

Computer Note CN-11

August 1972

PROGRAMMING THE
UNIVERSITY OF MARYLAND
OFFLINE DIGITAL INCREMENTAL PLOTTER

by

L. A. Cole



*Houston DP-5 Plotter
9-track magnetic tape
fortran callable software*

UNIVERSITY OF MARYLAND
COMPUTER SCIENCE CENTER
COLLEGE PARK, MARYLAND

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ABSTRACT

This Computer Note describes the offline digital incremental plotter in use at the Computer Science Center of the University of Maryland.

The plotter, a Houston Instrument Model DP-5, is driven by a 9-track magnetic tape written by FORTRAN callable plot software. A functional description of the instrument and a variety of subroutines representing the operations most often required by users are provided. Tables, figures and a sample program complete the illustration and enable the use of the installation without the need for further reference material.

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PLOTTER

GENERAL

The Computer Science Center maintains an offline digital incremental plotter for those users with a need for graphic output. The plotter is driven by a 9-TRACK magnetic tape written by FORTRAN callable plot software. Plots are produced on Z-FOLD paper 12 inches wide, 144 feet long, with a vertical perforation every 8 1/2 inches. (Figure 1.)

CHARGES

Plotting charges are billed separately at an hourly rate. The plot time is written on the plot by the software.

HARDWARE

Plotter:	Houston Instrument Model DP-5
Tape Drive:	Houston Instrument Model MTR-2, 9-TRACK
Speed:	1200 steps/second
Step Size:	.0025 inches
Pen:	Liquid Ballpoint, black ink

SOFTWARE AVAILABILITY

Plot software resides in a public library file UOM*PLOT in the UNIVAC 1108. An IBM 360 version is available from the program library.

PLOT AREA

Considering the plot area as a 2-dimensional plane, the X-axis is parallel to the sprocket holes and limited to the length of the paper. The Y-axis is perpendicular to the sprocket holes and it is limited to 11 inches, allowing 1/2 inch on each side for the sprocket holes, (Figure 2.)

POSSIBLE MOVEMENTS

- LIFT PEN
- LOWER PEN
- MOVE PEN UP (+Y) or DOWN (-Y) the paper
- MOVE PAPER LEFT (+X) or RIGHT (-X)
- ANY COMBINATION OF THE ABOVE

Care should be taken not to command the plotter to move off the available paper in the + or - direction. A limit switch is mounted on each end of the pen carriage to prevent damage to the servo motors if a plot command is given to go more than + or - 11 inches in the Y direction. When the limit switch is activated, all further Y movement in that direction is ignored until a command is given to move away from the limit switch in the opposite Y direction. The plot software does not check for excessive movement in either the X or Y direction. Activation of either limit switch will cause the origin to be lost and the plot will most likely be ruined. Operators should be notified by a note on the job submittal card if a plot will require more than 10 feet of paper.

REFERENCE POINT (ORIGIN)

The plotter is capable of movements in all directions in the standard (X,Y) coordinate system, however there is no "origin" built into the plotter. Once the pen has moved, it does not remember where it came from. The process of keeping track of the pen position relative to some fixed point is the responsibility of the programmer. Subroutine PLOTC "...PLOTC (described later) is ..." used to establish and change reference points in addition to moving the pen. Once an origin has been established, any point on the paper can be identified by its x and y coordinates, given in inches.

INITIAL PEN POSITION AND ORIGIN

The following origin exists before any plot routines are called:

PEN UP

X: over a vertical perforation (page boundry)

Y: + 1/2 inch above the -Y limit switch

This point is defined as (0,0).

NEW REFERENCE POINT ESTABLISHMENT

To establish a new reference point when the pen position is unknown, the programmer must call subroutine PLOTC twice as follows:

```
CALL PLOTC(0.0,-11.0,-3)
```

```
CALL PLOTC(X,Y,-3)
```

The first call drives the pen against the -Y limit switch, even if it was at the extreme +Y point. The second call moves the pen to the inch coordinates defined by the floating-point value of (X,Y) and establishes this point as the new origin (0,0).

