CALCOMP
BASIC SOFTWARE

PROGRAMMING THE CALCOMP EIA RS-274 PLOTTING SYSTEM

USER'S MANUAL

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PROGRAMMING THE CALCOMP EIA RS-274 PLOTTING SYSTEM

CALCOMP
CALIFORNIA COMPUTER PRODUCTS, INC.
2411 West La Palma Anaheim, California 92801
Tel. (714) 821-2011 TWX 910-591-1154

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Section 1
INTRODUCTION

This manual provides information on how to program for and operate a CalComp EIA RS-274 plotting system. The plotting system software consists of Host Computer Basic Software (HCBS) and Graphic Controller Software (GCS) for creating and plotting data in a modified EIA RS-274 tape format. The system hardware includes: a CalComp Controller with 16K memory; an input unit; a Communication Console (Teletype or equivalent); and a CalComp plotter.

The Host Computer Basic Software consists of a set of FORTRAN subroutines that runs on the user's computer, and may be called by his applications programs to create plot data in a modified EIA RS-274 format. This plot data is then plotted using the Graphic Controller Software, which operates on a CalComp Controller. The Graphic Controller Software provides for selective searching or plotting under teletype control; for scaling, rotation, and mirror imaging of the plot; and for corrections and/or additions to be input directly from the console.

Currently existing plot programs (which call the standard CalComp basic software subroutines) may be rerun with the HCBS subroutines to produce an EIA format tape, with little or no modification to the existing program. In addition, new features are provided with the HCBS which were not available with the standard CalComp basic software.

Section 2
FORMAT DESCRIPTION

The basic unit of the RS-274 format is a sentence. A sentence is a series of words which is terminated with a period. A word consists of a key letter specifying a particular function, followed by numeric digits which are coordinate values or additional function information. The words may appear in a sentence in any order and may appear more than once, with only the last word of a given type being effective. Actual plotting of the sentence does not begin until the terminal period is encountered. If a word necessary for plotting the sentence is not contained in the sentence, the last value given in a previous sentence is used. If no previous value is given, the default value shown in Table 1 is used. Blanks within a sentence will be ignored, except within a character string.

All numeric values in a word may be up to eleven digits. Signs may be used, with unsigned numbers assumed positive. Leading zeroes may be omitted. Coordinates are given as absolute values and in units of 0.0001 inches.

The word types implemented are as follows:

N	specifies the sentence number and is followed by up to *five* digits.
X, Y	are the coordinate values for linear, circular, or spline interpolation. The values are absolute coordinates, each may be up to eleven digits, and in steps of 0.0001 inch.

TABLE 1. SYSTEM DEFAULT VALUES

Word Type	Value
A	2500 (.25 inches)
B	2500 (.25 inches)
D	0
E	0
F	0
G	0
M	0
P	1000000 (1.0 no rotation)
Q	0
R	0
S	1000000
U	0
V	0
X	0
Y	0

P, Q, R, S — form a transformation matrix which is applied to all (X,Y), (I,J), and (U,V) coordinates prior to plotting, as follows:

let X_i, Y_i be input coordinates
X_f, Y_f be final plotted coordinates

then

$$\begin{pmatrix} X_f \\ Y_f \end{pmatrix} = \begin{pmatrix} P & Q \\ R & S \end{pmatrix} * \begin{pmatrix} X_i \\ Y_i \end{pmatrix}$$

This matrix permits scaling, rotation, mirror imaging, and axis interchanging operation. The unit scale factor is 1 followed by 6 zeroes; hence, the range of scale factors is 99999.999999 to 0.000001.

For general scaling and rotation, the PQRS values are:

$P = F_x \cos\theta$

$Q = -F_x \sin\theta$

$R = F_y \sin\theta$

$S = F_y \cos\theta$

where F_x and F_y are the X and Y axis scale factors, and θ is the angle of rotation.

To obtain a mirror image about the X-axis, use PQRS = (1,0,0,-1); about the Y-axis, use PQRS = (-1,0,0,1); to interchange axes, use PQRS = (0,1,1,0).

I, J — give the incremental distance from the current point to the center of a circle

U, V — give the origin offset in the X and Y directions respectively. This origin is subtracted from each X and Y before the PQRS transformation is applied.

G — specifies the current mode of operation, and is followed by a one or two-digit code:

- G1 linear interpolation
- G2 circular interpolation – clockwise
- G3 circular interpolation – counterclockwise
- G4 linear interpolation – dashed line
- G5 spline interpolation
- G25 reorigin at current X, Y coordinates
- G50 pen selection (also requires Dnn code to select pen nn)

G52 character string -- normal

G53 single character -- special symbols

D — controls certain plotter operations, and is also followed by a one or two-digit code:

In modes G1–G5, D1 = pen down
D2 = pen up

In mode G50, Dnn = select pen nn

M — controls stopping as follows:

M1 = temporary halt

M2 = final halt

A, B — give the length of pen down/pen up segments when using the G4 (dashed line) mode. The default values are A = 2500 (.25 inches) pen down and B = 2500 (.25 inches) pen up.

E, F — are the values that control the height and angle of characters within a symbol string as follows:

$E = H \cos\theta * 8/N$

$F = H \sin\theta * 8/N$

where H is the height of the characters, θ is the angle of rotation, and N is the number of grid units on which the character is based (15 for standard characters and 8 for centered symbols).

On magnetic tape, each record contains a group of sentences or portions of sentences such that the total number of characters in a record is less than 512.

Section 3
FUNCTION DESCRIPTIONS

Linear Interpolation

Linear interpolation (straight lines) may be used with the pen either up or down, or in dashed line mode. For dashed lines, the length of the pen-up and pen-down segments are programmable. Straight lines always begin at the current pen position and end at the absolute X, Y coordinates specified. The first and last moves of a dashed line are always made with the pen down.

Circles (Arcs)

Circles and circular arcs always start from the current pen position. The I, J values determine the distance to the center of the circle from the starting point. Note that I, J are always incremental, although absolute coordinates are used elsewhere. The X, Y values specified in the sentence specify the end point of the circle or arc.

Note: No check is made to see if the point (X, Y) actually lies on the circle; if it does not, a complete circle will be drawn. If the current coordinate transformation has unequal X and Y scale factors, ellipses or elliptical arcs will be plotted.

Spline Curve Fitting

Spline interpolation always begins plotting with the second X, Y values given. Thus, if no "phantom" initial point is given, the starting point should be repeated. The same is true of the end of the line, the curve will only be plotted to the second-last point. Hence, the end point should be repeated if no "phantom" end point is given. The system will begin plotting the curve when four points have been entered. The pen is raised, moved to the position of the second point, lowered, and moved along the computed curve to the third point. As each new point is entered, the pen is moved to the next point until a new G code is given at which point the pen is raised (at the next to last point entered).

