,10,14,etc.). The plotter address code, however, must always consist of two digits (e.g.,05,06,19,26, etc.). Note that if the plotter address is a one digit number (e.g., 5), a leading zero must be added to it (e.g., 05).

For example, to specify an interface set to 7 and a plotter set to 05, execute this statement:

```
psc705
```

To specify an interface set to 12 and a plotter set to 16, execute this statement:

```
psc 1216
```

The Plotter ROM automatically sets a psc 705 whenever any of the following conditions occur:

The calculator is first switched on
RESET is pressed
or
erase g is executed

Once a pcs statement is executed, all plotter statements that are executed by the calculator will be addressed to the plotter specified by that psc statement. To operate more than one plotter from the same calculator and interface, you must execute an appropriate pcs statement before each statement or group of statements that are sent to an individual plotter.

For example, you can plot on two different plotters (plotters A and B) connected to the same HP-IB interface, by setting each plotter to a different address code. Plotter A could be left at the factory setting of 05 (00101) and plotter B could be set to 06 (00110). Each statement or group of statements sent to a plotter must be preceded by the appropriate psc statement. To address plotter A, a psc 705 is executed. To address plotter B, a psc 706 is executed.

If more than one plotter is being used and the different plotters also use different plotting scales, the appropriate scale statement must be executed each time the psc is changed.

By executing a psc0, you can test all of the statements in a program except the Plotter ROM statements. This is because all Plotter ROM statements are completely bypassed when a psc0 is executed. Any error messages that are due to non-plotter program errors will be displayed. None of the Plotter ROM errors, however, will appear.

The Scale Statement

The scale (`scl`) statement is used to locate the origin (point 0,0) and to specify the scale units to be used for your plot.

The scale statement uses four parameters which correspond to the x and y coordinate values that you wish to assign to the scaling points P1 and P2.

Syntax:

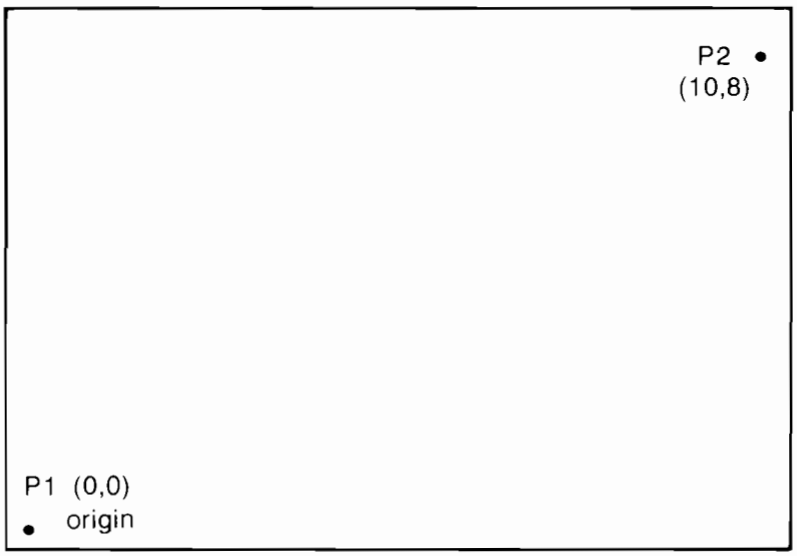
`scl` [X_{P1}, X_{P2}, Y_{P1}, Y_{P2}]

Once the units for a plot have been established, the physical size of the plot can be changed to fit a larger or smaller plotting area by resetting the scaling points, P1 and P2.

The following examples show various scale statements and the resulting origin locations.

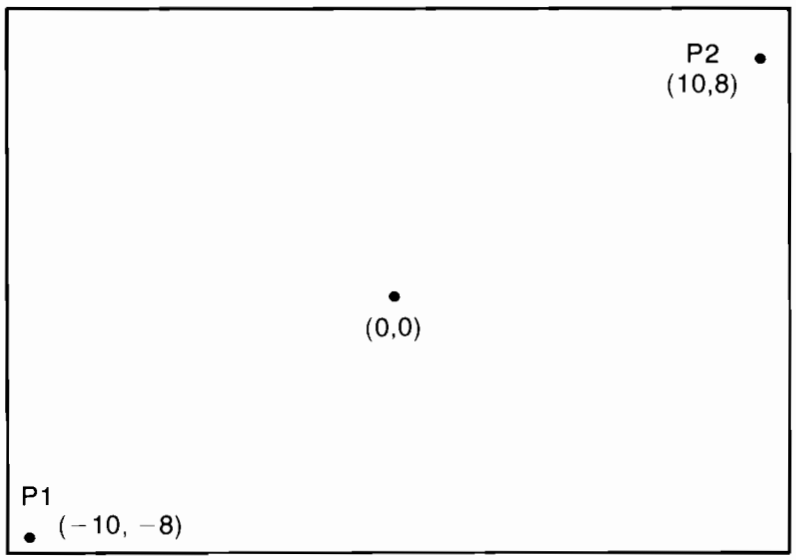
The scale statement below locates the origin at the lower left scaling point, P1.

```
scl 0,10,0,8
```



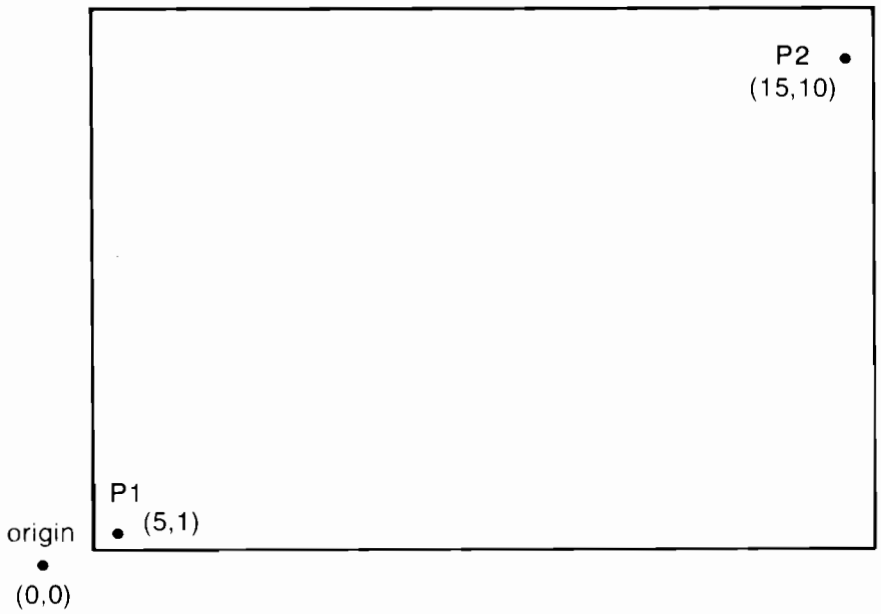
This scale statement locates the origin in the center of the plotting area.

```
scl -10,10,-8,8
```



The origin is located outside of the plotting area by this scale statement.

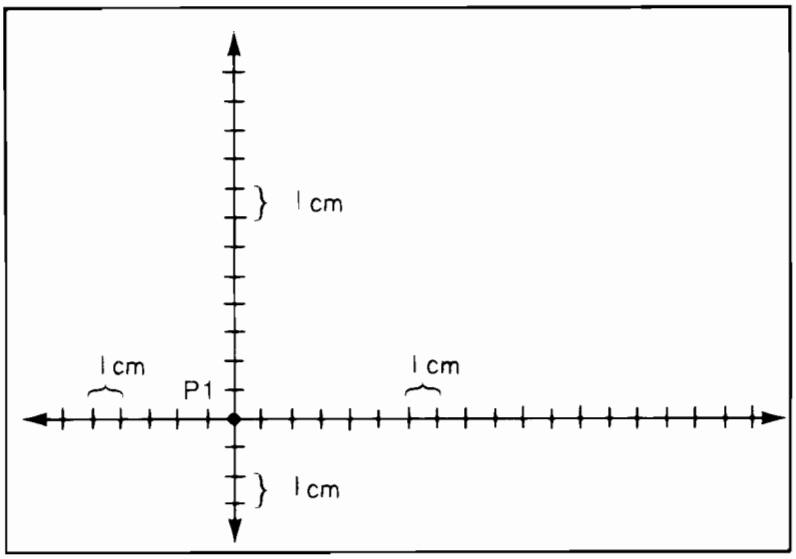
```
scl 5,15,1,10
```



Once a scale statement has been executed, its parameters remain in effect until:

Another scale statement is executed.
The RESET key is pressed.
`erase 0` is executed.
The calculator is switched off.
The plotter is initialized.

The following scale is automatically set whenever the plotter is initialized, or a scale statement without parameters is executed.



This scale corresponds to a centimeter unit of measure of the platen area with the origin (0,0)at the current location of P1. Since the scale corresponds to a unit measure (centimeters), the P2 scaling point is not referenced.

The Plotter Clear Statement

Syntax:

```
pclr
```

The plotter clear (`pclr`) statement sets all parameters that have been sent to the plotter to their default values with the following exceptions:

The current scale (`scl`) statement parameters remain unchanged.

The current plotter select code (`psc`) parameter remains unchanged.

P1 and P2 remain unchanged.

The current pen location remains unchanged although the pen is raised.

The pen that is selected remains unchanged.

A complete listing of the default values for each statement's parameters is given in the Appendix.

NOTE

It is a good practice to execute a `pclr` statement at the beginning of each program to clear any previously set conditions in the plotter.

The Axis Statements

The X Axis Statement

Syntax:

XAX Y-Offset [,Tic Interval[,Start Point[,End Point[,Number-of-Tics/Label]]]]

The X Axis (XAX) statement draws a horizontal axis, with or without tic marks or unit labels.

The Y Axis Statement

Syntax:

YAX X-Offset [,Tic Interval[,Start Point[,End Point[,Number-of-Tics/Label]]]]

The Y Axis (YAX) statement draws a vertical axis, with or without tic marks or unit labels.

NOTE

The following explanation of the axis-statement parameters pertains to both of the axis statements.

The y-offset parameter specifies the y coordinate at which the X axis will cross the Y axis.

The x-offset parameter specifies the x coordinate at which the Y axis will cross the X axis.

The tic interval parameter determines whether or not tic marks are drawn along the axis. If tic marks are to be drawn, the parameter value specifies the spacing, in scale statement units, between tics. A value of 0 results in no tic marks. If a parameter is not specified, a tic mark is drawn at each end of the axis.

The sign of the tic value can result in either normal tic marks being drawn or a tic mark drawn only at the starting point of the axis. This result is determined by the start and end point parameters and is explained next.

The start and end point parameters specify the location of the endpoints of the axis. The axis is always drawn from the start point to the end point. If the end point is not specified, the axis is drawn to the P2 coordinate value in the current scale statement (i.e., X_{P2} for the X axis and Y_{P2} for the Y axis). If both the start point and end point parameters are not specified, the axis is drawn from the P1 coordinate value to the P2 coordinate value specified by the current scale statement (i.e., X_{P1} to X_{P2} for the X axis and Y_{P1} to Y_{P2} for the Y axis).

The following relationship exists between the start and end point parameters and sign of the tic-interval parameter.

A positive tic interval results in:

Normal tic spacing if the start point is less than the end point.

A tic drawn only at the start point if the start point is greater than the end point.

A negative tic interval results in:

Normal tic spacing if the start point is greater than the endpoint.

A tic mark only at the start point if the start point is less than the end point.

The number-of-tics/label parameter determines whether or not the tic marks on an axis will be labeled. Specifying either a 0 or no parameter results in no labels. If labels are desired, the parameter specifies the number of tic marks between labels.A negative parameter will result in only the labels being lettered without the axis or tic marks being drawn. Labels will be lettered on an axis only if a non-zero tic parameter is specified.

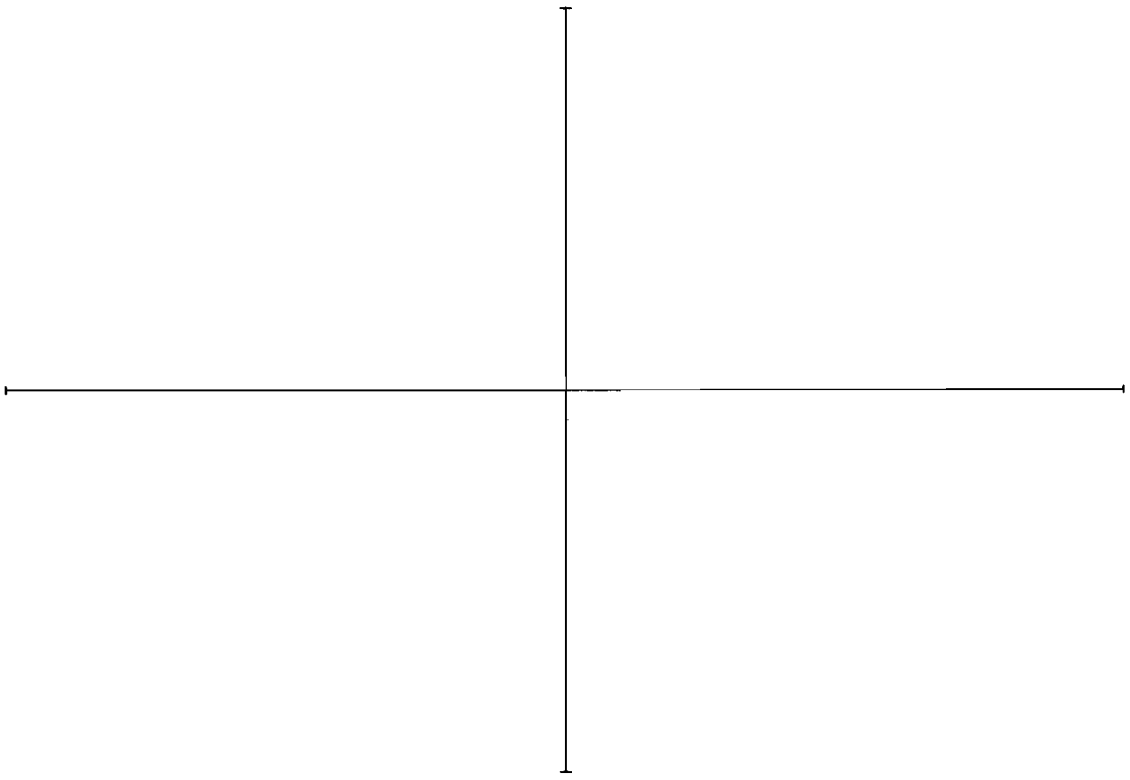
All labels are lettered according to the current character size (csiz) statement and in current number format (fixed or float statement). Character size is explained in Chapter 3, 'Lettering'.

All of the following axes drawing examples use this scale statement:

```
scl -10, 10 -8, 8
```

The following axes are drawn when only the offset parameters are specified.

