HDL-TM-89-16
February 1990

AD-A219 409


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A preliminary version of this report was issued as HDL-PRL-89-9 in September 1989.
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A preliminary version of this report was issued as HDL-PRL-89-9 in September 1989.
A new graphics routine in PC-BASIC for displaying waveforms is described. Linear plots are obtained in automatically scaled and labeled graticules. Specifiable options include window, viewport, and number of tic marks for each axis, and other options. The routine operates on any IBM-compatible PC. DOS is required with a version of the BASIC operating system. Comprehensive samples of output and a program listing are included.
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1. Introduction

The graphics capabilities of PC-BASIC are not sufficient to display data effectively. Low-level commands in BASIC such as DRAW, CIRCLE, and LINE simply cannot be readily used to plot data. Because of the continual increase in the use of personal computers (PC's), and the need for readily available graphics in data processing, a sufficient plotting routine had to be written.

This routine results from years of experience with the handling and display of data on computers. It contains the options and versatility needed for most software plotting applications.

2. Description

2.1 General Description

This BASIC routine graphs an array/waveform on the terminal screen in an automatically generated and scaled graticule. It produces linear plots and uses engineering-unit scaling, i.e., scaling to powers of 10 in multiples of 3. It uses enhanced graphics adapter (EGA) BASIC screen-9 or -10 mode graphics, which give a 640 x 350 pixel resolution, or screen-2 or -8 mode graphics, which give a 640 x 200 pixel resolution.

In order to use this graphics routine, certain computer requirements must be filled. One must have a computer which is IBM-PC compatible, which has minimum processor requirements, such as that of an IBM-XT, and which has a version of the BASIC operating system. For nominal performance it is recommended that it have a coprocessor. In addition, the computer must have a graphics monitor and a graphics card such as Hercules, computer graphics adapter (CGA), or EGA, to name a few. In GW-BASIC, the CGA will only support screen-2 mode whereas the EGA will support screen-8, -9 and -10 modes. The monochrome graphics adapter (MGA) will only support screen 10 mode.

2.2 Options

Although all the routine needs from the user is an array, many options can be specified to control the appearance of the plotting. These options, listed in Table 1, can be specified anywhere in the main program. The “aspects” of the graph which can be controlled are listed below.

1. Window—the minimum and maximum values, or “span,” of the graph; includes the horizontal (x-axis) and vertical (y-axis) minimum and maximum values.

2. Viewport—the portion of the terminal screen the graph will be displayed in; i.e., the size and location of the graph on the screen are specified in terms of pixel coordinates.

3. Tics—number of divisions of the graticule; specified for the x-axis and the y-axis; the number of vertical and horizontal tics can be specified.

4. Labels—the numbers printed on the screen to signify the value of the plot at each tic mark, and the units of each axis which are printed; the number of digits the labels contain can be specified.

5. Colors—the colors of each of the following can be specified:

   (a) Graticule—the grid the trace is displayed in.

   (b) Trace—the “curve” drawn on the graticule, which represents the actual waveform.

   (c) Labels—explained above.

   An additional term which needs defining is pixel—the smallest unit of discernible graphics on the terminal screen; e.g., in screen-9 mode, the screen consists of 640 x 350 pixels.

   If not specified, each option reverts to its default value. For example, if the window is not specified, it is autogenerated to give a trace which is full scale in the graticule and labels which are “nice, round” numbers. Not specifying the number of tics will have the routine automatically compute the correct number of tics to
Table 1. Options