Character Strings

Annotation may be specified at any size and angle through the use of the E and F code values, as follows:

let X_p, Y_p be actual coordinates within a character

X_s, Y_s be coordinates of lower-left corner of the character

X_c, Y_c be grid units within a character then

$$\begin{pmatrix} X_p \\ Y_p \end{pmatrix} = \begin{pmatrix} X_s \\ Y_s \end{pmatrix} + \begin{pmatrix} E & -F \\ F & E \end{pmatrix} * \begin{pmatrix} X_c \\ Y_c \end{pmatrix}$$

and the further application of the PQRS transformation matrix yields a final coordinate (X_f, Y_f) as follows:

$$\begin{pmatrix} X_f \\ Y_f \end{pmatrix} = \begin{pmatrix} P & Q \\ R & S \end{pmatrix} * \begin{pmatrix} X_p \\ Y_p \end{pmatrix}$$

There are 63 characters available for use in character strings (G52 code). These are shown in Appendix A. The ASCII "!" is not a legal character since it is used to delimit the symbol string.

There are 15 centered symbols available for use as single characters (G53 code). These are shown in Appendix B. Again the ASCII "!" is used as a delimiter.

Reorigining

Reorigining is specified by a G25 code, which causes the current pen position to become the new origin and all subsequent coordinates are measured from that point.

Offsets and Transformations

Origin offset values (U, V) are subtracted from each coordinate (X, Y) passed to the system. The origin offset values do not affect deltas (I, J). Origin offsets allow the user to specify the value of the initial pen position and thus place his logical origin anywhere on or off the plotter. The offsets are subtracted from the coordinates before any transformation is applied.

Halts

A final halt code (M2) causes the system to pause and display a message to the operator. A temporary halt code (M1) may or may not cause a pause depending upon whether the operator has requested the system to accept or ignore this code.

Section 4
HCBS SUBROUTINE DESCRIPTIONS

The basic software support provided consists of a set of FORTRAN subroutines which are called by the user's applications program to produce a plot tape. A summary of these subroutines is given in Table 2. Detailed descriptions follow.

SUBROUTINE PLOTS

Subroutine PLOTS performs initialization for the plotting subroutines. It should be called only once, prior to any of the other subroutines. The calling sequence is:

CALL PLOTS (IDUM, IDUM, LDEV)

where IDUM is a dummy parameter which is not used, and LDEV is the logical device number of the output tape unit.

TABLE 2. HCBS SUBROUTINES

Subroutine Calling Sequence	Function
CALL PLOTS (IDUM, IDUM, LDEV)	Initialization, setting output device number
CALL PLOT (XPAGE, YPAGE, IPEN)	Linear interpolation
CALL SYMBOL (XPAGE, YPAGE, HEIGHT, IBCD, ANGLE, ±NCHR)	Plots annotation and special symbols.
CALL NUMBER (XPAGE, YPAGE, HEIGHT, FPN, ANGLE, ±NDEC)	Plots numbers
CALL AXIS (XPAGE, YPAGE, IBCD, ±NCHR AXLEN, ANGLE, FIRSTV, DELTAV)	Plots annotated axis
CALL LINE (XARRAY, YARRAY, NPTS, INC, ±LINTYP, INTEQ)	Plots lines connecting sets of data points
CALL SCALE (ARRAY, AXLEN, NPTS, ±INC)	Scales graph data before plotting
CALL CURVE (XARRAY, YARRAY, NPTS, INC)	Spline interpolation
CALL CIRCLE (XPAGE, YPAGE, XCEN, YCEN, IC)	Circular interpolation
CALL SET (P1, P2, P3, P4, IC)	Sets system parameters
CALL NEWPEN (INP)	Selects pen
CALL FACTOR (FACT)	Scales size of plot
CALL WHERE (RXPAGE, RYPAGE, RFACT)	Returns current location of pen and value of scale factor
CALL BUFF (LOC, NCNT, ICNT)	System output routine (*not* called by user)
CALL TDUMP (LDEV)	Tape dump in RS-274 format.

A sentence number is inserted automatically in each sentence generated. Sentences are numbered sequentially starting with 1.

SUBROUTINE PLOT

The PLOT subroutine provides the capability to generate a straight line, with the pen either up, down, or in a dashed line mode, from the current pen position to the specified coordinates.

The calling sequence is:

CALL PLOT (XPAGE, YPAGE, IPEN)

The pen is moved from its current position to coordinates (XPAGE, YPAGE) using linear interpolation. The state of the pen during the move is determined by IPEN, as follows:

If IPEN = +2, the move is made with pen down.

If IPEN = +3, the move is made with pen up.

If IPEN = -2 or -3, the move is made with pen down or up, respectively, and the new pen position is established as the origin (0.0, 0.0) for future plot moves. In addition, a temporary halt (M1) is placed in the sentence.

If IPEN = ±23, action is as above concerning the sign of IPEN, but the move is made using a dashed line (G1 code).

If IPEN = 999, the move is made with pen up, and the plot file is closed with a final halt code (M2).

PLOT also contains entries used by the other basic software subroutines to convert coordinate values for output and to produce sentence numbers.

SUBROUTINE SYMBOL

The SYMBOL subroutine produces plot annotation at any angle and in practically any size. There are two SYMBOL call formats: 1) the "standard" call, which can be used to draw text such as titles, captions, and legends; and 2) the "special" call, which is used to draw special centered symbols such as a box, octagon, triangle, etc., for plotting data points.

The standard characters that are drawn by SYMBOL include the letters A-Z, digits 0-9, and certain special characters.

Both forms of the SYMBOL calling sequence have six arguments. The "standard" call is:

CALL SYMBOL (XPAGE, YPAGE, HEIGHT, IBCD, ANGLE, +NCHAR)

XPAGE, YPAGE — are the coordinates, in inches, of the lower left-hand corner of the first character to be produced. The pen is up while moving to this point.

Annotation may be continued from the position following that at which the last annotation ended. Continuation occurs when XPAGE and/or

YPAGE equals 999.0, and may be applied to X and Y independently. (Calling WHERE to obtain the current pen position and using RXPAGE, RYPAGE in another call to SYMBOL would not give the same results as using 999.)

HEIGHT — is the height, in inches, of the character to be plotted. The width of a character, including spacing, is normally the same as the height (e.g., a string of 10 characters 0.14 inches high is 1.4 inches wide).

IBCD — is the text, in internal computer representation (usually BCD or A-type format), to be used as annotation. The character(s) must be left-justified and contiguous in: a single variable, an array, or in a Hollerith literal (if the compiler permits). Blanks in the text do not cause any pen movement until the next non-blank character is started.

The text must be right-justified in IBCD if a single character is desired and NCHAR=0.

ANGLE — is the angle, in degrees from the X-axis, at which the annotation is to be plotted. If ANGLE = 0, the character(s) will be plotted right side up and parallel to the X-AXIS.

+NCHAR — is the number of characters to be plotted from IBCD. If NCHAR >0, the data must be left-justified in the first element of IBCD.

If NCHAR = 0, one alphameric character is produced, using a single character which is right-justified in the first element of IBCD.

The second form is the "special" call, which produces only a single symbol based on the index value of INTEQ – not on the BCD representation of a character.

CALL SYMBOL (XPAGE, YPAGE, HEIGHT, INTEQ, ANGLE, -ICODE)

XPAGE, YPAGE, and ANGLE — are the same as described for the "standard" call. If the symbol to be produced is one of the centered symbols, XPAGE, YPAGE represent the geometric center of the character produced.

