9831A

Matrix/Plotter Programming

Hewlett · Packard
Desktop Computer

Matrix/Plotter Programming
HP 9831A Desktop Computer

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

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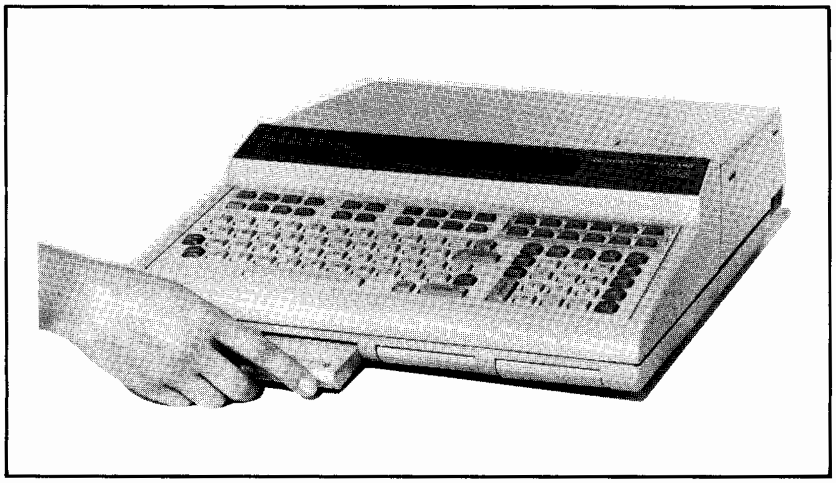
Chapter 1
Introduction

Description of ROMs

The 98223A or 98223B Matrix/Plotter plug-in ROM (Read-Only Memory) is supplied with the Matrix/Plotter Programming Manual (HP Part No. 09831-90021). The 98223A ROM adds matrix instructions and 9862A Plotter statements to the HP 9831A language. The 98223B ROM contains the same matrix instructions, but has 9872A Plotter statements.

Inspection and Installation

Either one of the ROMs can be plugged into any of the four ROM slots on the bottom front of the computer, as shown below.



ROM Installation

Before installing a ROM, switch the computer off. Then, with the label right side up, slide the ROM through the ROM slot door. Press it in so that the front of the ROM is even with the front of the computer. Then switch the computer on.

The test procedure for your ROM is in the System Test Booklet (HP Part No. 09831-90031) which is supplied with your desktop computer. The procedure to test the 9862A and 9872A Plotters is also in the System Test Booklet.

Syntax Conventions

The following conventions apply to the syntax for all Matrix/Plotter ROM statements found in this manual.

`dot matrix`	All items in dot matrix are required, exactly as shown.
[ ]	All items in square brackets are optional, unless the brackets are in dot matrix.
. . .	Three dots indicate that the previous item may be duplicated.

All Matrix/Plotter ROM statements can be executed from the keyboard or from a program, except where noted. All parameters shown in statements are values (i.e., they can be numbers, variables, or expressions). The LABEL statement is the only statement which contains a parameter that is not a value.

Error Messages

All error numbers generated by the Matrix/Plotter ROMs are in the 300 series. These errors are explained inside the back cover of this manual.

NOTE

Before using this manual, you should be familiar with the BASIC programming language used in the 9831A Desktop Computer, which is explained in the 9831A Operating and Programming Manual (HP Part No. 09831-90000).

Chapter 2
9862A and 9872A Plotter Operation

The operations explained in this chapter apply to both the 9862A and 9872A Plotters. Those operations which apply only to the 9872A Plotter are explained in Chapter 3.

Plotter Operations

The Matrix/Plotter ROMs enable the 9831A Desktop Computer to control either the 9862A Plotter or the 9872A Plotter. Both plotters provide you with hard copy graphic solutions to problems solved by the 9831A Desktop Computer.

The plotter instruction set consists of plotting and printing operations.

Plotting instructions are used to:

- Scale the units selected by the user and establish the origin point (0,0) anywhere on or off the plotting area.
- Draw X and Y axes, of any length, anywhere on the plotting area.
- Segment the axes by drawing tic marks at intervals selected by the user.
- Plot points with respect to a previously established origin.
- Raise or lower the pen either before or after moving the pen to the point to be plotted.
- Offset the origin point to any position and then plot with respect to that offset origin.
- Plot in increments – plot each new point with respect to the last point plotted instead of with respect to the origin.

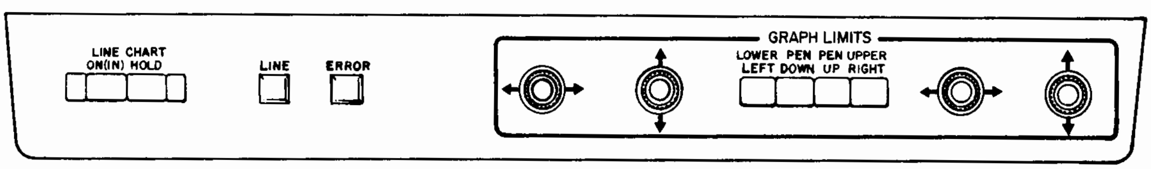
Printing instructions are used to:

- Print letters, digits, and other symbols.
- Specify character height, width, and printing angle.
- Position the pen, with respect to the point to be labelled, using character spaces as the plotting units.
- Reference FORMAT statements to format printing.
- Establish a typewriter mode to control printing entirely from the keyboard.

The 9862A Plotter

Information concerning the 9862A Plotter is contained in the Peripheral Manual (HP Part No. 09862-90012) for the plotter. Refer to that manual for information regarding plotter installation in the system, initial turn-on procedure and plotter maintenance. The following plotter set-up information is included here to provide you with information regarding the general use of your plotter once you have installed it.

Before plotting, the plotter must be prepared and the physical limits of the plotting area must be established. The front panel controls on the plotter are used for this purpose.



9862A Front Panel Controls

- Switch the plotter on by pressing LINE ON(IN) so that the white indicator lights up.
- Press CHART HOLD . Move the pen holder arm all the way to one side of the plotter and place a sheet of plotting paper on the surface of the plotter. Smooth out any irregularities in the paper.
- Secure the plotting paper to the platen by pressing CHART HOLD . Pressing it again releases the paper. The plotter cannot plot or letter when the paper is not secured.

Then set the limits of the plotting area on the paper by pressing the following keys in the order shown:

- First press [LOWER LEFT] and turn the two knobs at the left to manually adjust the location of the lower-left limit of the plotting area.
- Then press [UPPER RIGHT] and turn the two knobs at the right to manually adjust the location of the upper right limit of the plotting area.

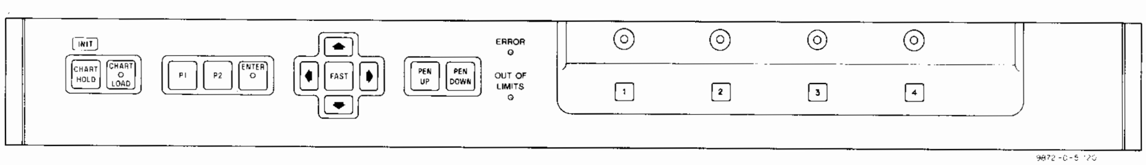
If the yellow ERROR light turns on when you're setting either the lower-left or upper-right limit, reset the limit within bounds.

Once you have set-up the plotting area limits, the plotting area can be relocated by moving the position of the lower-left limit. The upper-right limit will automatically be adjusted by the same direction and amount.

The 9872A Plotter

Information concerning power requirements, grounding, and plotter maintenance for the 9872A Plotter is contained in the HP 9872A Plotter Operating and Service Manual (HP Part No. 09872-90000) which is supplied with your plotter. The following plotter set-up procedure is included here for your convenience.

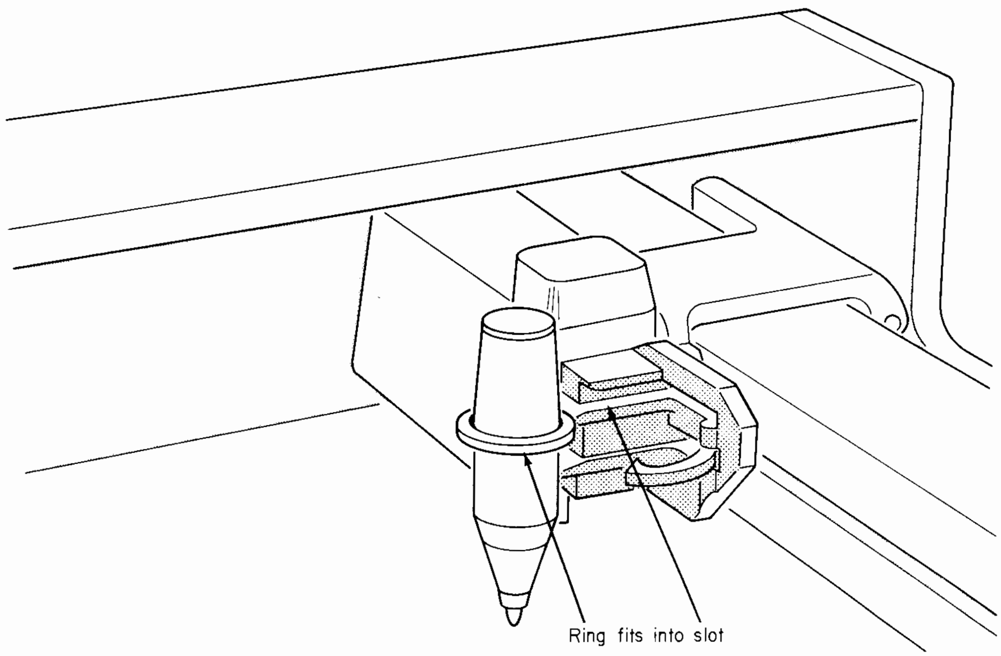
Plotter Set-Up Procedure



9872A Plotter Front Panel Controls

Switch on the plotter with the power switch located on the front lower-right corner. After the plotter initialization is complete (the plotter arm has stopped moving), you can install the plotter pens.

Pen Installation



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 the other pens substituting the appropriate empty pen location buttons for each one.

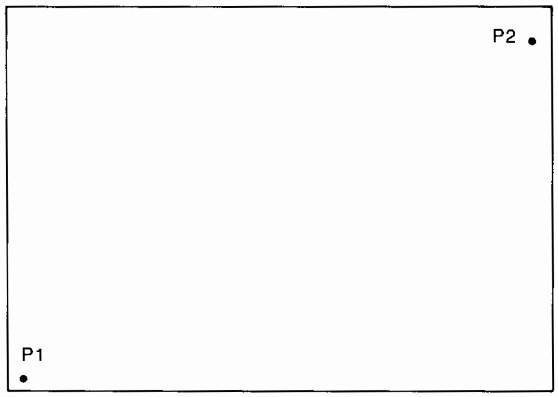
Loading Paper

To load a sheet of paper, first press [CHART LOAD]. This releases the paper hold-down mechanism and moves the plotter arm to the upper-right corner of the platen. Place a sheet of paper on the platen surface and smooth out any irregularities. Make sure that the paper is positioned squarely against the ridge at the bottom of the platen. Now press [CHART HOLD] to 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 page 9). These points are also referenced by other plotter statements that specify such things as character size and line pattern length.

The plotter sets P1 and P2 as shown in the following figure when it is initialized.



Initialized Location of P1 and P2

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

- Position the pen at the new location using the plotter arm controls.
- When the pen is at the desired location, press [ENTER o] [LOWER LEFT] if the point is to be lower-left, or press [ENTER o] [UPPER RIGHT] if the point is to be the upper-right. The coordinates for P1 must be less than the coordinates of P2 or error 378 will occur when a SCALE statement is executed.

Specifying The Plotter

If the 9862A Plotter ROM or both the 9862A and 9872A Plotter ROMs are installed, the default select code is 5 when the 9831A Desktop Computer is first switched on. When only the 9872A Plotter ROM is installed, the default select code is 705. These select codes correspond to the factory select code settings on the interface cards. If the select code on the interface card is changed for any reason, a new select code must be specified by executing the Standard Plotter Statement. When the Standard Plotter Statement (STDPLT) is executed, all subsequent plotting operations take place at the specified select code.

Syntax:

STDPLT [select code]

Select codes 2 thru 15 can be used with the 9862A. Select codes used with the 9872A use the HP-IB (Hewlett-Packard Interface Bus) select code format:

cdd or ccdd	c or cc is a one or two digit number from 2 thru 15 specifying the interface card select code. dd is a two digit number from 00 thru 30 which specifies the device address of the 9872A Plotter on the HP-IB.

When the STDPLT statement is executed without specifying a select code, the appropriate default select code is set.

Error 77 results if there is no peripheral at the select code specified. Select codes 0 and 1 are reserved for the computer's internal use and cannot be used for plotting operations.

Example statements:

```
STDPLT 7
STDPLT 707
```

User-Units

The user can designate his own units for plotting. The computer automatically scales (converts) these user-units to plotter-units (absolute units), which it uses to position the pen on the plotter surface.

Units are specified, indirectly, by means of the SCALE statement (described next). First adjust the front panel controls on the plotter to establish graph limits which fit the size of the plotter paper. Next, use the scale statement to specify the values of the graph limits. Specifying the limits also determines the user-units; all subsequent plotting commands then use those units so that the user never has to concern himself with plotter-units. As an example, you might specify that the left edge of the graph represents −10 and the right edge 100. This has the effect of dividing the horizontal axis into (in this case) 110 user-units. What the user-units represent is determined by you – they could be feet, centimeters, hours, or any other unit.

Once the units for a plot have been established, the size of the plot can be changed to fit a larger or smaller sheet of plotter paper. This is done by resetting the GRAPH LIMIT controls on the 9862A Plotter or by resetting P1 and P2 on the 9872A Plotter. It is not necessary to change units because the computer will automatically rescale them to fit the new plotting area.

Plotting Operations

The SCALE Statement

The SCALE statement establishes the full-scale values, in user-units, for the plot. X_{min} to X_{max} and Y_{min} to Y_{max} correspond exactly to the respective limits of the horizontal and vertical edges of the plotting area (the area is established mechanically, as previously described). This also establishes the point, on or off the plotting area, where the origin (point 0,0) of the coordinate system is located.

Syntax:

SCALE X_{min} , X_{max} , Y_{min} , Y_{max}

A SCALE statement must be executed before any plotting can occur. Once established, the scale remains established until one of the following occurs:

- A new SCALE statement is executed.
- The program is initialized.
- An ERASE, ERASE A, or ERASE V is executed.
- The computer is switched off.

The parameters in a SCALE statement must be given in the correct sequence. If the minimum and maximum values are switched, subsequent plotting commands may not be executed properly.

Example statements:

```
SCALE -10,10,-5,5
SCALE -4*PI,4*PI,Y1,Y2
```

The AXIS Statements

The AXIS statements draw an X-axis or Y-axis according to the parameters given in the statement. The pen is automatically raised before moving to the start point, and again after drawing the axis.

Syntax:

XAXIS Y-offset [, + or – tic [, start point , end point]]
YAXIS X-offset [, + or – tic [, start point , end point]]

NOTE

The following describes the X-axis; the same information is applicable to the Y-axis if "left" and "right" for the X-axis are read as "bottom" and "top", respectively, for the Y-axis.

---

1. If no optional parameters are given, a straight line is drawn from left to right across the complete plotting area (from X_{min} to X_{max}). The line crosses the Y-axis at the point specified by the value of the Y-offset.
2. If a tic parameter is included, tic marks are made along the axis as it is drawn; the value of the tic parameter determines the spacing, in user-units, between tics. The first tic is drawn at the starting point of the line. The tic parameter is usually positive (the plus sign is optional), but a negative tic spacing can also be used – see 4, below.
3. If the start point and end point parameters are given, then the axis is drawn only between those points; that is, from the start point to the end point. If the start point parameter is less than the end point parameter, then the axis is drawn from left to right. If the start point parameter is greater than the end point parameter, then the axis is drawn from right to left.

4. A tic parameter which has a positive value results in:
   a. Normal tic spacing if the axis is drawn from left to right.
   b. A tic only at the right end of the axis if the axis is drawn from right to left.