<table>
<thead>
<tr>
<th>Plot aspect</th>
<th>Range</th>
<th>Variable name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Window</td>
<td>$10^{-12}$ to $10^{15}$</td>
<td>XWINDMIN</td>
<td>Minimum value the x-axis will have; default is 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XWINDMAX</td>
<td>Maximum value the x-axis will have; default is largest x-value of the trace</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YWINDMIN</td>
<td>Minimum value the y-axis will have</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YWINDMAX</td>
<td>Maximum value the y-axis will have</td>
</tr>
<tr>
<td>Viewpoint</td>
<td>1 to 639</td>
<td>XVIEWMIN</td>
<td>Leftmost horizontal pixel coordinate the graticule will have</td>
</tr>
<tr>
<td></td>
<td></td>
<td>XVIEWMAX</td>
<td>Rightmost horizontal pixel coordinate the graticule will have</td>
</tr>
<tr>
<td></td>
<td>1 to 349</td>
<td>YVIEWMIN</td>
<td>Vertical pixel coordinate the upper side of the graticule will have</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YVIEWMAX</td>
<td>Vertical pixel coordinate the lower side of the graticule will have</td>
</tr>
<tr>
<td>Tics</td>
<td>0 to 20</td>
<td>XTICS</td>
<td>Number of divisions to make in the graticule’s x-axis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YTICS</td>
<td>Number of divisions to make in the graticule’s y-axis</td>
</tr>
<tr>
<td>Labels</td>
<td>1 to 8</td>
<td>XDIGITS</td>
<td>Number of digits the labels of the x-axis will have</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YDIGITS</td>
<td>Number of digits the labels of the y-axis will have</td>
</tr>
<tr>
<td>Colors</td>
<td>0 to 15</td>
<td>COLORGRA</td>
<td>Color of the graticule</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COLORLAB</td>
<td>Color of the labels</td>
</tr>
<tr>
<td></td>
<td></td>
<td>COLORTTRA</td>
<td>Color of the trace</td>
</tr>
</tbody>
</table>

use, based upon the viewport and the window specifications. In addition, in case of errors or incorrectly entered values, default values are assigned. Also, options specified as noninteger are rounded to the nearest integer except for the window parameters and sampling interval.

There are also variables that are associated with the waveform, rather than with the plotting. These include the sampling interval, horizontal units, and vertical units. They do not have to be specified and are listed in table 2.

Sample outputs with the various options set are given in appendix A. These are hard copies, made directly from the terminal screen in screen-10 mode. In figures A-1 to A-10 the plots display the same waveform, which consists of a 512-element array with a sampling interval of $9.7656 \times 10^4$. In figures A-11 through A-13 the plots display a 512-element array with a sampling interval of $1.9531 \times 10^8$, along with the aforementioned waveform. Figure A-14 contains a plot of two different waveforms on the same graticule. Every waveform has the variables `HORIZUNITS` AND `VERTUNITS` set to "S" and "V," respectively.

In order for the routine to function properly, a different scheme for printing numbers had to be devised. This is described in appendix B. Also, a pseudocode of the entire graphing routine is given in appendix C, and the program is listed in appendix D.
Table 2. Waveform Data

<table>
<thead>
<tr>
<th>Component</th>
<th>Variable name</th>
<th>Description</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling interval</td>
<td>SA</td>
<td>Default is 1</td>
<td>$10^{-3}$ to $10^3$</td>
</tr>
<tr>
<td>Horizontal units</td>
<td>HORZUNIT$</td>
<td>Default is no units displayed</td>
<td>10 characters</td>
</tr>
<tr>
<td>Vertical units</td>
<td>VERTUNIT$</td>
<td>Default is no units displayed</td>
<td>10 characters</td>
</tr>
</tbody>
</table>

3. Uses and Limitations

As stated earlier, in order to work the routine needs an array (in the proper array name, of course). The routine is called with the GOSUB command and it then plots the waveform on the screen. Although the routine only takes one array at a time, it can be used to plot many waveforms on the same graticule. This is easily done by first specifying the window and, second, by graphing each waveform separately, using the color options to omit redrawing of graticule and labels. An example of two waveforms displayed on the same graticule is shown in figure A-14 (app A).

