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ABSTRACT

Users of the Murray Hill HIS-6000 series computer frequently avail themselves of the TPLOT subroutine package (1) to obtain graphical data plots. These plots are usually converted to hard copy by the STARE or microfilm output facilities, but they may also be displayed on those few GLANCE CRT terminals which have been connected to the HIS computer in DAC (direct access) mode. These facilities can also be made available to the growing number of mini-computer time-sharing users by making use of the GERTS (remote terminal) communications software and hardware to send remote-entry jobs to the HIS-6000 computer. We describe a mini-computer time-sharing system, 516 TSS (2), which makes use of these facilities. Furthermore this time-sharing system has some second generation GLANCE terminals connected to it which makes it possible to generate TPLOT-like pictures locally, typically in less than a minute of computer time. These GLANCE pictures may be sent as a sequence of binary card images to the HIS-6000 computer to be plotted on STARE.

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No. Figures	<u>5</u>	No. Tables	<u>0</u>	No. Refs.	<u>10</u>

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Bell Laboratories

subject: **Plotting Facilities for
Mini-Computer Systems**

date: **June 14, 1974**

from: **H. Lycklama**

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Memorandum for File

INTRODUCTION

Users of the Murray Hill HIS-6000 series computer frequently avail themselves of the TPLOTT subroutine package (1) to obtain graphical data plots. These plots are usually converted to hard copy by the STARE or microfilm output facilities, but they may also be displayed on those few GLANCE CRT terminals which have been connected to the HIS-6000 computer in DAC (direct access) mode.

These facilities can also be made available to the growing number of mini-computer time-sharing users by making use of a GERTS (remote terminal) communications software and hardware (201 Dataphone terminal) to send remote entry jobs to the HIS-6000 computer which cause the graphical data to be plotted on STARE or microfilm. We describe here the implementation of a software package, called 516PLOT, written for the 516 TSS mini-computer

system (2). This program accepts Hollerith card images which specify the data and plot control information, converts this input into appropriate format and sends the output to TPLOT for plotting.

Furthermore, this 516 TSS system has a number of second generation GLANCE terminals which have the capability to display vectors as well as characters. A significant amount of software has been written to permit users to generate TPLOT-like graphical displays on these GLANCE terminals, typically in less than a minute of computer time. Since users wanted to obtain hard copies of "debugged" plots and no hard copy output equipment is connected to the 516 computer, a HIS-6000 program, called GS, was written to take GLANCE pictures, represented as a sequence of binary card images, and plot the identical picture on STARE.

This memorandum describes the 516PLOT TPLOT-like interface in sufficient detail that other users (particularly but not exclusively, mini-computer users whose systems have a GERTS interface) may make use of this program. It also describes the GPLOT software package (used to plot graphical data directly on a GLANCE terminal) for the benefit of users of systems which have GLANCE terminals and also as a guide for those with other systems and graphical terminals who might like to take advantage of the HIS-6000 graphical output facilities.

TPLOT Overview

TPLOT is a FORTRAN subroutine which will produce complete graphs, variable in size, including titling, labelling, scaling and identification of data on any of the graphical output devices with which it is suitably interfaced. This routine handles a wide range of plotting situations and performs automatically the many small decisions which must be made to generate a plot of one or more sets of data. The features of the subroutine are well described in reference (1) and will be developed further when the mini-computer plotting packages are described. To invoke the power of this subroutine, TPLOT, one makes a subroutine call from a HIS-6000 FORTRAN program:

```
CALL TPLOT(NPTS,X,Y,...,NGL)
```

with a total of 25 arguments. These arguments includes arrays of X and Y values to be plotted, a title, subtitle, X- and Y- axis labels and specifications of the options which are to be used. All of these arguments are fully described in reference (1) and will be further explained in the section on data generated by a mini-computer for plotting on STARE, the hard-copy graphics facility on the HIS central computer.

Some of the more sophisticated plotting features which are available include:

- (1) identification of individual curves on a multi-curve

plot,

- (2) character plotting,
- (3) dashed-line drawing,
- (4) general object plotting by means of a user specified plotting subroutine to generate the desired object at each data point,

e.g. vertical bar construction

mixed character plotting

phi symbol generation

- (5) more than one grid on a single frame.

It was felt desirable to make this powerful plotting package (which represents many man-months of programming) available to the various mini-computer installations at Bell Labs. This document describes how access to TPLLOT was gained for a particular mini-computer time-sharing system, 516 TSS (2). However the techniques applied are not limited to this system.

516 TSS Overview

A brief description of the 516 time-sharing system is first presented to provide some understanding of the software support available for generating plots on a GLANCE graphics terminal and for sending pictures as well as plot data to the central computing facility for plotting on the STARE facility. This system uses the GERTS communication link with the central computing

facility which makes it easy to obtain hard copies of plots generated locally by submitting batch jobs.