   A negative tic value results in:
   a. A tic at the left-end of the axis if the axis is drawn from left to right.
   b. Normal tic spacing if the axis is drawn from right to left.

5. If an OFFSET statement has previously been given, then all of the optional parameters must be included in any AXIS statement.

A possible problem exists with the 9862A Plotter operation. In the SCALE statement, the values for X_{min}, X_{max}, Y_{min}, and Y_{max} are defined. If, in the AXIS statement, the value for the optional parameters, "start point" and "end point" are omitted, the values used are computed from the values defined in the SCALE statement. A scale factor (SF) and an adjustment number (A) are computed in the SCALE statement.

$$SF = [9999 / (X_{max} - X_{min})]$$

$$A = SF * X_{min}$$

When the AXIS statement is executed, the value of X_{min} is recomputed using the formula:

$$X_{min} = A / SF$$

If the recomputed value generated by the computer is less than the actual X_{min} defined in the SCALE statement, error 382 will occur. To avoid this possible problem, define all of the parameters in the AXIS statement.

Example statements:

```
XAXIS 3,1,-4,4
XAXIS 0
YAXIS -3,PI/8
```

The PEN Statement

Syntax:

PEN

The PEN statement is used to raise the pen without otherwise changing the pen position relative to the plotting area. A control parameter to raise or lower the pen, either before or after pen movement, can also be included in two other statements (see PLOT and IPLOT).

The PLOT Statement

The PLOT statement moves the pen to the point specified by the X-coordinate and Y-coordinate parameters.

Syntax:

PLOT $X_{coordinate}$, $Y_{coordinate}$ [, Pen Control]

When no optional pen control parameter is given:

- If the pen was raised, it moves to the point specified and then lowers, marking a point on the paper.
- If the pen was lowered, it remains lowered while moving to the point specified, thus drawing a straight line on the paper.

The value and sign of the pen control parameter in the PLOT statement determines whether the pen will be raised or lowered before or after it moves to the specified point. If the parameter is:

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 (raised or lowered), moves to the point specified, and lowers or remains down.

The value of the control parameter can be any number in the range + or −32767. If the value is not an integer, then it is automatically rounded up or down; (rounding is the same as the standard rounding in the computer).

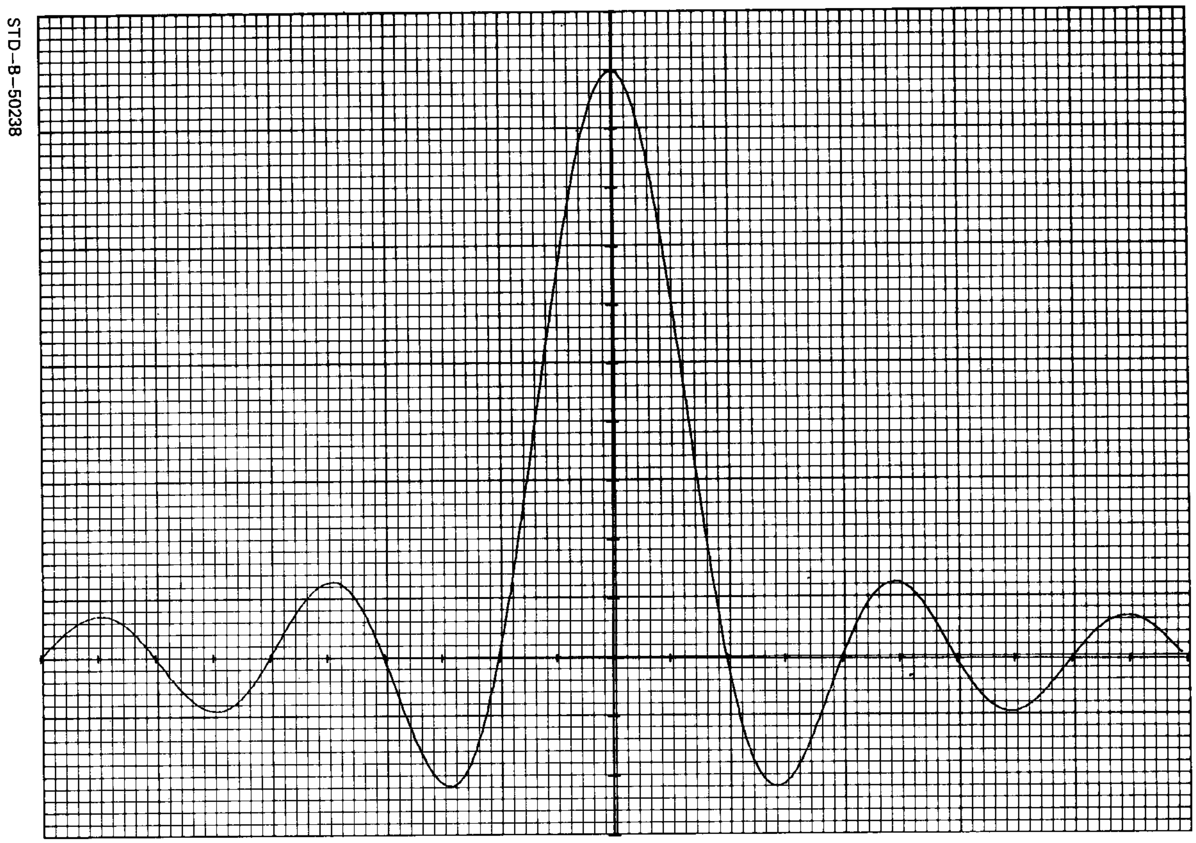
When plotting a function, it is sometimes useful to use a pen control parameter of zero in your PLOT statements so that you can make a dummy plot. First, raise the pen by pressing the PEN UP control on the plotter. Then run the part of the program which plots the function and watch the course of the pen over the plotter paper. If the pen movement does not appear to be correct, you can make any necessary changes to your program. When your program appears to be plotting correctly, stop the program, press PEN DOWN on the plotter and rerun the program to actually draw the plot.

Plotting a Function

This program plots the function (SIN X)/X. The scale is chosen to fit a sheet of 7 by 10 inch plotter paper. However, the plot can be made on any size of paper, up to the plotter limits.

Before running this program, be sure that the plotter is set-up for the size of paper you are using. The figure on the next page shows the plot resulting from this program – the height to width ratio of your plot may vary from that shown, depending on the dimensions of your paper.

```
5  LABEL (*) "a"
10 SCALE -5*PI,5*PI,-0.3,1.1
20 XAXIS 0,PI/2
30 YAXIS 0,0.1
40 FOR X=-5*PI TO 5*PI STEP PI/20
50 PLOT X,SIN(X)/X
60 NEXT X
70 PEN
80 END
```



Plot of Sin(X)/X

When you run the program, notice that the last point is not plotted. This is not an error, but results because the user-unit chosen, PI, is not an exact value. In this case (line 40) the method used to obtain the value of 5*PI for the FOR...NEXT loop (i.e., by incrementing, in steps of PI/20) results in a value which is slightly larger than the value obtained by simply multiplying 5 by PI. Thus the last point is assumed to be outside the range of the FOR...NEXT loop and is not plotted. The last required point (5*PI) will be plotted if line 40 is changed to:

```
40 FOR X=-5*PI TO 5*PI+PI/20 STEP PI/20
```

Whether or not this type of over-range is required for other plots depends upon the units used and can be easily ascertained by experimenting.

Another version of this graph is shown later in this chapter in a printing example that illustrates labelling graphs.

The OFFSET Statement

The OFFSET statement moves the origin (point 0,0) of the coordinate system to the point specified by the X-coordinate and Y-coordinate parameters. Subsequent plotting instructions are then made with respect to the new origin until that origin is changed by means of, for example, a new OFFSET or a new SCALE statement.

Syntax:

OFFSET $X_{coordinate}$, $Y_{coordinate}$

OFFSET statements are not cumulative; that is, a new offset is made with respect to the original origin and not with respect to the last offset origin.

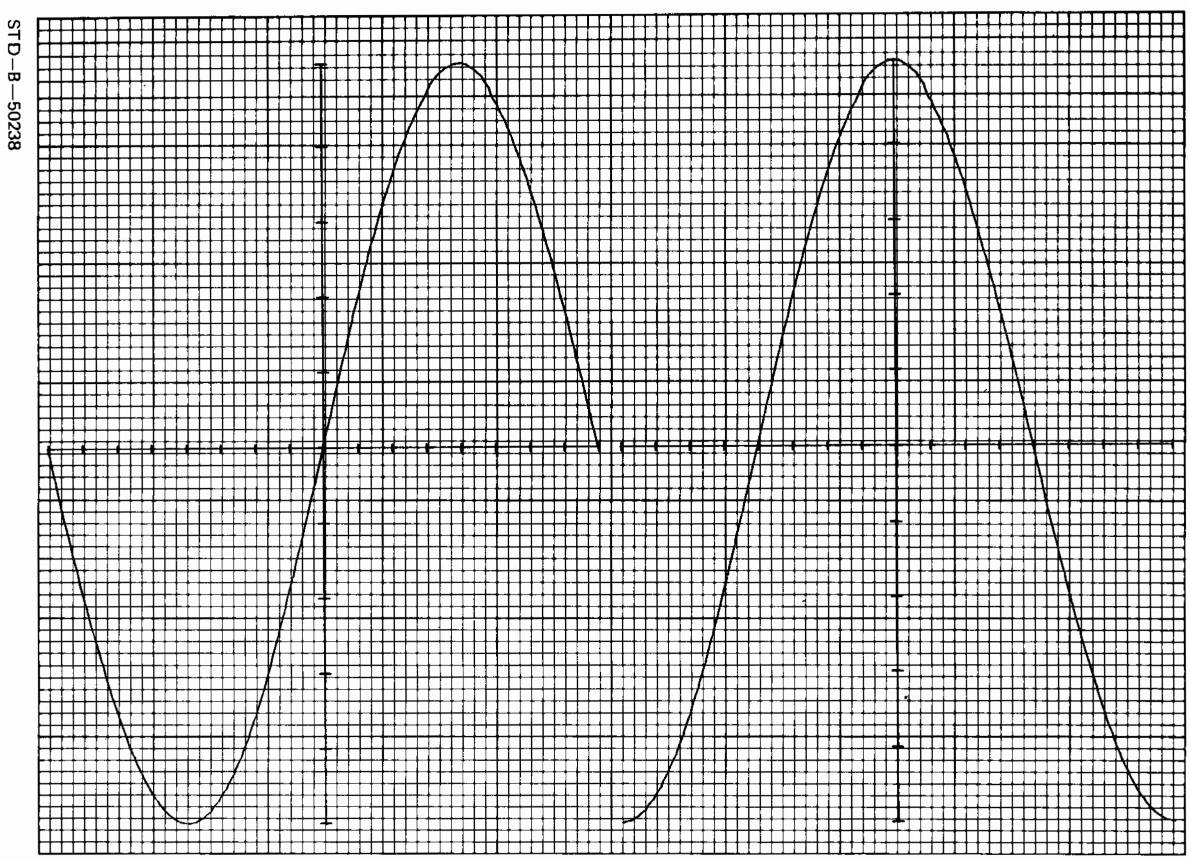
Offsetting greatly simplifies plotting from the user's point of view. For example, it sometimes becomes necessary to divide the plotting area into smaller segments and make a separate plot in each segment. While plotting in each segment, it is not necessary for the user to correct each point before plotting it. Instead, the OFFSET statement moves the origin to the specified point within that segment. The computer then automatically makes the necessary corrections for each point to be plotted.

Plotting with Offset

This program illustrates the use of the OFFSET statement. The purpose of this program is to make two plots, side-by-side, of different functions over the same range – in this case, SIN X and COS X over the range of −180 to 180 degrees (see the next figure). OFFSET is used in lines 30 and 80 to move the origin (0,0) of the graph. This enables the same AXIS statements (lines 150 and 160) to be used for both plots. The two FOR..NEXT loops (starting at lines 50 and 100) also have the same range.

The program is scaled to plot on a sheet of 7 by 10 inch paper; as in the previous example, other sizes of paper can be used.

```
[illegible]
10 SCALE 0,750,0,2.2
20 DEG
30 OFFSET 750/4,1.1
40 GOSUB 150
50 FOR X=-180 TO 180 STEP 5
60 PLOT X,SIN(X)
70 NEXT X
80 OFFSET 750*3/4,1.1
90 GOSUB 150
100 FOR X=-180 TO 180 STEP 5
110 PLOT X,COS(X)
120 NEXT X
130 PEN
140 STOP
150 XAXIS 0,22.5,-180,180
160 YAXIS 0,0.2,-1,1
170 RETURN
190 END
```



Sin X and Cos X Plotted with OFFSET

The IPLOT Statement

The IPLOT (Incremental Plot) statement moves the pen from its current position in the X and Y direction, by the amounts specified by the X-increment and Y-increment parameters.

Syntax:

IPLOT $X_{increment}$, $Y_{increment}$ [, Pen Control]

The pen control parameter is optional and operates exactly as described previously – see the PLOT statement.

The IPLOT statement plots a point with respect to the previously plotted point and not with respect to the origin (0,0) of the graph. The IPLOT statement is very useful when drawing regular geometric shapes such as a cross. In cases like this, it is easier to plot each point relative to the current position of the pen than it is to plot each point relative to the origin of the graph.

Executing the IPLOT statement immediately after the SCALE statement causes plotting to start at P1 on the 9872A or at the lower-left on the 9862A.

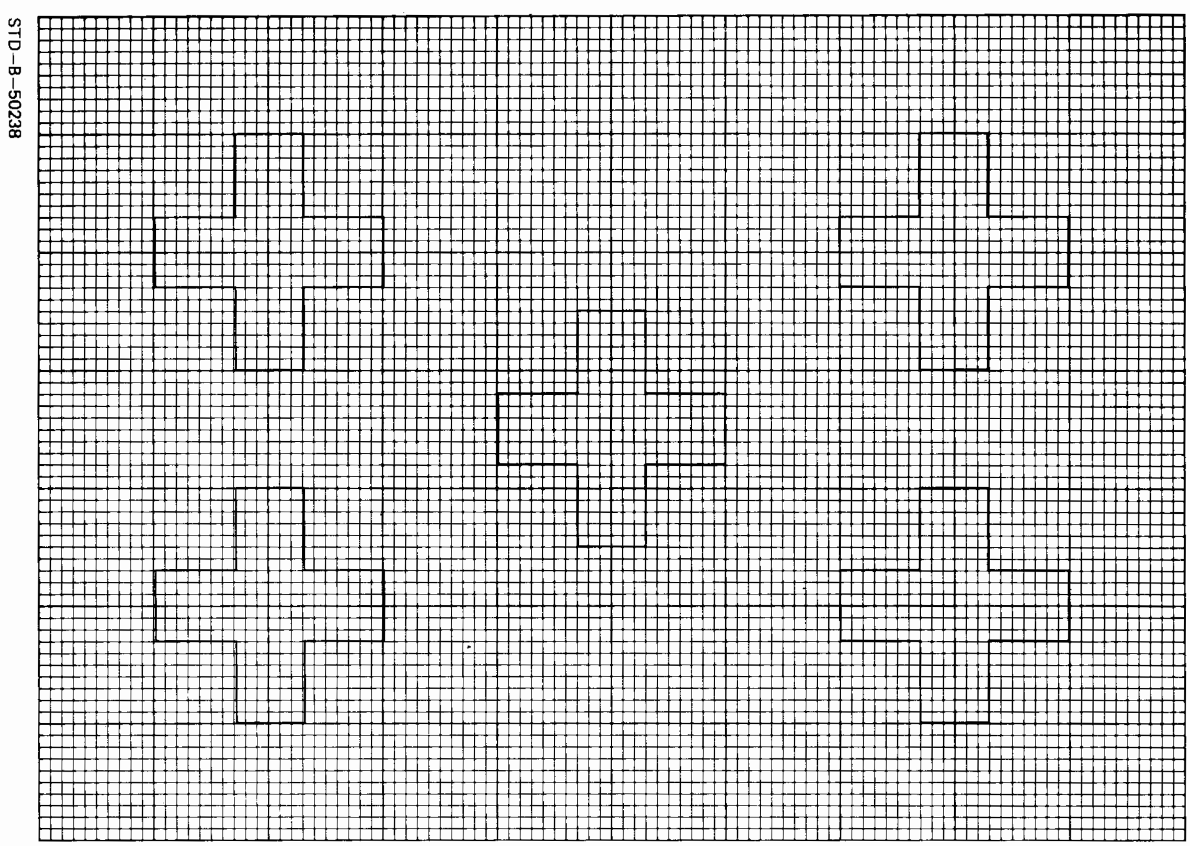
When an IPLOT statement is executed immediately after printing a letter or other character on the plotter, the pen movement is related to the last plotted position and not to the current position of the pen. "Plotted position" refers to a point plotted either by a PLOT statement or by an IPLOT statement.