In order to conserve memory in the computer, X-Y pairs are not used and only one array is assigned to a waveform. The method of X-Y pairs uses two arrays for each waveform. The first array holds the horizontal, or X-axis, value of each point and the second array contains the vertical, or Y-axis, value for each point. The two arrays are paired up to create X-Y pairs for each point of the waveform. In order to refrain from using X-Y value pairs, one would use only the Y-value array but also have a sampling interval, a number which is the horizontal value between each point of the waveform. The X-axis value of a point is found by multiplying the sampling interval times the array-element number of the point of interest. The advantage of representing a waveform in this way is that one conserves memory in the computer (about one half the memory space is saved). The most significant disadvantage of representing a waveform in this way is, obviously, that the waveform must have a uniform sampling interval, and thus, nonuniformly sampled waveforms cannot be displayed.

However, if a waveform consists of several sections with different sampling intervals, it can be displayed with the routine. The procedure used is the same as that when plotting more than one waveform, except that each differently sampled portion is used in place of a separate waveform.

In general, this graphics routine has two applications: (1) it can be used simply to plot a waveform which is in a computer or on a disk or (2) it can be a building block for a data processing/acquisition package. It has enough modularity so that it can be easily placed into a software package that is being written in BASIC. In fact it is anticipated that the routine will be used for this purpose in the near future.
Appendix A. Sample Output
Figure A-1. No options specified.

Figure A-2. YTICS=10, YWINDMIN=-.6, YWINDMAX=.6.
Figure A-3. YWINDMIN=-1.13, YWINDMAX=1.17.

Figure A-4. YWINDMIN=-.543, YWINDMAX=.577
Figure A-5. XWINDMIN=0, XWINDMAX=1E-05.

Figure A-6. XWINDMIN=4.829E-06, XWINDMAX=1.725E-05.
Figure A-7. COLORLAB=-1.

Figure A-8. COLORLAB=-1, COLORGRA=-1.
Figure A-9. YDIGITS=5.

Figure A-10. YDIGITS=5, XDIGITS=4.
APPENDIX A

Figure A-11. XVIEWMIN=50, XVIEWMAX=300; First Waveform: YVIEWMIN=35, YVIEWMAX=140; Second Waveform: YVIEWMIN=204, YVIEWMAX=309.

Figure A-12. YWINDMIN=-.543, WWINDMAX=.577, XVIEWMIN=50, XVIEWMAX=300; First Waveform: XVIEWMIN=35, XVIEWMAX=140; Second Waveform: YVIEWMIN=204, YVIEWMAX=309.
Figure A-13. YWINDMIN=-.6, YWINDMAX=.6, XVIEWMIN=50, XVIEWMAX=300; First Waveform: XVIEWMIN=35, XVIEWMAX=140; Second Waveform: YVIEWMIN=204, YVIEWMAX=309.

Figure A-14. Two waveforms.
Appendix B.—The Use of Graphically Produced Numbers
In GW-BASIC, one can only print characters in certain discrete places on the screen, namely in an 80 \times 25 grid. This is a major weakness of IBM-type BASIC—characters cannot be printed where desired. If one tries printing numbers to line up with graticule tic marks, their positions come out distorted. See figure B-1.

A remedy to this is to draw the numbers individually. To do this the numbers must first be designed, each in a 14 \times 8 pixel grid, the size of the regularly printed numbers. For ample space between the numbers when they are printed consecutively, the numbers must be made small enough inside the 14 \times 8 grid. Examples of number designs are shown in figure B-2. The numbers used here are 9 pixels high by 6 pixels wide.

One of these numbers is printed when we move the graphics cursor to any of the 350- \times 640-element locations at which to begin printing the number and use the DRAW command to highlight the appropriate pixel pattern on the screen. With the appropriate graphic string for each digit, an entire line of numbers can be printed.

![Figure B-1. "Distorted" labels.](image-url)
Figure B-2. Examples of graphically produced numbers.
Appendix C.—Pseudocode

Round option-variables to nearest integer except sampling interval and window parameters.