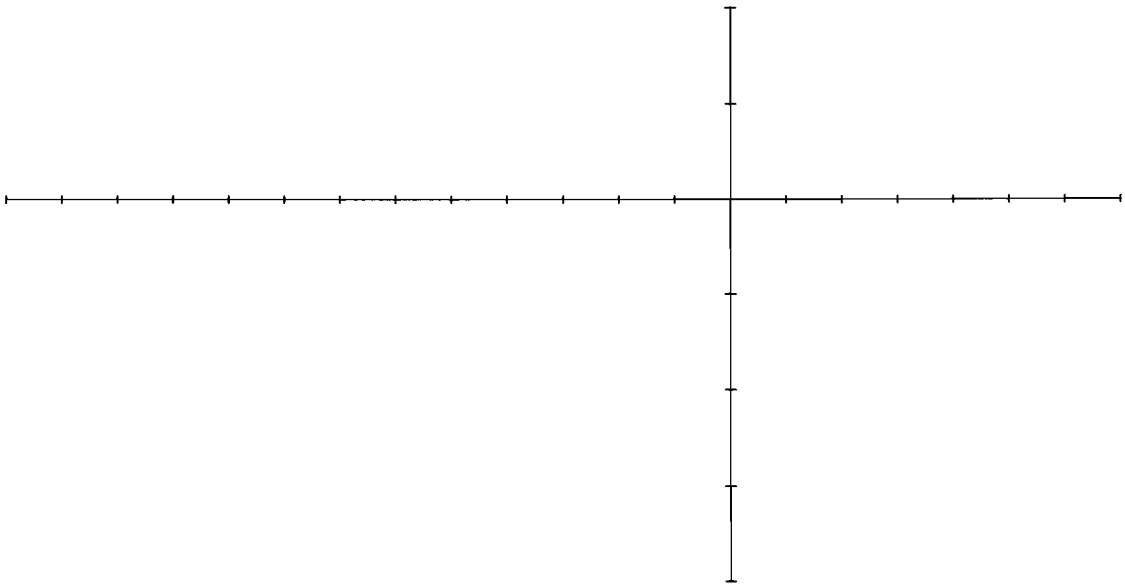
```
xax 0
yax 0
```



The axes cross at the point 0,0 with tic marks drawn only at the end points. The X axis is drawn from -10 to 10 (X_{P1} to X_{P2}) and the Y axis is drawn from −8 to 8 (Y_{P1} to Y_{P2}).

These statements draw the following axes:

```
ax2,1
yax3,2,-6,6
```



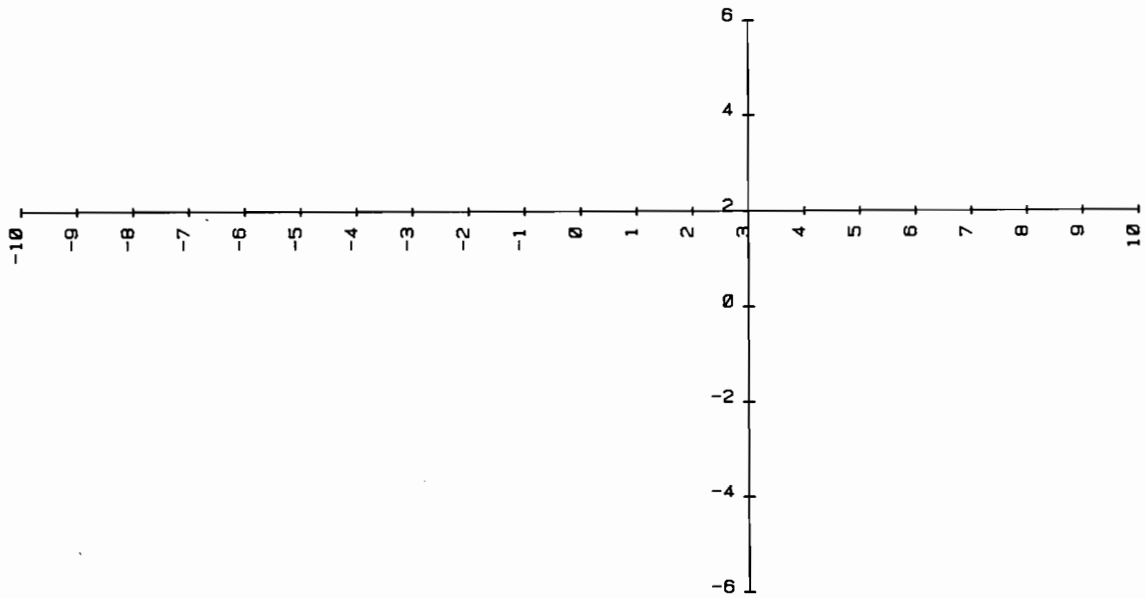
The X axis crosses the Y axis at the point Y = 2. Since the start and end point parameters aren't specified, the axis is drawn from -10 to 10 (X_{P1} to X_{P2}) with tic marks drawn at every unit (a tic interval of 1). No labels are specified.

The Y axis crosses the X axis at the point X = 3. The axis is drawn from -6 to 6 with tic marks every 2 units. Note that normal tic marks result from using a positive tic parameter with the start point (-6) less than the end point (6). No labels are specified.

These instructions draw the same axes as the previous instructions , but add labels in a fixed 0 number format.

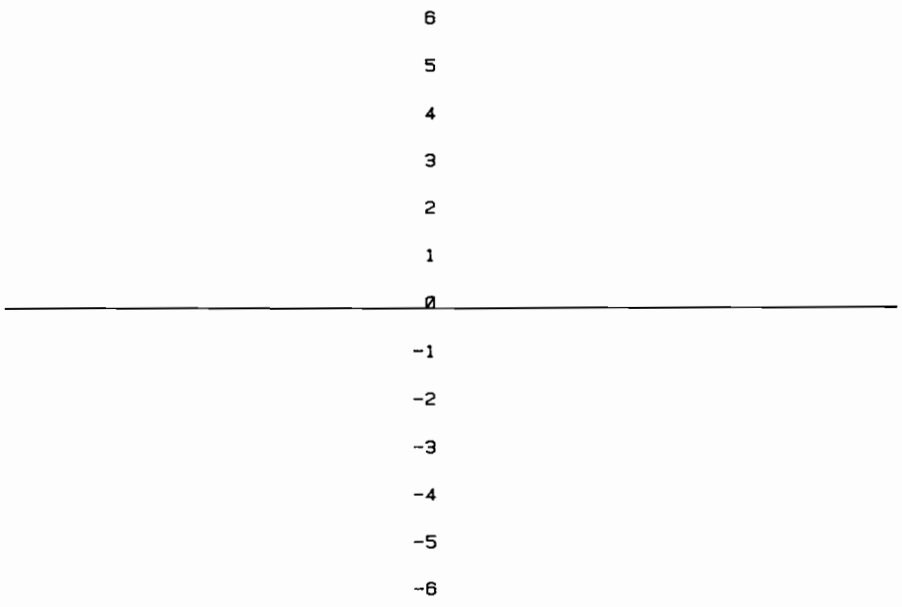
```
fxd 0
xax 2,1,-10,10,1
yax 3,2,-6,6,1
```

Note that to specify labels in the statement, the start and end point parameters must also be specified.



These statements draw the following axes:

```
fxd 0
xax 0,0,-8,8,1
yax 0,1,-6,6,-1
```

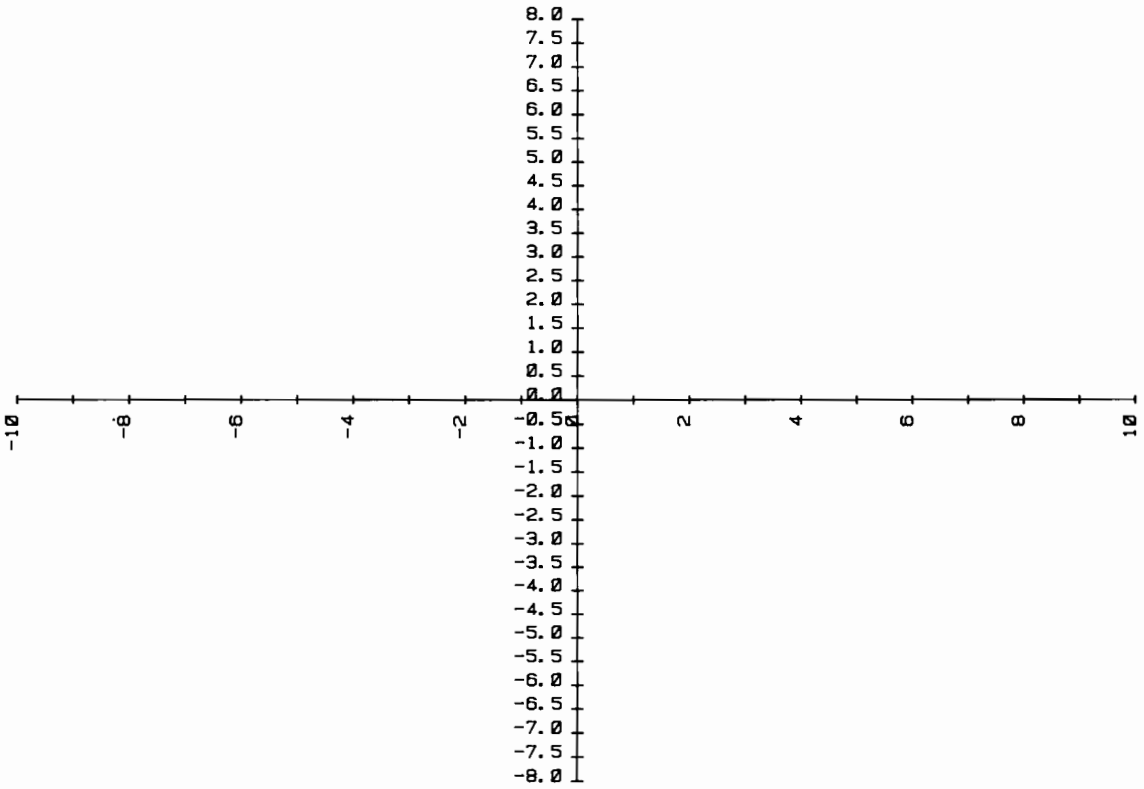


Since the X axis is drawn without tic marks, no labels were drawn even though they were specified. Labels cannot be lettered if tic marks are not specified.

The yax statement specifies a negative number-of-tics/label parameter which results in the labels being lettered without the axis and tic marks being drawn.

The following statements draw, tic mark and label the X and Y axes as shown.

```
fxd 0
xax 0,1,-10,10,2
fxd 1
yax 0,-.5,8,-8,1
```



The X axis is drawn from −10 to 10 with 1 unit tic marks and it is labeled every 2 units, beginning with the start point, in a fixed 0 number format.

The Y axis is drawn from 8 to −8 with .5 unit tic marks. (Note that normal tic marks are drawn since the tic interval is negative and the start point is greater than the end point). Labels are lettered at every tic mark in a fixed 1 number format.

The axes cross at the point (0,0).

NOTE

Axes are drawn with the currently specified line type and symbol mode character. Line type is explained later in this chapter and the symbol mode is explained in Chapter 5.

The Pen Statement

The pen (pen) statement raises the pen without moving it to a new location. This statement requires no parameters.

Syntax:

```
pen
```

Instructions to raise or lower the pen before or after movement can also be included as a parameter in the plot or iplot statements.

The Plot Statement

The plot (plt) statement moves the pen to the point specified by the X and Y coordinate parameters in the statement.

Syntax:

plt $X_{coordinate}$, $Y_{coordinate}$ [,pen control]

The plot statement requires that both the X and Y coordinates be specified. An optional pen control parameter raises or lowers the pen before or after movement.

If the point specified by a plot statement lies off the platen surface, a line is drawn to the platen limit and then the pen is raised. The pen remains raised until a point on the platen is specified.

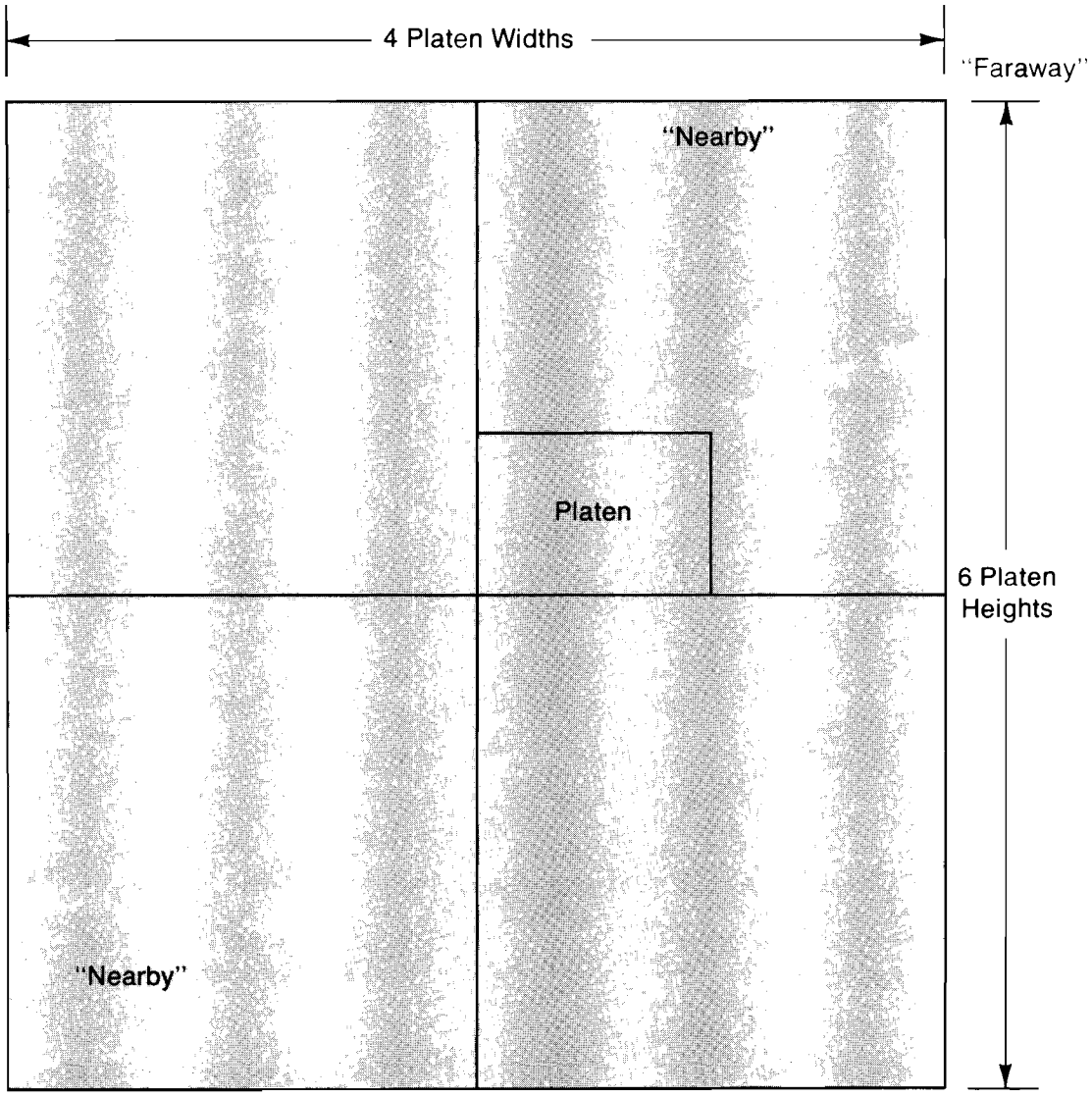
The optional pen control parameter can be an integer in the range −32768 thru 32767.

An odd, positive integer	The pen lifts before moving.
An odd, negative integer	The pen lifts after moving.
An even, positive integer	The pen lowers before moving.
An even, negative integer	The pen lowers after moving.
0	No change.
No parameters	The pen remains in its present position, moves to the point specified, and lowers or remains down.