Incremental Plotting

This program illustrates use of the IPLOT statement to plot incrementally. The program uses a subroutine to plot crosses at different locations on the paper (see the figure on the following page). Before each cross is plotted, an OFFSET statement moves the pen to the desired position. IPLOT statements are then used to plot the coordinates of each point of the cross relative to the previous plotted point. As can be seen from this example, plotting a regular shape is much easier to program with incremental plotting than it would be if the coordinates of each point had to be computed with respect to a fixed origin.

The scale assumes 7 by 10 inch plotter paper. If the height to width ratio of the paper to be used differs from 7:10, then the crosses will not be square. However, they will be drawn square if you change the parameters in the SCALE and OFFSET statements to suit the dimensions of your paper.

```
10 SCALE 0,100,0,70
20 OFFSET 20,20
30 GOSUB 130
40 OFFSET 20,50
50 GOSUB 130
60 OFFSET 80,50
70 GOSUB 130
80 OFFSET 80,20
90 GOSUB 130
100 OFFSET 50,35
110 GOSUB 130
120 STOP
130 PLOT -3,3,1
140 IPLOT 0,7,2
150 IPLOT 6,0
160 IPLOT 0,-7
170 IPLOT 7,0
180 IPLOT 0,-6
190 IPLOT -7,0
200 IPLOT 0,-7
210 IPLOT -6,0
220 IPLOT 0,7
230 IPLOT -7,0
240 IPLOT 0,6
250 IPLOT 7,0,-1
260 RETURN
270 END
```



Plotting Crosses with IPLOT

Printing Operations

Three statements – LABEL, LETTER, and CPLOT, – are used to print characters (letters, numbers, and symbols) on the plotter. One important aspect of these statements is that they are almost entirely independent from the plotting instructions described previously. However, the SCALE statement must be executed prior to using plotting or printing operations. Also, the pen must usually be positioned by means of a PLOT or IPLOT statement before printing is possible.

Letter sizes are specified by the user as a percentage of the height of the plotting area, which is established mechanically by means of the controls on the front panel of the plotter. The direction in which characters are to be printed, relative to the horizontal axis of the plotting area, is specified as an angle in degrees, radians, or grads. If the plotting area is rectangular, as opposed to square, then a simple compensation factor can be specified to prevent characters from appearing distorted.

Example programs illustrating the printing statements are included at the end of this section.

The LABEL Statement

The LABEL statement is similar to the WRITE statement; it is used to print alphanumeric characters on the plotter and to reference FORMAT statements to format the printout. In addition, LABEL can be used to specify the height and width of the printed characters and the direction in which they are printed.

Syntax:

LABEL (line number or * [, character height , aspect ratio , angle of rotation [, paper height/width ratio]]) [print list]

The line number of a FORMAT statement, or, if no FORMAT statement is referenced, an asterisk (*), must be included. The character parameters (height, aspect ratio, and angle of rotation) are optional, but, if one of them is used, then all three must be included. The last specification parameter, the ratio of paper height to paper width, is also optional; it can be included only if the other character parameters are also there.

1. The first parameter is the line number of the FORMAT statement used to format the printout (see "Print List" on page 21). The FORMAT statement referenced can contain any parameters normally allowed in FORMAT statements.

This parameter is a line number, so it must be a positive integer (it cannot be a variable or expression). Like any line number, it is subject to being changed automatically any time the program is renunumbered by means of the REN command.

If a FORMAT statement is not referenced, then an asterisk (*) must be used instead of a line number.

2. The character parameters determine the height and width of the characters as well as the direction in which they will be printed. Normally, it is assumed that the plotting area, set by the graph limit controls on the plotter, is square. If the plotting area is rectangular rather than square, then the fourth character parameter, paper height/width ratio, should also be included.

   Once character specifications have been established by means of a LABEL statement, they remain established until a new LABEL statement with new character specifications is encountered, until the computer or plotter is initialized, or until an ERASE is executed. At turn-on, or if no character specifications have been established, the computer automatically assumes the following:

   Character height = 1.5%

   Aspect ratio = 2

   Rotation = 0 degrees

   Paper height/width ratio = 1

Character Height is expressed as a percentage of the height of the plotting area. The height parameter can range from 0 to a maximum of 18.4% on the 9862A Plotter and from 0 to 127.9994999% on the 9872A Plotter. If the height of the plotting area is subsequently changed, the height of the characters will change accordingly.

Aspect Ratio is used by the computer to calculate the character width. The aspect ratio is expressed as the ratio of character height divided by character 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.

Angle of Rotation specifies the direction of printing. The angle is in degrees, radians, or grads, whichever was selected prior to execution of the LABEL statement. 0 degrees results in printing in the direction of the X-axis, from left to right; 90 degrees results in printing in the direction of the Y-axis, upwards, and so on. Any angle can be selected.

Paper Height/Width Ratio is a compensating parameter which should be used when the plotting area is rectangular, as opposed to square. Without this parameter, the computer assumes a square plotting area and therefore distorts the characters if they are printed in a non-square area. The distortion becomes particularly noticeable when printing at angles other than zero. The compensating parameter ensures that characters retain their proper shape, regardless of the angle of rotation.

Once the character parameters have been set, they remain in effect until a new LABEL statement with new character parameters is executed.

3. **The print list** is an optional part of the LABEL statement. It can contain characters, numbers, variables, etc., which are to be printed on the plotter. A LABEL statement containing the line number of a FORMAT statement and a print list is similar to a WRITE statement. The items in the print list are printed on the plotter in the format specified in the FORMAT statement. That FORMAT statement can contain any of the parameters normally allowed in FORMAT statements (such as field width, fixed or float, spaces, carriage return/line feed, and messages). FORMAT statements are fully described in the 9831A Operator's Manual. A table of codes for each character used with FORMAT B is in the appendix of this manual.

   When a LABEL statement has an asterisk (i.e., it does not reference a FORMAT statement) it acts like a PRINT statement. Items such as commas, semi-colons, and TABs have the same definitions they normally have in PRINT statements. Also, the form of any numerical printout depends upon whether the statement is executed in keyboard or program mode.

   Printing starts at the current pen position. When a carriage return/line feed is encountered, the pen lifts and returns to the character position directly below the first character position of the current line.

On the 9872A the LABEL statement always selects character set 1 for labelling operations. Character set 1 has characters that correspond to those on the computer keyboard. Refer to "Character Sets" in Chapter 3 for information concerning the available plotter character sets.

The CPLOT Statement

The CPLOT (character plot) statement lifts the pen and moves it from its current position in the direction and by the amounts specified. The horizontal movement is determined by the number of character spaces wide; the vertical movement is determined by the number of spaces high.

Syntax:

CPLOT # of character spaces wide , # of character spaces high

Since the size of a space is determined by the size of the characters (see below), one space wide will probably have a different length from one space high. In the CPLOT statement, the horizontal and vertical directions are subject to any angle of rotation established previously in a LABEL statement.

CPLOT is used to position the pen prior to printing labels for tic marks or for other specific points on the graph. It enables the user to immediately position the pen. Without CPLOT it would be necessary to first compute the distance in user-units, based on character size, and then position the pen that distance away. (Imagine trying to do that, for instance, at an angle of rotation of 48.73 degrees!) Following is an example:

It is desired that the word "FOCUS" be used to identify a point on a graph. As shown in the following figure, the word is to be located one character space to the left of the point and is to be centered vertically on the point (the angle of rotation is zero).

- Use any convenient method, such as a PLOT statement, to position the pen exactly at the point to be labelled (point A in the figure).
- On the 9862A, the following CPLOT statement will now move the pen six character spaces to the left and half a character height downward (to point B in the figure), ready to print:

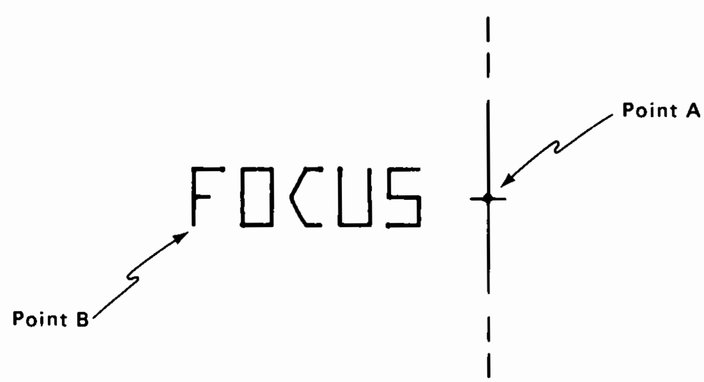
```
CPLOT -6,-0.3
```

- On the 9872A, this CPLOT statement is required to move the pen six character spaces to the left and half a character height downward.

```
CPLOT -6,-0.5
```

- The reason that the second parameter is −0.3 for the 9862A Plotter and −0.5 for the 9872A Plotter, is due to the difference between the location of the characters within their respective character spaces. The height and width relationships between characters and their character spaces is described under "The Character Space" below.
- A LABEL statement (or a LETTER statement) can now be used to print the word "FOCUS":

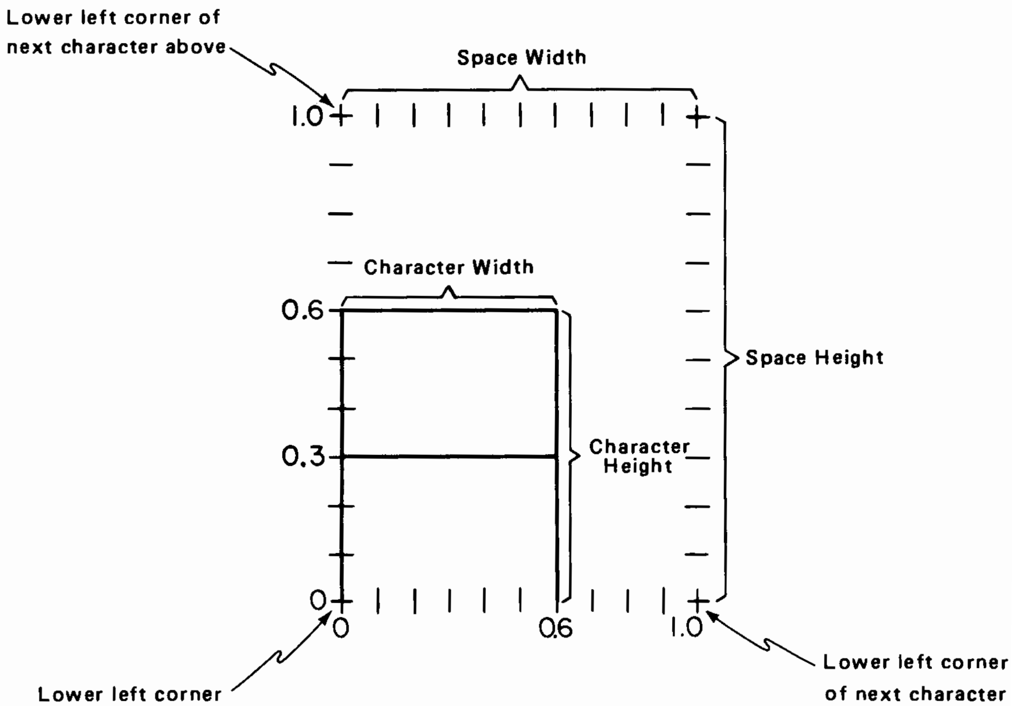
```
LABEL (*)"FOCUS"
```



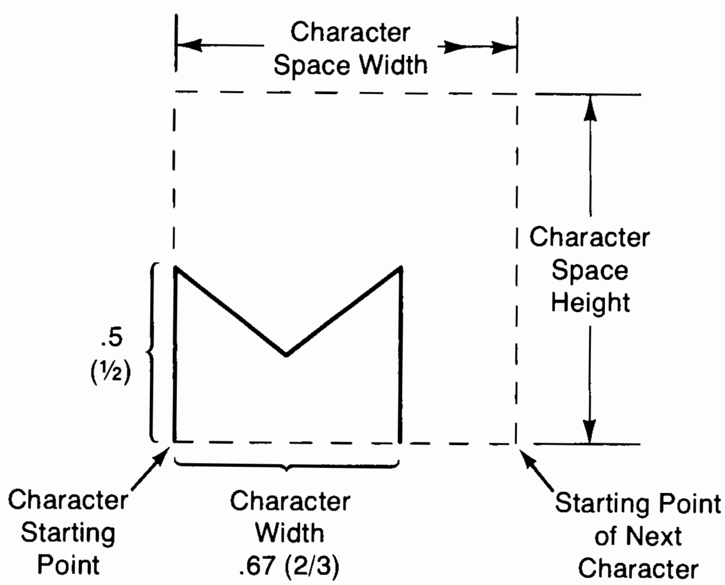
Lettering FOCUS on the 9862A Plotter

The Character Space

The character space is defined in the figures below. Notice that for the 9862A, the height and width are not necessarily equal and that each character dimension is six tenths of the corresponding space dimension. The 9872A character space is a 6 by 16 grid with the character origin at the lower-left corner of the character space. The parameters in a LABEL statement specify character height and aspect ratio, thus indirectly determining the size of the character space.



9862A Character Space



9872A Character Space

Labelling the Axis

This program illustrates the use of the LABEL and CPLOT statements for labelling graphs. The plot is similar to the one used in the first plotting example and requires the same size paper (7 by 10 inch). The program has four main segments:

Lines 20 thru 60 print the title.

Lines 90 thru 150 label the Y-axis.

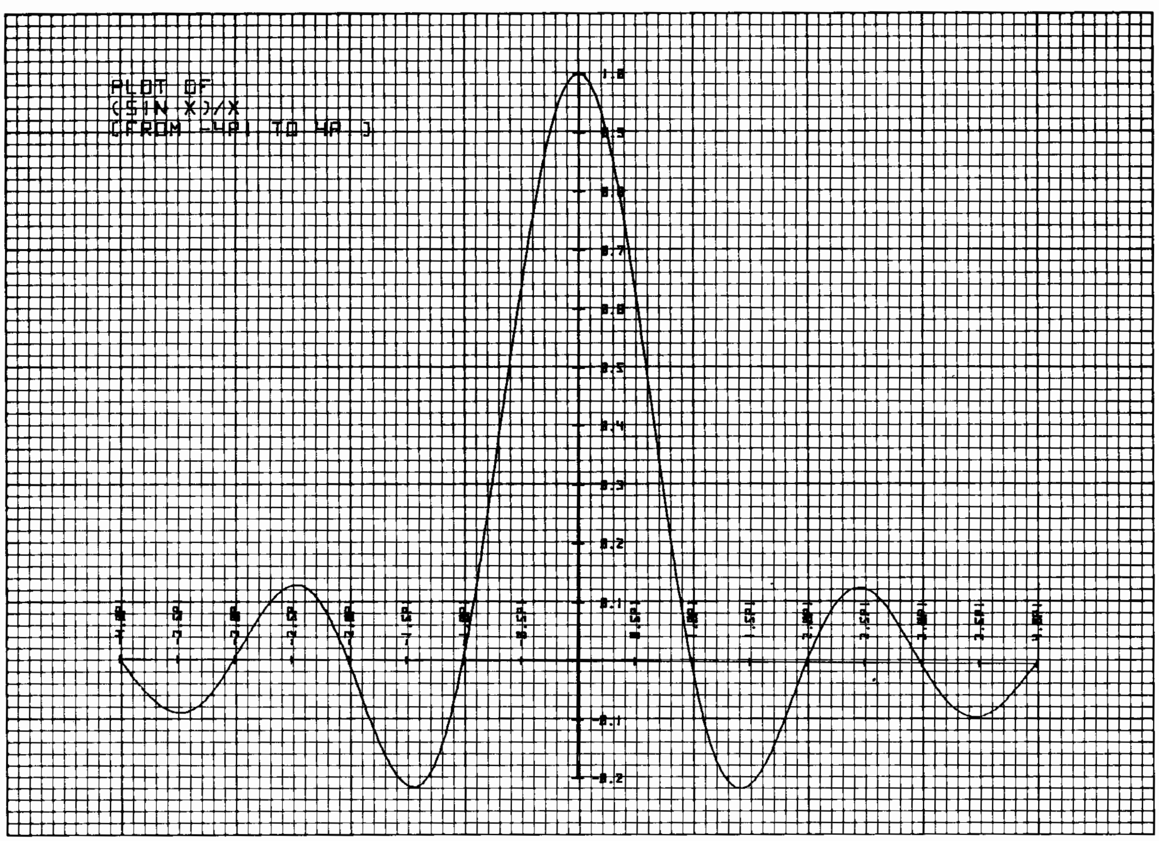
Lines 160 thru 220 label the X-axis.