Subroutine PLOTC

CALL PLOTC(X,Y,I)

This routine is used to control all pen movement and for the establishment of reference points.

X - Floating-point X coordinate in inches.

Y - Floating-point Y coordinate in inches.

I Integer pen indicator

I = 2 means pen down.

I = 3 means pen up.

The pen is moved from its current position to the point defined by (X,Y).

If I = 2, the pen will be down and a straight line will be drawn; if I = 3, the pen will be up and no line will be drawn.

If I is negative (-2 or -3) the action of the pen remains the same as above but the point (X,Y) becomes the new origin (0,0). Any other values of I will be ignored.

All other plot software is based on this routine.

Examples:

CALL PLOTC(2.0,2.0,-3) will lift the pen, move it to (2.0,2.0) and establish this point as the new origin.

CALL PLOTC(4.0,-5.5,2) will draw a line from the present pen position to the point (4.0,-5.5).

CALL PLOTC(0.0,0.0,3) will lift the pen and move it to the current origin.

Subroutine SCALE

CALL SCALE(A,S,N,K)

This routine examines a vector of data points and calculates appropriate scaling factors to be used by the LINE AND AXIS routines. SCALE is normally called twice, once with A = X for abscissas and once with A = Y for ordinates.

A - Floating-point vector of data points dimensioned at least N+2 in size.

S - Floating-point number representing the width in inches of the area in which the data points in vector A are to be plotted.

N - Integer number giving the number of data points in vector A.

K - Integer, must be set to 1.

The two outputs from this routine are stored in vector A as follows:

A(N+1) = AMIN

A(N+2) = ADELTA

AMIN is the truncated value of the minimum data point in vector A. This corresponds to "0" inches.

ADELTA is the scaling factor calculated as follows: $E + (AMAX-AMIN)/S$ where E is a round-up factor and AMAX is the maximum value in vector A.

The corresponding inch coordinates of a number X between AMIN and AMAX can be calculated by the user as: $XINCH = (X+A(N+1)) / A(N+2)$

SCALE must be called before AXIS and LINE as the outputs from SCALE are used by AXIS and LINE.

Example: The following calls to SCALE would be used for plotting the 100 data points in vectors X and Y, allowing 7 inches for the X axis and 10 inches for the Y axis.

```
DIMENSION X(102),Y(102)
```

```
.
```

```
.
```

```
CALL SCALE(X,7.0,100,1)
```

```
CALL SCALE(Y,10.0,100,1)
```

```
.
```

```
.
```

```
.
```

```
.
```

Subroutine AXIS

CALL AXIS(X,Y,ANAME,NA,S,T,AMIN,ADELTA)

This routine draws a labeled axis.

- X,Y - Floating-point coordinates of the origin of the axis. Note that the origin for an axis or axis system may be located anywhere relative to the current reference point.
- ANAME - Alphanumeric literal or name of a vector containing alphanumeric characters in an A6 format to be used as a label for the axis.
- NA - Integer, giving the number of characters in ANAME. If NA is positive, the scales, tic marks, and label will be drawn on the positive side of the axis. If NA is negative, they will be drawn on the negative side. Positive side means above the axis, negative means below, when looking at the axis as a horizontal line with the origin at the left hand side.
- S - Floating-point number giving the length of the axis in inches.
- T - Floating-point number giving the number of degrees between the axis and the +X direction, measured counter-clockwise, i.e. T = 0.0 corresponds to a +X axis, T = 90.0 corresponds to a +Y axis.
- AMIN - Minimum value calculated by the SCALE routine.
- ADELTA - Scaling factor calculated by the SCALE routine.

In addition to its label, the axis will have a tic mark at every inch with the value of the coordinate written above or below it. The value of the coordinate at the origin is AMIN and it is increased by ADELTA at every inch.

AXIS calls subroutines PLOTG, SYMBOL, and NUMBER

Example: To draw the axes for plotting the data in the SCALE example the following calls to AXIS could be made:

```
DIMENSION LABELY(2)
DATA LABELY/'Y VALUES'/
.
CALL AXIS(0.0,0.0,8HX VALUES,-8,7.0,0.0,X(101),X(102))
CALL AXIS(0.0,0.0,LABELY,8,10.0,90.0,Y(101),Y(102))
.
.
```

Note the 2 different ways of specifying ANAME. The axes will start at the current reference point.