See if each value is within right limits.

Assign default values to the appropriate option parameters.

Auto-compute window and number of tic marks, if needed.

Compute default number of digits in the labels, if needed.

Compute labels.

Draw graph:

    Draw graph border
    Draw tic marks
    Print labels (use graphically produced numbers described in app B)

Plot trace:

    For I = 1 to WAVEFORM_SIZE
        Do a matrix conversion from each point’s amplitude to screen coordinates
        Draw a line to connect each point of the waveform
    Next I

End
Appendix D. Program Listing
APPENDIX D

10 REM ********* GRAPHME.BAS *********
20 REM 4/89 N TESNY
30 REM THIS IS THE MAIN PROGRAM WHICH CALLS THE GRAPHING ROUTINE.
40 WFSIZE=1000
50 OPEN "I",1,"FILE.DAT"
60 DIM WAVEFORM(WFSIZE)
70 GA=1E-09
80 HORZUNITS="S"
90 VERTUNITS="V"
100 YMINIMUM=1E+20:YMAXIMUM=-1E+20
110 FOR I=1 TO WFSIZE
120 INPUT #1,WAVEFORM(I)
130 IF WAVEFORM(I)<YMINIMUM THEN YMINIMUM=WAVEFORM(I)
140 IF WAVEFORM(I)>YMAXIMUM THEN YMAXIMUM=WAVEFORM(I)
150 NEXT I
160 CLOSE #1
170 SCREEN 9
180 KEY OFF
190 CLS
200 GOSUB 5000
210 END
5000 REM 4/89 GRAPHME1.BAS *********
5010 REM GRAPHICS ROUTINE
5020 REM TAKE CINT OF ALL VARS, FIND DEFAULT VALUES:
5030 XVIEWMIN=CINT(XVIEWMIN):XVIEWMAX=CINT(XVIEWMAX)
5040 YVIEWMIN=CINT(YVIEWMIN):YVIEWMAX=CINT(YVIEWMAX)
5050 XWINOMN=0:XWINDMX=0:YWINDMN=0:YWINDMX=0
5060 IF XWINOMN=XWINDMX THEN XWINOMN:XWINDMX:XWINOMAX
5070 IF YWINOMN=YWINDMX THEN YWINOMN=YWINDMX:YWINDMAX
5080 IF XVIEWMIN=YVIEWMAX THEN XVIEWMIN=YVIEWMAX:YVIEWMAX
5090 XNTICS=CINT(XNTICS):IF XNTICS>20 OR XNTICS<0 THEN XNTICS=0
5100 YNTICS=CINT(YNTICS):IF YNTICS>20 OR YNTICS<0 THEN YNTICS=0
5110 XNDIGITS=CINT(XDIGITS):IF XNDIGITS<0 OR XNDIGITS>8 THEN XNDIGITS=0
5120 YNDIGITS=CINT(YDIGITS):IF YNDIGITS<0 OR YNDIGITS>8 THEN YNDIGITS=0
5130 SAMPINTV=SA:IF SAMPINTV=0 THEN SAMPINTY=1
5140 COLOGRA=CINT(COLORGRA):IF COLOGRA=0 OR COLOGRA=15 THEN COLOGRA=7
5150 COLOTRA=CINT(COLORTRA):IF COLOTRA=0 OR COLOTRA=15 THEN COLOTRA=12
5160 COLOLABE=CINT(COLOLABE):IF COLOLABE=0 OR COLOLABE=15 THEN COLOLABE=15
5170 IF XVIEWMIN=XVIEWMAX OR XVIEWMIN<0 OR XVIEWMAX>640 THEN XVIEWMIN:80:XVIEWMAX
5180 IF YVIEWMIN=YVIEWMAX OR YVIEWMIN<0 OR YVIEWMAX>350 THEN YVIEWMIN:80:YVIEWMAX
5190 XSPAN=(XWINOMAX-XWINOMN)/XNTICS
5200 REM COMPUTE WINDOW FOR GRAPH
5210 REM X-AXIS:
5220 XMAXIMUM=SAMPINTV*WFSIZE
5230 IF XNTICS=0 THEN XNTICS=CINT((XMAXIMUM-XVIEWMIN)/(6*8))
5240 XSPAN=(XWINOMAX-XWINOMN)/XNTICS
5250 REM COMPUTE XDIGITS:
5260 IF XNDIGITS<0 OR XSPAN=0 THEN 5290
5270 XNDIGITS=3:IF XWINOMN<XSPAN=100 AND XWINOMAX/XSPAN>100 THEN XNDIGITS=4
APPENDIX D