Lines 240 thru 260 plot the function.

- The printout in lines 30 thru 50 uses the default character specifications. Line 50 references B format to print the brackets.
- Lines 90 and 160 establish the character specifications for the labelling along the Y-axis and the X-axis, respectively. The only difference between these two statements is that line 90 specifies zero rotation whereas line 160 rotates the printout by PI/2 radians (90 degrees).
- Lines 110 and 180 prevent the point 0,0 from being labelled.
- The PLOT and CPLOT statements in lines 120 and 130 (and in lines 190 and 200) act together: first, to move the pen to the point to be identified, and then to move the pen the required number of character spaces away from that point before printing.
- The LABEL statements in lines 140 and 210 both reference the FORMAT statement in line 230. The parameter in the FORMAT statement is doubled to prevent a carriage return/line feed between the value for X and the word "PI" when line 210 is executed.

```
10 SCALE -5*PI,5*PI,-0.3,1.1
20 PLOT -4*PI,0.96,1
30 LABEL (*)"PLOT OF"
40 LABEL (*)"(SIN X)/X"
50 LABEL (60)91,"FROM -4PI TO 4PI"93
60 FORMAT 2B
70 XAXIS 0,PI/2,-4*PI,4*PI
80 YAXIS 0,0.1,-0.2,1
90 LABEL (*,1,1.7,0,7/10)
100 FOR Y=-0.2 TO 1 STEP 0.1
110 IF Y=0 THEN 150
120 PLOT 0,Y,1
130 CPLOT 2,-0.3
140 LABEL (230)Y
150 NEXT Y
160 LABEL (*,1,1.7,PI/2,7/10)
170 FOR X=-4 TO 4 STEP 1/2
180 IF X=0 THEN 220
190 PLOT X*PI,0,1
200 CPLOT 2,-0.3
210 LABEL (230)X"pi"
220 NEXT X
230 FORMAT 2F4.1
240 FOR X=-4*PI TO 4*PI+PI/20 STEP PI/20
250 PLOT X,SIN(X)/X
260 NEXT X
270 PEN
280 END
```

STD-B-50238



Plot of Sin(X)/X with Labels

Plotting with X's

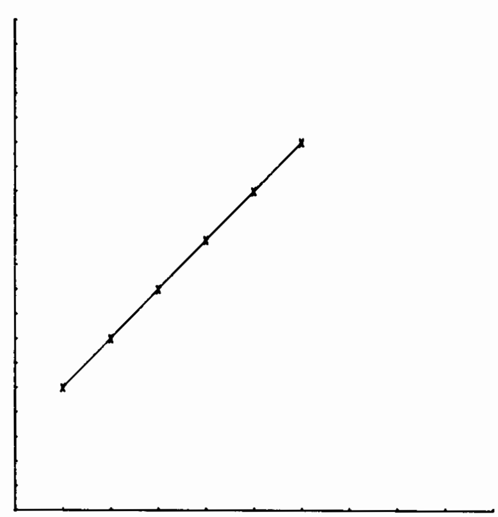
This program uses the CPLOT and LABEL statements to draw an X at each plotted point; at the same time a line is drawn between points. The program plots the function Y = 2*X+3 for X values from 1 thru 6.

This program illustrates a very important feature of the IPLOT statement, namely, that it moves the pen with respect to the last point plotted and is not affected by any intermediate CPLOT and LABEL statements.

After each point is plotted (line 50), the CPLOT and LABEL statements draw an X centered on that point. The next statement (line 80) is IPLOT 0,0 which, instead of leaving the pen exactly where it is as might be expected, returns the pen to the last point plotted.

The program assumes that the graph limits on the plotter are set for a square plotting area.

```
5 LABEL (*) "Δ"
10 SCALE 0,10,0,20
20 XAXIS 0,1
30 YAXIS 0,1
40 FOR X=1 TO 6
50 PLOT X,2*X+3
60 CPLOT -0.3,-0.3
70 LABEL (*)"x"
80 IPLOT 0,0
90 NEXT X
100 PEN
110 END
```



PLOTTING WITH X'S

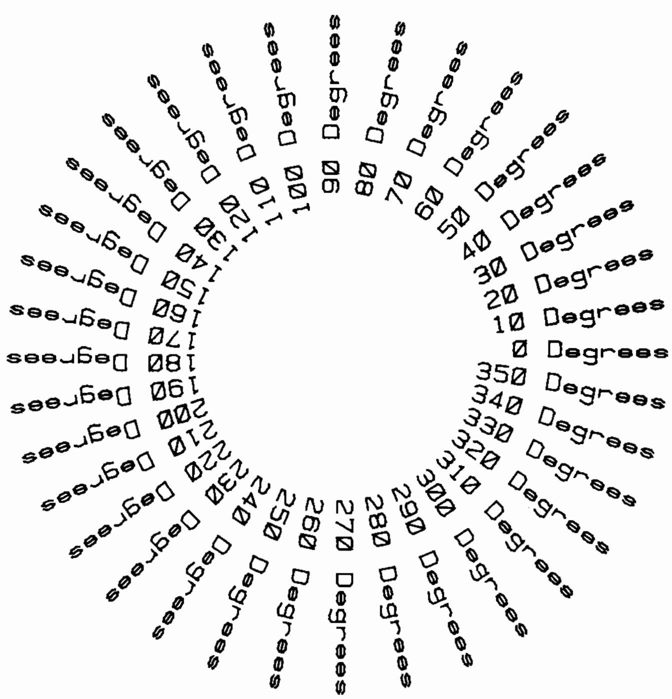
The 9872A Plotter has a symbol mode that automatically centers and draws a specified character at each plotted point. The symbol mode is explained in Chapter 3.

Rotating the Printout

This program demonstrates that a printout can be made at any angle simply by changing the value of the angle-of-rotation parameter in a LABEL statement.

A sheet of 7 by 10 inch plotter paper is required; if your paper has different dimensions, change the parameters in the SCALE statement and also the paper height/width parameter in the LABEL statement (line 50), to suit the size of your plotter paper.

```
10 DEG
20 SCALE 0,10,0,7
30 FOR D=0 TO 350 STEP 10
40 PLOT 5,3.5,1
50 LABEL (*,2,1.7,D,7/10)
60 CPLOT 8,-0.3
70 LABEL (90)D
80 NEXT D
90 FORMAT F4.0,X,"DEGREES"
100 END
```



Angle of Rotation Plot

The LETTER Statement

LETTER is a "stand alone" instruction requiring no parameters. When encountered in a program, or executed from the keyboard, it establishes a typewriter mode – with the computer keyboard acting as the typewriter keyboard and the plotter as the printing device. This command enables you to add any comments or labelling to your graphs without having to first program them.

As soon as the LETTER mode is established, a question mark (?) appears in the display. Any character or symbol can now be immediately printed by pressing the key which represents that character or symbol. The SHIFT key can be used to obtain the upper case characters. The dimensions of the characters and the direction of printing are determined by the current character specifications, derived from a previously encountered LABEL statement or from the default specifications if no previous LABEL statement was executed.

If the LETTER statement is encountered in a program, the program halts. The program automatically resumes at the next statement when the LETTER mode is terminated by pressing the STOP key.

When in the LETTER mode:

1. The question mark reappears in the display as soon as the plotter has finished printing the previous character and is ready for the next one.
2. The pen lifts after printing each character and moves to the next character position with the 9862A Plotter. With the 9872A Plotter, the pen lifts and remains at that character position.
3. All non-character keys are deactivated, except the RESET key and those mentioned below.
4. The four DISPLAY keys, with vertical and horizontal arrows on them, can be used to move the pen one character space in the direction indicated by the arrow on the key pressed (the direction is subject to the angle of rotation previously specified). With the 9862A Plotter, pressing the SHIFT key while a DISPLAY key is being pressed will move only one tenth of a character space. (See CPLOT, for a description of a character space.)
5. On the 9872A, the underline character (shifted Enter Exponent key) is a true underline. Thus, when an underline is encountered during a LABEL or LETTER statement, the result on the 9872A Plotter is a backspace and then an underline.

6. A carriage return/line feed instruction is simulated by pressing the EXECUTE key.
7. The LETTER mode is terminated by pressing the STOP key.

On the 9872A, the LETTER mode always selects character set 1. For information about the plotter's additional character sets, refer to "Character Sets" in Chapter 3.

Chapter 3

Additional 9872A Operations

Introduction

The operations which apply only to the 9872A Plotter are explained in this chapter. The additional operations include window plotting, pen selection, variable pen velocity, setting scaling points (P1 and P2) from the computer, specifying character slant, and digitizing. In addition, the entire set of 9872A Plotter mnemonics are listed and those that are unique are explained.

Window Plotting

Often it is useful to plot a small portion of a large plot, or to enlarge or emphasize a section of a plot. Window plotting provides this capability. The WINDOW instruction restricts programmed pen motion to a specific rectangular area on the platen, called a window.

Syntax:

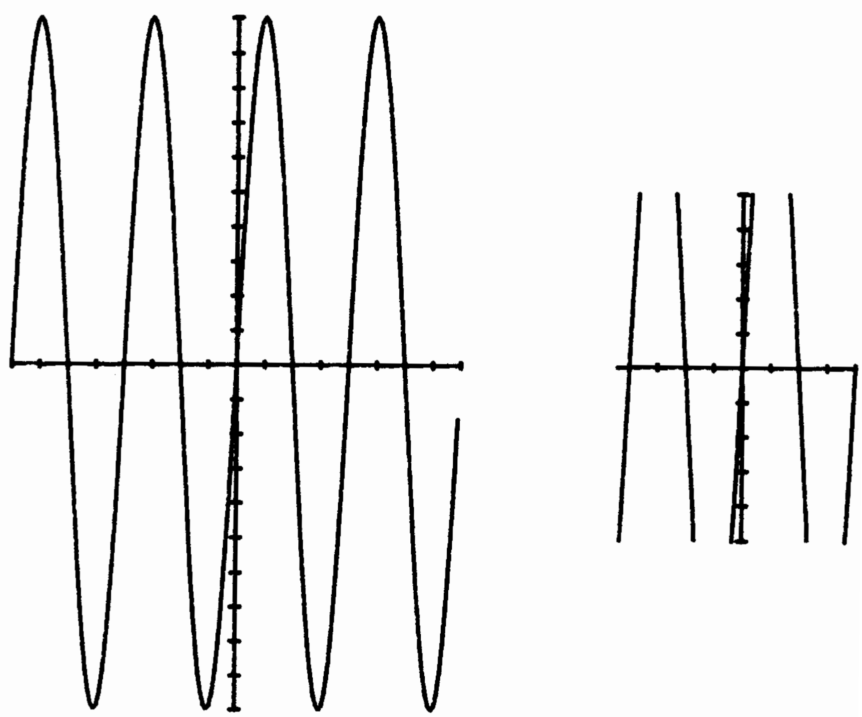
WINDOW [X_{min} , X_{max} , Y_{min} , Y_{max}]

If the X and Y parameters are omitted, the values are assumed to be the same as the mechanical limits.

Since the front panel controls on the 9872A Plotter override the window limits, points outside the window may be digitized in the digitize mode (see page 39).

In the following example, the function sin(X) is plotted on the left side of the paper from -4π to 4π along the X axis and from -1 to 1 along the Y axis. An OFFSET statement is then used to plot the function on the right side of the paper. The WINDOW statement in line 100 restricts the plot to an area of -2.2π to 2π along the X axis and $-.5$ to $.5$ along the Y axis.

```
5 LABEL (*) "∆"
10 SCALE -9*PI,9*PI,-1,1
20 RAD
30 OFFSET -4.5*PI,0
40 XAXIS 0,0.5*PI,-4*PI,4*PI
50 YAXIS 0,0.1,-1,1
60 FOR X=(-4*PI) TO (4*PI) STEP (PI/20)
70 PLOT X,SIN(X)
80 NEXT X
90 OFFSET 4.5*PI,0
100 WINDOW -2.2*PI,2*PI,-0.5,0.5
110 XAXIS 0,0.5*PI,-4*PI,4*PI
120 YAXIS 0,0.1,-1,1
130 FOR X=(-4*PI) TO (4*PI) STEP (PI/20)
140 PLOT X,SIN(X)
150 NEXT X
160 PEN
170 END
```



Plot of Sin (X) with WINDOW

Line Patterns

Normally, a solid line is satisfactory for plotting the graph of a function, but it is often desireable to use a different line pattern, such as a dotted line. Besides the normal solid line, seven other line patterns are available using the LINE statement.

Syntax:

```
LINE [pattern number [ , pattern length %]]
```

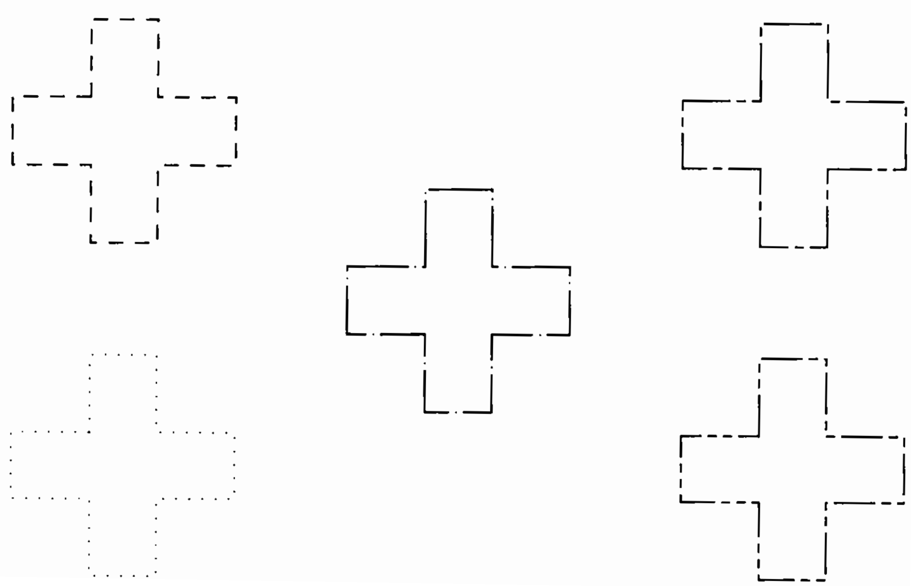
The pattern number specifies the desired line pattern as follows:

Pattern Number	Line Pattern (1 complete segment shown in color)
No parameter	Solid line.
0	Dots only at plotted points.
1	
2	
3	
4	
5	
6	

The pattern length parameter specifies the length of one complete pattern segment as a percentage of the diagonal distance between P1 (lower-left) and P2 (upper-right). If a pattern length parameter is not specified, a lenth of 4% is used. The pattern length can be from 0 thru 127.9995. The pattern is always continued from where it left off.