HEIGHT — is the height (and width), in inches, of the centered symbol to be drawn. Preferably, it should be a multiple of four times the plotter's increment size.

INTEQ — is the integer equivalent of the desired symbol. Valid integers and their symbols are listed in Appendix B. If INTEQ is 0 through 15, a centered symbol is produced.

-ICODE — is negative and determines whether the pen is up or down during the move to XPAGE, YPAGE.

When -ICODE is:

-1, the pen is up during the move, after which a single symbol is produced;

-2, or less, the pen is down during the move, after which a single symbol is produced.

The height and angle parameters are used to construct the E, F parameters, which control scaling and rotation for the character string.

The symbol string itself is output delimited on each end by an "!" character. It is preceded by a G52 code if NCHR $\geq$ 0, and a G53 code if NCHR $<$ 0.

SUBROUTINE NUMBER

NUMBER converts a floating-point number to the appropriate decimal equivalent so that the number may be plotted in the FORTRAN F-type format. The NUMBER calling sequence has six arguments.

CALL NUMBER (XPAGE, YPAGE, HEIGHT, FPN, ANGLE, ± NDEC)

XPAGE, YPAGE, HEIGHT, and ANGLE — are the same as those arguments described for subroutine SYMBOL. The continuation feature, where XPAGE or YPAGE equals 999., may also be used.

FPN — is the floating-point number that is to be converted and plotted.

± NDEC — controls the precision of the conversion of the number FPN. If the value of NDEC $>$ 0, it specifies the number of digits to the right of the decimal point that are to be converted and plotted, after proper rounding. For example, assume an internal value (perhaps in binary form) of -0.12345678×10^3. If NDEC were 2, the plotted number would be -123.46.

If NDEC = 0, only the number's integer portion and a decimal point are plotted, after rounding.

If NDEC = -1, only the number's integer portion is plotted, after rounding. (The above example would be plotted as -123 with no decimal point.)

If NDEC $<$ -1, | NDEC | -1 digits are truncated from the integer portion, after rounding.

The magnitude of NDEC should not exceed 9.

SUBROUTINE AXIS

Most graphs require axis lines and scales to indicate the orientation and values of the plotted data points. The most common type of scaled axis is easily produced by the AXIS subroutine, which draws any length line at any angle, divides it into one-inch segments, annotates the divisions with appropriate scale values, and labels the axis with a centered title. When both the X and the Y axes are needed, AXIS is called separately for each one.

There are eight arguments in the calling sequence:

CALL AXIS (XPAGE, YPAGE, IBCD, ± NCHAR, AXLEN, ANGLE, FIRSTV, DELTAV)

XPAGE, YPAGE — are the coordinates, in inches, of the axis line's starting point. The entire line and terminal ends should be at least one-half inch from any side to allow space for the scale annotation and axis title. Usually, both the X and the Y axes are joined at the origin of the graph, where XPAGE and YPAGE equal zero; but other starting points can be used if desired. When using the LINE subroutine to plot data on an axis, at least one of the coordinates must be 0; i.e., for an X-axis, XPAGE=0, and for a Y-axis, YPAGE=0.

IBCD — is the title, which is centered and placed parallel to the axis line. This parameter may be an alphameric array, or it may be a Hollerith literal if the FORTRAN compiler being used permits it. The characters have a fixed height of 0.14 inches (about seven characters per inch).

± NCHAR — specifies the number of characters in the axis title, and determines by its sign which side of the line the scale (tick) marks and labeling information shall be placed. Since the axis line may be drawn at any angle, the line itself is used as a reference.

If the sign is *positive,* all annotation appears on the positive (counterclockwise) side of the axis. This condition is normally desired for the Y-axis.

If the sign is *negative,* all annotation appears on the negative (clockwise) side of the axis. This condition is normally desired for the X-axis.

AXLEN — is the length of the axis line, in inches.

ANGLE — is the angle, in positive or negative degrees, at which the axis is to be drawn. Normally, this value is zero for the X-axis and 90.0 for the Y-axis.

FIRSTV — is the starting value (either minimum or maximum) which will appear at the first tick mark on the axis. This value may be computed by the SCALE subroutine and stored at subscripted location ARRAY (NPTS*INC+1), or may be determined by the user and stored anywhere.

This number and each scale value along the axis is always drawn with two decimal places. Since the digit size is 0.105 (about 10 characters per inch), and since a scale value appears every inch, no more than six digits and a sign should appear to the left of the decimal point.

DELTAV — represents the number of data units per inch of the axis. This value (increment or decrement), which is added to FIRSTV for each succeeding one-inch division along the axis, may be computed by SCALE and stored beyond FIRSTV at ARRAY (NPTS*INC+INC+1), or may be determined by the user and stored anywhere.

In order to use a standard format of two decimal places, the size of DELTAV is adjusted to less than 100, but not less than 0.01. As a result, the decimal point may be shifted left or right in the scale values as drawn, and the axis title is then followed by "$*10^n$", (where n is the power-of-ten adjustment factor).

SUBROUTINE LINE

The LINE subroutine produces a line plot of the pairs of data values in two arrays (X and Y). LINE computes the page coordinates of each plotted point according to the data values in each array and the respective scaling parameters. The data points may be represented by centered symbols and/or connecting lines between points.

The scaling parameters corresponding to FIRSTV and DELTAV (see SCALE) must immediately follow each array. If these parameters have not been computed by the SCALE subroutine, they must be supplied by the user.

The calling sequence has six arguments:

CALL LINE (XARRAY, YARRAY, NPTS, INC, ±LINTYP, INTEQ)

XARRAY — is the name of the array containing the abscissa (X) values and the scaling parameters for the X-array.

YARRAY — is the name of the array containing the ordinate (Y) values and the scaling parameters for the Y-array.

NPTS — is the number of data points in each of the two arrays just mentioned. The number does not include the extra two locations for the scaling parameters. The number of points in each array must be the same.

INC — is the increment that the LINE subroutine is to use in gathering data from the two arrays, as described previously for the SCALE subroutine.

±LINTYP — is a control parameter which describes the type of line to be drawn through the data points. The magnitude of LINTYP determines the frequency of plotted symbols; e.g., if LINTYP = 4, a special symbol (denoted by INTEQ) is plotted at every fourth data point.

If LINTYP is *zero*, the points are connected by straight lines but no symbols are plotted.

If LINTYP is *positive*, a straight line connects every data point defined in the array. (The pen is up when moving from its current positive to the first point.)

If LINTYP is *negative*, no connecting lines are drawn, only the symbols are plotted.

INTEQ — is the integer equivalent of the special plotting symbol centered at each data point. This value normally can be 0 through 14 and has meaning only when LINTYP is not zero.

SUBROUTINE SCALE

The SCALE subroutine examines the data values in an array and determines a starting value, either minimum or maximum, and a scaling factor, positive or negative, such that: 1) The scale annotation drawn by the AXIS subroutine at each division will properly represent the range of real data values in the array; and 2) the data points, when plotted by the LINE subroutine, will fit in a given plotting area. These two values are computed and stored by SCALE at the end of the array.