5280 REM Y-AXIS:
5290 NTICNOM=CINT((YVIEWMAX-YVIEWMIN)/(2*14))
5300 MAX=YMAXIMUM;MIN=YMINIMUM
5310 IF MIN<MAX OR YWINDDN<YWINDM THEN 5360
5320 IF YNTICS<>0 THEN NTICNOM=YNTICS
5330 MIN=MIN*(1-NTICNOM/200)
5340 MAX=MAX*(1+NTICNOM/200)
5350 IF MIN<0 THEN MIN=-.000001*INT(NTICNOM/2);MAX=-.000001*INT(-NTICNOM/2)
5360 IF YWINDDN=YWINDM AND YNTICS<>0 THEN 5430
5370 IF YWINDDN<>YWINDM AND YNTICS=0 THEN 5550
5380 IF YWINDDN<>YWINDM AND YNTICS<>0 THEN 5640
5390 REM MODULE 1: REM TICS AND WINDOW DEFINED
5400 YSPAN=(YWINDM-YWINDDN)/YNTICS
5410 GOTO 5790
5420 REM MODULE 2: WINDOW NOT DEFINED, #TICS SPECIFIED
5430 Y=(MAX-MIN)/YNTICS
5440 K=0
5450 REM ROUND Y UP TO NEAREST INTEGER:
5460 IF Y>10 THEN Y=INT(Y/10):K=K+1:GOTO 5660
5470 IF Y<1 THEN Y=INT(Y*10):K=K-1:GOTO 5660
5480 Y=INT(Y)
5490 YSPAN=10*K * Y
5500 YWINDM=YSPAN*INT(MIN/YSPAN)
5510 YWINDDN=YWINDM+YNTICS*YSPAN
5520 IF YWINDDN<MAX THEN Y=INT(Y):GOTO 5660
5530 GOTO 5790
5540 REM MODULE 3: WINDOW DEFINED, TICS NOT SPECIFIED
5550 IF NTICNOM<5 THEN 5600
5560 FOR YNTICS=NTICNOM TO (NTICNOM-2) STEP -1
5570 YSPAN=(YWINDM-YWINDDN)/YNTICS
5580 IF YSPAN<INT(YSPAN) THEN 5610
5590 NEXT YNTICS
5600 YNTICS=NTICNOM
5610 YSPAN=(YWINDM-YWINDDN)/YNTICS
5620 GOTO 5790
5630 REM MODULE 4: WINDOW AND #TICS NOT SPECIFIED
5640 Y=(MAX-MIN)/NTICNOM
5650 -K=0
5660 REM ROUND Y UP TO NEAREST 1,2, OR 5:
5670 IF Y>10 THEN Y=INT(Y/10):K=K+1:GOTO 5670
5680 IF Y<1 THEN Y=INT(Y*10):K=K-1:GOTO 5680
5690 Y=INT(Y)
5700 IF Y=1 OR Y=2 OR Y=5 OR Y=10 THEN 5730
5710 Y=Y+1 : GOTO 5690
5720 REM FIND YNTICS, YSPAN:
5730 YSPAN=10*K * Y
5740 YWINDDN=YSPAN*INT(MIN/YSPAN)
5750 YWINDM=YSPAN*INT(-MAX/YSPAN)
5760 YNTICS=(YWINDM-YWINDDN)/YSPAN
5770 IF YNTICS>NTICNOM THEN Y=Y+1:GOTO 5670
5780 REM COMPUTE YNDIGITS:
APPENDIX D