The following program plots five crosses, each with a different line pattern.

```
10 SCALE 0,100,0,70
20 OFFSET 20,20
30 LINE 1,1
40 GOSUB 180
50 OFFSET 20,50
60 LINE 2,2
70 GOSUB 180
80 OFFSET 80,50
90 LINE 4,6
100 GOSUB 180
110 OFFSET 80,20
120 LINE 5
130 GOSUB 180
140 OFFSET 50,35
150 LINE 6
160 GOSUB 180
170 STOP
180 PLOT -3,3,1
190 IPLOT 0,7,2
200 IPLOT 6,0
210 IPLOT 0,-7
220 IPLOT 7,0
230 IPLOT 0,-6
240 IPLOT -7,0
250 IPLOT 0,-7
260 IPLOT -6,0
270 IPLOT 0,7
280 IPLOT -7,0
290 IPLOT 0,6
300 IPLOT 7,0,-1
310 RETURN
320 END
```



Character Slant

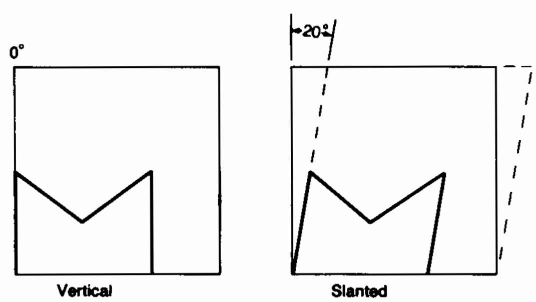
To print characters in an "italic" format, the SLANT statement is used.

Syntax:

SLANT [angle from vertical]

Character slant does not affect any parameters specified in the CSIZE statement. The angle can have any value except odd multiples of 90 degrees (n*90 degrees for n = odd integer). Thus angles such as 90 or 270 will result in ERROR 373. The same error results for odd multiples of $\pi/2$ radians or odd multiples of 100 grads. No parameter results in vertical characters, the same as SLANT 0. The parameter must be specified in the angular units currently set in the computer (i.e., radians, degrees or grads).

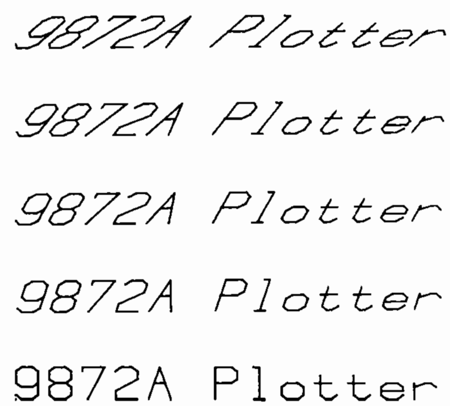
The illustration below shows two corresponding characters; one without character slant, and the other with a 20 degree character slant. Notice that only the vertical lines are changed, not the horizontal lines.



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

```
10 DEG
20 SCALE 0,10,0,10
30 SLANT 20
40 PLOT 1,9,-1
50 GOSUB 190
60 SLANT 30
70 PLOT 1,7,-1
80 GOSUB 190
90 SLANT 40
100 PLOT 1,5,-1
110 GOSUB 190
120 SLANT 50
130 PLOT 1,3,-1
140 GOSUB 190
```

```
150 SLANT
160 PLOT 1,1,-1
170 GOSUB 190
180 STOP
190 LABEL (*,4,2,0)"9872A Plotter"
200 RETURN
210 END
```



Pen Selection

One of four pens can be selected using the SPEN (select pen) statement.

Syntax:

`SPEN` [pen number]

The pen number can range from 1 thru 4, specifying the corresponding pen in the pen storage location. When SPEN is executed, the pen-arm lifts from the current pen position, returns the pen to its empty slot, selects the specified pen, moves back to the previous pen position and sets the pen down if it was down previously.

If the pen-number parameter is omitted or if it is 0, the pen is returned to an empty pen storage slot without selecting another pen. The pen arm then returns to its previous location on the platen. This is useful at the end of a plot to prevent the pen from drying out.

Error 373 occurs if a pen number outside the range of 0 through 4 is specified.

If all of the pen storage slots are empty, or if they are all full and the pen holder has a pen, no operation occurs.

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

```
5 LABEL (*) "x"
10 SCALE -10,10,-100,100
20 SPEN 1
30 XAXIS 0,1,-10,10
40 YAXIS 0,10,-100,100
50 SPEN 2
60 FOR X=-10 TO 10
70 PLOT X,X↑2
80 NEXT X
90 PEN
100 SPEN 3
110 FOR X=-10 TO 10
120 PLOT X,10*X
130 NEXT X
140 PEN
150 SPEN 4
160 FOR X=-10 TO 10
170 PLOT X,-10*X
180 NEXT X
190 PEN
200 SPEN
210 END
```

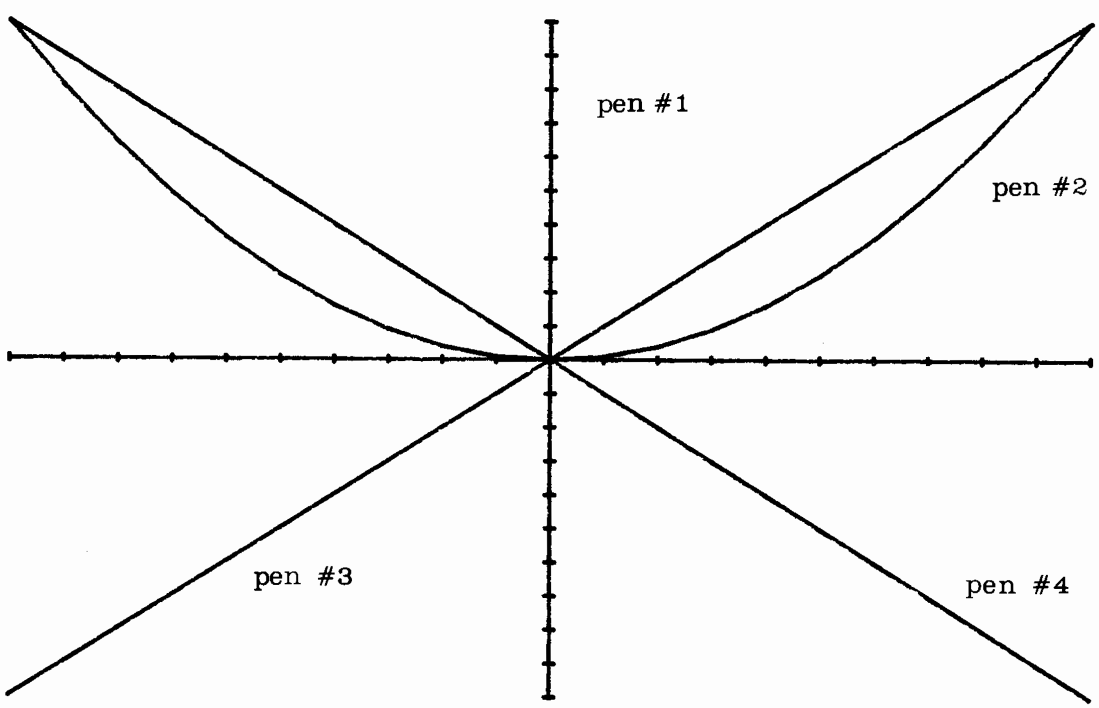
The axes are drawn in black (pen #1) by lines 10-40.

The function (Y = 10X is plotted in red (pen #2) by lines 50-90.

The function Y = 10X is plotted in green (pen #3) by lines 100-140.

The function Y = 10X is plotted in blue (pen #4) by lines 150-190.

The pen is put away. Line 200.



Pen Velocity

The pen velocity can be changed from 1 cm/sec to a maximum of 36 cm/sec using the VEL statement. The normal pen velocity is 36 cm/sec. This statement is useful for enhancing line quality, especially for reproduction purposes.

Syntax:

VEL [centimeters/second [, pen number]]

The pen velocity of an individual pen is specified by the pen number parameter. The pen number corresponds to the pen numbers marked on the front of the plotter. If a pen number is omitted, the specified velocity applies to all the pens. Error 373 occurs if the velocity is outside the range of 1 through 36, or if the pen number is outside the range of 1 through 4.

Changing Scaling Points

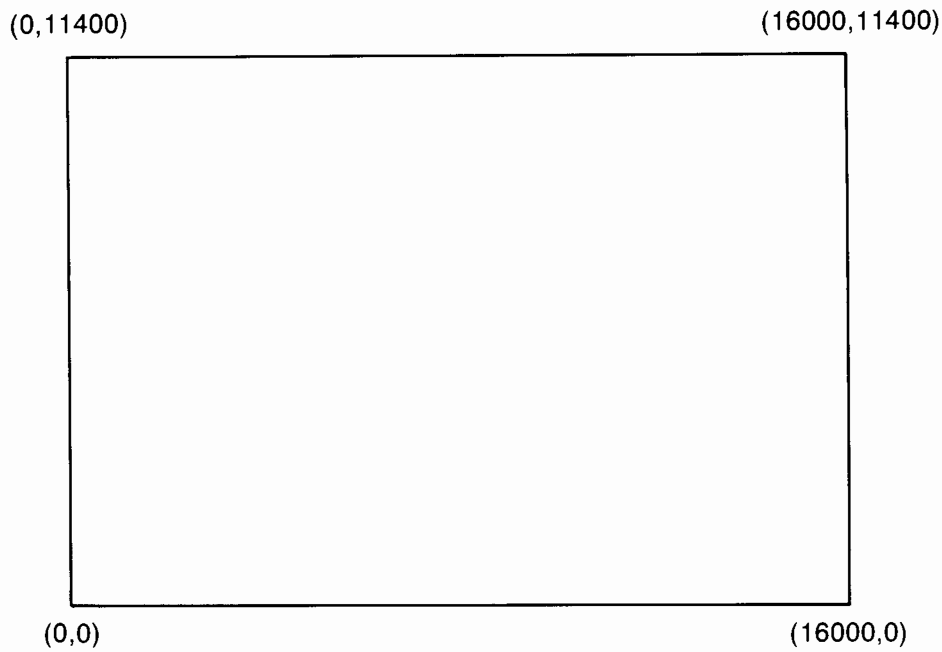
The scaling points of the 9872A Plotter, P1 (lower-left) and P2 (upper-right), can be set from the computer by means of the MAP statement.

Syntax:

MAP [X_{P1} , X_{P2} , Y_{P1} , Y_{p2}]

The X and Y coordinates of P1 and P2 must be specified in absolute units (.025mm/unit). This statement makes it possible to set the plotter limits from a program without having to manually set them from the plotter front panel.

The absolute coordinates for the platen are shown in the following illustration:



X values outside the range 0 through 16000 and Y values outside the range 0 through 11400 causes an error 383. X_{P1} must be less than X_{P2} and Y_{P1} must be less than Y_{P2} or error 378 will occur. When a SCALE statement is executed specifying no parameters results in the same operation as `MAP 520, 15720, 380, 10380`.

Digitizing

The 9872A has an additional capability called digitizing. Digitizing is the opposite of plotting. Instead of plotting points, points from a graph are entered into the computer as discrete X,Y coordinates. Digitizing can be useful for converting graphic data to numeric data for storage, for enlarging or reducing a graph, or for modifying a plot.

Syntax:

`DIG` X-variable , Y-variable [, pen status variable]

The X coordinate of the digitized point is stored in the X-variable and the Y coordinate in the Y-variable. The pen status (1 = up, 0 = down) can be entered into the optional pen-status variable. All three return variables must be numeric variables (e.g., A[10], P, etc.).

To digitize a point, first execute the DIG statement from the computer. This causes the light on the [ENTER] key to come on. Then move the point of the plotter pen to the point to be digitized using the pen control buttons on the front of the plotter. When you have positioned the pen point, press the [ENTER] key. The light on the key will go out and the coordinates of the point will be stored in the specified variables in the computer.

A special plotter pen is available for digitizing which allows you to visually position the pen directly over the point to be digitized.

If DIG has been executed and no point is to be entered, you can terminate the digitize mode by pressing the [STOP] key on the computer. The values of the return variables (X-variable and Y-variable) will not be changed. If the terminated DIG statement is in a program, the program stops at the end of the line containing the DIG statement.

When the plotter is in the digitize mode, indicated by the enter key light being on, the enter key cannot be used to initialize, to set new scaling points, or to return the pen to the pen storage location. The enter light must be off before any of these operations can be performed.

The following example draws a square figure and then allows you to digitize points around it by moving the pen, via the pen movement 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.

```
10 SCALE 0,20,0,16
20 PLOT 5,4,-1
30 IPLOT 0,8,2
40 IPLOT 10,0
50 IPLOT 0,-8
60 IPLOT -10,0,-1
70 X=Y=A=B=C=D=P=0
80 DISP "Digitize the first point, please."
90 DIG X,Y
100 A=C=X
110 B=D=Y
120 DISP "Enter the next point, please.";
130 DIG X,Y
140 P=P+SQR(((X-A)↑2)+((Y-B)↑2))
150 A=X
160 B=Y
170 IF SQR(((X-C)↑2)+((Y-D)↑2))<0.1 THEN 190
180 GOTO 120
190 DISP "The perimeter = ";P;
200 END
```

Plotter Mnemonics

The 9872A Plotter has its own instruction set which allows it to perform all of the functions described previously, including several of operations which are not described elsewhere. These instructions are sent to the plotter by the WRITE statement. (For example, to send the Adaptive Velocity instruction, VA, execute WRITE(705,*)"VA".) Only instructions which are not implemented by the Matrix/9872A Plotter ROM are described in detail in the following pages.

Table of 9872A Plotter Instruction Mnemonics

Mnemonic	Description	Equivalent Plotter ROM Instruction
Axes Group		
TL	Tic length	none
XA	X-Axis	XAXIS*
YA	Y-Axis	YAXIS*
Plot Group		
AP	Automatic Pen Pick-up	none
PA	Plot Absolute	PLOT
PR	Plot Relative	IPLOT*
PU	Pen Up	PEN
PD	Pen Down	PLOT* or IPLOT*
Character Group		
CA	Designate Alternate Character Set	none
CS	Designate Standard Character Set	none
CP	Character Plot	CPLOT
DI	Direction Absolute	LABEL*
DR	Direction Relative	LABEL*
LB	Label	LABEL
SR	Character Size Relative	LABEL*
SL	Character Slant (absolute)	SLANT
SS	Select Standard Character Set	none
SA	Select Alternate Character Set	none
UC	User Character (definable)	none
Line Type Group		
LT	Line Type	LINE
SM	Symbol Mode	none
SP	Select Pen	SPEN
VA	Velocity Adaptive	none
VN	Velocity Normal	VEL*
VS	Velocity Select	VEL

Window Instruction		
IW	Input Window	WINDOW
Digitize Group		
DC	Digitize Clear	DIG*
DP	Digitize Point	DIG
OC	Output Current Pen Position to Computer	DIG*
OD	Output Digitized Point to Computer	DIG
Configuration and Status Group		
DF	Default Values	none
IM	Input Mask	none
IN	Initialize	none
IP	Input P1,P2 into Plotter	MAP
OE	Output Error	none
OP	Output P1,P2 to Computer	none
OS	Output Status	none

* Not directly equivalent, but operation is similar.

The Tic Length Instruction

WRITE (ccdd;*) "TL [Up and Right Tic Length [; Down and Left Tic Length]]"

The tic length instruction 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.

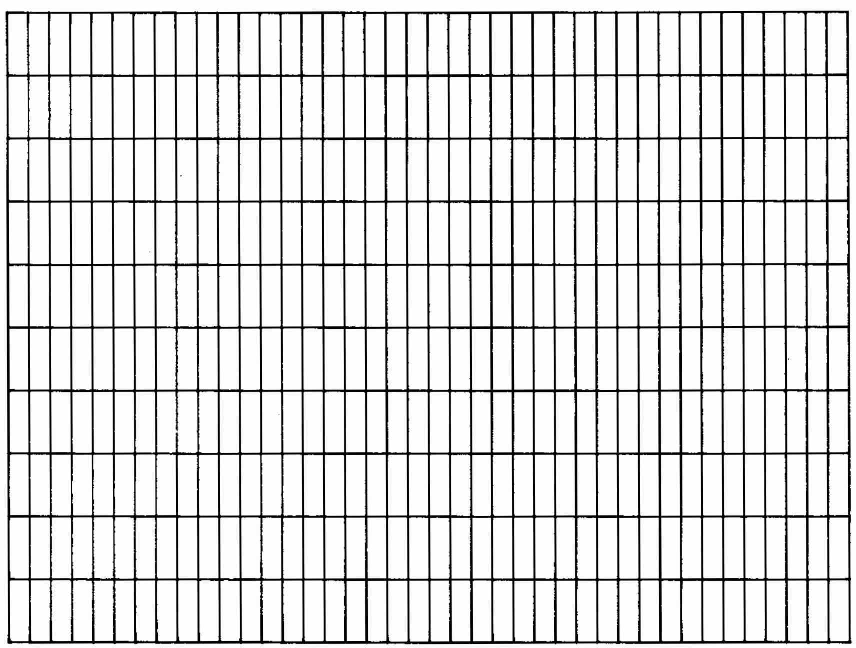
The "up and right tic length" determines the length of the upward portion of the tic marks drawn along the X axis and the right side portion of the tic marks drawn along the Y axis. This value is specified as a percentage of the vertical scale length, .$Y_{p2} - Y_{p1}$..