Subroutine LINE

CALL LINE(A,B,N,K,J,L)

This routine plots a curve identified by the data points in vectors A and B.

- A - Floating-point vector containing the x-coordinates of the data.
- B - Floating-point vector containing the y-coordinates of the data.
- N - Integer giving the number of points in vectors A and B.
- K - Integer, must be set to 1.
- J - Integer, used to control symbols placed on data points. J = 0 will produce only a line curve; J = 1 will produce a symbol at every point; J = 2 will produce a symbol at every second point; etc. A negative value of J will suppress the line between points, giving a point plot.
- L - Integer, used to specify the symbols to be used. The value of L must be between 0 and 31. The corresponding symbols can be found in Table 2. The symbol height is .08 inch. (See drawing for dimensions of characters.)

LINE calls subroutines PLOT and SYMBOL.

Subroutine SCALE must be called before subroutine LINE, as subroutine LINE expects to find scaling factors present in A(N+1),A(N+2),B(N+1),B(N+2).

Example: Continuing the example presented in SCALE and AXIS, to plot the curve, the following call to LINE could be used:

```
.  
CALL LINE(X,Y,100,1,0,0)  
.
```

This call would produce a line curve without symbols at each data point. To produce a curve with a symbol at each point, the following call would be used:

```
CALL LINE(X,Y,100,1,1,3)
```

A '+' would be plotted at each data point, in addition to the line connecting each point.

Subroutine SYMBOL

CALL SYMBOL(X,Y,H,BCD,T,NS)

This routine draws alphanumeric characters or single specific symbols. A sample of the character set can be found in Table 1.

- X,Y - Floating-point inch coordinates specifying the lower left hand corner of the first alphanumeric character or the center of the single specific character.
- H - Floating-point number indicating the height of the character in inches. H must be greater than .07 and less than 10.0. The width of a character is $4/6 * H$. The distance between characters is $6/7 * H$. (Figure 3.)
- BCD - is an alphanumeric literal or the name of a vector containing characters in A6 format or, in the case of special centered symbols, an integer between 0 and 31.
- T - Floating-point number indicating the angle in degrees that the character string is to be plotted, assuming the +X direction is 0.0 degrees.
- NS - Integer, indicating the number of characters in BCD to plot if BCD is a vector or alphanumeric literal (NS must be greater than 0 in this case); or, if NS is negative, indicating that BCD is an integer between 0 and 31, and single special centered symbol from Table 2 is to be plotted.

SYMBOL calls subroutine PLOTTC.

Examples:

```
CALL SYMBOL(2.5,6.0,.25,'GRAPH OF X VS Y',0.0,15)
```

Will move the pen to (2.5,6.0) and plot the characters within the quotes with a height of .25 inches.

```
CALL SYMBOL(XX,YY,.1,14,0.0,-1)
```

Will move the pen to the coordinates (XX,YY) and plot the special centered symbol number 14 (star) at that point, with a height of .1 inch.

Subroutine NUMBER

CALL NUMBER(X,Y,H,F,T,NN)

This routine draws a floating point or integer number.

X,Y - Floating-point coordinates specifying the lower left hand corner of the first digit of the number to be drawn.

H - Floating-point number giving the height of the number in inches. H must be greater than .07 inches and less than 10.0 inches.

F - Floating-point number to be drawn.

T - Floating-point number indicating the angle in degrees from the +X direction in which the number is to be plotted.

NN - Integer specifying the number of decimal digits to the right of the decimal point to be drawn. A value of zero will print the decimal point. A negative value of NN will suppress the decimal point, in effect drawing an integer.

NUMBER calls subroutine SYMBOL.