5790 IF YNDIGITS<>0 OR YSPAN<>0 THEN 5820
5800 YNDIGITS=3:IF YWINDMN/YSpan>100 AND YWINDMX/YSpan>100 THEN YNDIGITS=4
5810 NTICS=CINT(YNTICS)
5820 REM THE ACTUAL WAVEFORM PLOTTING
5830 IF COLOGRAT<0 THEN 6070
5840 REM DRAW GRAPH BORDER:
5850 DRAW "C"+STR$(COLOGRAT)
5860 X=STR$(XVIEWMIN)+","+STR$(YVIEWMAX)
5870 DRAW "BM "+X
5880 DRAW "M "+STR$(XVIEWMAX-XVIEWMIN)+",0"
5890 DRAW "M "+Y+STR$(YVIEWMIN-YVIEWMAX)
5900 DRAW "M "+Y+STR$(YVIEWMAX-YVIEWMIN)
5910 DRAW "M "+Y+STR$(YVIEWMAX-YVIEWMIN)
5920 REM DRAW X-UNIT TIC MARKS:
5930 FOR I=1 TO XNTICS-1
5940 X=XVIEWMIN+(XVIEWMAX-XVIEWMIN)*I/XNTICS
5950 X=CINT(X)
5960 DRAW "BM "+STR$(X)+","+STR$(YVIEWMIN)
5970 DRAW "MM "+Y+STR$(YVIEWMAX-YVIEWMIN)
5980 NEXT I
5990 REM DRAW Y-UNIT TIC MARKS:
6000 FOR I=1 TO YNTICS-1
6010 Y=YVIEWMIN+(YVIEWMAX-YVIEWMIN)*I/YNTICS
6020 Y=CINT(Y)
6030 DRAW "BM "+STR$(X)+","+STR$(Y)
6040 DRAW "MM "+Y+STR$(YVIEWMAX-YVIEWMIN)
6050 NEXT I
6060 REM COMPUTE SCALING FACTORS FOR ENG. UNITS FOR GRAPH
6070 X=XWINDMX
6080 GOSUB 6760
6090 XEXPON$=EXPONENT$:XFACTOR=10*X
6100 X=YWINDMN
6110 Y=ABS(YWINDMN):IF Y=X THEN X=Y
6120 GOSUB 6760
6130 YEXPON$=EXPONENT$:YFACTOR=10*X
6140 REM PRINT X-LABELS:
6150 IF COLOLABE<0 THEN .6540
6160 DRAW "C"+STR$(COLOLABE)
6170 AXISTYPEw1:NDIGITSzXNDIGITS
6180 ImXWINDMX
6190 IF ABS(XWINDMN)>1 THEN l=ABS(XWINDMN)
6200 IF I/XFACTOR<100 THEN NDIGMAX=2
6210 IF I/XFACTOR<10 THEN NDIGMAX=1
6220 NUMBER=XWINDMN/XFACTOR
6230 GOSUB 6880:REM PRINT LABEL
6240 FOR T=1 TO XNTICS
6250 X=XVIEWMIN+(XVIEWMAX-XVIEWMIN)*T/XNTICS
6260 X=CINT(X)
6270 NUMBER=(XWINDMN+XSPAN*T)/XFACTOR
6280 X=XVIEWMIN+(XVIEWMAX-XVIEWMIN)*T/XNTICS
6290 NUMBER=(XWINDMN+XSPAN*T)/XFACTOR
APPENDIX D