The scaling factor (DELTAV) that is computed represents the number of data units per inch of the axis, but is adjusted so that it is always an interval of 1, 2, 4, 5, or 8 x 10^n (where n is an exponent consistent with the original unadjusted scaling factor). Thus, an array may have a range of values from 301 to 912, to be plotted over an axis of 10 inches. The unadjusted scaling factor is (912-301)/10 = 61.1 units/inch. The adjusted DELTAV would be 8 x 10^1 = 80.

The starting value (FIRSTV), which will appear as the first annotation on the axis, is computed as some multiple of DELTAV that is equal to or outside the limits of the data in the array. For the example given above, if a minimum is wanted for FIRSTV, 240 would be chosen as the best value. If a maximum is desired instead, 960 would be selected.

There are four arguments in the calling sequence:

CALL SCALE (ARRAY, AXLEN, NPTS, ± INC)

ARRAY — is the first element of the array of data points to be examined.

AXLEN — is the length of the axis to which the data is to be scaled. Its value must be greater than 1.0 inch.

NPTS — is the number of data values to be scanned in the array. The FORTRAN dimension statement should specify at least two elements more than the number of values being scanned, to allow room for SCALE to store the computed starting value and scaling factor at the end of the array.

± INC — is an integer whose magnitude is used by SCALE as the increment with which to select the data values to be scanned in the array. Normally | INC | = 1; if it is 2, every other value is examined.

If INC is positive, the selected starting value (FIRSTV) approximates a minimum, and the scale factor (DELTAV) is positive.

If INC is negative, the selected starting value (FIRSTV) approximates a maximum, and the scaling factor (DELTAV) is negative.

If INC = ±1, the array must be dimensioned at least two elements larger than the actual number of data values it contains. If the magnitude of INC > 1, the computed values are stored in (INC) elements and (2*INC) elements beyond the last data point. The subscripted element for FIRSTV is ARRAY (NPTS*INC+1); for DELTAV it is ARRAY (NPTS*INC+INC+1).

SUBROUTINE NEWPEN

This subroutine enables a user to select a pen on multiple pen plotters. If the plotter has only one pen, no action will be taken.

The calling sequence is:

CALL NEWPEN (INP).

Pen number INP is selected and moved to the location of the current pen. The pen is left up.

SUBROUTINE FACTOR

The FACTOR subroutine allows the user to scale the size of his plot only, without changing the rotation.

The calling sequence is:

CALL FACTOR (FACT)

FACT — is the ratio of the desired plot size to the normal plot size. For example, if FACT = 2.0, all subsequent pen movements will be twice their normal size. When FACT is reset to 1.0, all plotting returns to normal size.

This subroutine calls SET to change the plot size but does not affect the rotation. If SET is called after a call to FACTOR, it will override whatever FACTOR had been given. It is sometimes faster to produce a check plot at smaller than normal size to reduce plot time. This can be done either by using FACTOR or by the operator at plot time.

SUBROUTINE CURVE

The CURVE subroutine accepts arrays of X and Y coordinates and plots a smooth curve through them, using spline interpolation.

The calling sequence is:

CALL CURVE (XARRAY, YARRAY, NPTS, INC)

where XARRAY, YARRAY contain the (X, Y) values, NPTS is the number of elements in XARRAY and YARRAY, and INC is the increment used in gathering data from the two arrays.

Since the spline interpolation method is used, which requires 4 points at a time, an extra, or "phantom" point must be specified at each end of the curve. This must be done by the programmer. To plot the curve, the pen is: raised, moved to the position of the second point specified, lowered, and moved along the curve to the second-last point specified, and then raised again. If the true position of the "phantom" points is unknown, the first and/or last points may be repeated.

The first sentence contains a sentence number and a G5 code (spline interpolation). Succeeding sentences contain only (X, Y) values in addition to a sentence number until all of the points have been processed.

SUBROUTINE CIRCLE

This subroutine provides the capability to draw circles or circular arcs either clockwise or counterclockwise. All circles and arcs start at the current pen position.

The calling sequence is:

CALL CIRCLE (XPAGE, YPAGE, XCEN, YCEN, IC)

(XPAGE, YPAGE) are the coordinates of the end point of the circle or arc. (XCEN, YCEN) are the coordinates of the center of the circle or arc. IC is +1 for clockwise direction and -1 for counterclockwise direction.

Note, if the P, Q, R, S transformation matrix has been set to specify different scaling factors in the X and Y directions, circles will be plotted as ellipses.

SUBROUTINE SET

The SET subroutine allows the user to set the P, Q, R, S values for scaling and rotating his plot; the U, V values for origin offset; and the A, B values which control dash line spacing; and SET also allows the user to return the current values of any of these parameters. The P, Q, R, S values generated by the HCBS contain a maximum of eight digits, corresponding to the precision of the 26-bit mantissa used in the controller. Thus, the maximum P, Q, R, or S which can be specified through HCBS is 99.999999.

The calling sequence is:

CALL SET (P1, P2, P3, P4, IC)

where P1, P2, P3, P4 contain parameter values or are the locations to which they are returned. IC indicates which parameters are to be set or returned.

If IC = 1, the P, Q, R, S values which control image size, rotation, and mirror image are set from P1, P2, P3, P4.

If IC = 2, the U, V values for origin offset are specified in P1 and P2; P3 and P4 are dummy values.

If IC = 3, the A, B values for controlling dashed line pen down/up distances are set from P1 and P2. P3 and P4 are dummy values.

If IC = -1, -2 or -3, the corresponding current values of the parameters are returned to the user in P1, P2, P3 and P4.

The values that are initially set (and which will be returned if the parameters have not been set by the user) are as follows:

P=1, Q=0, R=0, S=1 plot scaling and rotation

U=0, V=0 origin offsets

A=0.25, B=0.25 dashed line pen down/pen up standard values

The pen should be positioned at the origin before changing PQRS.

SUBROUTINE WHERE

The WHERE subroutine returns to the user the current location of the pen and the current plot scale size.

The calling sequence is:

```
CALL WHERE (RXPAGE, RYPAGE, RFACT)
```

The current coordinates are returned to the user in RXPAGE and RYPAGE.

The current plot scale factor (from the last call to FACTOR) is returned in RFACT. Note, this may not be the true plot scale factor if SET has been called directly to set P, Q, R, S. If WHERE is called immediately following a call to SYMBOL, the coordinates returned are those of the *beginning* of the character string.

SUBROUTINE BUFF

The BUFF subroutine is called by the other basic software subroutines, primarily PLOT and SYMBOL in order to insert codes in the buffer and to write the buffer on tape when full. It also performs other actions such as translating symbol strings to ASCII.

The calling sequence is:

```
CALL BUFF (LOC, NCNT, ICNT)
```

where LOC is a single element or an array containing data to be inserted in the buffer; NCNT is the number of characters from NLOC to be used; and ICNT is a flag which determines the type of action to be taken.

This subroutine should not be called directly by the user.

SUBROUTINE TDUMP

This subroutine may be called if desired after the plot is completed. It will rewind the tape and print a tape dump of the tape in RS-274 format. This dump may be useful for reference to sentence numbers when debugging a plot.

The calling sequence is:

```
CALL TDUMP (LDEV)
```

where LDEV is the logical device number of the plot tape.