NOTE

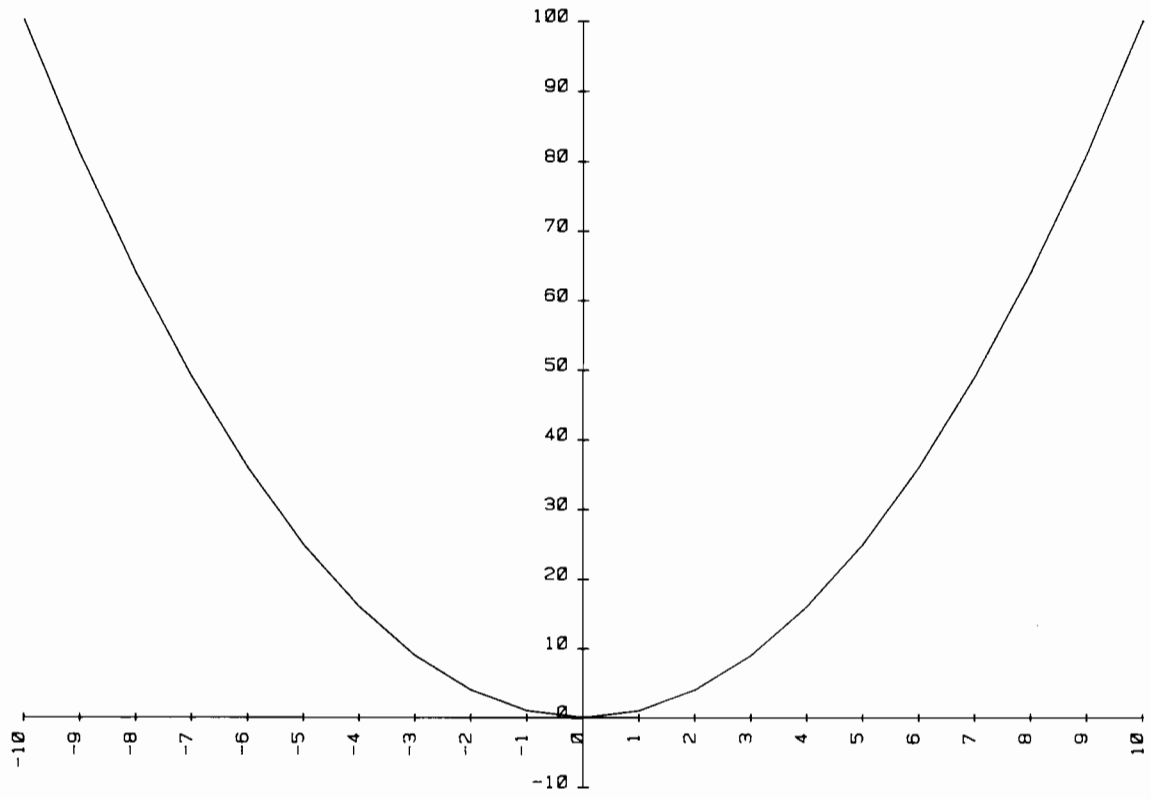
A pen control parameter of 0 or a positive integer should be used with all plot statements executed in interupt service routines (see the Extended I/O Programming Manual for details concerning interrupts).

If the point lies off the platen but is within the 'nearby' area (shown below), the out-of-limit light will turn on. If the point lies in the 'faraway' area, the out-of-limit light will blink.



The following example program plots values of the function $Y = X^2$.

```
0: pclr
1: scl -10,10,-
 10,100
2: fxd 0
3: xax 0,1,-10,
 10,1
4: yax 0,10,-10,
 100,1
5: -10→X
6: plt X,X↑2;if
 (X+1→X)<=10;
 jmp 0
7: pen
8: end
```



Plot of $y = x^2$

The Pen Select Statement

The pen select (pen#) statement provides the capability of programmed pen selection.

Syntax:

pen# [pen-position number]

When the pen# statement is executed, the pen arm raises the pen it is currently holding (if any) and returns it to an empty pen-storage position. If a valid pen-position number is specified (1 thru 4), the pen in that position is taken and the pen arm returns to its last location on the platen.

A parameter value of 0 or no parameter directs the pen arm to return the pen it is currently using to an empty storage position without taking a new pen.

If the specified pen position is empty or if all of the pen positions are full and there is a pen in the arm, then no operation occurs.

The following example plots three functions on the same plot with each function a different color.

```
0: pclr;fxd 0
1: scl -10,10,-
 100,100
2: pen# 1;xax 0,
 1,-10,10,1
3: yax 0,10,-
 100,100,1
4: pen# 2;-10→X
5: plt X,X↑2;if
 (X+1→X)<=10;
 jmp 0
6: pen# 3;-10→X;
 pen
7: plt X,10*X;
 if (X+1→X)<=10;
 jmp 0
8: pen# 4;-10→X;
 pen
9: plt X,-10X;
 if (X+1→X)<=10;
 jmp 0
10: pen# ;plt
 10,100,1
11: end
```

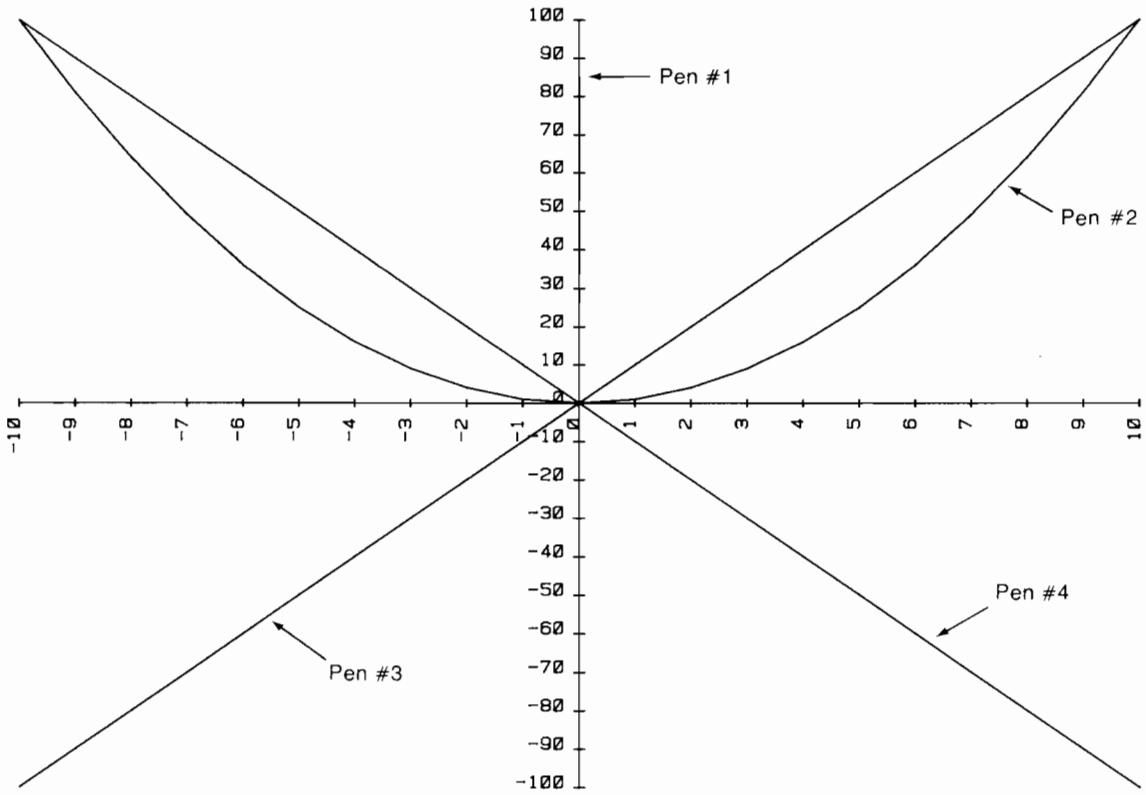
The axes are drawn and labeled in black (pen#1)

The function ($Y = X^2$) is plotted in red (pen#2)

The function Y = 10X is plotted in green (pen#3)

The function Y = −10X is plotted in blue (pen#4)

The pen is put away.



Pen Select Example Plot

The Offset Statement

The offset (ofs) statement moves the origin (point 0,0) from its present location to a new position specified by the X and Y increment values in the statement.

Syntax:

ofs X increment, Y increment

The X increment specifies the number of horizontal scale-statement units that the origin is to be moved.

The Y increment specifies the number of vertical scale-statement units that the origin is to be moved.

The signs of the increment-parameters specify the direction that the origin moves as follows:

A positive parameter moves the origin in a positive direction as defined by the current scale statement.

A negative parameter moves the origin in a negative direction as defined by the current scale statement.

Here is an example that uses the offset statement to make two separate plots on the same sheet of paper.

```
0: pclr;scl -9π,
 9π,-1,1
1: rad;-4π→X
2: ofs -4.5π,0
3: pen# 1;fxd 2;
 xax 0,.5π,-4π,
 4π,2
4: fxd 1;yax 0,
 .1,-1,1,2
5: pen# 2;plt X,
 sin(X);if (X+π/
 20→X)<=4π;jmp 0
6: ofs 9π,0;-
 4π→X
7: pen# 3;fxd 2;
 xax 0,.5π,-4π,
 4π,2
8: fxd 1;yax 0,
 .1,-1,1,2
9: pen# 4;plt X,
 cos(X);if (X+π/
 20→X)<=4π;jmp 0
10: pen# ;end
```

Sets the scale large enough for both plots.

The offset statement moves the origin from the center of the page, 4.5π units to the left.

Draws the X axis and the Y axis at this origin.

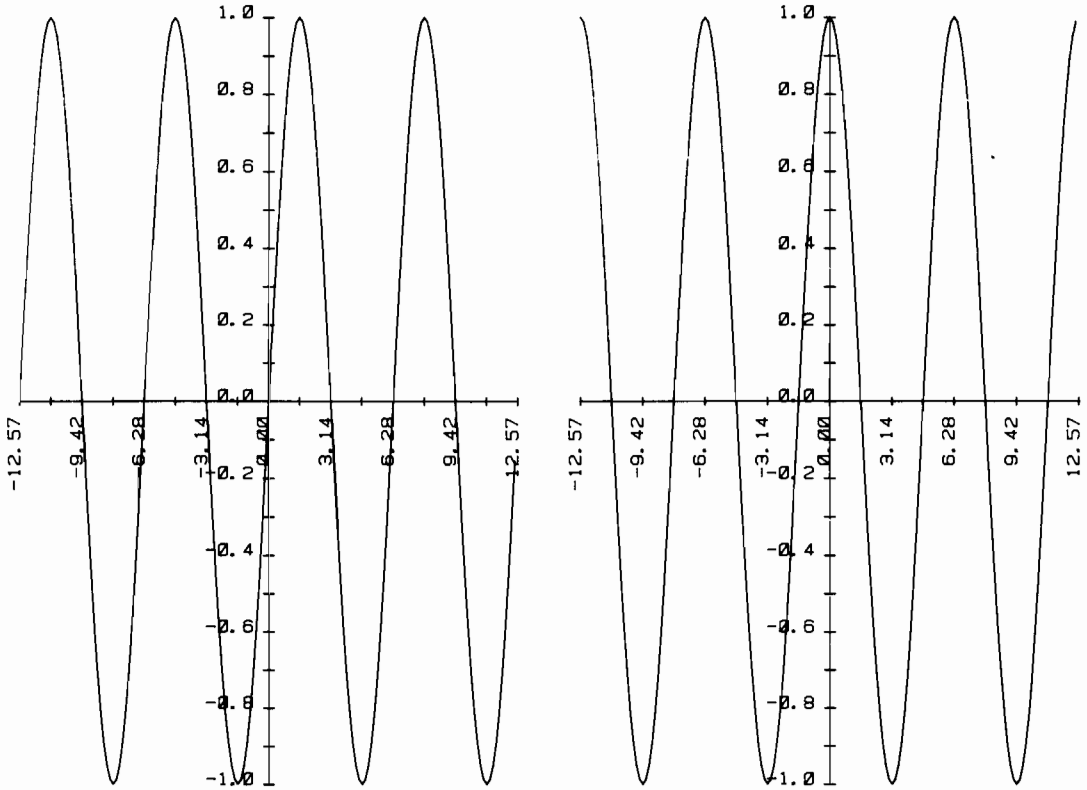
Plots sin X from -4π to 4π.

The offset statement moves the origin 9π units horizontally and 0 units vertically.

Draws an X axis and a Y axis at the new origin.

Plots cos X from -4π to 4π.

Replaces the pen.



Offset Plotting Example

The Incremental Plot Statement

The incremental plot (`iplt`) statement moves the pen from its current location to the new location specified by the X and Y parameters.

Syntax:

`iplt` $X_{increment}$, $Y_{increment}$ [,pen control]

The X increment parameter specifies the number of scale-statement units that the pen is to move horizontally.

The Y increment specifies the number of scale-statement units that the pen is to move vertically.

The signs of the increment parameters determine the relative direction that the pen moves as follows:

A positive value moves the pen in a positive direction as defined by the current scale statement.

A negative value moves the pen in a negative direction.

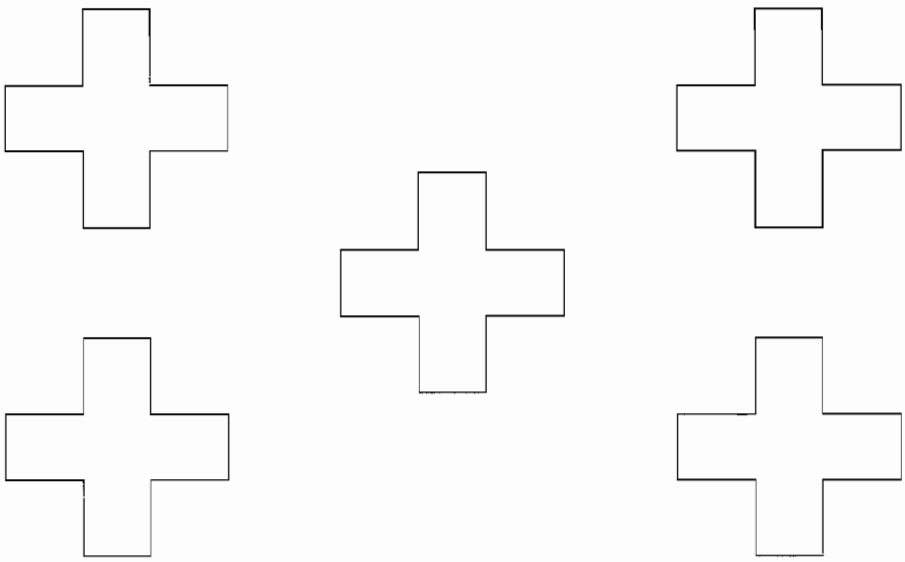
The optional pen control parameter is the same as that used with the plot statement.

An odd, positive integer	The pen lifts before moving.
An odd, negative integer	The pen lifts after moving.
An even, positive integer	The pen lowers before moving.
An even, negative integer	The pen lowers after moving.
0	No change.
No parameter	The pen remains in its present position, moves to the point specified, and lowers or remains down.

The following example uses iplot statements to draw crosses at five different locations. The iplot statements are programmed in a subroutine and the origin for each cross is located by an offset statement. Each cross is drawn in the color specified by the pen# statements.