6300 GOSUB 6880:REM PRINT LABEL
6310 NEXT T
6320 Y=Y/14+2:IF Y>25 THEN Y=25
6330 LOCATE Y,(XVIEWMAX+XVIEWMIN)/16
6340 PRINT XEXPONS;HORZUNITS;:LOCATE 1,25
6350 REM PRINT Y-LABELS:
6360 AXISTYPE=3:NDIGITS=YNDIGITS
6370 NDIGMAX=3
6380 I=YVIEWMAX
6390 IF ABS(YVIEWMAX)>I THEN I=ABS(YVIEWMAX)
6400 IF I/YFACTOR<100 THEN NDIGMAX=2
6410 IF I/YFACTOR<10 THEN NDIGMAX=1
6420 NUMBER=YVIEWMAX/YFACTOR
6430 X=XVIEWMAX:Y=YVIEWMAX
6440 GOSUB 6880:REM PRINT LABEL
6450 FOR T=1 TO YNTICS
6460 Y=YVIEWMAX-(YVIEWMAX-YVIEWMIN)*T/YNTICS
6470 Y=CINT(Y)
6480 NUMBER=(YVIEWMAX+YSPAN*T)/YFACTOR
6490 GOSUB 6880:REM PRINT LABEL
6500 NEXT T
6510 X=XVIEWMAX/8-LEN(XEXPONS+VERTUNITS):IF X<1 THEN X=1
6520 Y=YVIEWMIN/14+1:IF Y<1 THEN Y=1
6530 LOCATE Y,X:PRINT XEXPONS;VERTUNITS
6540 REM PLOT TRACE:
6550 IF COLOTRAC<0 THEN 6730
6560 DRAW "C"+STR$(COLOTRAC)
6570 ARRAYPT1=CINT(XVIEWMIN/SAMPINTV)
6580 ARRAYPT2=INT(XVIEWMAX/SAMPINTV)
6590 IF ARRAYPT1<1 THEN ARRAYPT1=1 : STARTPOS=1
6600 IF ARRAYPT2>WFSIZE THEN ARRAYPT2=WFSIZE
6610 J=XVIEWMIN-XVIEWMAX+XVIEWMAX-XVIEWMIN
6620 K=YVIEWMIN-YVIEWMAX+YVIEWMAX-YVIEWMIN
6630 X=XVIEWMIN+(ARRAYPT1*SAMPINTV-XVIEWMIN)/J*K
6640 Y=YVIEWMAX-(WAVEFORM(ARRAYPT1)-YVIEWMIN)/M*N
6650 X=CINT(X):Y=CINT(Y)
6660 DRAW "RTM"+STR$(X)+","+STR$(Y)
6670 FOR I=ARRAYPT1+1 TO ARRAYPT2
6680 X=XVIEWMIN+(I*SAMPINTV-XVIEWMIN)/J*K
6690 Y=YVIEWMAX-(WAVEFORM(I)-YVIEWMIN)/M*N
6700 X=CINT(X):Y=CINT(Y)
6710 DRAW "RTM"+STR$(X)+","+STR$(Y)
6720 NEXT I
6730 RETURN
6740 END

6750 REM SUBROUTINE TO COMPUTE SCALING FACTORS FOR ENGINEERING UNITS
6760 IF X<1E+12 THEN EXPONENTS="1E+12 ";X=12:RETURN
6770 IF X<1E+9 THEN EXPONENTS="1E+9 ";X=9 : RETURN
6780 IF X<10000001 THEN EXPONENTS="1E+6 ";X=6 : RETURN
6790 IF X<10001 THEN EXPONENTS="1E+3 ";X=3: RETURN
6800 IF X>11 THEN EXPONENTS=" ":X=0: RETURN
APPENDIX D