Examples:

A = 987.65

CALL NUMBER(X,Y,.1,A,0.0,2)

Will move the pen to (X,Y) and plot the characters 987.65 .1 inch high

CALL NUMBER(X,Y,.25,500.00,0.0,-1)

Will move the pen to (X,Y) and plot the characters 500 .25 inch high

Subroutine FACTOR

CALL FACTOR(SF)

This routine sets a plot scale factor to enlarge or reduce an entire drawing.

SF - Floating-point number which indicates the factor by which an entire drawing is to be scaled.

The plot scale factor is initially set to 1.0. The x and y coordinates on all calls to PLOTG are multiplied by the plot scale factor. Changing the origin does not reset the plot scale factor. FACTOR must be called before any other plot subroutines if the entire drawing is to be scaled.

Example:

CALL FACTOR(2.0) will double the size of the plot
produced by any subsequent calls
to plot subroutines

Subroutine WHERE

CALL WHERE(X,Y)

This routine sets (X,Y) equal to the current pen location, relative to the last established reference point.

Subroutine PAGEUP

CALL PAGEUP

This routine indexes the pen to the perforation on the next unwritten page, moves the pen 1/2 inch above the -Y limit switch, and redefines this point as a new reference point (0,0).

Subroutine ENPLOT

CALL ENPLOT

This routine is used to terminate the plot software. It closes out the plot buffer, writes an end-of-file on the plot tape and unloads the tape unit. In the UNIVAC 1108 version, the following FORTRAN statements will have the same effect:

```
STOP  
CALL EXIT  
CALL ERROR  
END
```

In the IBM 360 version, a CALL ENPLOT is absolutely necessary.

PLOT SOFTWARE ON THE UNIVAC 1108

The plot subroutines reside in a public library file on mass-storage with the name UOM*PLOT.

The following card must follow the @MAP card to tell the collector to search this file for the plot subroutines:

```
LIB UOM*PLOT.
```

EXAMPLE:

```
@RUN
```

```
@FOR,IS      PROGRAM
```

```
.
```

```
. (FORTRAN program calling plot subroutines)
```

```
.
```

```
@MAP,ISX
```

```
LIB UOM*PLOT.
```

```
@XQT
```

Plotting from batch jobs.

Normally a scratch tape is dynamically assigned by the plot software as plot tape. The reel number of this tape may be found with the run termination information on your printout. Plot tapes are saved for 24 hours after plotting.

If you desire to use your own tape as a plot tape, the following @ASG card must be included in your runstream before the @XQT card:

```
@ASG,T PLOT$TAPE,8C9,xxxxR
```

where xxxx is the reel number of your tape.

IN EITHER CASE, THE PLOT TAPE WILL BE @FREE'ed BY THE SOFTWARE WHEN THE PROGRAM EXITS.

Plotting from a teletype.

Because of the great demand for tape drives, the demand user who wishes to make offline plots should direct his plot output to a FASTRAND file instead of a tape. This can be done with the following @ASG card:

```
@ASG,T PLOT$TAPE.,F
```

The plot output will be written into that file; the file must then be copied onto a 9-TRACK tape via a @COPY,M statement for plotting. If the medium of file PLOT\$TAPE is not tape, it will not be @FREE'ed by the software when the program exits.

TABLE 1

@	[]	#	△	A	B
C	D	E	F	G	H	I
J	K	L	M	N	O	P
Q	R	S	T	U	V	W
X	Y	Z)	-	+	<
=	>	&	\$	*	(%
:	?	!	,	\	0	1
2	3	4	5	6	7	8
9	'	;	/	.	◇	≠

TABLE 2

0		1		2		3	
4		5		6		7	
8		9		10		11	
12		13		14		15	
16		17		18		19	
20		21		22		23	
24		25		26		27	
28		29		30		31	

