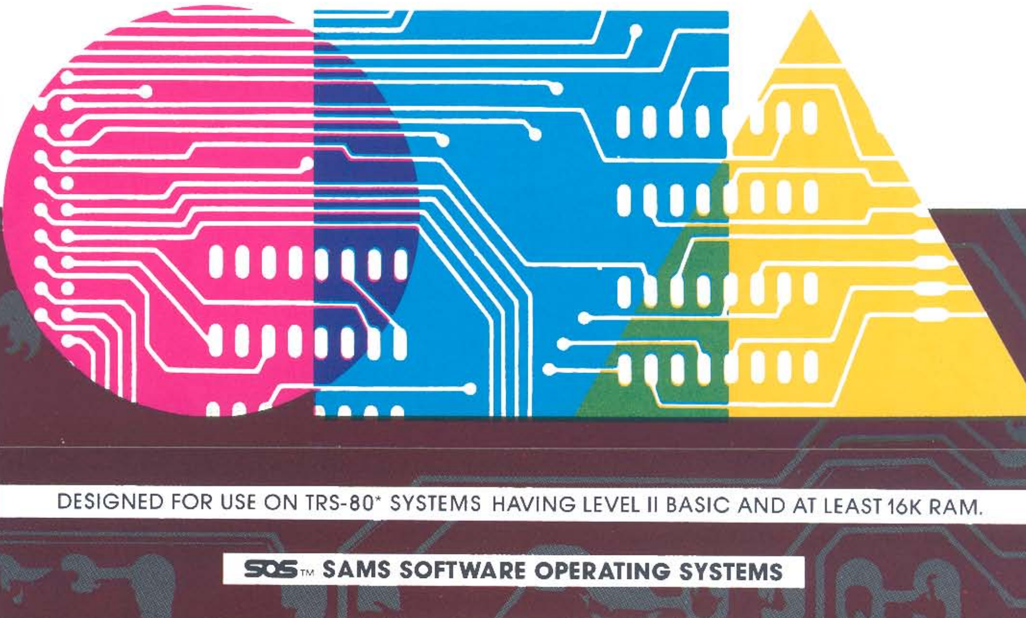
PLOTTING GRAPHS FOR VIDEO DISPLAY

• Histograms • Cartesian Plots
• Semi-Logarithmic Plots
• Log-Log Plots • Polar Plots

BY HOWARD M. BERLIN



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PLOTTING GRAPHS FOR VIDEO DISPLAY

This TAPE illustrates how it is possible to graph functions or discrete data points on your video display in the form of histograms, Cartesian, semilogarithmic, log-log, or polar plots. Most of these programs are primarily written as subroutines so that they may be easily used in conjunction with your own special programs.

HISTOGRAMS

One of the simplest types of graphs is the histogram, or bar graph, which is usually used to display frequency distributions. Required input variables are: the number of data points N, the horizontal and vertical values X(I) and Y(I), respectively, for each point, and the graph title T$. Fig. 1 illustrates a simple driver program that can be used with the PHISTGM subroutine. The program assumes that each X-axis value has only a single corresponding Y-axis value. Consequently, only a maximum of 101 individual bars may be plotted. The DIM statement in line 101 must be included, as the coordinate values are stored before they are plotted on the display.

```
100 'MAIN PROGRAM FOR PHISTGM
101 CLS:DIM X(101), Y(101)
102 INPUT "NUMBER OF DATA POINTS TO BE PLOTED ";N
103 FOR I=1 TO N
104 PRINT "POINT";I;
105 INPUT "X, Y ";X(I),Y(I)
106 NEXT I
107 INPUT "TITLE FOR GRAPH ";T$
108 GOSUB 5000                    'PHISTGM SUBROUTINE
109 END
```

Fig. 1. Simple main program for PHISTGM.

Example 1

Plot a histogram of the result of measuring the values of a sample of 55, 10% resistors, all of which are supposed to have the same nominal value, 100 ohms. As a result of our sampling, we find that the values vary, with several resistors having like values, as listed in Table 1.