6810 IF X<1E-09 THEN EXPONENTS="1E-12 ": X=-12: RETURN
6820 IF X<.000001 THEN EXPONENTS="1E-9 ": X=-9: RETURN
6830 IF X<.001 THEN EXPONENTS="1E-6 ": X=-6: RETURN
6840 IF X<.0001 THEN EXPONENTS="1E-3 ": X=-3: RETURN
6850 RETURN
6860 REM LABEL ROUTINE:************************************************************
6870 REM ROUNDING ROUTINE
6880 IF NDIGITS<=4 THEN NUMBER=CINT(NUMBER*10^(NDIGITS-NDIGMAX))/JOA(NDIGITS-NDIGMAX)
6890 REM PADDING ROUTINE:
6900 NUMBERS=STRENS(NUMBER)
6910 IF INSTR(NUMBERS,1,1)=1 THEN NUMBERS=RIGHTS(NUMBERS,LEN(NUMBERS)-1)
6920 IF NDIGMAX=NDIGITS THEN 7020
6930 L=LEN(NUMBER)
6940 J=INSTR(NUMBER,1,1)
6950 IF J=1 THEN NUMBERS=0+NUMBERS
6960 IF J=0 THEN NUMBERS=NUMBERS+1: J=L
6970 FOR I=1 TO (NDIGITS-NDIGMAX)-(L-J)
6980 NUMBERS=NUMBER+"0"
6990 NEXT I
7000 IF L-J+NDIGITS-NDIGMAX THEN NUMBER=LEFTS(NUMBER,L-(L-J)+NDIGITS-NDIGMAX)
7010 REM PRINTING ROUTINE:
7020 LENPIXES=8*LEN(NUMBER)
7030 IF INSTR(NUMBERS,1,1)>0 THEN LENPIXES=LENPIXES-3: REM A "." ONLY 5 PIXELS LONG
7040 REM FIND STARTING POINT:
7050 IF AXISTYPE=1 THEN XSTART=X-INT((LENPIXES-1)/2): YSTART=Y+12
7060 IF AXISTYPE=2 THEN XSTART=X-LENPIXES-3: YSTART=Y+4
7070 REM IF LABEL IS OFFSCREEN THEN SLIDE IT ONSCREEN:
7080 IF XSTART<0 THEN XSTART=0
7090 IF YSTART>350 THEN YSTART=350
7100 REM PRINT NUMBERS:
7110 DRAW "IBM"+STRENS(XSTART)+","+STRENS(YSTART)
7120 FOR I=1 TO LEN(NUMBER)
7130 DIGITS=MIDS(NUMBER,1,1)
7140 IF DIGITS="0" THEN DRAW "BR5 L3 H U6 E R3 F D6 BF BR":GOTO 7260
7150 IF DIGITS="1" THEN DRAW "BR U R D BR2":GOTO 7260
7160 IF DIGITS="2" THEN DRAW "BU4 BR R5 BD4 BR2":GOTO 7260
7170 IF DIGITS="3" THEN DRAW "BU6 BR3 E U D8 L2 R4 BR2":GOTO 7260
7180 IF DIGITS="4" THEN DRAW "BU7 BR E R3 F D G5 D R5 BR2"
7190 IF DIGITS="5" THEN DRAW "BE F R3 E U2 H L3 R3 E U2 H L3 G BR7 BD7"
7200 IF DIGITS="6" THEN DRAW "BR5 U8 G4 D1 R5 BD3 BR2"
7210 IF DIGITS="7" THEN DRAW "BE F R3 E U2 H L4 U4 R5 BR2 BD8"
7220 IF DIGITS="8" THEN DRAW "BU4 BR R4 F D2 G3 H U6 E R3 F BR2 BD7"
7230 IF DIGITS="9" THEN DRAW "BR BU8 R5 D2 G3 D3 BR5"
7240 IF DIGITS=A THEN DRAW "BU5 BR D2 F R3 E U2 H L3 H U2 E R3 F D2 BR2 BD5"
7250 IF DIGITS=B THEN DRAW "BE F R3 E U2 H L3 U2 E R3 F D3 BR2 BD4"
7260 NEXT I
7270 RETURN
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