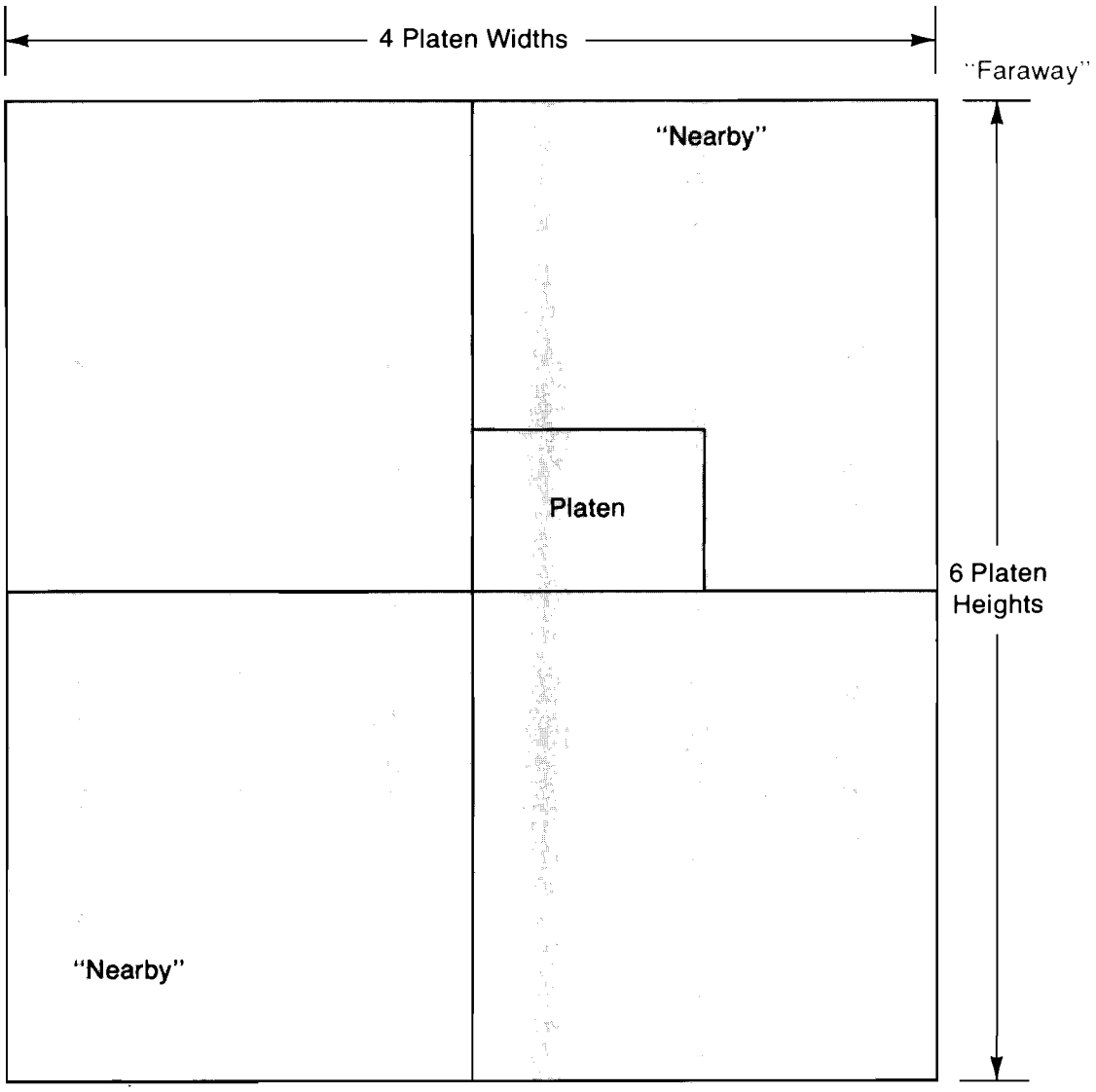
```
0: pclrisc1 0,
 100,0,70
1: ofs 20,20;
 pen# 1;gsb 7
2: ofs 0,30;pen#
  2;gsb 7
3: ofs 30,-15;
 pen# 3;gsb 7
4: ofs 30,15;
 pen# 4;gsb 7
5: ofs 0,-30;
 pen# 2;gsb 7
6: pen# ;end
```

```
7: plt -3,3,1
8: iplt 0,7,2
9: iplt 6,0
10: iplt 0,-7
11: iplt 7,0
12: iplt 0,-6
13: iplt -7,0
14: iplt 0,-7
15: iplt -6,0
16: iplt 0,7
17: iplt -7,0
18: iplt 0,6
19: iplt 7,0,-1
20: ret
```



Incremental Plot Example

If an iplot statement specifies a point off the platen, the pen draws a line to the limit of the platen and stops. If the point lies off the platen in the "nearby" area (shown next), the out-of-limit light turns on. The plotter recognizes iplot statements in this area. If the point specified lies in the "faraway" area (shown below), the out-of-limit light flashes and the plotter does not recognize iplot statements. A regular plot (plt) statement must be used to specify a point that is either on the platen or in the 'nearby' area before any further iplot statements are recognized by the plotter.



The Line Type Statement

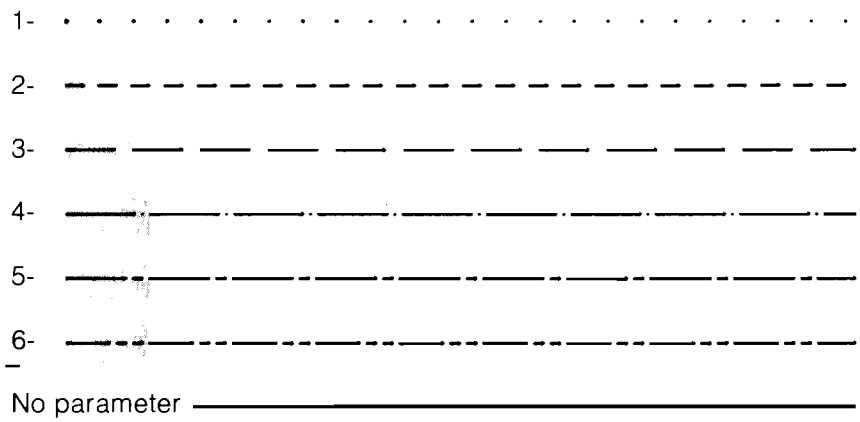
The line type (`line`) statement specifies the type of line that will be used with plt, iplt, xax and yax statements.

Syntax:

`line` [pattern number [, pattern length]]

Shown below are the line patterns and their pattern numbers.

0-specifies dots only at the points that are plotted.



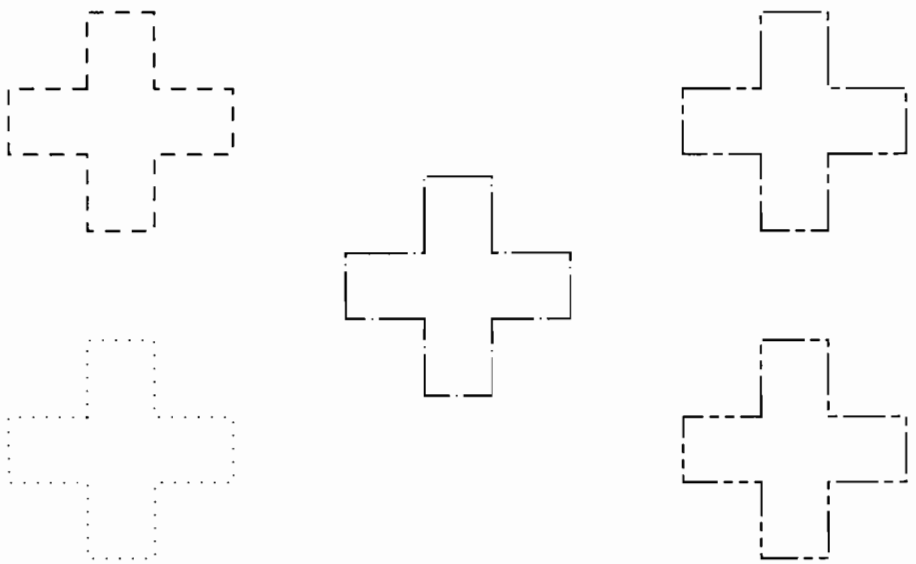
The shaded portion of each of the line patterns above is one complete segment of the pattern.

The optional pattern length parameter specifies the length of one complete segment of the pattern and is expressed as a percentage of the diagonal distance between the scaling points, P1 and P2. If a pattern length parameter is not specified, a length of 4% is used. The range of the pattern length parameter is from 0 thru 127.99994999.

This example plots 5 crosses with each cross plotted in a different line type.

```
0: pclr;scl 0,
 100,0,70
1: ofs 20,20;
 line 1,1;esb 7
2: ofs 0,30;line
  2,2;esb 7
3: ofs 30,-15;
 line 4,6;esb 7
4: ofs 30,15;
 line 5;esb 7
5: ofs 0,-30;
 line 6;esb 7
6: pen# ;end
```

```
7: plt -3,3,1
8: iplt 0,7,2
9: iplt 6,0
10: iplt 0,-7
11: iplt 7,0
12: iplt 0,-6
13: iplt -7,0
14: iplt 0,-7
15: iplt -6,0
16: iplt 0,7
17: iplt -7,0
18: iplt 0,6
19: iplt 7,0,-1
20: ret
```



Line Type Example Plot

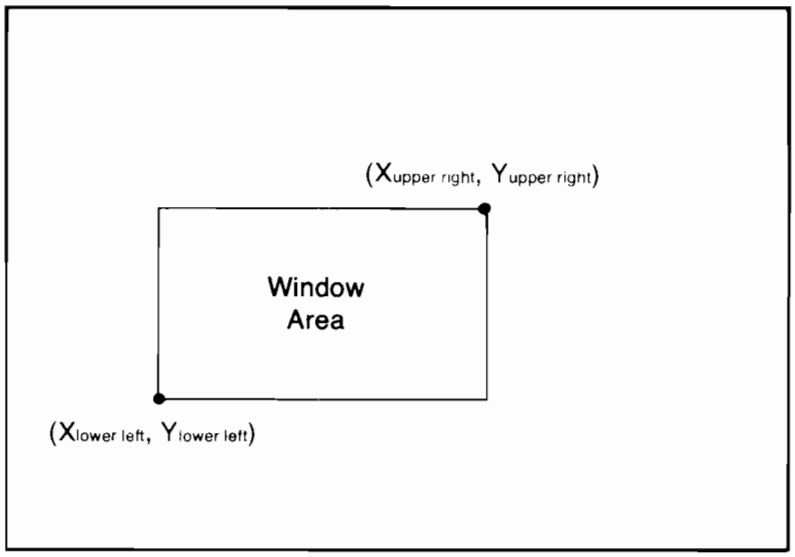
The Limit Statement

The limit (lim) statement restricts programmed pen motion to a specific rectangular area on the platen. This area is called the 'window'.

Syntax:

lim [$X_{lower\ left}$, $X_{upper\ right}$, $Y_{lower\ left}$, $Y_{upper\ right}$]

The four parameters specify, in the current scale-statement units, the X and Y coordinates of the lower left and the upper right corners of the window area as shown below.

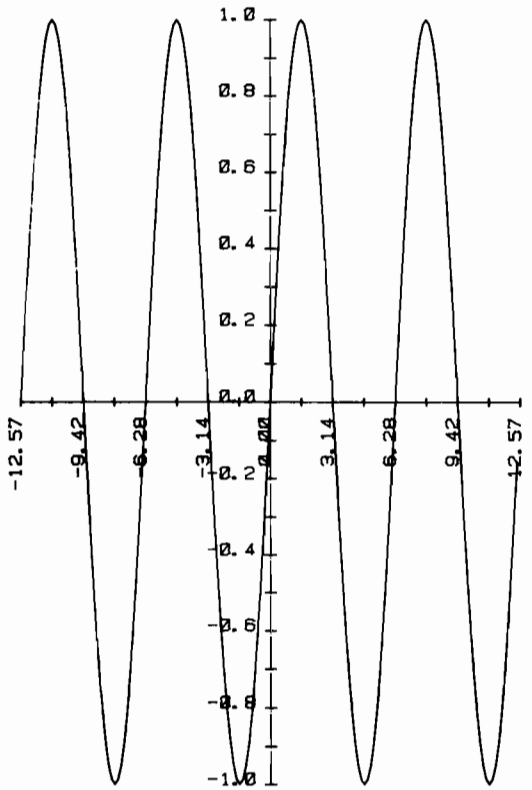


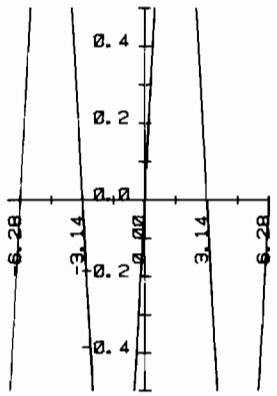
If a limit statement is not executed, or if a limit statement without parameters is executed, the window is automatically set at the mechanical limits of the plotter.

The limit statement can be used to emphasize a specific portion of a plot. The following example plots the function sin (X) from -4π to 4π and -1 to 1 on the left side of the paper. An offset statement is then used to move the plot origin to the right side of the paper. The plot of sin (X) is repeated except that a window is specified by a limit statement to restrict the plot so that only the points contained in the rectangle -2.2π to 2π and $-.5$ to .5 are plotted.

```
0: pclr;scl -9π,
 9π,-1,1
1: rad;-4π→X
2: ofs -4.5π,0
3: pen# 1;fxd 2;
 xax 0,.5π,-4π,
 4π,2
4: fxd 1;yax 0,
 .1,-1,1,2
5: pen# 2;plt X,
 sin(X);if (X+π/
 20→X)<=4π;jmp 0
6: ofs 9π,0;-
 4π→X
7: lim -2.2π,2π,
 -.5,.5
8: pen# 3;fxd 2;
 xax 0,.5π,-4π,
 4π,2
9: fxd 1;yax 0,
 .1,-1,1,2
10: pen# 4;plt
 X,sin(X);if (X+
 π/20→X)<=4π;
 jmp 0
11: pen# ;end
```

lim statement sets the window for the sin (X) plot.





Chapter 3
Lettering

This chapter describes the statements that enable you to letter alphanumeric characters and symbols with the plotter. You can also specify the size and width of the characters (relative to the scaling points), as well as the direction in which the characters are lettered.

The Label Statement

The label (`lbl`) statement enables you to letter characters on the plotter. This statement is used like a print (`prt`) statement to letter expressions, text or string variables* on the plotter.

Syntax:

`lbl` any combination of 'text', expressions or string variables*.

Text is specified in a label statement by enclosing it in quotes. Here is an example of text in a label statement.

```
lbl "9872A Plotter"
```

Here is an example that letters expressions.

```
lbl X,X+1,X+2
```

* A String Variable ROM is required to letter strings.

The value assigned to X will be lettered in the current number format (fixed or float). The value resulting from the expression X+1 is lettered next, followed by the value resulting from the expression X+2. The digits in these expressions are lettered as a string of characters. This requires you to add any spaces needed to fit the numbers into the context of the item being lettered.

For example, this statement letters the same expressions above with four spaces between each of the values.

```
lbl X," ",X+1," ",X+2," "
```

This example letters the characters contained in the string variable A$ (the String Variable ROM is required).

```
lbl A$
```

Before using the label statement, the pen should be moved to the location where labeling is to begin by using one of the plot statements (cplot, iplot or plot) or by using the four direction controls on the plotter front panel. This point will be the lower-left corner of the first character. After lettering a character, the pen stops at the lower-left corner of the next character space.

Character Sets

The plotter has five character sets available. The plotter, when initialized, automatically sets both the "standard" set and "alternate" set to the ANSI*-ASCII character set (Set 0). The `pclr` statement, however, designates the 9825 character set (Set 1) as the standard set. Refer to "Assigning Character Sets" in Chapter 5 for a complete listing of the characters in each character set and the statements used to change the character set designated as either standard or alternate.