Table 1. Data for Example 1

Point No.	Value	Frequency
1	90	1
2	92	1
3	93	2
4	94	4
5	95	3
6	96	4
7	98	7
8	99	8
9	100	11
10	101	4
11	103	2
12	104	3
13	106	3
14	110	2
		Total = 55

Using the above data, Fig. 2A shows the results of executing the main program of Fig. 1 and the PHISTGM subroutine as one pro-

```
NUMBER OF DATA POINTS TO BE PLOTTED ? 14
POINT 1 X, Y ? 90,1
POINT 2 X, Y ? 92,1
POINT 3 X, Y ? 93,2
POINT 4 X, Y ? 94,4
POINT 5 X, Y ? 95,3
POINT 6 X, Y ? 96,4
POINT 7 X, Y ? 98,7
POINT 8 X, Y ? 99,8
POINT 9 X, Y ? 100,11
POINT 10 X, Y ? 101,4
POINT 11 X, Y ? 103,2
POINT 12 X, Y ? 104,3
POINT 13 X, Y ? 106,3
POINT 14 X, Y ? 110,2

TITLE FOR GRAPH ? 100 OHM RESISTOR SAMPLE

MIN — MAX X VALUES ARE:  90                110
MIN — MAX Y VALUES ARE:  1                 11
MIN,MAX X-AXIS SCALE: ? 80,120
MIN,MAX Y-AXIS SCALE: ? 0,15
```

Fig. 2A. Plot of histogram of resistors. (output results)

gram (refer to the appendix to see how a program stored on tape can be merged with another program already in memory). After all the 14 individual points and the graph title are entered, the display informs us as to the current ranges of the two axes. The program then asks us how we want the axes scaled, such as having the horizontal axis range from 80 to 120 while the vertical axis varies from 0 to 15. Because of the method in which the axes

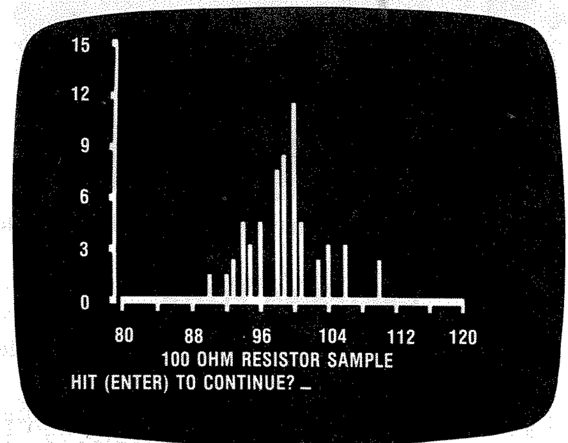


Fig. 2B. Plot of histogram of resistors. (video plot)

are scaled, it is best to have the vertical axis (i.e., the "frequency" axis) incremented by a number that is easily divisible by five, since there are five major divisions, or tic marks, on this axis. When the ENTER key is pressed, the resultant histogram is drawn on the video display, as shown in Fig. 2B.

The histogram then remains on the screen until the ENTER key is pressed, after which we are asked whether or not we are satisfied with how the axes were scaled, as shown by the new entries in Fig. 3A and the resultant graph in Fig. 3B. The process of changing the axis scales can be repeated as many times as desired.

```
ANY CHANGES IN SCALE FACTORS (YES/NO) ? YES
MIN — MAX X VALUES ARE:  80          120
MIN — MAX Y VALUES ARE:  0           15
MIN,MAX X-AXIS SCALE: ? 50,150
MIN,MAX Y-AXIS SCALE: ? 0,15
```

Fig. 3A. Histogram entries for new scale.

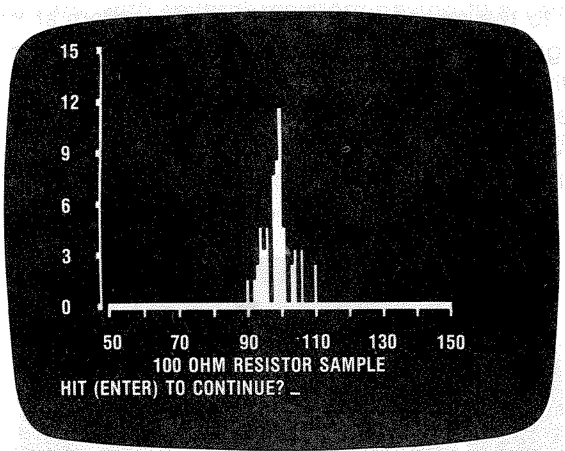


Fig. 3B. Histogram of resistors with new scales. (video plot)

CARTESIAN PLOTS

The program for generating a Cartesian, or rectangular X-Y coordinate plot is similar to the histogram. The PCARTXY subroutine can be used with the plot driver program of Fig. 1, except that the GOSUB 5000 statement in line 108 is now replaced with GOSUB 5050.