Section 5
SYSTEM OPERATION

The software necessary to control the operation of the RS-274 plotting system is loaded into the CalComp controller from a magnetic tape cartridge. The loading procedure is described in the Controller Operator's manual, and requires about 15 seconds. Before starting execution, the operator should ensure that the teletype and plotter are turned on and that the plotter is in AUTO mode. To begin execution, the operator presses the EXECUTE button on the controller. The system will type 'WHAT?' on the teletype and wait for a response. Any legal command may now be entered.

SYSTEM EXECUTION

The operator has complete control of system operation from the teletype. He can scale the plot to any size, scale X or Y coordinates independently, rotate the plot about the origin, specify a mirror image about the X axis, the Y axis, or a 45^{o} line (axis interchange). He can search to any sentence number and begin plotting either forward or backward from that point. He can list sentences and modify the data before plotting. During operation, the current sentence number is displayed on the controller.

The operator controls the system by entering commands from the teletype. The system responds by executing the command, responding 'OK' on the teletype, and waiting for another command. If an invalid command is entered, the system ignores it, responds 'WHAT?', and waits for another command. Valid system commands and their effect are listed below. Note the following when entering commands:

1. Each line of input must be terminated with a carriage return.
2. A ' ← ' character acts as a backspace character within a line.
3. Typing 'ESC' causes the entire line to be deleted. The system types '. . .' at the end of the line and waits for a new command.
4. Normal control commands should not end with a period. Any line that ends with a period followed by a carriage return is assumed to be a sentence in RS-274 format, which is to be plotted.
5. Only the characters underlined are required by the system to identify the command. Blanks are not significant.

CONTROL COMMANDS

System control commands are as follows:

INIT — causes the system to be reinitialized to the initial load state. Scaling, rotation, and mirror image are reset; the tape is rewound; current plotter position is established as the origin.
Note: For plotting systems that provide operator control over plotter velocity and acceleration, the cartridge must be reloaded to change these parameters; they can not be reset using INIT.

SCALE xxxx.xxxx	causes plot to be scaled in X and Y by the scale factor specified. The decimal point may be omitted if the desired scale factor is an integer, e.g., to plot at twice normal size, specify SCALE 2 or SCALE 2.0 (but *not* SCALE 2. – see 4 above).
SCALE X xxxx.xxxxx SCALE Y xxxx.xxxxx	causes plot to be scaled in the X or Y direction only. The scale factor in the direction not specified remains unchanged.
ROTATE ± xxxx.xxxxx	specifies the amount of rotation of the plot, in degrees.
MIRROR X MIRROR Y MIRROR XY NOMIRROR	Mirrors the plot about the Y axis. Mirrors the plot about the X axis. Interchanges X and Y axes. Resets to normal condition.
SEARCH [±] nnnnn	Search function. If no sign is entered, nnnnn is a sentence number. The tape is positioned at Sentence Number nnnnn. If a sign is entered, the system searches forward (+) or reverse (–) nnnnn sentences from the current sentence.
PLOT [±] nnnnn	Plot function. If no sign is entered, nnnnn is a sentence number. Sentences are plotted starting from the current sentence up to but not including Sentence Number nnnnn. If a sign is entered, the system plots nnnnn sentences forward (+) or reverse (--) from the current sentence.
LIST	prints the current sentence on the teletype in RS-274 format.
HALT NOHALT	controls whether the system pauses and prints a message when a temporary halt code (M1) is encountered, or whether the code is ignored. If not specified, NOHALT is assumed.

The scale, rotate, and mirror functions are combined with any PQRS values appearing on tape to produce the effective PQRS used in the coordinate transformation. Thus, for example, if the programmer has specified a PQRS that would produce a plot ½ normal size, if the operator also specifies

SCALE 0.5

then the resulting plot will be produced at ¼ normal size.

The scale, rotate, and mirror specifications are not cumulative in effect; only the value last given is used. For example, if the operator specifies

ROTATE 30

followed by

ROTATE 20

the plot will be rotated by 20 degrees, not 50 degrees.

If any combination of scaling, rotation, or mirroring functions is specified, they are applied in the order given. For example, if the operator specified

ROTATE 30

followed by

MIRROR X

the plot would first be rotated 30^{o} and then mirrored. If the same commands were given in reverse order, the mirroring would precede the rotation, which will produce a different plot. Care should be taken when using different X and Y scale factors to specify scaling before rotation if an orthogonal transformation is required.

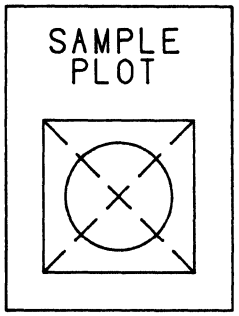
Figures 1 through 4 illustrate the effects of scaling, rotating, and mirroring a plot.

In addition to these control commands, the operator may enter any sentence in RS-274 format. Such a sentence is distinguished from a control command, in that sentences must end with a period, and control commands may not. If a sentence is entered, it is plotted immediately. This facility may be used to produce plots directly from the teletype but it will be used more commonly to add or modify data when plotting from tape. Refer to the OPERATING EXAMPLES at the end of this section for examples of this capability.

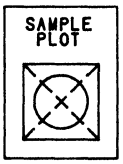
SYSTEM MESSAGES

If a condition arises which requires operator assistance or correction, the system will print a message on the teletype. The operator will normally correct the condition responsible for the message, and then type in a response. System messages, their meanings, and appropriate responses are listed below.

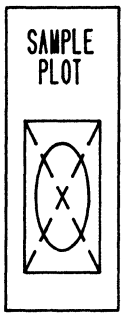
OPERATOR INTERRUPT	This message is in response to the operator pressing the EXECUTE button to interrupt the system while searching or plotting. The system finishes processing the current sentence before responding. The operator may enter 'C' to continue processing, or he may enter any new command.
PLOTTER NOT READY	If the operator attempts to plot when the plotter is in manual mode, the system responds with this message. The operator should put the plotter in AUTO model and type 'C' to continue, or type a new command.
TAPE NOT READY	This message indicates that no tape is mounted when the operator requests a function which requires tape input, such as SEARCH, PLOT, or LIST. The operator should mount a Tape, then type 'C' to continue, or type a new command.
PARITY ERROR	A parity error has occurred on the input tape which the system was unable to correct. The operator should enter 'RT' to retry the read operation, or 'AC' to accept the data as is (not recommended). Or, the operation may be aborted by entering a new command.