* American National Standard Institute

The Character Size Statement

The csize (csiz) statement specifies the size and shape of the characters and symbols as well as the direction in which they are to be lettered.

Syntax:

csiz [height [, aspect ratio [, paper ratio [, angle of rotation]]]]

The csize statement can specify up to four parameters. If any of the parameters are omitted, a specific default value for the parameter is assummed. Note that when a parameter is omitted, the parameter listed to its right must be omitted as well.

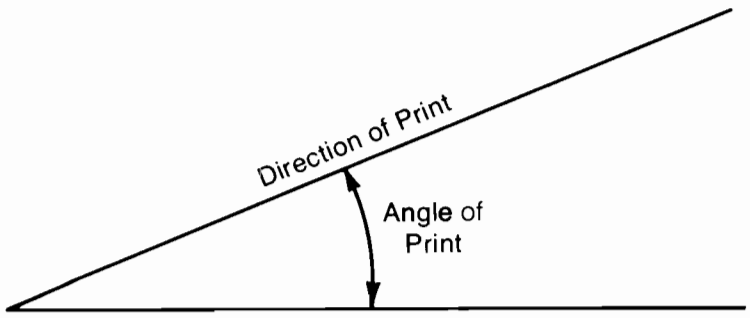
Here is a description of each of the four parameters:

The height parameter specifies the height of the characters as a percent of the scale height defined by the scaling points, P1 and P2. This parameter must be within the range of 0 thru 127.99994999.

The aspect ratio parameter specifies the ratio of the height of a character to its width. For example, an aspect ratio of 2 specifies characters that are twice as high as they are wide. An aspect ratio of 1 specifies square characters.

The paper ratio parameter specifies the ratio of the height of the scaling area to its width. The scaling area is defined by the scaling points, P1 and P2. For example, a 10 inch high by 15 inch wide scaling area has a paper ratio of 10/15 or 2/3.

The angle of rotation parameter specifies the direction in which the characters are printed. The direction is expressed as the angle (measured counter-clockwise) between the line of print and the X axis, as shown below.



This parameter is expressed in the current angular units (degrees, radians or grads).

The default values for the four parameters are as follows:

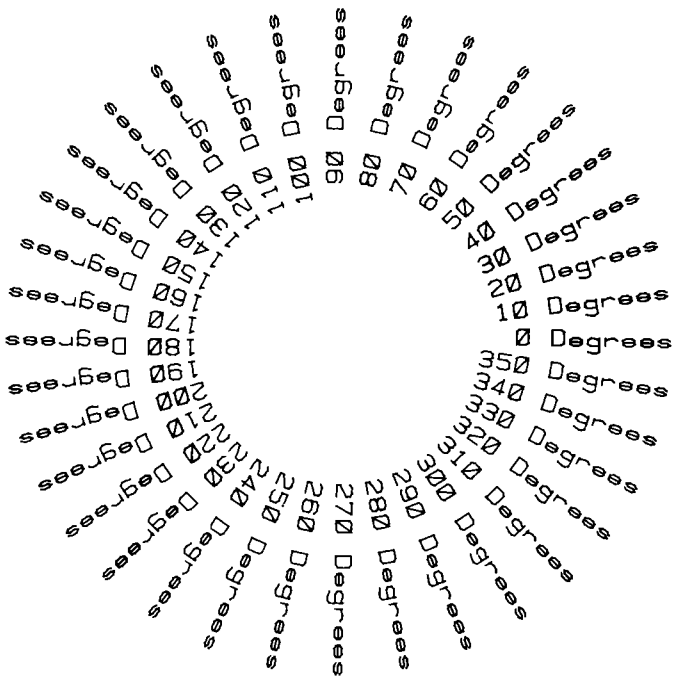
Height	1.5%
Aspect Ratio	2
Paper Ratio	1
Angle of Rotation	0

Executing a csize statement without parameters, sets the default values. These values are also set when the plotter is initialized or cleared (pclr).

The following example program uses the csize instruction (line 3) to specify the character dimensions and shape and to rotate the lettering direction through an entire circle in 10 degree intervals. The plot statement (line 2) centers the pen for each printing sequence.

Lines 4 and 5 add extra spaces (if needed) to right justify the values that precede 'DEGREES'. This example assumes that the scaling area is set for 8 inch high by 10 inch wide paper.

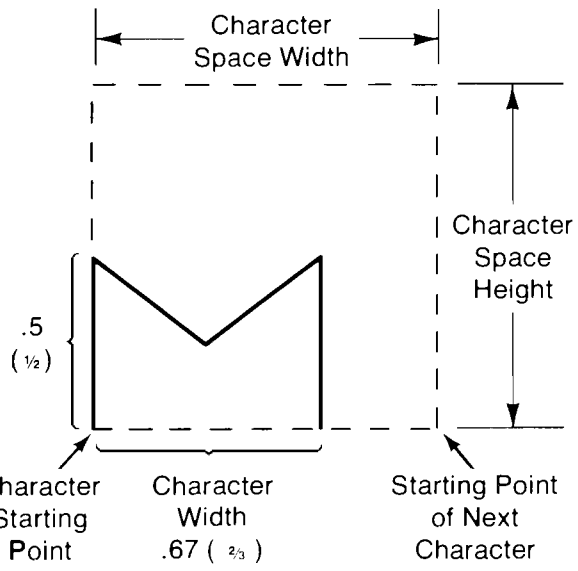
```
0: pclr;0→R→X;
 deg;fxd 0
1: scl 0,30,0,24
2: csiz 2,1.5,8/
 10,R
3: plt 15,12,1
4: if R<10;lbl
 " "
5: if R<99;lbl
 " "
6: lbl "
 ",R," Degrees"
7: if (R+10→R)<3
 60;jmp -5
8: plt 30,20,1
9: end
```



Angle of Rotation Plot

Spacing Between Characters

In the diagram at the right, you can see the relative position of a character, in this case M, within the character-space field. The character-space field is set indirectly by the csize statement, since the character space height is twice the character's height and the character space width is 1 1/2 times the character width. The space above and beside a character becomes the spacing between lines and characters.



When you specify the height of a character in a csize statement, however, you should specify the character height and not the height of the character-space field.

The Character Plot Statement

The character plot (cplt) statement moves the pen the specified number of character-space fields. If no parameters are specified, a cplt statement performs a carriage return and line feed operation by moving one character-space height down and returning to the margin defined by the the last point that the pen was sent to by either a plot statement, iplot statement, or the plotter front-panel controls. If a csize statement is executed after the pen is positioned by a plot, iplot or the front panel controls, the location of the pen when the csize statement is executed becomes the margin that the pen returns to when a cplt is executed without paramters.

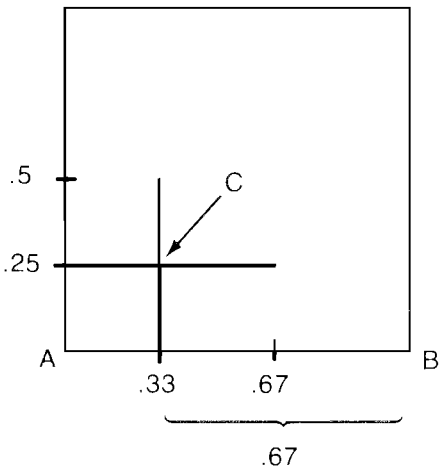
Syntax:

cplt [# of character-space widths, # of character-space heights]

When parameters are specified, the cplt statement moves the pen the specified number of character-space widths to the right (a positive value) or to the left (a negative value) and the number of character-space heights up (a positive value) or down (a negative value). The pen's position (raised or lowered) does not change when a cplot statement is executed. The parameters must be within the range of ±127.9994999.

The following example plots the function Y = X + 3 and labels each plotted point with a +.

The diagram at the right shows the character spacing around the symbol +. The pen begins to draw the symbol at point A and ends at point B, ready to draw another character.

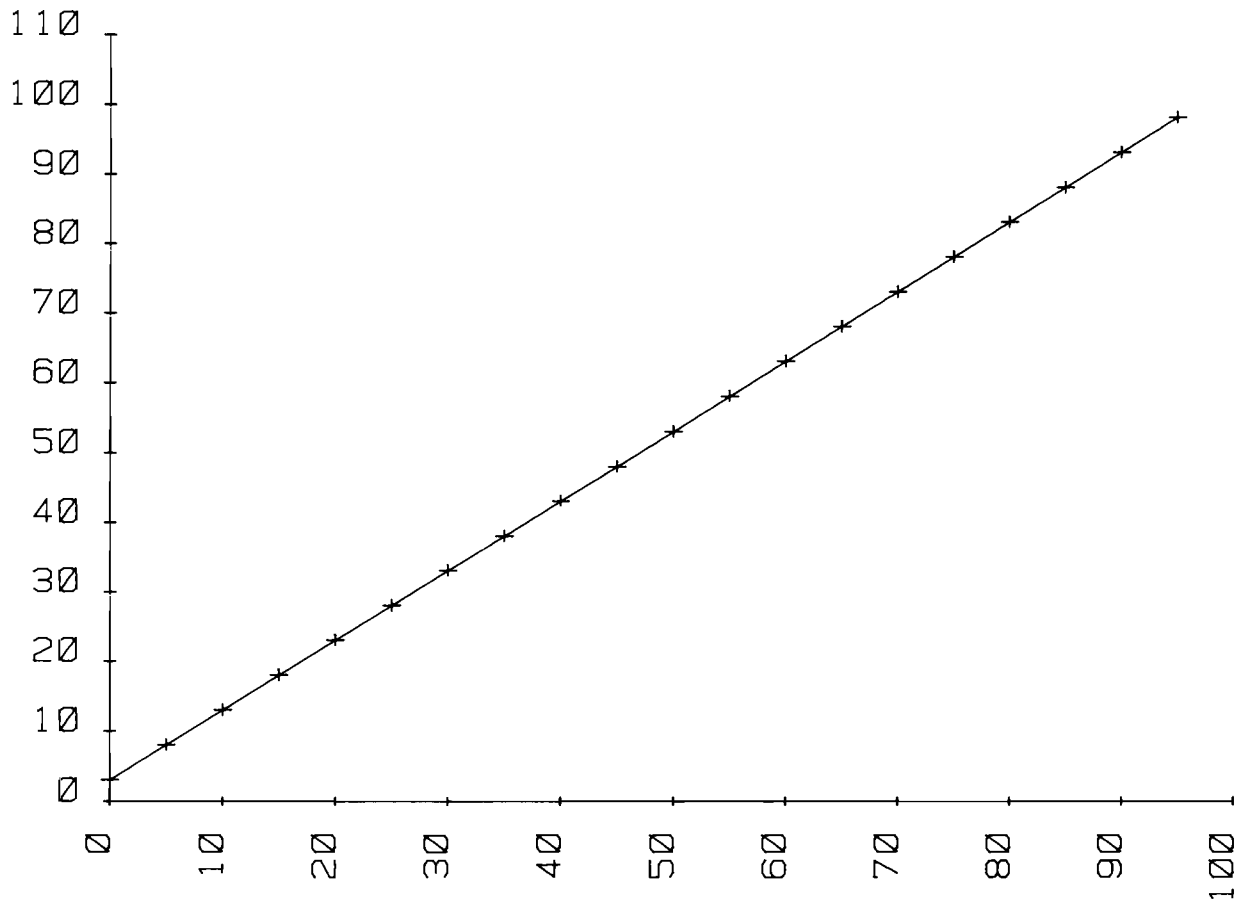


To center the symbol on point C, which represents a plotted point, the pen must be moved to point A. This can be done by executing a cplot statement specifying the parameters -.33, -.25. After the symbol is drawn, the pen must be returned from point B to point C to continue plotting the next point. This can be done by executing a cplot statement specifiying the parameters -.67, .25.

Here is the printout of the program used to plot this example. The value 2 is used in the plot statement in line 5 to lower the pen before continuing the plot. The pen statement raises the pen before the cplt statement in line 6 is executed. Line 6 moves the pen to the lower left corner of the character space where the + is drawn and line 8 moves the pen back to the center point to continue on with the plot.

```
0: pclr:scl 0,
 100,0,110
1: fxd 0:csiz 3
2: xax 0,10,0,
 100,1
3: yax 0,10,0,
 110,1
4: plt 0→X,X+3,1
5: "loop":plt X,
 X+3,2:pen
```

```
6: cplt -.33,-
 .25
7: lbl "+"
8: cplt -.67,.25
9: if (X+5→X)<10
 0:goto "loop"
10: end
```



Y = X + 3 Plotted with +'s

The Plotter Typewriter Statement

The plotter typewiter statement sets a manual lettering mode.

Syntax:

```
ptyp
```

After the ptyp statement is executed (either in a program, in the live keyboard mode or from the keyboard), you type the desired characters on the calculator keyboard and they are lettered by the plotter. To end the ptyp mode, press the [STOP] key once.

The pen can be positioned by plot, iplot or cplot statements before the ptyp mode is established. Once the ptyp mode is established, the four calculator display keys or the four pen movement keys on the plotter's front panel can be used to position the pen for lettering.

The following keys perform these functions while the ptype mode:

Space	[→]
Backspace	[←]
Line Feed	[↓]
Inverse Line Feed	[↑]
Carriage Return	[STORE]

Character Sets

The plotter, when initialized, automatically specifies the ANSI-ASCII character set (Set 0) as both the "standard" set and the "alternate" set. The `pclr` statement, however, designates the 9825 character set (Set 1) as the standard set and Set 0 as the alternate set. The following keys are used to switch from the standard character set to the alternate set and back.

Select the Standard Set	SHIFT f_2
Select the Alternate Set	SHIFT f_3

Refer to "Character Sets" in Chapter 5 for the description of the available character sets and the statements used to designate which set will be the standard set and which will be the alternate set.

When a statement is executed from a program or from the live keyboard, the program will stop execution as long as the typewriter mode is set. When the mode is ended by pressing STOP, the program will continue from where it was interrupted by the statement. Since the statement leaves the pen raised, it is best not to execute a ptyp statement while a plot is in progress.

Chapter 4
Digitizing

The plotter can be used as a digitizer as well as a plotter since digitizing is basically the inverse of plotting. Instead of sending the coordinates of a point to the plotter and the plotter then moving the pen to that point, you move the pen to a point on the plotter (typically by using the front panel controls) and the plotter sends the coordinates of that point to the calculator.

The Digitize Statement

Syntax:

dig Variable #1, Variable #2 [,Variable #3]

The digitize statement enables the digitizer mode. When the digitizer mode is set, the 'ENTER' light on the plotter is lit. You can use the plotter pen-movement controls to position the pen at a point on the platen. Now, pressing ENTER on the plotter front panel sends the coordinates, in scale-statement units, to the calculator where they are assigned to the variables specified by the digitize statement. The coordinate values are assigned to the variables in the following order:

X coordinate value	→	Variable #1
Y coordinate value	→	Variable #2
Pen condition (0 = up, 1 = down)	→	Variable #3 (If specified)

To cancel a digitize statement without entering coordinate values, press the STOP key. If the digitize statement is executed from a program, the STOP key will also stop the program at the end of the line containing the digitize statement.

A special digitizing sight is provided with the plotter which allows you to visually position the pen directly over the point to be digitized. The sight is loaded and stored like a pen.