Example 2

Graph the following 6 discrete (X,Y) points: (0,0.032), (0.02,0.135), (0.04,0.187), (0.06,0.268), (0.08,0.359), and (0.1,0.435). Fig. 4A shows the results after this data is entered. The resultant Cartesian plot is drawn on video display, as shown in Fig. 4B. The X-axis varies

```
NUMBER OF DATA POINTS TO BE PLOTTED ? 6
POINT 1 X, Y ? 0,0.032
POINT 2 X, Y ? 0.02,0.135
POINT 3 X, Y ? 0.04,0.187
POINT 4 X, Y ? 0.06,0.268
POINT 5 X, Y ? 0.08,0.359
POINT 6 X, Y ? 0.1,0.435

TITLE FOR GRAPH ? EXAMPLE 2-2 DATA
CURRENT MIN — MAX X VALUES ARE:  0           .1
CURRENT MIN — MAX Y VALUES ARE:  .032                .435
DESIRED MIN,MAX X-AXIS SCALE: ? 0,.1
DESIRED MIN,MAX Y-AXIS SCALE: ? 0,.45
```

Fig. 4A. Results after data is entered. (output results)

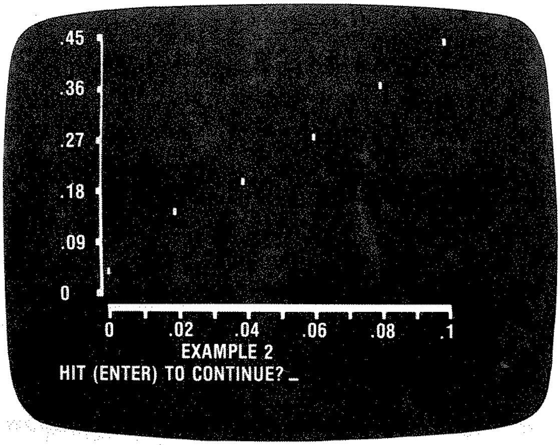


Fig. 4B. Number of data points plotted. (video plot)

from 0 to 0.1 as Y ranges from 0.032 to 0.435, based on our data points. The X-axis was then scaled from 0 to 0.1 while the Y-axis was conveniently set to range from 0 to 0.45.

On the other hand, suppose we are interested in graphing continuous mathematical functions, instead of discrete data points. The following example illustrates how this is accomplished.

Example 3

The transient response of a given network has the known time varying solution:

$$y(t) = 2.3te^{-5t}$$

Fig. 5 lists the main program used to plot this function, which is defined in line 106 in terms of the variables y, and time, t (the independent variable). Line 107 transforms these two variables to the variable arrays Y(I) and X(I), respectively, which are required by the PCARTXY subroutine. Since most functions are single-valued, there will be 101 continuous points, which are recognized by the DIM statement in line 101. When this main program is run, we are first asked to select the minimum and maximum values of time over which this function is to be plotted, after which we are asked for a suitable title for our graph.

For this example, we are interested in how this function appears as time varies from 0 to 2.0 seconds. When executed, we find that

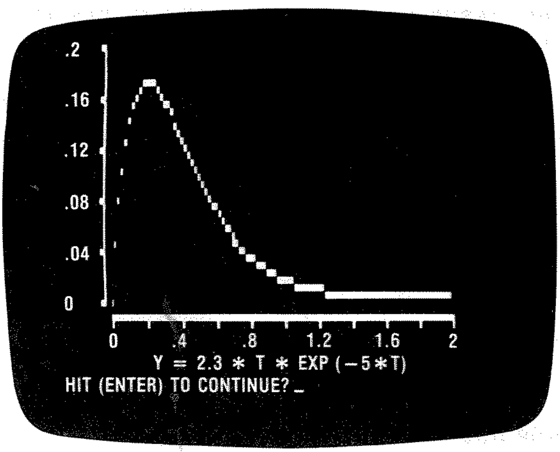
```
100 'SAMPLE PROGRAM FOR PLOTTING A FUNCTION USING PCARTXY
101 CLS:DIM X(101),Y(101)
102 N=101:I=1
103 INPUT"MINIMUM AND MAXIMUM VALUES OF T TO BE PLOTTED
    ";A,B
104 C=(B-A)/100
105 FOR T=A TO B STEP C
106 Y=2.3*T*EXP(-5*T)            'SAMPLE FUNCTION
107 X(I)=T:Y(I)=Y:I=I+1
108 NEXT T
109 INPUT"TITLE FOR GRAPH ";T$
110 GOSUB 5050
111 END
```