8½" x 12" pages

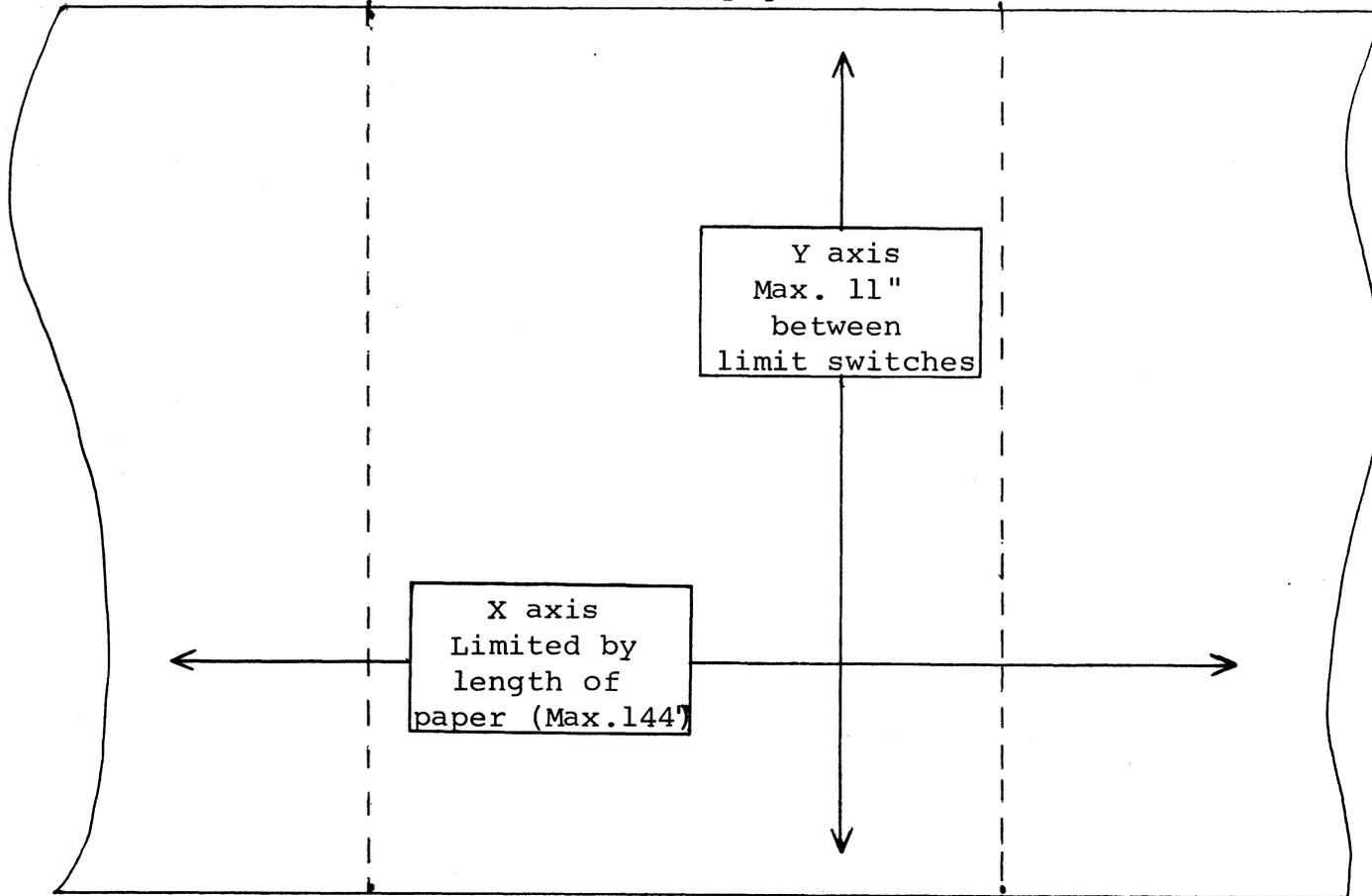