The following example draws a rectangular figure and then allows you to digitize points around it by moving the pen, via the pen movemement controls, to each of the figure's corners. At each corner, you press ENTER to send the coordinates of that corner to the calculator. The program uses the coordinates to calculate the line length or perimeter of the figure.

```
0: pclr;scl 0,
 20,0,16
1: plt 5,4,-1;
 iplt 0,8,2;iplt
  10,0;iplt 0,-
 8;iplt -10,0,-1
2: 0→X→Y→A→B→C→D
 →P
3: dsp "digitize
  the first poin
 t, please.";
 dig X,Y
4: X→A→C;Y→B→D
5: dsp "Enter
 the next point,
  please.";dig
 X,Y
6: P+√((X-A)↑2+
 (Y-B)↑2)→P
7: X→A;Y→B
8: if √((X-C)↑2+
 (Y-D)↑2)<.1;
 jmp 2
9: jmp -4
10: prt "Perimet
 er = ",P
11: end
```

This portion of the program scales the plot and uses iplot statements to draw a rectangular figure.

The first digitize statement enables you to enter the coordinates of the first point.

The next digitize statement enables you to enter the rest of the coordinates until the first point is reached again.
The distance formula is used to calculate the length of each digitized line segment and the lengths are summed in P.

Chapter 5

Additional Plotter Control

In addition to the statements described in the previous chapters, the plotter has the following additional capabilities:

Pen Control Commands	Character Control Commands
Plot Control Commands	Plotter Configuration and Status Commands

The additional control commands are sent to the plotter as ASCII coded characters (data messages) via write (wrt) statements. Refer to the General I/O ROM Programming Manual for details concerning write and format statements.

The wrt statement without a format statement reference (as used in the examples in this chapter) automatically references format 0. Format 0, unless it has been redefined in a format statement, selects the default free field output format. All of the plotter instructions that are sent in quote fields, typically use the free field format. Therefore, it is recommended that format 0 (fmt 0 or fmt) be reserved, if possible, for use with wrt statements that send character instructions to the plotter.

Some of the instructions that send parameter values to the plotter can send the values from wrt statements in the form of variables rather than as numeric characters within quotes. When variables are used to send parameter values, an appropriate numeric format (fxd) statement should be executed prior to sending the values to insure that integer parameters (fxd 0) or decimal parameters (fxd 3) are sent properly from the free field format. The following tables list the instructions that use parameters, the parameters numeric format (integer or decimal) and the fxd statement that should be executed prior to the wrt statement containing the instructions.

Instruction	Parameter Format	Fxd Statement
VS(page 50)	Integer	fxd0
TL(page 53)	Decimal	fxd3
IP(page 54)	Integer	fxd0
SL(page 56)	Decimal	fxd3
UC(page 60)	Integer	fxd0

Pen Control Commands

The Automatic Pen Pickup Command

wrt select code ; "AP"

The automatic pen pickup command, AP, causes the plotter to automatically raise the pen whenever it has been down without motion for 65 seconds. This condition is set automatically when the plotter is initialized.

Sending the characters "AP0" to the plotter will disable the automatic pen pickup.

The Pen Down Command

wrt select code ; "PD"

The pen down command, PD, lowers the pen to the paper.

The Select Pen Velocity Command

wrt select code, "VS 1 thru 36 [, Pen #]"

The select pen velocity command specifies the pen speed, in centimeters/second, for plotting and lettering operations. The velocity can be any value between 1 and 36. If the optional pen number (1 thru 4) is specified, the speed will apply only to that pen. If a pen number is not specified, the speed applies to all pens.

Whenever the plotter is initialized, the pen velocity is set to 36 centimeters/second.

The Adaptive Pen Velocity Command

wrt select code ; "VA"

This command sets the plotter to an adaptive pen velocity mode. The plotter will adapt the pen speed, automatically, to approximate the rate that the calculator sends coordinate data to the plotter. This mode provides a smoother plot than the normal velocity mode when plotting coordinates that are generated by a relatively slow program routine (fewer than 15 coordinates/second).

The Normal Velocity Command

wrt select code ; "VN"

The normal velocity command cancels the adaptive velocity mode. The pen speed is now controlled by the current pen velocity command.

Plot Control Commands

The Symbol Mode Command

wrt select code ; "SM (character)"

The symbol mode command sets the symbol mode for use with plot, iplot, x axis and y axis statements. The plot, iplot, x axis and y axis statements function as described in Chapter 2 except that the specified character is drawn, centered on each plotted point or tic mark. The character is drawn according to the currently selected character set. If a character is not specified, the symbol mode is canceled. All of the ASCII characters from decimal 31 thru 127 can be specified except the following:

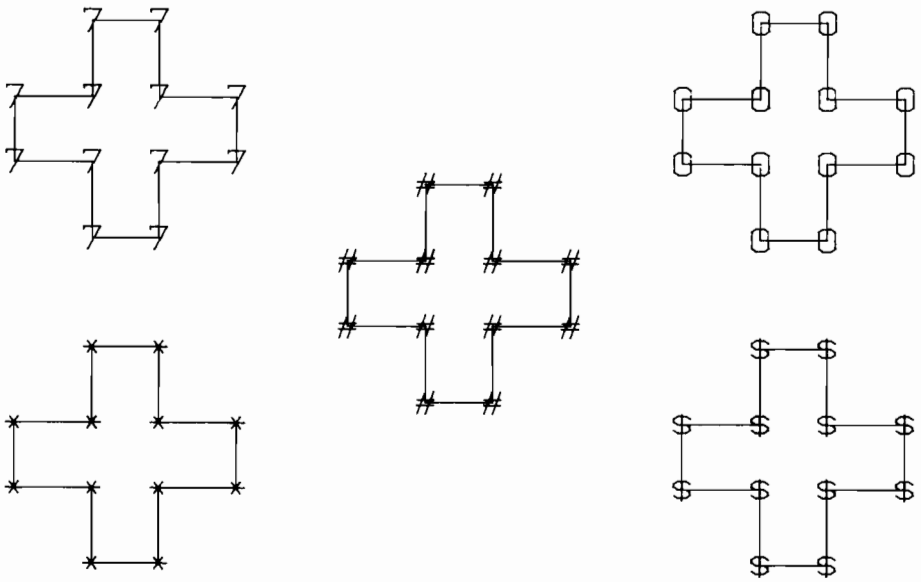
Set 0 Character	Decimal Value	Set 0 Character	Decimal Value
!	33	?	63
"	34	@	64
%	37	[	91
&	38	\	92
'	39	]	93
(	40	^	94
)	41	_	95
/	47	`	96
:	58	{	123
;	59	|	124
<	60	}	125
=	61	~	126
>	62		

The characters shown above are from Set0. Characters in other character sets that replace any of these are also not usable with the symbol mode.

The following example plots five crosses on the plotting area using iplot and offset statements. The symbol mode is used to specify a specific character to be drawn at each corner point for each of the crosses.

```
0: pclr;scl 0,
 100,0,70;csiz 3
1: ofs 20,20;
 wrt 705,"sm*";
 gsb 7
2: ofs 0,30;wrt
 705,"sm7";gsb 7
3: ofs 30,-15;
 wrt 705,"sm#";
 gsb 7
4: ofs 30,15;
 wrt 705,"sm0";
 gsb 7
5: ofs 0,-30;
 wrt 705,"sm$";
 gsb 7
6: pen# ;end
```

```
7: plt -3,3,1
8: iplt 0,7,2
9: iplt 6,0
10: iplt 0,-7
11: iplt 7,0
12: iplt 0,-6
13: iplt -7,0
14: iplt 0,-7
15: iplt -6,0
16: iplt 0,7
17: iplt -7,0
18: iplt 0,6
19: iplt 7,0,-1
20: ret
```



Symbol Mode Example Plot

The Tic Length Command

wrt select code : "TL [Up and Right Tic Length [,Down and Left Tic Length]]"

The tic length command specifies the length of the tic marks drawn by axis statements. The tic lengths are specified as a percentage of the horizontal and vertical distances between the scaling points, P1 and P2.

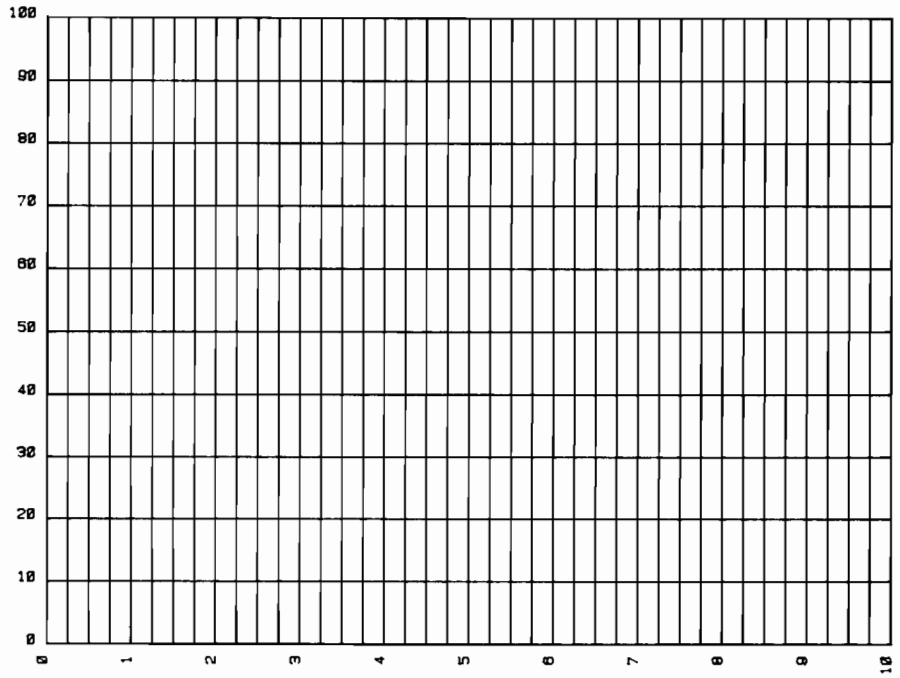
The up and right tic length determines the length of the upward portion of the tic marks drawn along the X axis and the right-side portion of the tic marks drawn along the Y axis. This value is specified as a percentage of the vertical scale length, $|Y_{P2} - Y_{P1}|$.

The down and left tic length determines the length of the downward portions of the tic marks drawn down along the X axis and the left-side portion of the tic marks drawn along the Y axis. The value is specified as a percentage of the horizontal scale length $|X_{P2} - X_{P1}|$.

The plotter, when initialized, automatically sets the tic length values to 0.5% of the scaling lengths ($|Y_{P2} - Y_{P1}|$ and $|X_{P2} - X_{P1}|$).

The program shown below uses the tic length command to draw a grid on the plotting area of a plot. Note that only the up and right tic length parameter is specified since only the area above the X axis and to the right of the Y axis is being used. Since the down and left tic length is not specified, the plotter uses a length of 0 (no tic marks).

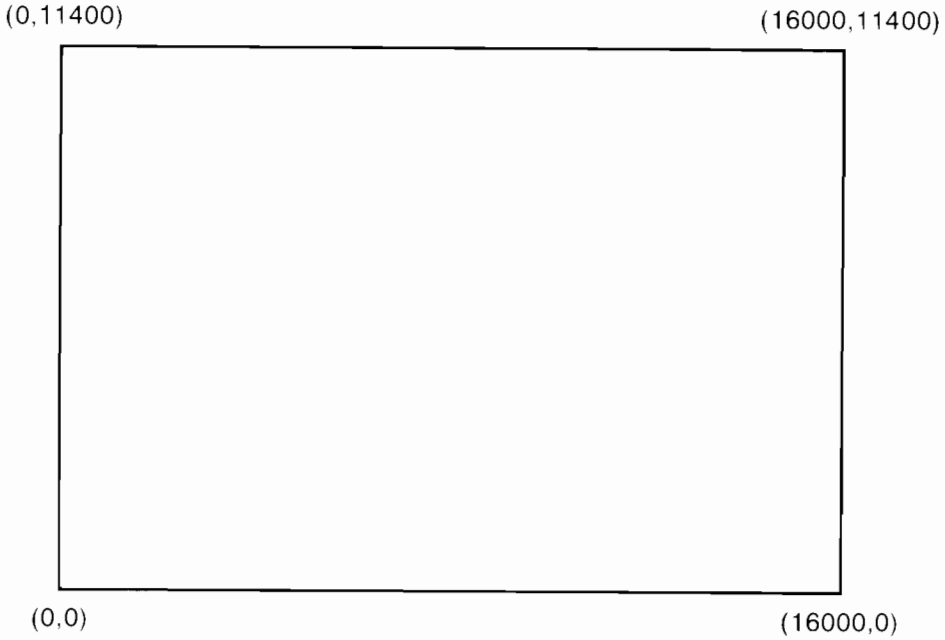
```
0: pclr;scl 0,
 10,0,100
1: wrt 705,"TL10
 0"
2: fxd 0;xax 0,
 .25,0,10,4
3: yax 0,10,0,
 100,1
```



Tic Length Example

Relocating The Scaling Points P1 and P2

The scaling points P1 and P2 can be positioned from program control as well as from the front panel controls. The coordinates of P1 (X_{P1} and Y_{P1}) and P2 (X_{P2} and Y_{P2}) are specified in absolute plotter scale units. The absolute plotter scale is shown below.



Absolute Platen Area Scale

When the plotter is initialized, P1 and P2 are set at the points P1 = (520, 380) and P2 = (15720, 10380).

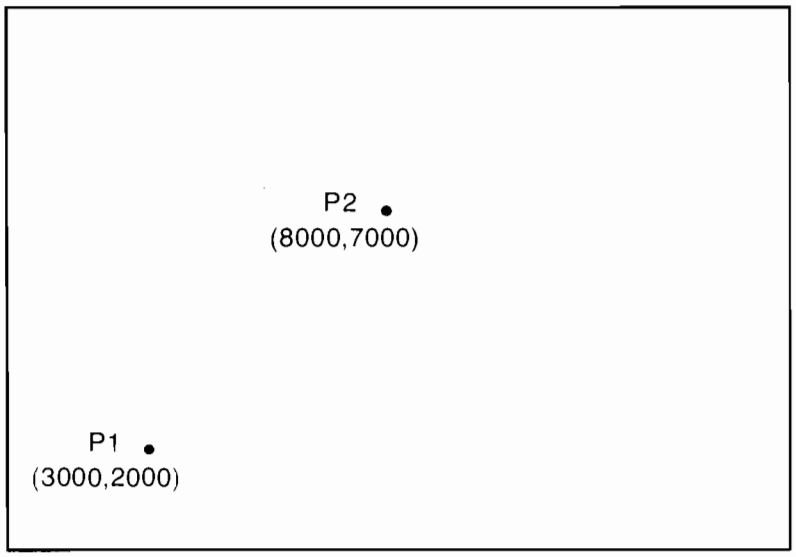
wrt select code; "IP X_{P1}, Y_{P1}, X_{P2}, Y_{P2}"

This command is used to relocate the scaling points P1 and P2. The new coordinates of P1 and P2 are specified in the order shown above. These coordinates must be in the absolute plotter-scale units.

For example, the statement below relocates the scaling points P1 and P2 to the positions shown in the next figure.

X_{P1} Y_{P1} X_{P2} Y_{P2}

```
wrt 705;"ip3000,2000,8000,7000"
```



Locating the Current Position of P1 and P2

```
wrt select code ; "OP"
```

```
red select code ; variable 1 ; variable 2 ; variable 3 ; variable 4
```

The write statement above commands the plotter to output the current coordinates (in absolute plotter-scale units) of the scaling points P1 and P2. The read statement (red) inputs the coordinates and assigns the values to the variables (any 4 variables can be used).