Fig. 5. Main program for plotting a function of time.

y ranges from 0 to .17 as t varies from 0 to 2.0, as shown in Fig. 6A, while the resulting plot is shown in Fig. 6B. The graph remains on the screen until the ENTER key is pressed, after which we are asked whether or not we wish to change the scale of either one or both axes.

```
MINIMUM AND MAXIMUM VALUES OF T TO BE PLOTTED ? 0,2
TITLE FOR GRAPH ? Y = 2.3*T*EXP(-5*T)
CURRENT MIN - MAX X VALUES ARE:  0                2
CURRENT MIN - MAX Y VALUES ARE:  0                .169225
DESIRED MIN,MAX X-AXIS SCALE: ? 0,2
DESIRED MIN,MAX Y-AXIS SCALE: ? 0,.2
```

(A) Output results.



(B) Video plot.

Fig. 6. Minimum and maximum values of T plotted.

Periodic, or circular functions, such as those which have sine or cosine terms are also easily graphed on the display, as illustrated by the following example.

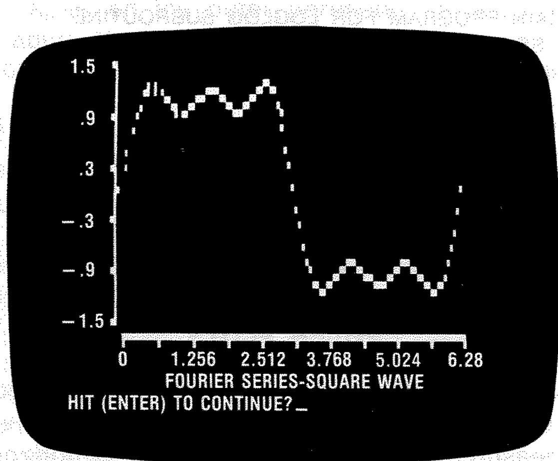
```
100 'SAMPLE PROGRAM FOR PLOTTING A FUNCTION USING PCARTXY
101 CLS:DIM X(101),Y(101),H(6)
102 N=101:I=1
103 INPUT"ENTER MINIMUM AND MAXIMUM VALUES OF X TO BE
    PLOTTED ";A,B
104 C=(B-A)/100
105 FOR X=A TO B STEP C
106 Y=1.273*SIN(X)+.424*SIN(3*X)+.255*SIN(5*X)      'FUNCTION TO
    BE PLOTTED
107 X(I)=X:Y(I)=Y:I=I+1
108 NEXT X
109 INPUT"TITLE FOR GRAPH ";T$
110 GOSUB 5050
111 END
```

(A) Main program.

```
MINIMUM AND MAXIMUM VALUES OF X TO BE PLOTTED ? 0,6.28
TITLE FOR GRAPH ? FOURIER SERIES - SQUARE WAVE

CURRENT MIN - MAX X VALUES ARE:   0              6.28
CURRENT MIN - MAX Y VALUES ARE: -1.18677                  1.18653
DESIRED MIN,MAX X-AXIS SCALE ? 0,6.28
DESIRED MIN,MAX Y-AXIS SCALE ? -1.5,1.5
```

(B) Output results.



(C) Video plot.

Fig. 7. Plotting a function using PCARTXY.

Example 4

Plot the first three terms for the Fourier series of a square wave, such that:

$$f(x) = 1.273\sin(x) + 0.424\sin(3x) + 0.255\sin(5x)$$

Fig. 7A lists the main program used, plotting the function in terms of radians. Fig. 7B shows the output results along with the plot of this function in Fig. 7C.