The "down and left tic length" determines the length of the downward portions of the tic marks drawn 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 ($|X_{p2} - X_{p1}|$ and $|Y_{p2} - Y_{p1}|$).

The program shown below uses the tic length instruction 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).

```
5 LABEL (*) ">"
10 SCALE 0,10,0,100
20 WRITE (705,*)"t1100"
30 XAXIS 0,0.25,0,10
40 YAXIS 0,10,0,100
50 END
```



The Automatic Pen Pick-up Instruction

WRITE (ccdd,*) "AP"

The automatic pen pick-up instruction, AP, causes the plotter to automatically raise the pen whenever it has been lowered 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 pick-up.

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).

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.

Character Set1

! "#$%&'()*+,-./Ø123456789:;<=>?

@ABCDEFGHIJKLMNOPQRSTUVWXYZ[ſ]↑

_`abcdefghijklmnopqrstuvwxyzπ⊢→~

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

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

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

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

The Designate Standard Character Set Instruction

WRITE (ccdd,*) "CS (0 thru 4)"

This instruction designates one of the five character sets (0 thru 4) as the standard character set. This character set will be used for all labelling 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 Instruction

WRITE (ccdd,*) "CA (0 thru 4)"

The alternate character set is specified by this instruction. 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 Instruction

WRITE (ccdd,*) "SS"

This instruction selects the character set that has been designated as the standard set for use with the "LB" instruction.

The Select Alternate Set Instruction

WRITE (ccdd ; *) "SA"

This instruction selects the character set that has been designated as the alternate character set for use with the "LB" instruction.

Note

Both the LETTER and LABEL statements use only character Set 1.

The LB Instruction

WRITE (ccdd ; *) "LB (character)(character)..... " ; WBYTE 3

The LB instruction causes the plotter to letter the characters sent after "LB. The characters are lettered according to the currently specified character set (standard or alternate). The last character in the string must be the decimal value 3 (EOT) to terminate the instruction.

For example, this line prints '9872A Plotter'.

```
10 WRITE (705,*)"LB9872A Plotter";WBYTE3
```

It is also possible to send characters to the plotter using a format B statement with a WRITE statement. The characters are sent as the decimal equivalent of their ASCII code. A complete table of ASCII characters is given in the Appendix.

For example, these lines also print '9872A Printer'.

```
20 FORMAT 16B
30 WRITE (705,20)76,66,57,56,55,50,65,32,80,108,111,116,116,101,114,3
```

The User Defined Character Instruction

WRITE (ccdd ; *) "UC o 99, X increment, Y increment, o 99, X increment, Y increment, o 99...... "

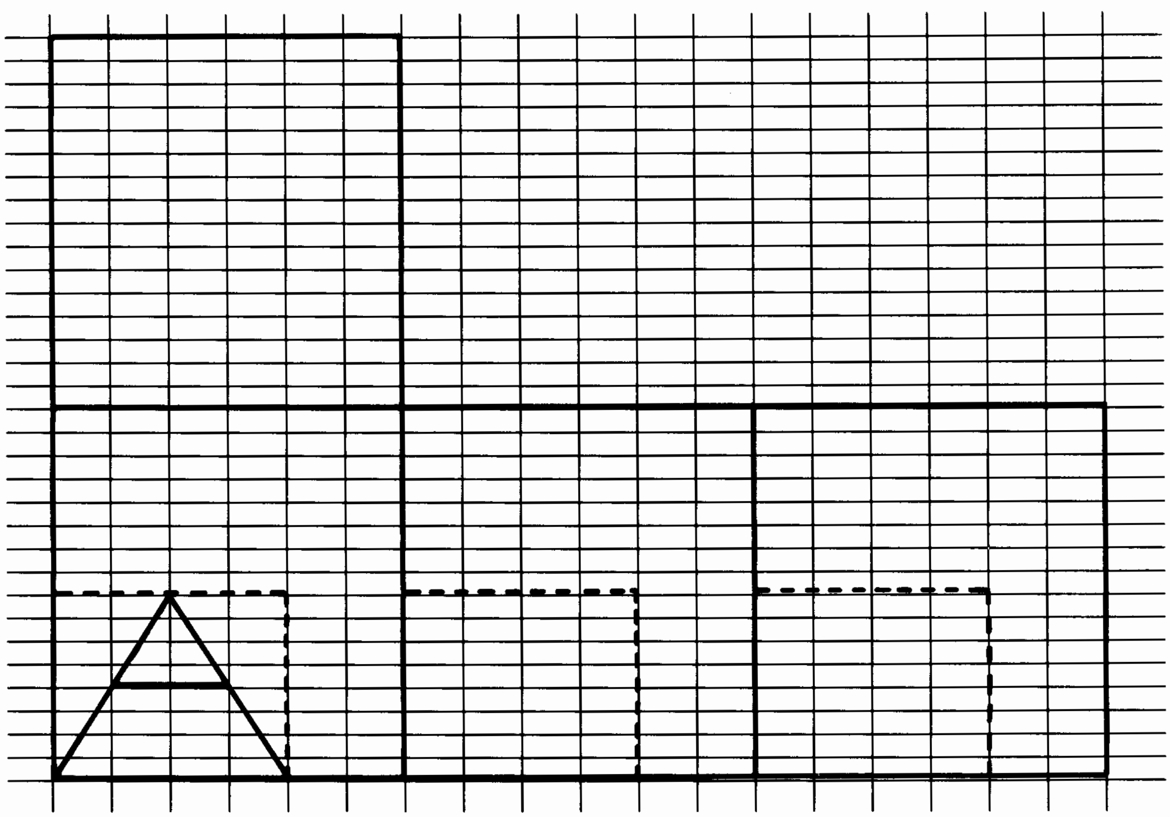
The user defined character instruction is used to draw characters of your own design. Each segment of the character is drawn according to three parameter values as follows:

o 99 − +99 = pen down and −99 = pen up

X increment – specifies the number of character grid units that the pen will move horizontally. A positive value moves the pen to the right, and a negative value moves it to the left. The increment value can range from −98 thru +98 units.

Y increment – specifies the number of character grid units that the pen will move vertically. A positive value moves the pen up and a negative value moves it down. The increment value can range from −98 thru +98 units.

The character grid units are scaled by the current LABEL statement as shown below. Each character block contains 6 horizontal units and 16 vertical units.



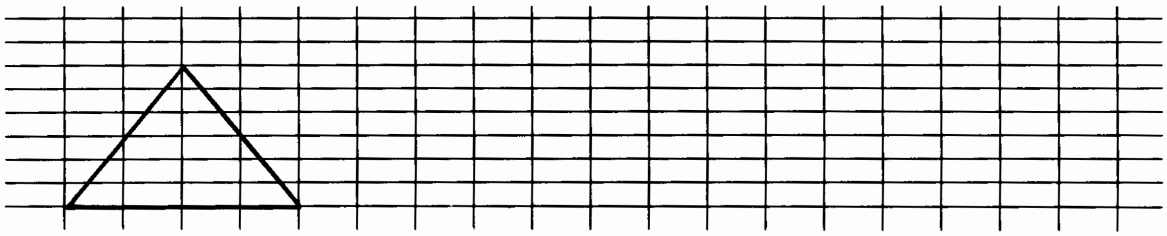
Character Grid

Each character starts from the character block origin point. When the character is completed, the LF that is sent automatically by the write statement at the end of the string of characters returns the pen to the next character-block's origin (6 grid units from the initial starting point). This may not be a valid starting point if the new character was larger than a normal character. A PLOT, IPLOT or CPLOT statement may be needed to properly position the pen for the next characters, if any, to be lettered.

A user defined character is drawn with the current character slant.

The following example draws the Greek character delta, Δ.

```
10 WRITE (705,*)"uc99,2,6,99,2,-6,99,-4,0"
```



User Defined Character Example

The Symbol Mode Instruction

```
WRITE (ccdd,*) "SM(character)"
```

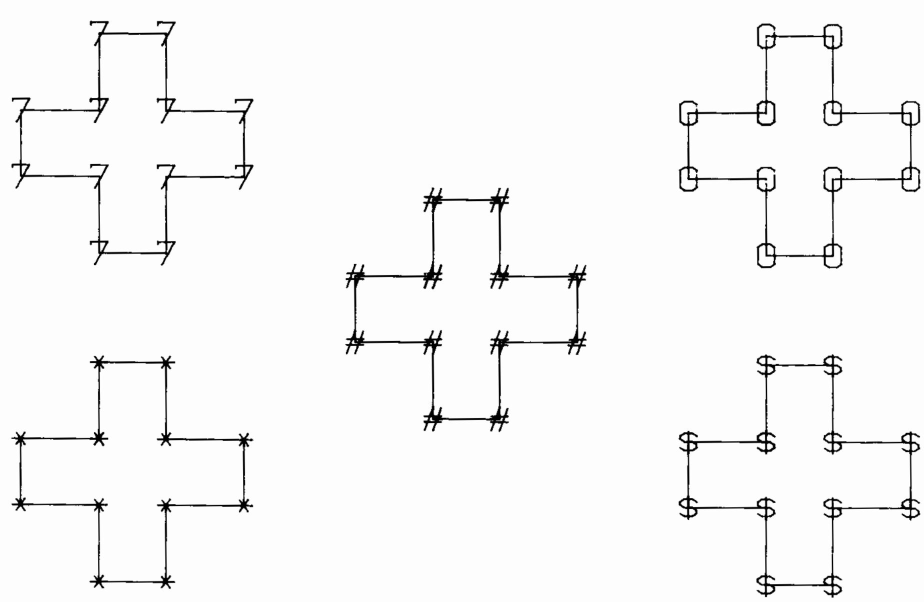
The symbol mode instruction sets the symbol mode for use with PLOT or IPLOT statements. The PLOT and IPLOT statements function as described in Chapter 2 except that the specified character is drawn, centered on the plotted point. The character is drawn according to the currently selected character set. If a character is not specified, the symbol mode is cancelled. 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 are from Set 0. In addition, characters that replace any of these in other character sets cannot be used 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 select a specific character to be drawn at each corner point for each of the crosses.

```
10 SCALE 0,100,0,70
20 OFFSET 20,20
30 WRITE (705,*)"sm7"
40 GOSUB 180
50 OFFSET 20,50
60 WRITE (705,*)"sm*"
70 GOSUB 180
80 OFFSET 80,50
90 WRITE (705,*)"sm#"
100 GOSUB 180
110 OFFSET 80,20
120 WRITE (705,*)"smO"
130 GOSUB 180
140 OFFSET 50,35
150 WRITE (705,*)"sm$"
160 GOSUB 180
170 STOP
180 PLOT -3,3,1
190 IPLOT 0,7,2
200 IPLOT 6,0
210 IPLOT 0,-7
220 IPLOT 7,0
230 IPLOT 0,-6
240 IPLOT -7,0
250 IPLOT 0,-7
260 IPLOT -6,0
270 IPLOT 0,7
280 IPLOT -7,0
290 IPLOT 0,6
300 IPLOT 7,0,-1
310 RETURN
320 END
```

Symbol Mode Plots

The Adaptive Pen Velocity Instruction

WRITE (ccdd;*) "VA"

This instruction 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 relative slow program routine (fewer than 15 coordinates/second).

The Normal Velocity Instruction

WRITE (ccdd;*) "VN"

The normal velocity instruction cancels the adaptive velocity mode. The pen speed is now controlled by the current pen velocity instruction (VEL).

The Default Instruction

WRITE (ccdd;*) "DF"

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

Function	Conditions
Automatic Pen Pick-up	ON
Alternate Character Set	Set 0
Character Size (size)	1.5, 2, 1, 0
Window Area (limit)	Total platen area
Line	Solid Lines
Line Pattern Length	4% of P1 − P2 diagonal
Character Slant	Slant = 0 °
Symbol Mode	Disabled
Selects Standard Character Set	Set 0
Tic Length	.5% of P1 − P2 for each half of the tic mark
Pen Velocity	36 cm/sec.
Adaptive	Disabled

The default command does not affect the current location of P1 or P2, the current pen position, the current scale statement or the current stdplt statement.

The Initialize Instruction

WRITE (ccdd,*) "IN"

This instruction is the equivalent of switching the plotter off and then on again or initializing it from the front panel. The initialize instruction sets the plotter to the same conditions as the default instruction 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 tothe points P1 = (520, 380) and P2 = (15720, 10380).

The Mask Instruction

WRITE (ccdd,*) "IM E−mask value, S−mask value, P−mask value;"

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

The E-mask value 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 to the computer. Since the 9831A does not respond to the require-service message, the S-mask value should always be zero. An S-mask value of zero will prevent the plotter from sending a require-service message.

The P-mask value specifies the status-byte bits that can cause the plotter to respond to a parallel poll. Since the 9831A computer does not have parallel-poll capability, the p-mask value should be zero.

The Output Status Instruction

```
WRITE (ccdd;*) "OS"
READ (ccdd;*) variable
```

This instruction causes the plotter to output the decimal sum of its status-byte bits. If a bit is set to a logical 1 (indicating that the condition represented by that bit is "true"), the positional value of that bit will be summed with the other bits that are set to the logical 1 condition. The summed total of these bits is then sent to the computer and assigned to a variable by a READ statement as shown above. The following table shows the positional values and conditions represented by the various bits of the status byte.

Bit Positional Value	Status Bit Number	Condition
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 sent (SRQ)

Locating Current P1 and P2

```
WRITE (ccdd;*) "OP"
READ (ccdd) variable 1, variable 2, variable 3, variable 4
```

The "OP" instruction causes the plotter to send the computer the coordinates of the scaling points, P1 and P2. These coordinates, in absolute plotter units, are input by the computer using a READ statement with four variables. The coordinates are assigned to the variables in the following order:

Xp1	→	Variable 1
Yp1	→	Variable 2
Xp2	→	Variable 3
Yp2	→	Variable 4

This command is useful for determining the current P1 and P2 locations for reference with a MAP statement.

Chapter 4
Matrix Operations

Description

A matrix is a two-dimensional collection of data elements arranged in rows and columns. A vector is a collection of data elements arranged in a single column or row. Here is an example of a matrix:

Grade	Boys	Girls
1	10	7
2	9	8
3	9	10
4	7	9
5	7	10
6	9	11

Here is an example of a vector:

Test Scores
93
85
79
89
68
95
100

Matrix Names

A matrix name consists of any single letter from A thru Z, hence, up to 26 matrices can be assigned at the same time in one program.

Matrix Definition

To reserve storage space for arrays (matrices and vectors), a DIM or COM[1] statement is used. Arrays not mentioned in a DIM statement are assumed to have 10 elements if they are one-dimensional, or 10 rows and 10 columns if they are two-dimensional.

The number of elements in a vector, or the number of rows or columns in a matrix, must be specified as an integer from 1 thru 32767 in a DIM statement as:

```
10 DIM A[100]
20 DIM B[75,5]
30 DIM C[20,20]
```

In statement 10 above, array A is a column vector of 100 row elements.

In statement 20, array B is dimensioned 75 rows by 5 columns. This row-column convention is used throughout this manual.

In statement 30, array C has the same number of rows and columns, and is square. A square matrix has the same number of rows and columns. Some matrix operations, such as matrix inversion, can only be performed on square matrices.