The plotter outputs the coordinates in the following order:

$$X_{P1},\ Y_{P1},\ X_{P2},\ Y_{P2}\ \text{CR LF}$$

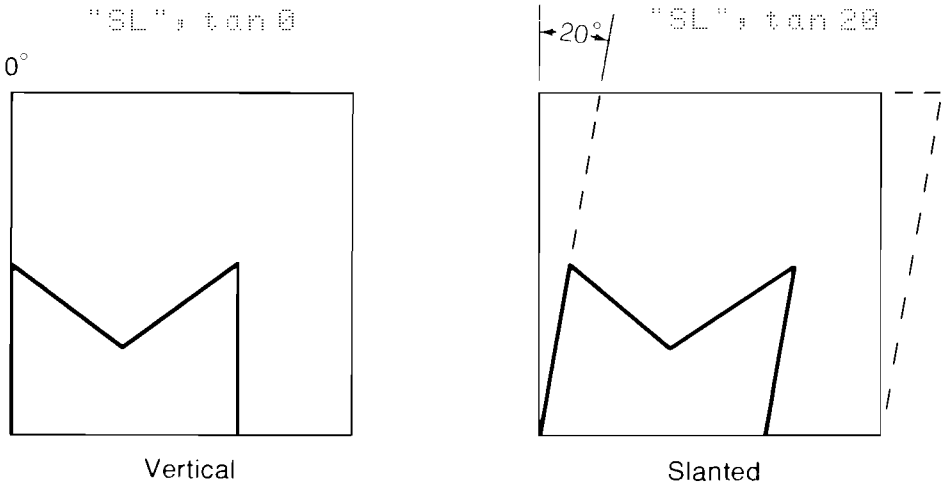
These statements are useful in determining the current locations of the scaling points as a reference for a command to relocate the points.

Character Control Commands

The Character Slant Command

```
wrt select code ; "SL", Tan θ
```

The character slant command specifies the slant with which characters are lettered. The angle θ specifies the slant as shown below:

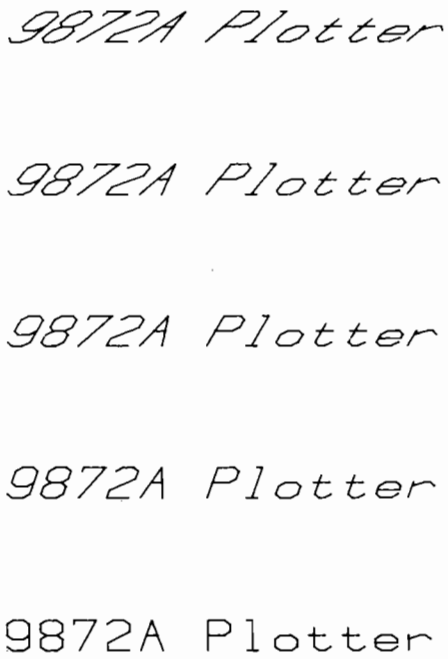


Vertical Slanted

Sending "SL" or "SL0" to the plotter defaults the character slant to verticle or 0°.

The following example letters the words "9872A Plotter" with four different character slants.

```
0: pclr;scl 0,
 10,0,10;csiz 4
1: plt 2,2;lbl
 "9872A Plotter"
2: wrt 705,"sl",
 tan(20)
3: plt 2,4,-1;
 lbl "9872A Plot
 ter"
4: wrt 705,"sl",
 tan(30)
5: plt 2,6,-1;
 lbl "9872A Plot
 ter"
6: wrt 705,"sl",
 tan(40)
7: plt 2,8,-1;
 lbl "9872A Plot
 ter"
8: wrt 705,"sl",
 tan(50)
9: plt 2,10,-1;
 lbl "9872A Plot
 ter"
10: end
```



Character Sets

The plotter has the capability of lettering with any of five designatable character sets. Each of the five character sets has identical characters with the exception of certain symbols.

Shown next are the characters contained in Set 1. These characters correspond to those on the calculator keyboard. They are shown in order (from left to right) of the decimal-equivalent value of their ASCII codes (32 thru 126).

Character Set1

! "#$%&' ()*+, -./0123456789:;<=>?
@ABCDEFGHIJKLMNOPQRSTUVWXYZ[ƒ]↑
_`abcdefghijklmnopqrstuvwxyzπ⊢→~

Shown next are the symbols in the various character sets that are changed from Set 1. An asterisk (*) beside a symbol indicates that the plotter will perform an automatic backspace when that symbol is drawn.

Set 1	Decimal Value	Set Ø
'	39	′
ƒ	92	\
↑	94	^
* _	95	_
* `	96	`
π	123	{
⊢	124	¦
→	125	}
* ~	126	~

Set 1	Decimal Value	Set 2
#	35	£
'	39	´ *
ƒ	92	ç
↑	94	^ *
π	123	¨ *
⊢	124	• *
→	125	¨ *
~	126	'

Set 1	Decimal Value	Set 3
#	35	£
[	91	Ø
\	92	Æ
]	93	ø
↑	94	æ
π	123	¨ *
|	124	• *
→	125	¨ *
~	126	• *

Set 1	Decimal Value	Set 4
#	35	¿
'	39	´ *
\	92	¡
↑	94	^ *
π	123	~ *
|	124	˜ *
→	125	~ *

The Designate Standard Character Set Command

wrt select code; "CS (0 thru 4)"

This command designates one of the five character sets (0 thru 4) as the standard character set. This character set will be used for all labeling and lettering operations when the standard set is specified. Character Set 0 is automatically set whenever the plotter is initialized.

The Designate Alternate Character Set Command

wrt select code; "CA (0 thru 4)"

The alternate character set is specified by this command. Any of the five character sets (0 thru 4) can be specified. Character Set 0 is automatically specified as the alternate character set whenever the plotter is initialized.

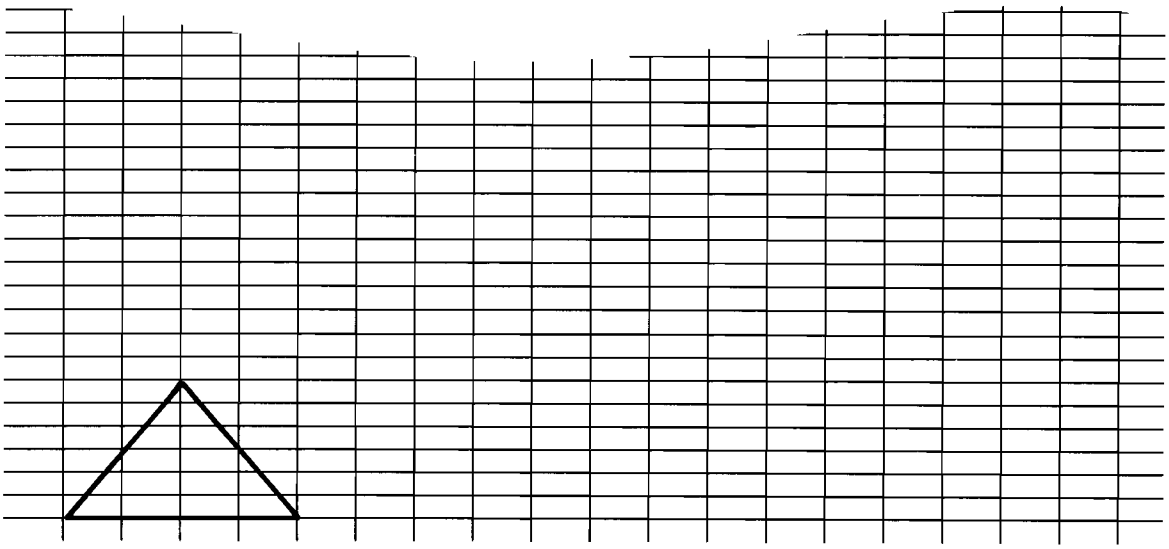
The Select Standard Set Command

wrt select code; "SS"

This command selects the standard set as the character set to be used for all labeling statements (lbl, ptype, xax and yax). The standard set is selected automatically when the plotter is first switched on, initialized, or cleared.

The following example draws the greek character delta, Δ.

```
0: wrt 705,"uc99
 ,2,6,99,2,-6,
 99,-4,0,-99,6,
 0"
```



Plotter Configuration and Status Commands

Serial and Parallel Polling

The plotter responds to a serial poll by sending the following status byte:

Bit Value	Bit Position	Bit Meaning
1	0	
2	1	P1 or P2 changed
4	2	Digitized point available
8	3	Initialized
16	4	Ready for data
32	5	Error
64	6	Require Service message sent
0	7	Not used (always set to 0)

The calculator reads status function, rds (select code), inputs the decimal equivalent value of the status byte. Each bit is set to logical 1 if its meaning is true and a logical 0 if it is false.

The plotter can also respond to a parallel poll by sending a logical 1 on one of the 8 data lines. The line used is determined by the plotters address value as shown in the table below:

Plotter Address	Parallel Poll Bit Position	HP-IB Data Line Number
0	7	8
1	6	7
2	5	6
3	4	5
4	3	4
5	2	3
6	1	2
7	0	1

The address settings from 8 thru 30 will not respond to a parallel poll.

The Mask Command

wrt select code ; "IM E-mask value ; S-mask value ; P-mask value "

The three parameters used by the mask command allow you to specify the conditions under which an error message, require service message and parallel poll response will occur.

E-mask specifies the decimal equivalent of the bit values of the plotter error numbers that will set the error bit (bit 5) of the plotter status byte and turn-on the error light on the plotter front panel.

E-Mask Bit Value	Error Number	Meaning
1	1	Instruction not recognized
2	2	Wrong number of parameters
4	3	Bad parameters received
8	4	Illegal character
16	5	Unknown character set
32	6	Position overflow
64	7	Not used
128	8	Not used

For example an E-mask value 252 (4 + 8 + 16 + 32 + 64 + 128) will specify that error numbers 3 thru 8 can set the error bit in the status byte and turn on the error light whenever they occur. Errors 1 and 2, however, will not set the error bit or turn on the error light if they occur since they are not included in the E-mask value.

The S-mask value specifies the status-byte conditions that can send the require service message by setting interface line SRQ to a logical 1.

The S-mask is the decimal equivalent of the bit values of the selected status-byte bits.

S-Mask Bit Values	Status Bit	Meaning
1	0	Pen down
2	1	P1 or P2 changed from default; cleared on "OP"
4	2	Digitized point available; cleared on "OD" or dig
8	3	Initialized; cleared on "OS"
16	4	Ready for data
32	5	Error; cleared on "OS"
	6	Require service sent (SRQ)
	7	Not used

Only combinations of the first 6 bits can be specified to send the require service message. Bit 6 is used to specify whether or not the plotter has sent the require service message or not and bit 7 is not used (always set to logical 0).

For example, an S-mask value of 16 specifies that the ready for data bit (bit 4) of the status byte will send the require service message. The other 5 bits (bits 0 thru 3 and bit 5) will not send the require service message.

The P-mask value specifies which of the status-byte conditions that will result in a logical 1 response to a parallel poll (see the Extended I/O Programming Manual for details concerning polling).

P-Mask Bit Value	Status Bit Number	Meaning
1	0	Pen down
2	1	P1 or P2 changed
4	2	Digitized point available
8	3	Initialized
16	4	Ready for data
32	5	Error
	6	Require service sent (SRQ)
	7	Not used

For example, a P-mask value of 48 specifies that only bits 4 and 5 (16 + 32) of the status byte can cause the plotter to respond to a parallel poll with a logical 1 on the appropriate data line.

All three mask values must be specified when the command is sent.

The following example uses the P-mask command to specify that error numbers 3 thru 8 will set the error bit of the status byte (an E-mask the value of 252), only the error bit of the status byte can send the require service message (an S-mask value of 32) and only the ready for data bit of the status byte can cause a parallel poll response of logical 1 (a P-mask value of 16). The remainder of the program sets an interrupt (line 1) that will branch to the "error" routine whenever the require service is received. When the parallel poll in line 4 detects a logical 1 for bit 2 of the parallel poll byte,indicating that the plotter is ready for data, the program branches to the "plot" subroutine.

```
0: wrt 705,"IM25
 2,32,16"
1: oni 7,"error"
 ;eir 7
2:
3: "loop":
4: if bit(2,pol(
 7));gsb "plot"
5: gto "loop"
6: "plot":
7: plt I,I,0
8: I+1→I
9: ret
10:
11: "error":
12: if not bit(5
 ,rds(705));eir
 7;iret
13: wrt 705,"OE"
 ;red 705,E
14: fmt 1,"p",
 f.0;wrt 16.1,E
15: beep;eir 7;
 iret
```

This example requires that the Extended I/O ROM be properly installed in the calculator.

The plotter, when cleared or initialized, automatically sets the E-mask to 223 (error numbers 1, 2, 3, 4, 5, 7, 8), the S-mask to 0 (none of the status-byte bits can send the require service message) and the P-mask to 0 (none of the status-byte bits can cause a parallel poll response of logical 1).

The Default Command

```
wrt select code; "DF"
```

This command resets the following plotter functions to the conditions shown below:

Default Conditions

Function	Conditions
`psc`	Not changed
`scl`	Not changed
`line`	Solid line
Line pattern length	4% of the distance from P1 to P2
`lin`	Total platen area
`csiz`	1.5, 2, 1, 0
Automatic pen pickup	on
Pen velocity	36 cm/sec
Adaptive pen velocity	off
Symbol mode	off
Tic length	.5% of/P1-P2/length for each half
Standard character set	Set 0
Alternate character set	Set 0
Character slant	0°
Mask value	223,0,0

P1 and P2 are not changed.

The current pen location is not changed.

The Initialize Command

```
wrt select code; "IN"
```

This command is the equivalent of switching the plotter off and then on again or initializing it from the front panel. The initialize command sets the plotter to the same conditions as the default command and sets these additional conditions.

The pen is moved to the lower right corner of the platen.

The scaling points P1 and P2 are set to the points P1 = (520, 380) and P2 = (15720, 10380).

The Output Error Command

```
wrt select code; "OE"
red select code, variable
```

The output error command causes the plotter to send the decimal value of the current error (if any) to the calculator when a read (`red`) statement is executed after the "OE" command. The error numbers are as follows:

0	No error
1	Instruction not recognized
2	Wrong number of parameters
3	Out of range parameters
4	Illegal characters
5	Unknown character set
6	Position overflow
7	Not used (always 0)
8	Not used (always 0)

After the error value has been set to the plotter, the error bit is cleared and the error light (if lit) is turned off.

The Output Status Command

```
wrt select code; "OS"
red select code; variable
```

The output status command causes the plotter to send the decimal equivalent of the sum of the bits of the status byte. The value is output when the plotter is addressed by a read instruction. The status byte bits are defined as follows:

Bit Value	Bit Position	Meaning
1	0	Pen down
2	1	P1 or P2 changed
4	2	Digitized point available
8	3	Initialized
16	4	Ready for data
32	5	Error
64	6	Require service message set
128	7	Not used (always set to 0)

Appendix

Binary Coding and Conversions

Binary is a base 2 number system using only 1's and 0's. By giving the 1's and 0's positional value, any decimal number can be represented. For example, this diagram shows how decimal 41 = binary 101001:

Decimal		Binary					
10^1	10^0	2^5	2^4	2^3	2^2	2^1	2^0
↓	↓	↓	↓	↓	↓	↓	↓
10	1	32	16	8	4	2	1
4	1	1	0	1	0	0	1

Binary-Decimal Conversions

To convert from binary to decimal, the positional values for the 1's are added up. From the above example this would be:

$$2^5 + 2^3 + 2^0 = 32 + 8 + 1 = 41$$

To convert from decimal to binary, the decimal number is repeatedly divided by 2. The remainder is the binary equivalent. For example:

		Remainder (read up)
$2\overline{)41}$	→	1
$2\overline{)20}$	→	0
$2\overline{)10}$	→	0
$2\overline{)5}$	→	1
$2\overline{)2}$	→	0
$2\overline{)1}$	→	1

Octal-Binary Conversions

Octal is a base 8 number system. Octal numbers are often used since conversion from binary to octal and vice-versa is easy when electronic circuits are used.