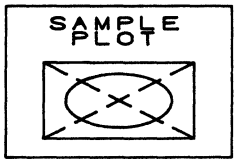
(A) NORMAL



(B) SCALE 0.5

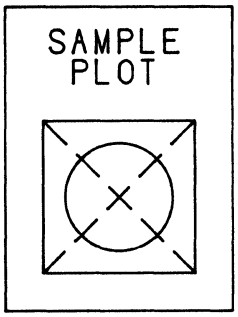


(C) SCALE X 0.5

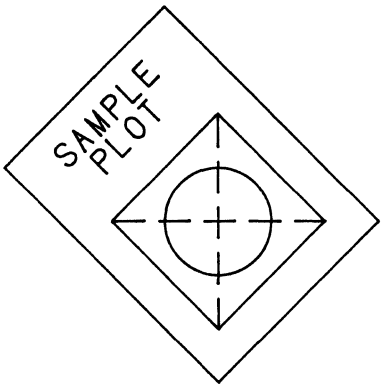


(D) SCALE Y 0.5

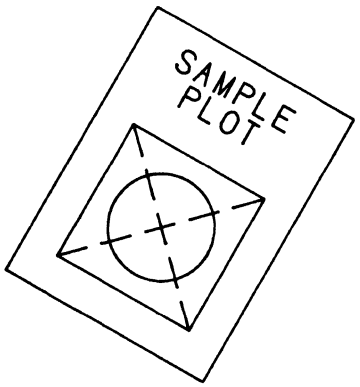
Figure 1. Scaling a Sample Plot



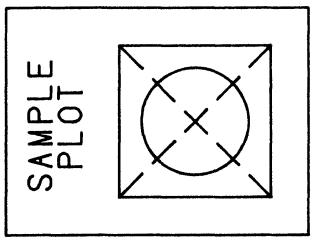
(A) NORMAL



(B) ROTATE 45°



(C) ROTATE –30°



(D) ROTATE 90°

Figure 2. Rotating a Sample Plot

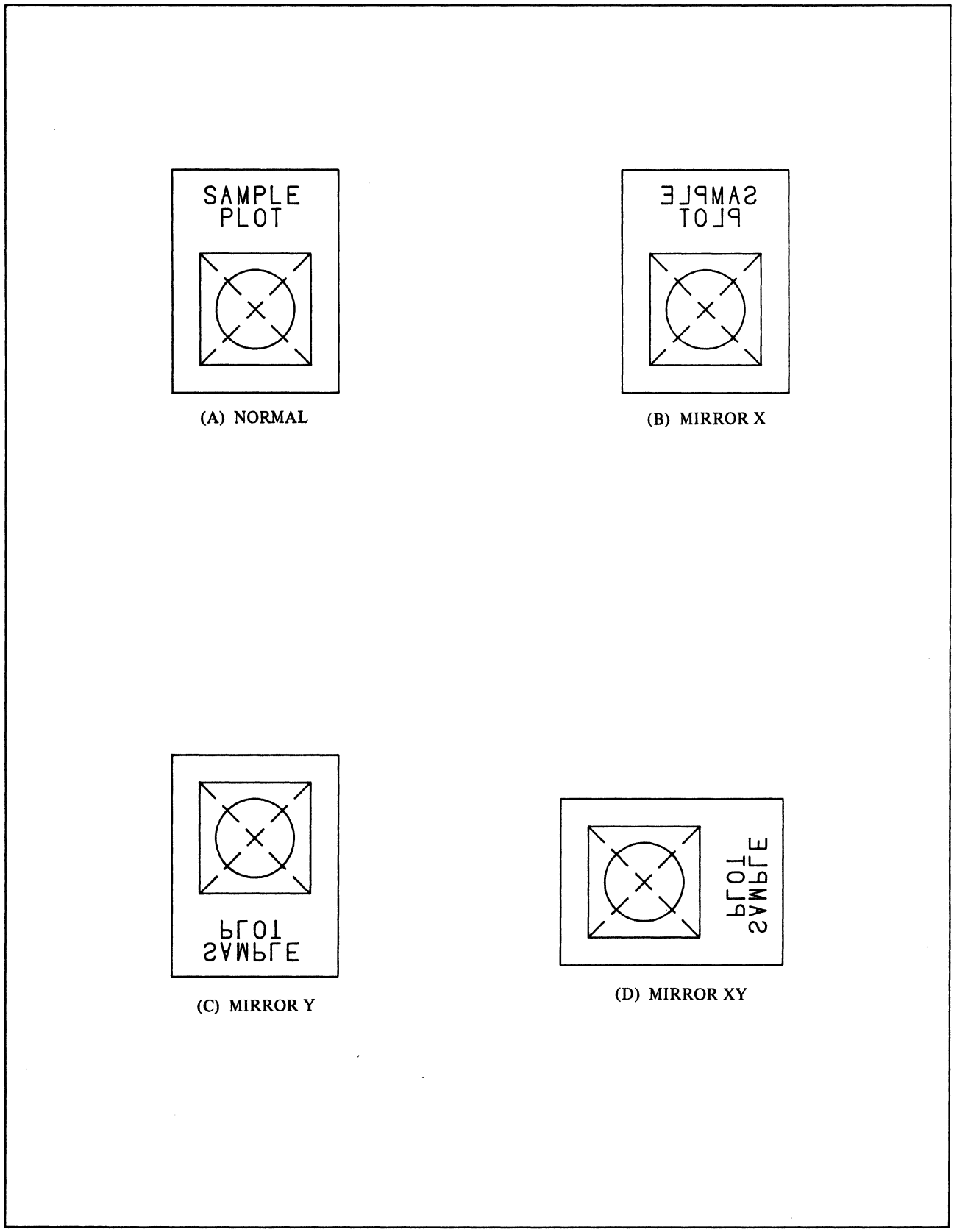


Figure 3. Mirroring a Sample Plot

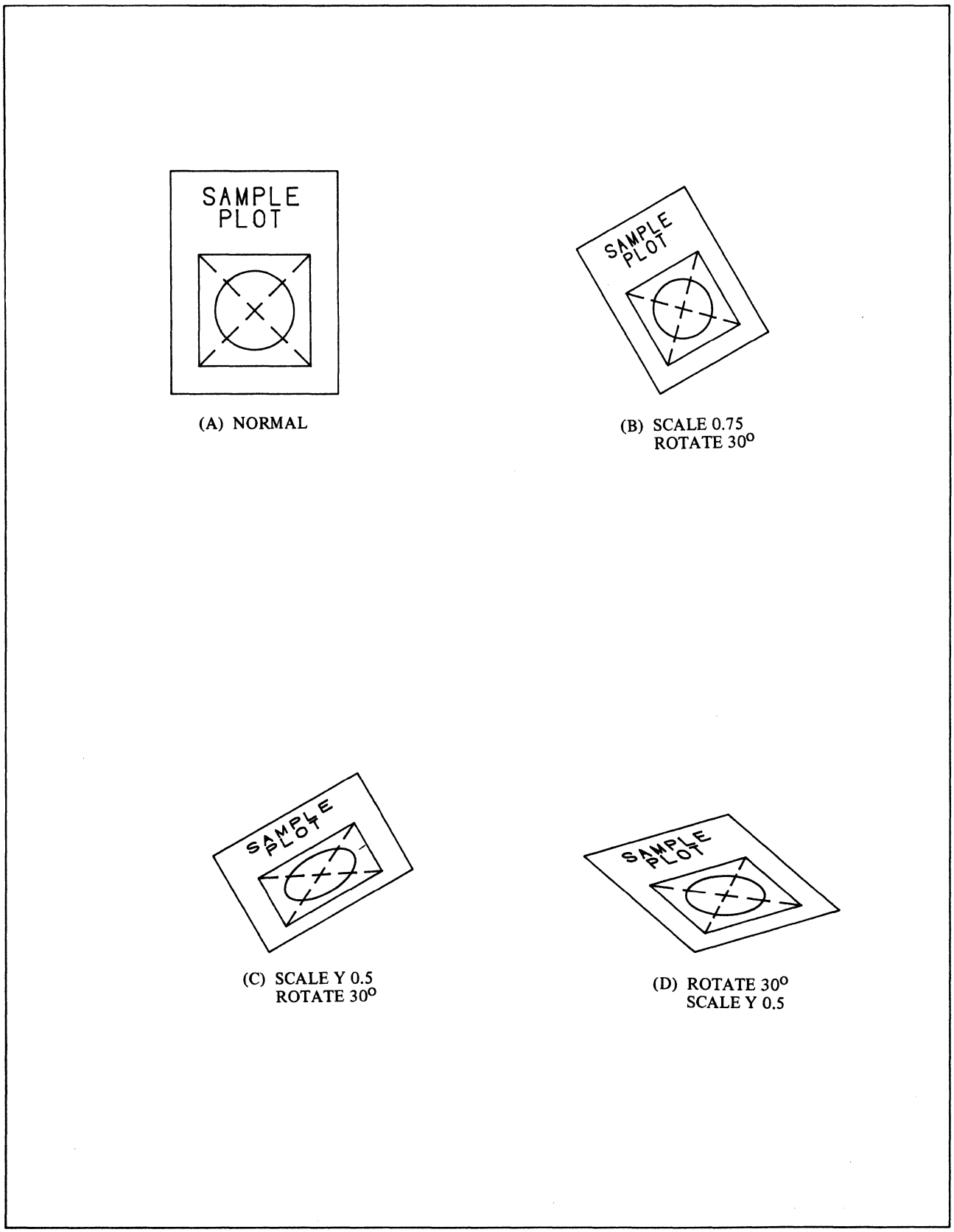


Figure 4. Combinations of Scaling and Rotation Applied to a Sample Plot.

TEMP HALT	While in plot mode, a sentence was encountered which contained an M1 code, and the operator had previously specified HALT to cause a pause on M1 codes. If NOHALT is in effect, no message is given. The operator may type 'C' to continue or may type a new command.
FINAL HALT	While in plot mode, a sentence was encountered which contained an M2 code. The operator should enter a new command.
SYSTEM INITIALIZED	This message is typed in response to the INIT command when the system has been reinitialized.
PLOT ERROR	While plotting, a plotter limit switch has been activated. The plot will have lost origin by some amount. The operator should move the plotter away from the limit switch, and then type C to continue plotting, or type a new command.

OPERATING EXAMPLES

Following is a set of typical operating examples shown with operator commands and system response. The system response is shown as indented but will not actually be so on the teletype. Each example assumes that the system starts in the initialized state; that a plot tape is mounted; that the plotter is correctly set-up and in AUTO mode; and that the system has just typed 'WHAT' and is waiting for a command.

Example 1: Plot an entire tape.

Command/Response	System Action
PLOT 99999	All data is plotted until a final halt code (M1) is encountered.
FINAL HALT	Plot completed.

Example 2: Same as Example 1 except that the entire plot is to be made at half size.

Command/Response	System Action
SCALE 0.5	Plot X and Y scale factors are each set to 0.5.
OK	
PLOT 99999	All data is plotted until a final halt code is encountered.
FINAL HALT	Plot completed.

Example 3: Same as Example 1 except that the entire plot is to be rotated 90^{o}.

Command/Response	System Action
ROTATE 90	Plot rotation set to 90^{o}.
OK	
PLOT 99999	All data is plotted until a final halt code is encountered.
FINAL HALT	Plot completed.

Example 4: Same as Example 1 except that entire plot is to be mirrored about the Y axis.

Command/Response	System Action
MIRROR X	Set up for mirror image in X.
OK	
PLOT 99999	All data is plotted until a final halt code is encountered.
FINAL HALT	Plot completed.

Example 5: Plot sentence numbers 125-760 only from the plot tape.

Command/Response	System Action
SEARCH 125	Tape is searched for sentence number 125. Sentence numbers are displayed as they are processed.
OK	Sentence 125 found.
PLOT 760	Sentences are plotted, starting with the current sentence (125) up to (but not including) sentence 760.
OK	Plot completed.