Generally, the operations which apply to matrices also apply to vectors. So it is convenient to think of a column vector of n elements as an "n by 1" matrix, and a row vector of n elements as a "1 by n" matrix.

In this manual, arrays, whether they are one- or two-dimensional, are referred to as matrices. A distinction is made only when special rules apply to the use of vectors.

Space can be saved when storing large quantities of array data by specifying integer or split precision. This is because while full (normal) precision requires four words of computer memory per array element, split precision requires two words and integer precision requires only one word per array element. Matrices using split or integer precision must be specified in the DIM statement as shown below:

```
10 DIM AS[200,5]
20 DIM BI[100,14]
```

1 The COM statement can also be used to reserve storage space for arrays, but must be the first statement entered into the computer memory. Refer to the 9831A Operator's Manual for more information about the COM statement.

Although computer memory can be saved using split or integer precision when storing data, the determinant and inverse of a matrix should be performed only on full precision matrices. This is because when integer or split precision are specified, errors due to repetitive internal rounding are multiplied during complex operations and often result in illogical answers. Therefore, use full precision whenever memory is available, and do not use split or integer precision when inverting or finding the determinant of a matrix.

Matrix Boundaries

The working size of a matrix can be smaller than its physical size, which is the space reserved in the DIM or COM statement. For example, a 20 by 20 matrix specified in a DIM statement can be used to store fewer than 400 data elements; the DIM statement supplies only an upper bound on the number of elements.

Redimensioning a Matrix

The working size of a matrix can be changed using the REDIM statement.

Syntax:

REDIM matrix name[expression [, expression]],....

The working size of the matrix is specified by the optional expressions shown in the syntax. If the working size is not specified, the size is set equal to the physical size reserved for the matrix. A REDIM statement may contain more than one matrix name provided that they are separated by commas.

Four other statements can be used to change the working size of a matrix. They are: MAT READ, CON, ZER, and IDN explained later in this chapter.

Note

When a new working size is specified for a matrix containing data, the data is rearranged.

The following example shows matrix A which has a working size of 2 by 3.

4	7	9
5	8	10

The following REDIM statement changes the working size to 3 by 2.

```
REDIM A[3,2]
```

Matrix A is now:

4	7
9	5
8	10

When you have a large program, a matrix which contains data that is no longer needed can be redimensioned and used to store new data. This allows you to use the same space in the computer memory more than one time instead of allocating memory for more arrays.

Input and Output of Matrices

Some of the methods for entering a table or list of data in a matrix and for printing a table or list of data from a matrix are discussed in this section.

Keyboard Data Input

The INPUT statement, with the FOR and NEXT statements, makes it easy to enter a matrix from the keyboard. The following instructions enable a 5 by 3 matrix to be entered one row at a time.

```
10 DIM A[5,3]
20 FOR J=1 TO 5
30 INPUT A[J,1],A[J,2],A[J,3]
40 NEXT J
```

Data Input From A Program

You can include the values to be stored in a matrix using programmed DATA and READ statements with the FOR and NEXT statements, to assign values to elements in the matrix. With the following instructions, a 3 by 2 matrix is read.

```
10 DIM A[3,2]
20 DATA 12,10,5,3,14,7
30 FOR M=1 TO 3
40 FOR N=1 TO 2
50 READ A[M,N]
60 NEXT N
70 NEXT M
```

The MAT READ Statement

Using the MAT READ statement, the FOR...NEXT loop that is used with the READ statement is not needed. The entire matrix is read from the corresponding DATA statement.

Syntax:

MAT READ matrix name [(expression [, expression])],...

The following lines read a 3 by 2 matrix using the MAT READ statement:

```
10 DATA 12,10,5,3,14,7
20 MAT READ A[3,2]
```

The MAT READ statement causes the matrix to be filled from the DATA statement in the conventional row-column order: 1,1; 1,2; 2,1; and so forth.

```
10 MAT READ A
20 MAT READ X[6]
30 MAT READ M[N,P]
40 MAT READ C,D,E[6,N]
```

A new working size (created by an implied REDIM statement, see page 55) may be specified, as in statements 20 and 30 above, but must be within the limits of the DIM statement.

If no size specification is included, as in 10, above, the working size of the matrix is unchanged. If your program does not contain a dimension specification a 10 by 10 matrix is assumed and the first 100 elements in the DATA statement are used, or a 10 element vector is assumed and the first 10 elements in the DATA statement are used. For example, the statement `A(5) = 32` causes a vector to be assumed.

More than one matrix name can appear in a MAT READ statement, as in statement 40, above.

Printing Matrices

The PRINT statement provides control in printing headings and other information with a matrix. Using the following instructions, the data in the 3 by 2 matrix A can be printed and labelled.

```
10 DIM A[20,20]
20 DATA 12,10,5,3,14,7
30 MAT READ A[3,2]
40 PRINT "Grade   Boys   Girls"
50 FOR M=1 TO 3
60 PRINT M;A[M,1];A[M,2]
70 NEXT M
```

The MAT PRINT Statement

Although a matrix can be printed element-by-element by using the PRINT statement, the MAT PRINT statement is easier to use. The MAT PRINT statement causes an entire matrix to be printed row by row. Each row starts a new line, but when all the elements in a row will not fit in one line, the elements overflow into additional lines. Each row is separated by a blank line.

Syntax:

`MAT PRINT` matrix name [`,` or `;` matrix name] ...

The spacing between row elements is controlled by the use of the comma or the semicolon. The comma causes the matrix to be printed with a maximum of five elements per line, while the semicolon causes the matrix to be printed with up to twelve elements per line. If a single matrix or the last matrix in a statement does not have either a comma or a semicolon after it, the matrix will be printed as if a comma were there. A one-dimensional array, or column vector, is printed one element per line with double spacing.

```
10 MAT PRINT A
20 MAT PRINT M;
30 MAT PRINT A,X;Y
```

Matrix Arithmetic

The operations discussed in this section are specifically intended for use with matrices. However, all BASIC language operations that can be performed on simple variables can also be performed on individual matrix elements, such as IF, WRITE, SQR, ABS, and so on.

Matrix Addition

The corresponding elements of two matrices can be added together using the MAT (matrix) statement.

Syntax:

MAT matrix name = matrix name + matrix name

Each element in the second matrix is added to the corresponding element in the third matrix and the result is stored in the corresponding position in the first matrix. The dimensions of the three matrices must be the same. Memory space can be saved if the result is accumulated in one of the matrices already containing data, as with X in the line:

```
MAT X=X+Y
```

Matrix Subtraction

The corresponding elements of two matrices can be subtracted using the MAT (matrix) statement.

Syntax:

MAT matrix name = matrix name − matrix name

As with matrix addition, all matrices must have the same dimensions. Example:

```
110 MAT C=A-B
120 MAT X=X-Y
```

Scalar Multiplication

Each element in a matrix can be multiplied by a number or by the value of any arithmetic expression. The number must be enclosed in parenthesis and must precede the matrix name.

Syntax:

MAT matrix name = (expression) * matrix name

Each matrix must have the same dimensions if more than one matrix is named. In statements 120 and 130, below, N is a simple variable.

```
110 MAT A=(5)*A
120 MAT X=(N/3)*Y
130 MAT P=(SQR17+3↑N)*R
```

Copying Matrices

To duplicate a matrix into another matrix, the MAT (matrix) statement is used.

Syntax:

MAT matrix name = matrix name

Each matrix must have the same dimensions. Example:

Matrix Arithmetic Example

The two tables below contain the Math, Science, and Reading grades achieved by five students during two quarters of one school year.

First Quarter

Student No.	Math	Science	Reading
1	80	85	78
2	71	80	72
3	97	92	83
4	77	82	98
5	93	94	98

Second Quarter

Student No.	Math	Science	Reading
1	78	81	80
2	73	82	88
3	93	90	85
4	81	88	94
5	91	90	84

We will use the grades in the first quarter for matrix A, and in the second quarter for matrix B:

Matrix A

80	85	78
71	80	72
97	92	83
77	82	98
93	94	98

Matrix B

78	81	80
73	82	88
93	90	85
81	88	94
91	90	84

If the statement `MAT C=A+B` is executed, matrix C contains:

158	166	158
144	162	160
190	182	168
158	170	192
184	184	182

The grades for each student in each class have been added. To find the average of the two term grades for each student in each class, execute `MAT C=(1/2)*C`. The result in C is now:

79	83	79
72	81	80
95	91	84
78	85	96
92	92	91

The array now represents the average grade for each student in each of the three subjects:

Average Mid-Year Grades

Student No.	Math	Science	Reading
1	79	83	79
2	72	81	80
3	95	91	84
3	95	91	84
4	79	85	96
5	92	92	91

Matrix Multiplication

Matrices can be multiplied only when the number of columns in the first matrix equals the number of rows in the second matrix; the resulting matrix must have the same number of rows as the first matrix and the same number of columns as the second matrix. The name of the resulting matrix cannot appear on the right side of the equal sign.

Syntax:

MAT matrix name = matrix name * matrix name

Unless you are familiar with matrix multiplication, you might assume that matrix multiplication is the same as scalar multiplication explained earlier. In matrix multiplication, for MAT C=A*B, the elements in each column of matrix B are multiplied by the corresponding elements in each row of matrix A. The row products are then added together and stored in the appropriate row and column of matrix C. Mathematically, the product of two matrices, MAT C=A*B, is represented as:

$$C(I,K) = \sum_{J=1}^{N} A(I,J) * B(J,K)$$

Where N is the number of columns in matrix A, and the number of rows in matrix B.

In Summary

For any matrix multiplication, MAT C=A*B, if the dimensions of A are [M,N] and the dimensions of B are [N,P], the result is a matrix of dimensions [M,P]. For example, a 5 by 4 matrix multiplied by a 4 by 1 matrix results in a 5 by 1 matrix. The value of N, above, must be the same in the two matrices. Also, the result of MAT C=A*B is not necessarily the same as MAT C=B*A. An example of matrix multiplication follows:

Below is a table of ticket sales for four bus routes, and a table of ticket prices for the three kinds of tickets. Matrix multiplication can give you the total sales for each route.

Ticket Sales By Route

Single Trip	Round Trip	Commuter	Route 1
143	200	18	2
49	97	24	3
314	77	22	4
82	65	16	

Ticket Prices

Trip	Price
Single trip	.25
Round Trip	.45
Commuter	18.00

Here are the instructions to read the values of Tables A and B into matrix A and B, respectively, and perform the matrix multiplication (`MAT C=A*B`).

```
10 DIM A[4,3],B[3],C[4]
20 DATA 143,200,18,49,97,24,314,77,22,82,65,16
30 DATA 0.25,0.45,18
40 MAT READ A[4,3],B[3]
50 MAT C=A*B
60 FIXED 2
70 MAT PRINT C
```

After A and B have been multiplied, matrix C contains the total sales, in dollars, for each route: C(1) contains sales for route 1, C(2) contains sales for route 2, and so on.

Matrix C

449.75	(.25*143+.45*200+18*18)
487.90	(.25*49+.45*97+18*24)
509.15	(.25*314+.45*77+18*22)
337.75	(.25*82+.45*65+18*16)

In the preceding example, A, a 4 by 3 matrix, is multiplied by B, a 3 by 1 matrix, giving C, a 4 by 1 matrix.

Suppose a price change is being considered and matrix B contains two columns of ticket prices:

	Old Price	New Price
Single Trip	.25	.30
Round Trip	.45	.50
Commuter	18.00	17.00

Then A, a 4 by 3 matrix, multiplied by B, a 3 by 2 matrix, results in C, a 4 by 2 matrix:

449.75	448.90	(.30*143+.50*200+17*18)
487.90	471.20	(.30*49+.50*97+17*24)
509.15	506.70	(.30*314+.50*77+17*22)
337.75	329.10	(.30*82+.50*65+17*16)

Here are the instructions to perform this multiplication. Note that the data in statement 30 has been rearranged.

```
10 DIM A[4,3],B[3,2],C[4,2]
20 DATA 143,200,18,49,97,24,314,77,22,82,65,16
30 DATA 0.25,0.3,0.45,0.5,18,17
40 MAT READ A[4,3],B[3,2]
50 MAT C=A*B
60 FIXED 2
70 MAT PRINT C
```

Transposition Of Matrices

The transposition of a matrix causes the rows in the matrix to become columns, and the columns to become rows.

Syntax:

MAT **matrix name** = TRN (**matrix name**)

The same matrix name cannot appear on both sides of the equals sign. The dimensions of the transposed matrix must equal the reverse of the dimensions of the original matrix, that is, if the dimensions of B are (P,Q), transposition of matrix B results in a matrix of dimensions (Q,P). The transposition of:

2	3
4	5
6	7

results in:

2	4	6
3	5	7

Row 1 in the first matrix becomes column 1 in the second. Then row 2 becomes column 2 and so on.

The Constant Matrix

A constant matrix is any matrix with all elements equal to 1. To generate a constant matrix, use this syntax:

Syntax:

MAT matrix name = CON [(expression [, expression])]

If the optional expressions are not given, the constant matrix has the most recent working dimensions specified. If expressions are given, they cause the matrix to be redimensioned to the specified working size.

The statement MAT B=CON(3,3) results in the following 3 by 3 matrix:

1	1	1
1	1	1
1	1	1

Since 1 has a logical value of "true", the constant matrix is useful for logic initialization.

The Zero Matrix

A zero matrix is any matrix with all elements equal to zero. To generate the zero matrix, use this syntax:

Syntax:

`MAT` matrix name `=` `ZER` [`(`expression [`,` expression] `)`]

If the optional expressions are not given, the zero matrix has the most recent working dimensions specified. If expressions are given, they cause the matrix to be redimensioned to the specified working size. Both subscripts can be expressions.

The statement `MAT B=ZER(3,3)` results in the following 3 by 3 matrix:

0	0	0
0	0	0
0	0	0

Since 0 has a logical value of "false", the zero matrix is useful for logic initialization.

The Identity Matrix

An identity matrix is a square matrix containing zeros with a principal diagonal containing all ones.

Syntax:

`MAT` matrix name `=` `IDN` [expression, expression]

If the size expressions are specified, they must be equal (i.e., a square matrix) and they cause the matrix to be redimensioned to the specified size. If the expressions are not specified, the identity matrix has the most recent working dimensions specified.

The statement `MAT B=IDN(3,3)` results in the following matrix:

1	0	0
0	1	0
0	0	1

The identity matrix is defined as the matrix which, when multiplied (using matrix multiplication) by any matrix A, results in matrix A.

Inversion of Matrices

The inverse of a matrix A is a matrix B which, when multiplied by the original matrix A, produces the identity matrix. **Both matrix A and B should be full precision matrices to ensure accuracy.** Only a square matrix can be inverted.

Syntax:

MAT matrix name = INV (matrix name)

The same matrix name may appear on both sides of the equals sign.

In performing the inversion, the computer must generate an additional internal work area. For an N by N matrix, the additional amount of internal work area required is N words of computer memory.

Since the result of inverting an integer or split precision array may be illogical, it is discouraged (see page 55).

Inversions can be used to help solve sets of simultaneous linear equations. Here is a word problem which is solved by using simultaneous linear equations:

John bought 3 oranges and 4 apples for 47 cents, and Mary bought 2 oranges and 2 apples for 28 cents. How much is 1 orange? How much is 1 apple?

We set up the following equations from the problem (O for oranges, A for apples):

```
3*O + 4*A = 47
2*O + 2*Y = 28
```

Using the values of the coefficients on the left side of the equations in matrix A, we have the following 2 by 2 matrix:

```
3   4
2   2
```

Using the values of the constants on the right side of the equations in matrix A, we have the following 2 by 1 matrix:

```
47
28
```

To find the values for X and Y, we use the matrix inversion command and a matrix multiplication:

The price of an orange, O, is contained in element C(1,1), and the price of an apple, A, is contained in element C(2,1).

Here is the program to perform the matrix inversion and print the result.

```
10 DIM A[2,2],B[2,1],C[2,1]
20 MAT READ A,B
30 DATA 3,4,2,2,47,28
40 MAT A=INV(A)
50 MAT C=A*B
60 FORMAT F4.0," Cents each",/,F4.0," Cents each"
70 WRITE (2,60)"Apples  ",C[1,1],"Oranges",C[2,1]
```

Even though a matrix is square, it may not have an inverse. Error 368 will occur when an inversion is attemped and the matrix has no inverse. To prevent this error, check if the determinant (explained next) is not zero. If the determinant is zero, there is no inverse. More detailed information on matrix inversion can be found in a textbook on matrices.