SEMILOGARITHMIC PLOTS

The PSEMILOG subroutine permits the plotting of points on a semilogarithmic coordinate system, which is logarithmic in X and linear in Y. Depending on the range of values for the horizontal axis, the subroutine automatically scales the X-axis for values with a minimum of 4 cycles. However, the user is able to set the range for the Y-axis scale.

LOG-LOG PLOTS

The LOGLOG subroutine is used for plotting points whose range requires logarithmic scales for both axes. The main program of Fig. 8 can be used to run with the subroutine LOGLOG.

```
100 'MAIN PROGRAM FOR LOGLOG SUBROUTINE
101 CLS:DIM X(101),Y(101),H(6),V(6)
102 INPUT"NUMBER OF DATA POINTS TO BE PLOTTED ";N
103 FOR I=1 TO N
104 PRINT"POINT";I;
105 INPUT"X, Y ";X(I),Y(I)
106 NEXT I
107 GOSUB 5200                     'LOGLOG SUBROUTINE
108 END
```

Fig. 8. Simple main program for LOGLOG.

POLAR PLOTS

Polar plots are frequently used in field theory and control systems, where the plot describes both a radial distance as well as the angle (as measured counterclockwise from the horizontal) associated with it. Examples are the electric field distribution of an antenna, or Nyquist plots of the stability of feedback systems.

The VPOLAR program permits the plotting of either discrete data points or functions expressed in polar coordinates. The polar function must be defined in line 152. The variable I is in degrees and is converted to radians by dividing it by 57.29577. As examples, Table 2 lists the polar forms of a variety of frequently used functions, where the angle is expressed in radians.

Table 2. Common Polar Functions

Name	Equation
Circle:	$r = A\cos\theta$ or $r = \lvert A\sin\theta\rvert$
Cardioid:	$r = A(1 + \cos\theta)$ or $r = \lvert A(1 + \sin\theta)\rvert$
Lemninscate:	$r = \lvert A\text{Cos}(n\theta)\rvert$ or $r = \lvert A\sin(n\theta)\rvert$
Limacon:	$r = \lvert A + B\cos\theta\rvert$ or $r = \lvert A + B\sin\theta\rvert$
N-Leaved Rose:	$r = \lvert A\cos(n\theta)\rvert$ or $r = A\sin(n\theta)\rvert$
Archimedian Spiral:	$r = A\theta$
Hyperbolic Spiral:	$r = A/\theta$
Logarithmic Spiral:	$r = e^{B\theta}$

After the data points are entered or the polar function is determined, the program asks for a graph title, and then determines the maximum radius that exists. We are then asked to enter a value for the radius which is the maximum scale for both axes. The plot is then shown on the video display, which contains markers 30 degrees apart on the outer perimeter. In addition, the title, maximum radius, X-axis (DX) and Y-axis (DY) increments are also shown.

Example 5

Plot the cardioid

$$r = 2(1 + \cos(\theta))$$

so that there will be a point plotted every 4 degrees. Line 152 should then read:

```
152 R(K) = 2*(1+COS(I/57.29577))
```

When run, the maximum radius was found to be 4.0, giving the results shown in Fig. 9. Other polar functions plotted using the VPOLAR routine are also shown in Fig. 9.