To convert from binary to octal, the octal number is broken up into groups of three bits (starting from the right). Each 3 bit group represents an octal number.

For example, to convert binary 10110100011001 to octal:

Binary Number	10	110	100	011	001
	↓	↓	↓	↓	↓
Octal Number	2	6	4	3	1

Notice that only values from 0 through 7 are used in octal.

To convert from octal to binary, the process is reversed:

Octal Number	1	4	0	7	2	6
	↓	↓	↓	↓	↓	↓
Binary Number	001	100	000	111	010	110

ASCII

Binary is often used as a code to represent not only numbers, but also alphanumeric characters such as "A" or "," or "?" or "x" or "2". One of the most-common binary codes used is ASCII[1]. ASCII is an eight-bit code, containing seven data bits and one parity bit. The plotter uses ASCII for most I/O operations. No parity bit is used. For example:

A complete list of ASCII characters and their octal and decimal representations is given next.

Character	ASCII Binary Code	ASCII Decimal Code
A	01000001	65
B	01000010	66
?	00111111	63

1 American Standard Code for Information Interchange.

Plotter Default Conditions

psc	705 (not changed with pclr or "DF")
scl	Centimeter unit of measure from P1 (not changed with pclr or "DF")
line	Solid line
Line pattern length	4% of the distance from P1 to P2
lim	Total platen area
csiz	1.5, 2, 1, 0
Automatic pen pickup	On
Pen velocity	36 cm/sec
Adaptive pen velocity	Off
Symbol mode	Off
Tic length	.5% of /P1-P2/ length for each half
Standard character set	Set 0 (Set 1 for pclr)
Alternate character set	Set 0
Character slant	0°
Mask value	223,0,0

P1 and P2 are changed only with the initialize command (IN). They are not affected by pclr and the default command (DF).

The pen is raised by pclr.

The current pen location is moved to the lower right corner with the initialize command (IN) but is unaffected by pclr and the default command (DF).

Syntax and Formulas

This section lists the formal syntax for each plotter statement. The statements that involve internal calculations to process parameters are shown with the formulas used by these calculations.

Parameter Range Restrictions

The numeric parameters used by the various plotter ROM statements may be constants, variables or expressions.

The usable range of each parameter is listed with the syntax for each statement. If a specific range is not given, the parameter can be within the calculating range of the calculator (1e ± 511) but will be truncated to be within the I/O range (1e ± 99) before being processed by the ROM.

Plotter Select Code Statement

psc cdd	c or cc = one or two-digit interface select code of 0 or in the range of 2 thru 15.
or	
psc ccdd	dd = two digit plotter address code ranging from 0 thru 30.

Scale Statement

scl X_{U1}, X_{U2}, Y_{U1}, Y_{U2}

Let the absolute coordinate positions of P1, P2 in plotter units be represented by X_{P1}, Y_{P1}, X_{P2}, Y_{P2}.

wrt select code, "OP"
red select code, X_{P1}, Y_{P1}, X_{P2}, Y_{P2}

The scale statement calculates the quantities XA, XB, YA and YB for use with later plotting statements.

$$XA = \frac{X_{P2} - X_{P1}}{X_{U2} - X_{U1}} \qquad XB = X_{P1} - X_{U1} * XA$$

$$YA = \frac{Y_{P2} - Y_{P1}}{Y_{U2} - Y_{U1}} \qquad YB = Y_{P1} - Y_{U1} * YA$$

Plot Statement

plt X, Y [, pen control parameter]

The plot statement calculates the values of XL and YL, the current pen location in plotter units. The plotter determines the actual pen location if XL or YL is off-scale.

$$XL = XB + XA * X$$
$$YL = YB + YA * Y$$

The optional pen control parameter is restricted to the range −32768 to 32767.

Offset Statement

ofs $X_{increment}$, $Y_{increment}$

The offset statement calculates new values for XB and YB to move the origin (X = 0, Y = 0) specified by the scale statement.

$$XB = XB + XA * X$$
$$YB = YB + YA * Y$$

Incremental Plot Statement

iplt X, Y[, pen control parameter]

The iplot statement calculates the values of XL and YL as the new pen position using XA and YA, the previous pen position.

$$XL = XL + XA * X$$
$$YL = YL + YA * Y$$

The optional pen control parameter is restricted to the range −32768 to 32767.

X Axis Statement

xax Y-offset [,Tic Interval [,Start Point[,End Point[,Number of Tics/Label]]]]

Y Axis Statement

`yax` X-offset [,Tic Interval[,Start Point[,End Point[,Number of Tics/Label]]]]

Start location, tic mark locations and the end location are calculated as in `plt`. Label locations are calculated by setting character direction, plotting to the tic mark and then executing `cplot -(L+1),0` where L is the label length in characters.

Pen Statement

`pen`

Parameters are not used.

Plotter Clear Statement

`pclr`

Parameters are not used.

Pen# Statement

`pen#` [pen number]

The range restriction on pen number is 0 thru 4.

Line Statement

`line` [pattern number [,pattern length]]

The range of the pattern number is from 0 thru 6.

The range of the pattern length is ± 127.999949999.

Limit Statement

lim [$X_{Lower\ Left}$, $X_{Upper\ Right}$, $Y_{Lower\ Left}$, $Y_{Upper\ Right}$]

The lim statement converts the values of the limit parameters from scale statement units to plotter absolute units using the following formulas:

$X_{Lower\ Left}$ (in absolute units) = XA * $X_{Lower\ Left}$ (in scale statement units) + XB
$X_{Upper\ Right}$ (in absolute units) = XA * $X_{Upper\ Right}$ (in scale statement units) + XB
$Y_{Lower\ Left}$ (in absolute units) = YA * $Y_{Lower\ Left}$ (in scale statement units) + YB
$Y_{Upper\ Right}$ (in absolute units) = YA * $Y_{Upper\ Right}$ (in scale statement units) +YB

XA, XB, YA, YB are calculated in the scale statement.

Ptype Statement

ptyp

Label Statement

lbl any combinations of text, expressions or string variables*

Character Plot Statement

cplt [number of character space widths : number of character space heights]

Both parameters in a cplot statement must be within the range ±127.999949999.

* String Variables ROM required to use strings.

Character Size Statement

csiz[height [, aspect ratio [, paper ratio [, angle of rotation]]]]

If any or all of the above parameters are omitted, default values are assumed –

height – 1.5%
aspect ratio – 2
paper ratio – 1
angle of rotation – 0°

The csize statement calculates these values as parameters to the SR & DR instructions.

$$\%\ \text{width} = \frac{\%\ \text{height} * \text{paper ratio}}{\text{aspect ratio}}$$

if paper ratio > 1, run = cos (angle of rotation)
rise = sin (angle of rotation)/paper ratio

if paper ratio < 1, run = cos (angle of rotation)*paper ratio
rise = sin (angle of rotation)

The height parameter as well as the calculated values for width must be within the range ±127.999949999.

Digitize Statement

dig X, Y, [, pen status]

The digitize statement calculates the values of X and Y, the digitized pen location in problem units, from XL and YL, the digitized pen location in plotter units.

$$X = (XL - XB)/XA$$
$$Y = (YL - YB)/YA$$

HP 9862A/9872A Plotter ROM Comparison

The following statements have identical parameters and operation with both ROMs.

```
plt
iplt
pen
ofs
lbl
csiz
```

These statements are similar but have minor differences.

9862A ROM	9872A ROM
`ptyp`	`ptyp`
Upon exiting the ptype mode, the pen returns to the location that it had when the mode was entered.	Upon exiting the ptype mode, the pen remains at the location of the next character's origin point.
The shift key reduces the pen movement to 1/10 the increment controlled by the calculator display keys.	The shift key does not affect pen movement that is controlled by the calculator display keys.
`psc`	`psc`
"psc 0" prevents all transmissions to the plotter, but otherwise Plotter ROM statements execute normally. All errors are displayed.	"psc 0" prevents execution of Plotter ROM statements thereby preventing error detection for Plotter ROM statements.
`cplt`	`cplt`
Parameters are required by cplot statements. Cplot lifts the pen before moving.	Executing a cplot statement without parameters performs a CR/LF function. Cplot does not lift the pen before moving.

scl	scl
A scale statement must be executed before plotting can be done.	Executing a scale statement without parameters or no scale statement sets a cenitmeter-unit-of-measure scale with the origin at P1.

These statements are new with the 9872A ROM.

xax	Draws, tic marks and labels a horizontal axis.
yax	Draws, tic marks and labels a veritical axis.
lim	Restricts programmed pen motion to a specific rectangular area.
pen#	Allows programmed selection of the various pens.
line	Specifies one of seven line types for use with plt, iplt, xax and yax. Pattern length can also be selected.
dig	Converts the plotter to a digitizer and converts the coordinates of the pen's location to scale-statement units.
pclr	Resets all programmable functions in the plotter to their default values.

The 9872A Plotter ROM does not use the axe or ltr statements found in the 9862A Plotter ROM.

Axe and Ltr Conversions

The following provides parameter conversions to replace axe with xax and yax statements and to replace ltr with plt and csiz statements.

axe X, Y [, P [, Q]]

Two Parameter Conversion
xax Y, 0; yax X, 0

Three Parameter Conversion
Assume scl A, M, B, N.

if P = 0; xax Y, 0
if P > 0; xax Y, Psgn(A − X), X, A; xax Y, Psgn (M − X), X, M: yax X, 0

Four Parameter Conversion
Assume scl A, M, B, N

if P = 0; xax Y, 0
if P > 0; xax Y, Psgn (A − X), X, A; xax Y, Psgn(M − X), X, M
if Q = 0; yax X, 0
if Q > 0; yax X, Qsgn(B − Y), Y, B; yax X, Qsgn(N − Y), Y, N

ltr X, Y, [,Z]

Two Parameter Conversion
plt X, Y, 1

Three Parameter Conversion
Let D = 90 for deg
= π/2 for rad
= 100 for grad

plt X, Y, 1
csiz 0.64int(Z/100), int(Z/100)/(int(Z/10)mod10),1, (Zmod10 − 1)D

Points of Interest

1. The General I/O ROM must reside in the calculator for the 9872A Plotter ROM to function properly.
2. The 9862A Plotter ROM and the 9872A Plotter ROM cannot reside concurrently in the calculator.
3. Interrupt Service Routines:

   a. Restrict pen control parameter in `plt` and `iplt` to 0 or positive values.

   b. Send only one point or one character during each execution of an ISR.

4. Changing P1 and P2 from the usual lower left/upper right orientation will not rotate a plot.
5. The 9872A Plotter ROM truncates numeric parameters from calculator range (e ± 511) to user range (e ± 99) before using them.
6. The 9872A Plotter ROM automatically rescales the plotter according to the most recently executed `scl` statement whenever P1 and/or P2 change.

Interface Functions

Interface Functions provide the physical capability to communicate via HP-IB. These functions are defined in the IEEE Standard, 488-1975. This standard, which is the disigner's guide to the bus, defines each interface function in terms of state diagrams that express all possible interactions. Bus capability is grouped under 10 interface functions, for example: Talker, Listener, Controller, Remote/Local. The following table lists the functions.

HP-IB Interface Functions

Mnemonic	Interface Function Name
SH	Source Handshake
AH	Acceptor Handshake
T	Talker (or TE = Extended Talker)*
L	Listener (or LE = Extended Listener)*
SR	Service Request
RL	Remote Local
PP	Parallel Poll
DC	Device Clear
DT	Device Trigger
C	Any Controller
C_N	A specific Controller (for example: C_A, C_B...)
C_S	The System Controller

*Extended talkers and listeners use a two-byte address. Otherwise, they are the same as Talker and Listener.

Since interface functions are the physical agency which bus messages are implemented, each device must implement one or more functions to enable it to send or receive a given bus message.

HP 9872A HP-IB Implementation

1. Functions implemented (IEE STD 488-1975)

    a. Source Handshake (SH1)
    b. Acceptor Handshake (AH1)
    c. Talker (T2) Serial Poll
    d. Listener (L2)
    e. Service Request (SR1)
    f. No Remote Local (RL0)
    g. Parallel Poll (PP2)
    h. Device Clear (DC1)
    i. No Device Trigger (DTO)

2. Device Clear or Selected Device Clear causes the plotter to:

    a. Complete the present vector then stop with the pen up.
    b. Reset parser to expect instruction next.

3. PPRN for parallel poll is assigned by the rear panel address switch. Listen addresses zero through 7 assign DIO lines 8 – 1 respectively. All other listen addresses disable parallel poll.

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Subject Index

o

p

r

s

t

u

v

w

x

y

9872A Plotter ROM Error Messages

error P1 **Attempt to store into constant**

Occurs when one or more parameters in a dim instruction are constants rather than variables.

error P2 **Wrong number of parameters**

Occurs on instructions with numeric-only parameter lists (scl, ofs, plt, iplt, cplt, xax, yax, lin, dim, csiz, line, pen#, and psc).

In certain unusual cases where a parameter list contains user-level function calls, an instruction having an incorrect number of parameters may be executed.

For example, scl 'funct' is executed as scl. The function call 'funct' is ignored.

error P3 **Wrong type of parameter or illegal parameter value**

Examples:

```
lbl A[*]
psc 31
```

error P4 **No HP-IB device number specified**

Occurs on a psc instruction when the parameter is between 0 and 14 inclusive and an HPIB card is at the corresponding select code.

error P5 **Pen control value not in −32768 thru 32767 range**

Occurs on plt and iplt. May also occur if hardware transmission error occurs between plotter and calculator.

error P6 **No HP-IB card at specified select code**

Occurs on psc instruction when the interface card set to the specified select code is not an HPIB card.

error P7 axe, ltr **instructions executed**

Occurs on axe and ltr instructions because the ROM recognizes these instructions but cannot execute them. This error flags all axe and ltr instructions for the purpose of converting 9825/9862 programs.

error P8 **Calculator STOP key cancelled operation**

Occurs on any instruction when the plotter fails to respond for 3 seconds after the STOP key has been pressed. This error is most likely to occur when the pen is traveling slowly.

`error p0` **Transmission error**

The calculator has received an illegal ASCII input from the plotter.

`error p1` **Instruction not recognized**

The plotter has received an illegal character sequence.

`error p2` **Wrong number of parameters**

Too many or too few parameters have been sent with an instruction.

`error p3` **Bad parameter**

The parameters sent to the plotter with an instruction are out of range for that instruction.

`error p4` **Illegal character**

The character specified as a parameter is not in the allowable set for that instruction.

`error p5` **Unknown character set**

A character set out of the range 0 thru 4 has been designated as either the standard or alternate character set.

`error p6` **Position overflow**

An attempt to draw a character or perform a cplot that is located outside of the plotters numeric limit of −32768 to +32767.

Error messages generated by write (`wrt`) and read (`red`) statements will typically be displayed as an error in the next executed plotter ROM statement. This can be avoided by using an output error command (`wrt` select code, `"OE";`) followed by a read statement (`red` select code, variable) to check for errors after read or write statements that address the plotter.