Determinants

The determinant of a square matrix is computed using the DET function.

Syntax:

DET (matrix name)

If the determinant of a square matrix of simultaneous linear equations is not zero, the system of equations has a solution; that is, the inverse of the matrix can be obtained. However, if the determinant is zero, the system has no solution, the inverse does not exist, and the matrix is termed "singular". Therefore, it may be useful to use the DET function to examine the matrix before inversion is performed in order to prevent a computer error condition. Following is an example:

```
10 DIM A[2,2],B[2,2]
20 DATA 4,3,5,1
30 MAT READ A
40 IF DET(A)=0 THEN 70
50 MAT B=INV(A)
60 GOTO 80
70 MAT B=A
80 MAT PRINT A;B
90 PRINT "DET A";DET(A)
```

The determinant of a matrix should only be performed on full precision matrices. This is because errors due to repetitive internal rounding are multiplied during complex operations and often result in illogical answers.

The additional work area required to perform the determinant function for an N by N matrix (e.g., A[N,N]) is equal to the original size of the matrix plus N words.

Chapter 5
Cross Referencing

The Cross Reference Command

The capability to cross reference each variable and the lines in which it occurs is provided by the Cross Reference (XREF) command. When XREF is executed, each variable in your program, along with the line numbers of the lines in which it appears is printed on the standard printer.

Syntax:

```
XREF
```

Since XREF is a command, it cannot be stored as part of a program.

All variables referenced in mainline memory programs are listed by XREF unless you are currently located at a Special Function key; in which case only the variables referenced in the program lines on that key are listed.

The variables are listed in a column according to first program reference. Each program line that the variable appears in is referenced by a line number. These line numbers are listed by row next to the variable name.

The XREF command is particularly useful in large programs where it is often difficult to keep track of the variables that have been used.

Example:

```
10 Y=12
20 A=B=C=3
30 G[1]=B↑3-Y
40 DISP FNP(B)
50 C=C+1
60 PRINT G[1];C↑2-Y
70 G[2]=12.63
80 GOTO 50
90 DEF FNP(K)=PI↑K
```

```
Y     10    30    60

A     20

B     20    30    40

C     20    50    50    60

G[ ]  30    60    70

FNP   40    90

K     90    90
```

Suppose you want to know where the variables B and C are used. With this listing, you can quickly see that the variable B is used once in lines 20, 30, and 40. Variable C is used once in line 20, twice in line 50, and once in line 60.

Notice that all array elements (array G) are combined under the array name and are not referenced by element. Also notice that function names are referenced (in this case, FNP).

Appendix

Syntax Summary
9862A and 9872A Plotter Statements

Standard Plotter Statement

STDPLT [select code]

Selects the plotter that will be addressed by subsequent statements.

SCALE Statement

SCALE X_{min} , X_{max} , Y_{min} , Y_{max}

Scales plotting area to user units and establishes the origin (0,0) of the coordinate system.

PEN Statement

PEN Raises the pen.

OFFSET Statement

OFFSET $Y_{coordinate}$, $Y_{coordinate}$

Redefines the specified point (X,Y) to be the temporary origin (0,0) of the coordinate system.

AXIS Statement

XAXIS Y-offset [, ±Tic [, Start Point , End Point]]

- If no optional parameters – draws horizontal line from X_{min} to X_{max}; crosses Y-axis at point defined by 'Y-offset'.
- ±tic – specifies spacing between tic marks; first tic at start point of axis.
- start point, end poing – specifies start point and end point of axis other than X_{min} and X_{max}.

YAXIS Statement

YAXIS X-offset [, ±Tic [, Start Point , End Point]]

Similar to XAXIS except draws vertical line.

PLOT Statement

PLOT $X_{coordinate}$, $Y_{coordinate}$ [, Pen Control]

- Moves pen to specified point (X,Y)

- Pen control:

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
zero –	No change
No parameter –	The pen remains in its present position, moves to the point specified, and lowers or remains down.

IPLOT Statement

IPLOT $X_{increment}$, $Y_{increment}$ [, Pen Control]

Moves pen in X-direction and in Y-direction by the amounts specified by the X-increment and Y-increment parameters. For 'pen control' see PLOT above.

LABEL Statement

LABEL (Line Number or *) [, Character Height , Aspect Ratio , Angle of Rotation [, Paper Ratio]][Print List]

Parameters are:

Line Number of a FORMAT statement or an asterisk.

Character height (0 thru 18.4 for the 9862 and 0 thru 127.9994999 for the 9872A) percentage of the scaling points area or plot area.

Aspect ratio equals character height/width.

Angle of rotation (degrees, radians or grads)

Paper Ratio (paper height/paper width) corrects character distortion for plotting areas that are not square.

Print List can consist of expressions or text (enclosed in quotation marks), or both.

If no optional character parameters, following are assumed:

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

CPLOT Statement

CPLOT character spaces wide , character spaces high

Raises pen and moves it horizontally and vertically by the number of character spaces specified. Size of space is determined by previous LABEL statement as follows:

9862A

One character height = 0.6 of one character space
One character width = 0.6 of the width of one character space

9872A

One character height = 0.5 of the height of one character space
One character width = 0.33 of the width of one character space

Horizontal and vertical directions are subject to any angle of rotation previously specified in a LABEL statement.

LETTER Statement

LETTER

- Establishes a typewriter mode – prints a character as each key is pressed.
- DISPLAY keys move the pen without printing.
- EXECUTE gives a carriage return/line feed.
- STOP terminates the mode.

9872A Only Statements

Window Statement

WINDOW X_{min} , X_{max} , Y_{min} , Y_{max}

Restricts programmed pen motion to a specific rectangular area defined by the parameter in the statement.

Line Statement

LINE [Pattern Number[, Pattern Length%]]

Selects one of the seven line patterns (0 thru 6) or a solid line (no parameter) to be used for all plotting operations.

Slant Statement

SLANT [Angle From Vertical]

Specifies the character slant (as measured in the currently set angle units) for lettering operations.

Select Pen Statement

SPEN [pen number]

Selects one of the four pens (1 thru 4) or puts the current pen away (0 or no parameter).

Velocity Statement

VEL [Centimeters/Second [, Pen Number]]

Specifies the speed at which a pen (1 thru 4) or all pens (no Pen Number Parameter) will travel for all plotting and lettering operations. This speed can range from 1 cm/sec thru 36 cm/sec.

Map Statement

MAP [X_{p1} , X_{p2} , Y_{p1} , Y_{p2}]

Relocates the scaling points P1 and P2, to the absolute-unit coordinates specified. No parameter sets P1 and P2 to their initialized locations.

Digitize Statement

DIG X-Variable , Y-Variable [, Pen Status Variable]

Sets the plotter to a digitize mode and inputs the selected pen-location coordinates into the variables.

X-coordinate = X-Variable
Y-coordinate = Y-Variable
Pen Status (1 = up, 0 = down) = Pen Status Variables

Matrix Statements

DIM Statement

DIM matrix name [[expression [, expression]]]

Example: `DIM A[20,30], BI[10,5]`

Reserves space for a matrix of the specified physical dimensions. Initially, the working size is the same as the physical size for a matrix, as specified in the DIM statement. More than one matrix can appear in a DIM statement.

REDIM Statement

REDIM matrix name [[expression [, expression]]]

Example: `REDIM A[10,15]`

Specifies a new working size for a matrix. The working size must not be greater than the physical size. If a new working size is specified, the working size will be changed to the physical size. More than one matrix can appear in the REDIM statement.

MAT READ Statement

MAT READ matrix name [[expression [, expression]]]

Example: `MAT READ A, X[5,5]`

Reads an entire matrix from DATA statements. The matrix is filled in conventional row-column order. More than one matrix can be included in a MAT READ statement, and a new working size can be specified.

MAT PRINT Statement

MAT PRINT matrix name [, or ; matrix name]...

Example: `MAT PRINT A, Y; Z;`

Prints an entire matrix row by row, with spacing of the columns controlled by the use of the comma and the semicolon. More than one matrix can appear in a MAT PRINT statement.

Matrix Addition

MAT matrix name = matrix name + matrix name

Example: `MAT X = A+C`

The same matrix can appear on both sides of the equals sign.

Matrix Subtraction

MAT matrix name = matrix name – matrix name

Example: MAT X=A–C

The same matrix can appear on both sides of the equals sign.

Scalar Multiplication

MAT matrix name = (expression) * matrix name

Example: MAT A = (2*PI)*B

Each element in Matrix B is multiplied by the scalar value (expression in parentheses). The same matrix can appear on both sides of the equals sign.

Matrix Multiplication

MAT matrix name = matrix name * matrix name

Example: MAT A = B*C

If the dimensions of A=(P,N) and B=(N,Q), the resulting matrix has dimensions (P,Q). The same matrix cannot appear on both sides of the equals sign.

Copying Matrices

MAT matrix name = matrix name

Example: MAT A=B

Copies values of Matrix B into Matrix A.

Transposition of Matrices

MAT matrix name = TRN (matrix name)

Example: MAT A = TRN (B)

Transposes a matrix. If the dimensions of B=(P,N), the resulting matrix has dimensions (N,P). The same matrix cannot appear on both sides of the equals sign.

The Constant Matrix

MAT matrix name =CON[(expression[, expression])]

Example: MAT B = CON[10,15]

Sets all elements of the matrix equal to 1. A new working size can be specified.

The Zero Matrix

MAT matrix name = ZER[(expression[; expression])]

Example: `MAT X=ZER[5;5]`

Sets all elements of the matrix equal to 0. A new working size can be specified.

The Identity Matrix

MAT matrix name = IDN [expression ; expression]

Example: `MAT X = IDN[4;4]`

Establishes an identity matrix – a square matrix containing all zeros with a principal diagonal of ones.

Inversion of Matrices

MAT matrix name = INV (matrix name)

Example: `MAT X = INV(X)`

Inverts a square matrix. A matrix can be inverted into itself.

Determinants

DET (matrix name)

Example: `X = DET(A) + DET(B)`

Returns the value of the determinant of a square matrix to an expression.

Cross Referencing

The Cross Reference Command

XREF

Lists each variable in your program, along with the linenumbers of the lines in which each one appears on the standard printer. XREF cannot be stored as a program line.

ASCII Character Codes

ASCII Character	Octal Code	Decimal Code	ASCII Character	Octal Code	Decimal Code
NUL	00	0	SP	40	32
SOH	01	1	!	41	33
STX	02	2	"	42	34
ETX	03	3	#	43	35
ETO	04	4	$	44	36
ENQ	05	5	%	45	37
ACK	06	6	&	46	38
BEL	07	7	'	47	39
BS	10	8	(	50	40
HT	11	9	)	51	41
LF	12	10	*	52	42
VT	13	11	+	53	43
FF	14	12	,	54	44
CR	15	13	—	55	45
SO	16	14	.	56	46
SI	17	15	/	57	47
DLE	20	16	0	60	48
DC1	21	17	1	61	49
DC2	22	18	2	62	50
DC3	23	19	3	63	51
DC4	24	20	4	64	52
NAK	25	21	5	65	53
SYN	26	22	6	66	54
ETB	27	23	7	67	55
CAN	30	24	8	70	56
EM	31	25	9	71	57
SUB	32	26	:	72	58
ESC	33	27	;	73	59
FS	34	28	<	74	60
GS	35	29	=	75	61
RS	36	30	>	76	62
US	37	31	?	77	63

ASCII Character	Octal Code	Decimal Code	ASCII Character	Octal Code	Decimal Code
@	100	64	(Apost.)	140	96
A	101	65	a	141	97
B	102	66	b	142	98
C	103	67	c	143	99
D	104	68	d	144	100
E	105	69	e	145	101
F	106	70	f	146	102
G	107	71	g	147	103
H	110	72	h	150	104
I	111	73	i	151	105
J	112	74	j	152	106
K	113	75	k	153	107
L	114	76	l	154	108
M	115	77	m	155	109
N	116	78	n	156	110
O	117	79	o	157	111
P	120	80	p	160	112
Q	121	81	q	161	113
R	122	82	r	162	114
S	123	83	s	163	115
T	124	84	t	164	116
U	125	85	u	165	117
V	126	86	v	166	118
W	127	87	w	167	119
X	130	88	x	170	120
Y	131	89	y	171	121
Z	132	90	z	172	122
[	133	91	{	173	123
\	134	92	:	174	124
]	135	93	}	175	125
^	136	94	∿	176	126
—	137	95	DEL	177	127

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***Service Only**

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Error Messages

NOTE

The machine approximates + and − infinity (∞) by 9.99999999999E+99 and −9.99999999999E+99, respectively.

Matrix Errors –

366 Matrix must be square for the attempted operation.

368 Matrix has no inverse. The data contained in the matrix does not have a solution.

369 Incompatible dimensions. Dimensions of added, subtracted, multiplied, copied, or transposed matrices must agree.

Plotter Errors –

370 Attempt to execute a 9872A Plotter operation on the 9862A Plotter.

Invalid plotter select code. 9862A requires a select code between 2 and 15. The 9872A Plotter uses a 3 or 4 digit select code with the format ccdd, where cc is a number from 1 thru 15 designating the interface select code and dd is a number from 00 thru 30 designating the device number on the HP-IB.

371 Instruction not recognized. The plotter has received an illegal character sequence. (9872A only.)

372 Wrong number of parameters. Too many or too few parameters have been sent with an instruction. (9872A only.)

373 Bad parameter. The parameters sent to the plotter with an instruction are out of range for that instruction. (9872A only.)

374 Illegal character. The character specified as a parameter is not in the allowable set for that instruction. (9872A only.)

375 Unknown character set. A character set out of the range 0 thru 4 has been designated as either the standard or alternate character set. (9872A only.)

376 Position overflow. An attempt to draw a character or perform a cplot that is located outside the plotters numeric limits. (9872A only.)

377 Transmission error. The computer has received an illegal ASCII input from the plotter. (9872A only.)

378 Attempt to scale on 9872A when P1 (lower left) is not less than P2 (upper right). (9872A only.)

379 Stop key pressed during plot execution. (9872A only.)

380 Attempt to execute an AXIS, OFFSET, PLOT, or IPLOT statement before executing a SCALE statement.

381 9862A only.

Character height specification in a LABEL statement is greater than 18.4% of the height of the plotting area.

Aspect ratio in a LABEL statement specifies a character width greater than 18.4% of the height of the plotting area.

The X or Y parameter in a CPLOT statement requires a pen movement greater than 18.4% of the height of the plotting area.

382 Attempt to execute an AXIS statement with the specified start point outside of the plotting area.

Attempt to execute an AXIS statement with the tic mark spacing too small (i.e., space between tics is less than 1/9999 of the maximum width or height of the plotting area). (9862A only.)

HEWLETT hp PACKARD

PART NO. 09831-90021
MICROFICHE NO. 09831-90021

PRINTED IN U.S.A.
April 1, 1977

Supplement
Matrix/Plotter Manual
(HP P/N 09831-90021)
Dated April 1, 1977

CAUTION

An anomaly within the 9872A Plotter's internal ROM (read only memory) can cause the plotter to ignore all instructions from both the controller and the front panel controls. Once this condition occurs, the plotter must be switched off and then on again before it will respond to its front panel controls or to the controller.

This anomaly can occur randomly when the plotter has been initialized (power on, front panel control or the "IN" instruction) and one of the statements listed below is executed before a label (LABEL) statement has been executed.

- The CPLOT statement
- The user definable character instruction

To prevent the possibility of this anomaly occurring, the following statement should be executed prior to any of the statements listed above.

LABEL (*) "(space)"

This statement should also be added as line 5 in the example programs on pages 13, 16, 18, 27, 32, 37 and 43 of the Matrix/Plotter Programming Manual.

Should this anomaly cause a problem in your particular plotting application, contact the nearest HP Sales and Service Office for assistance. See the Appendix of the Matrix/Plotter Programming Manual for the location of an office near you.