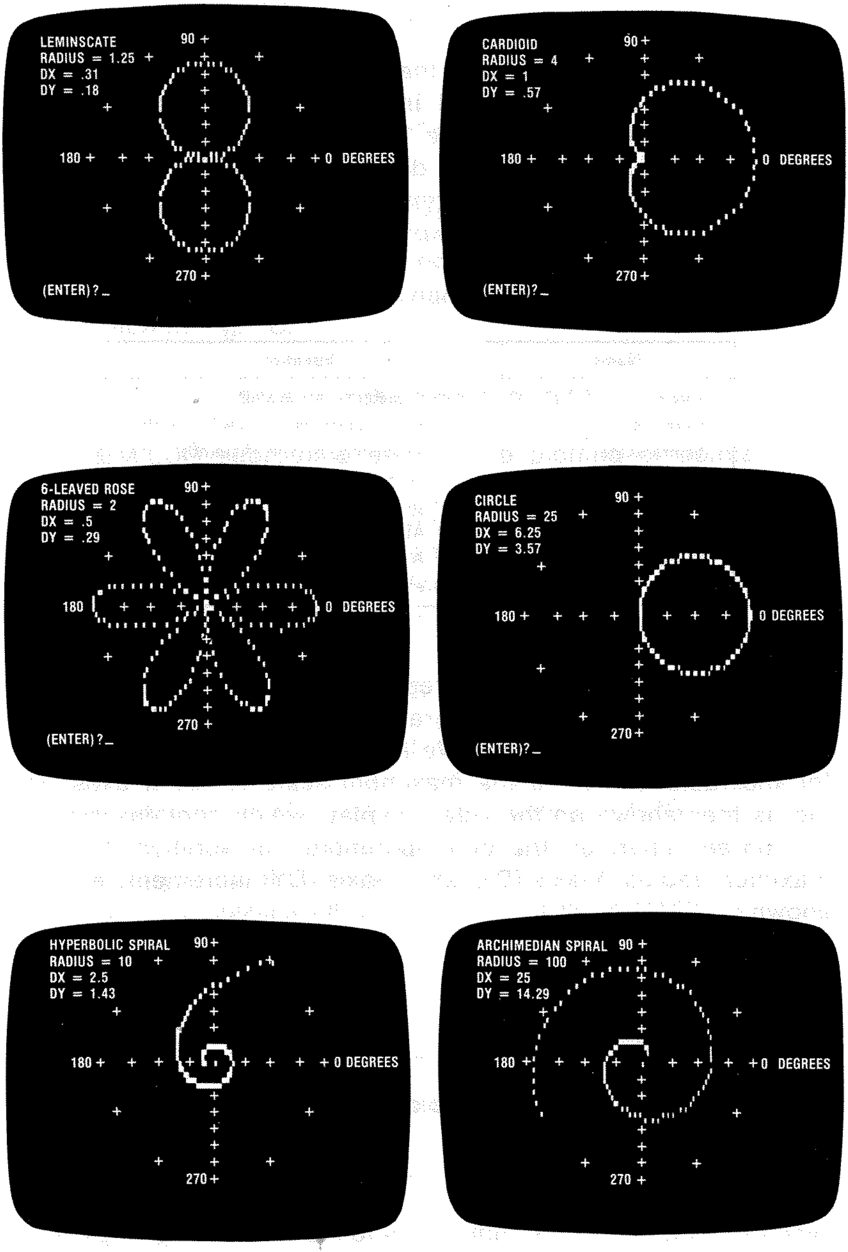


Fig. 9. Common polar functions using VPOLAR. (video plots)

APPENDIX

MERGING A PROGRAM WITH A SUBROUTINE

A number of programs in this book were purposely written as subroutines so that they may be made part of your own application programs. These include a variety of plotting routines, and mathematical functions, such as a four-quadrant arctangent function. Rather than retype the subroutine each time it is needed, one can easily merge, or combine, the subroutine which is already stored on tape with the main program which is presently in memory.

To merge a subroutine already stored on tape with a main program in memory, perform the following steps:

1. The line numbers of the subroutine must be larger than the highest line number of the main program. The subroutines in this book start with line numbers 5000 and higher, and no two subroutines have the same inclusive line numbers.
2. While in BASIC II's COMMAND mode, determine the values stored in locations 16633 and 16634 by typing:

   ```
   PRINT PEEK(16633),PEEK(16634)
   ```

   and then pressing the ENTER key.
3. If the value stored in location 16633 is equal to or greater than 2, then execute the following two statements in the COMMAND mode:

   ```
   POKE 16548,PEEK(16633)—2
   POKE 16549,PEEK(16634)
   ```

   and then use the CLOAD command to load the program stored on cassette tape from the tape recorder, after which the following two statements are executed:

   ```
   POKE 16548,233
   POKE 16549,66
   ```

   The merged program can then be saved on tape using the CSAVE command.

4. If the value stored in location 16633 is less than 2, then execute the following two statements:

```
POKE 16548,PEEK(16633)+254
POKE 16549,PEEK(16634)—1
```

and then use the CLOAD command to load the program stored on cassette tape from the tape recorder, after which the following two statements are executed:

```
POKE 16548,233
POKE 16549,66
```

The merged program can then be saved on tape using the CSAVE command.