Example 6: Plot an entire tape, with editing. Assume that the tape contains incorrect X, Y coordinates in sentence 485. They are to be changed from X = 23504, Y = -14625 to X = 22490, Y = -15000. Aside from this change, the tape is to be plotted as is.

Command/Response	System Action
PLOT 485	Sentences 1-484 are plotted. Sentence 485 is processed, but not plotted.
OK	
LIST	The current sentence (Sentence 485) is listed on the teletype.
N485G1D2X23504Y-14625.	[It is not necessary to list the sentence, but it provides a means of verifying that the right sentence is being modified.]
X22490Y-15000.	System plots Sentence 485 using these coordinates.
OK	
PLOT 99999	Rest of tape is plotted until a final halt code is encountered.
FINAL HALT	Plot completed.

Example 7: Same as Example 6 except that instead of changing coordinates, Sentence 485 is to be skipped entirely, and the rest of the tape plotted as is.

Command/Response	System Action
PLOT 485	Sentences 1-484 are plotted.
OK	
SEARCH + 1	Skip one sentence.
OK	
PLOT 99999	Rest of tape is plotted.
FINAL HALT	Plot completed.

Example 8: The operator wishes to plot an entire tape at ½ size. However, in the middle of the plot, one of the pens begins to run out of ink.

Command/Response	System Action
SCALE 0.5	Set plot scale to 0.5.
OK	
PLOT 99999	Operator wants to plot entire tape, but in the middle of the plot he sees a pen is running out of ink. Operator presses EXECUTE button to interrupt plot.
OPERATOR INTERRUPT	Before typing a new command, the operator corrects the pen problem.
SEARCH-50	The tape is repositioned backwards 50 sentences, so that the part of the plot where the pen skipped may be replotted.
OK	
PLOT 99999	Plot rest of tape.
FINAL HALT	

Example 9: A plot tape contains several separate plots, each is terminated with a temporary halt code, the last with a final halt code. The plots are to be made one at a time, each being removed from the plotter before the next one is started.

Command/Response	System Action
HALT	System sets flag to pause on temporary halt (M1) codes.
OK	
PLOT 99999	Plot until a temporary halt is encountered.
TEMP HALT	Before responding, operator can remove current plot, and set up for next
PLOT 99999	Make second plot.
TEMP HALT	End of second plot
.	.
.	.
.	.
PLOT 99999	Make final plot.
FINAL HALT	End of data on tape.

Example 10: A plot is produced correctly, but is supposed to have an 8½" x 11" border line drawn around it; however, the border was left off when the tape was produced. The plot does not end with the pen at the origin, but somewhere in the middle of the plot.

Command/Response	System Action
PLOT 99999	Plot data on tape.
FINAL HALT	Plot completed, but no border is drawn.
G1D2XY.	Move with pen up to origin of plot.
OK	
D1Y110000.	Draw left edge of border.
OK	
X85000.	Draw top edge of border.
OK	
Y.	Draw right edge of border.
OK	
X.	Draw bottom edge of border.
OK	Plot now completed with border drawn.

Note: This sequence of editing commands would be the same even if the plot were scaled, rotated, or mirrored, since the scale factors, etc. would be applied to these coordinates as well as those on the plot tape.