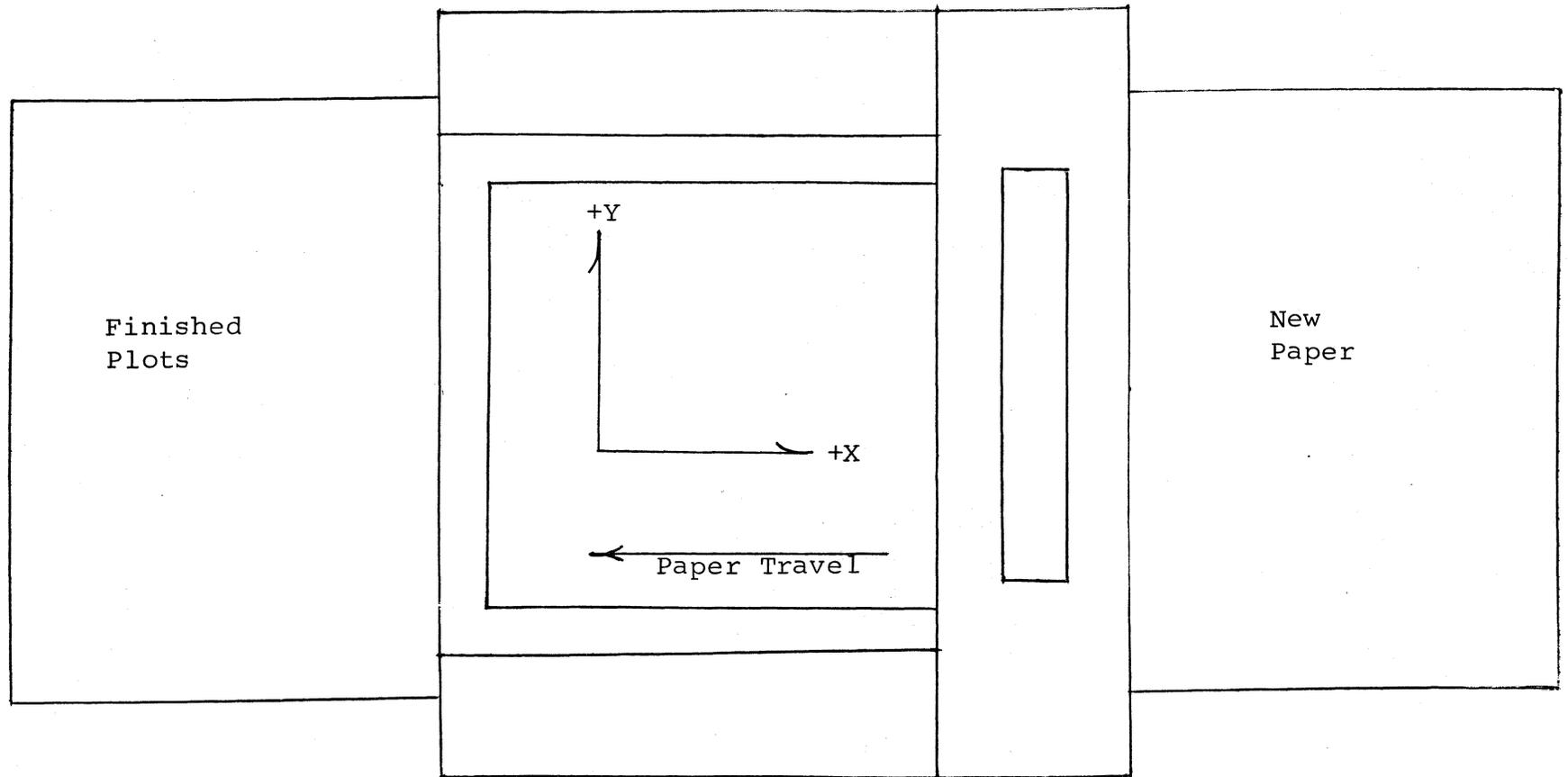