Example 11: Part of a plot has been changed somewhere close to the end of the plot. The operator wishes to verify the changed part without plotting the entire tape.

Command/Response	System Action
SEARCH 99999	Search to end of plot.
FINAL HALT	End of data encountered.
PLOT 1	System plots backward starting at end of plot. When part that was changed has been verified, operator presses EXECUTE button.
OPERATOR INTERRUPT	Verification complete.
INIT	System is reinitialized for next job.
SYSTEM INITIALIZED	Initialization complete.
WHAT?	Waiting for command.

Example 12: The operator wishes to create the sample plot shown in Figure 1(a) directly from the teletype. No plot tape is used.

Command/Response	System Action
G1D1XY20000.	Draw left edge of border.
OK	
X15000.	Draw top edge of border.
OK	
Y.	Draw right edge of border.
OK	
X.	Draw bottom edge of border.
OK	
D2X2500Y2500.	Move to lower left corner of box.
OK	
D1Y12500.	Draw left side of box.
OK	
X12500.	Draw top of box.
OK	
Y2500.	Draw right side of box.
OK	
X2500.	Draw bottom of box.
OK	
G4A2000B1000X12500 Y12500.	Draw diagonal line dashed
OK	
D2Y2500.	Position for other diagonal
OK	
D1X2500Y12500.	Draw diagonal line dashed
OK	
G1D2X5000Y10000.	Position for circle
OK	

```
G2I2500J-2500.          Draw circle
  OK
G1D2X3000Y17000.        Position for annotation
  OK
G52E800F! SAMPLE!       Print "SAMPLE"
  OK
G1D2X4500Y15000.        Position for annotation
  OK
G52! PLOT!              Print "PLOT"
  OK
G1D2XY.                 Return to origin
  OK
```

ASCII CHARACTERS AVAILABLE WITH THE SYMBOL ROUTINE

CODE NEXT TO EACH SYMBOL IS INTEGER CODE USED IN SPECIAL SYMBOL CALL.

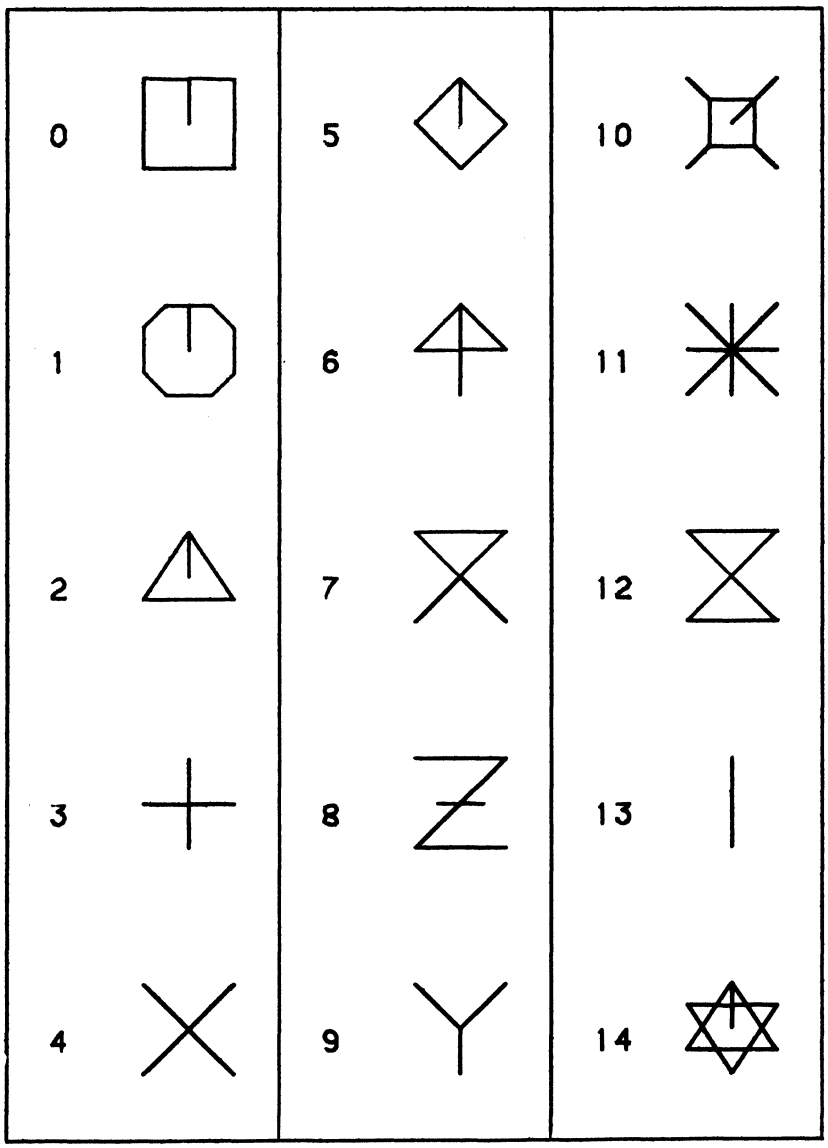
FIRST 64 CHARACTERS ONLY CAN BE PLOTTED WITH SPECIAL SYMBOL CALL.

0		16		32	0	48	@	64	P
1		17		33	1	49	A	65	Q
2		18	"	34	2	50	B	66	R
3		19	#	35	3	51	C	67	S
4		20	$	36	4	52	D	68	T
5		21	%	37	5	53	E	69	U
6		22	&	38	6	54	F	70	V
7		23	'	39	7	55	G	71	W
8		24	(	40	8	56	H	72	X
9		25	)	41	9	57	I	73	Y
10		26	*	42	:	58	J	74	Z
11		27	+	43	;	59	K	75	[
12		28	,	44	<	60	L	76	/
13		29	-	45	=	61	M	77	]
14		30	.	46	>	62	N	78	↑
15		31	\	47	?	63	O	79	←

APPENDIX B

CENTERED SYMBOLS AVAILABLE IN RS-274

INTEGER EQUIVALENT ON LEFT OF SYMBOL



CHARACTERS AVAILABLE IN SYMBOL ROUTINE FOR CALCOMP 900 AND IBM 360

INTERNAL EQUIVALENT (MOD 64) ON LEFT OF SYMBOL

00		10	&	20	—	30	0
01	A	11	J	21	/	31	1
02	B	12	K	22	S	32	2
03	C	13	L	23	T	33	3
04	D	14	M	24	U	34	4
05	E	15	N	25	V	35	5
06	F	16	O	26	W	36	6
07	G	17	P	27	X	37	7
08	H	18	Q	28	Y	38	8
09	I	19	R	29	Z	39	9
0A	[	1A	]	2A	↑	3A	:
0B	.	1B	$	2B	,	3B	#
0C	<	1C	*	2C	%	3C	@
0D	(	1D	)	2D	←	3D	'
0E	+	1E	;	2E	>	3E	=
0F	/	1F	←	2F	?	3F	"

CALIFORNIA COMPUTER PRODUCTS. INC.
2411 West La Palma Anaheim, California 92801
Tel. (714) 821-2011 TWX 910-591-1154

1058 50 573