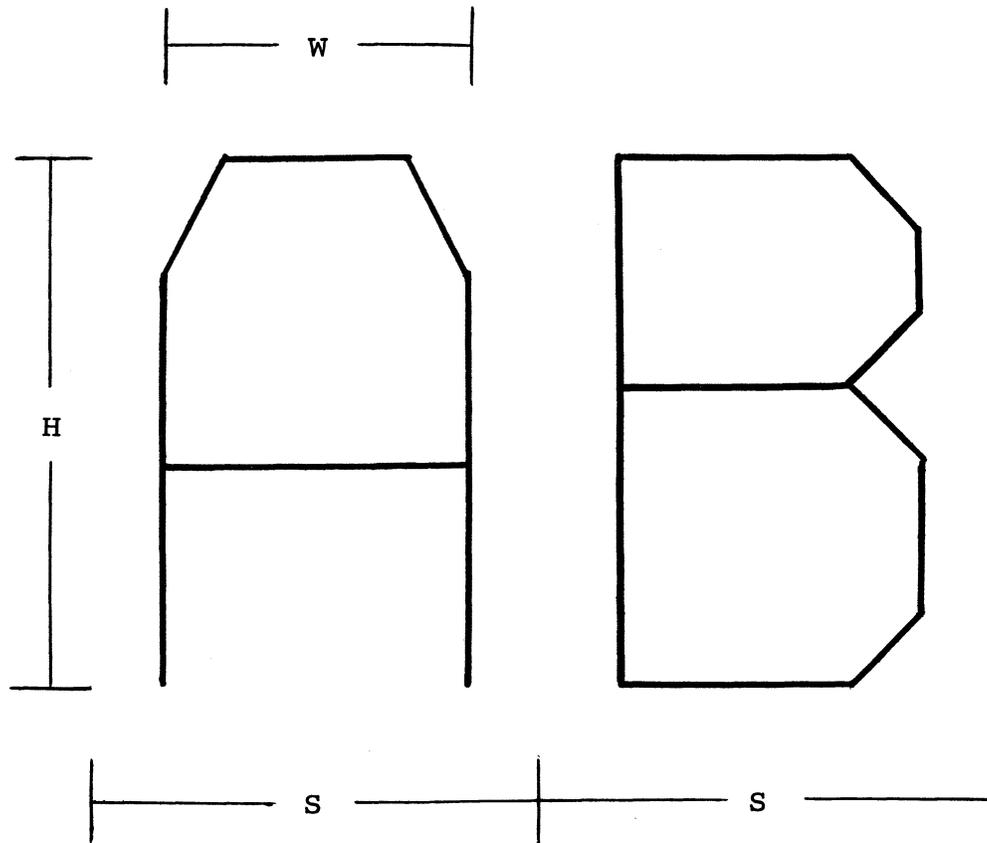
Figure 1

Vectors are pen movement
Not paper movement



Top view of Plotter

Figure 2



H = height of character = HT.

W = width of character = $4/7 \cdot HT$.

S = width of reference area of character = $6/7 \cdot HT$.

Figure 3

SAMPLE PROGRAM

```
@FOR,IS SAMPLE
C ** SAMPLE PLOT PROGRAM - PLOT SINE FUNCTION
  DIMENSION X(362),Y(362)
C ** NOW ESTABLISH ORIGIN 1 INCH IN THE +Y DIRECTION
  CALL PLOT(0.0,1.0,-3)
C ** CALCULATE X AND Y VALUES IN RADIANS
  DO 100 I = 1,360
    X(I) = (I-1) * .017453
100  Y(I) = SIN(X(I))
C ** SET SCALE FACTOR FOR X DIRECTION OF 6 INCHES
  CALL SCALE(X,6.0,360,1)
  XMIN = X(361)
  XDELTA = X(362)
C ** SET SCALE FACTOR FOR Y DIRECTION OF 6 INCHES
  CALL SCALE(Y,6.0,360,1)
  YMIN = Y(361)
  YDELTA = Y(362)
C ** DRAW X AXIS
  CALL AXIS(0.0,0.0,7HRADIANS,-7,6.0,0.0,XMIN,XDELTA)
C ** DRAW Y AXIS
  CALL AXIS(0.0,0.0,6HINCHES,6,6.0,90.0,YMIN,YDELTA)
C ** DRAW THE CURVE
  CALL LINE(X,Y,360,1,0,0)
C ** DRAW THE TITLE
  CALL SYMBOL(1.5,6.5,.4,10HY = SIN(X),0.0,10)
  STOP
  END
@MAP,IS
LIB UOM*PLOT
@XQT
```

The resultant plot is shown on the next page. Plot time was three minutes.

$$Y = \sin(X)$$