The 516 time-sharing system is a virtual memory system implemented on a Honeywell DDP-516 computer (2) with 12K memory of 16-bit words. It is capable of supporting up to 12 interactive users in the 8K words of memory available to users. The other 4K words of memory are dedicated to system code. Secondary storage consists of 376,000 words on a fixed head disk. The computer is connected to a unique serial I/O ring (4) which makes it possible to distribute its computing power to various locations in the labs. The I/O ring serves the purpose of making it easy to interface non-standard peripherals to the computer. For instance, the current system in Dept. 1352 has more than 20 "nodes" (connection points) on the I/O ring, which interface to such diverse peripherals as dataphones, mini-computers (PDP-11, PDP-8 and DDP-316), memory zappers and GLANCE graphics terminals. Other peripherals not interfaced to the I/O ring include a 201 Dataphone terminal for communication with the Central computing facility and a card reader for input of programs and data. The limited file storage capability available on this machine is augmented by archiving infrequently used files on a large (80M bytes of secondary storage) file store machine accessed via a switching machine (5) which has a node on the 516 I/O ring.

Software supported by the virtual memory system consists of a text editor, an assembler, a loader and assorted programs to drive the wide variety of I/O peripherals on the ring. The main higher level language available on the machine is FS NAP (6) - a file-oriented numerical calculating language - which has some of the features of FORTRAN, FOCAL and BASIC. It was written specifically to run in a virtual memory environment. This language is used to generate and analyze data in a completely interactive manner. One has the capability to write data to and read data from a number of files with the format being simply specified by the programmer. The need to plot and display this data has led to the development of software packages to send the data to be plotted on the HIS-6000 computer by means of T PLOT. The program which accomplishes this is called GE PLOT on the 516 time-sharing system.

GE PLOT Description

Basically, GE PLOT (7) submits a batch job to the HIS-6000 machine by means of the GERTS remote terminal subsystem, using a 201 Dataphone terminal. The HIS program (called 516 PLOT) is a FORTRAN program which interprets the options sent by GE PLOT and accordingly sets up the appropriate arguments for the call to T PLOT. The remote job which is sent to the HIS machine is as follows:


```
SNUMB  xxxxxx  
SGRADE  1  
IDENT  M0000,M000xxxxxxxx  
SELECT  GEDISK/516PLOT
```

data

```
SELECT  CC/GRAPHB  
ENDJOB
```

The data sent to the central computing facility is equivalent to a Hollerith card deck (one line = one card) which contains an options card, titles, sub-titles and the actual X,Y pairs of data points. A total of 16 options are specified in the option card. Some options required by TPLOT are given default values. The format is as follows:

```
LLX,LLY,NGL,ARX,ARY,YREF,LABOP,KO,XMIN,XMAX,YMIN,YMAX,KX,KY,ITYCUR,N  
TTL (Title)  
STL (Sub-title)  
YLB (Y axis label)  
XLB (X axis label)  
NCURVES (Number of curves)  
CHAR (only present for certain values of ITYCUR)  
NPTS (Number of data pairs)  
Data set consisting of NPTS (X,Y) pairs,  
NPTS X points or NPTS Y points as specified by KX,KY.
```

The parameters (LLX,LLY,NGL,ARX,ARY,YREF,LABOP) specify the grid selection options. The parameters (KO,XMIN,XMAX,YMIN,YMAX) specify the scaling options. The parameters (KX,KY,ITYCUR,NTT) specify the curve drawing options. The meanings of the options specified on the first line are summarized here for reference:

LLX	linear log scale option X direction
LLY	linear log scale option Y direction
NGL	grid line option, lines or ticks
ARX	X direction aspect ratio
ARY	Y direction aspect ratio
YREF	vertical reference point
LABOP	grid line labelling control
KO	scaling option, automatic or specified
XMIN	minimum X value
XMAX	maximum X value
YMIN	minimum Y value
YMAX	maximum Y value
KX	X or X or previous X array
KY	Y or Y or previous Y array
ITYCUR	connection option for data points
NTT	number of times curve is traced.

These options are more fully explained in the TPLLOT (1) and GEPLLOT (7) manuals and also in the discussion of options used

for GPLOT in a later section of this memorandum.

By means of the WRITE statement in a FSNAP program it is possible to produce the data required for GEPlot in the proper format in a specified output file. The plot can then be generated by invoking:

GEPlot,OUTPUTFILE

Under normal central computer (HIS-6000) load conditions, one can obtain a STARE plot within 15 minutes.

GLANCE Terminal Description

The development of the second generation GLANCE scope terminals (3) with vector capabilities has made possible the plotting of data sets locally on the 516 TSS mini-computer time-sharing system. This has opened up a whole new field of plotting possibilities for this system. Some of the details of the design of this terminal are described to show how the terminal can be utilized to plot one's data.

Basically the GLANCE terminal consists of a scope screen and a keyboard which are interfaced to a node on the 516 I/O ring. The contents of the scope display memory are displayed on the scope screen continuously. The display memory actually consists of two separate memories, each of which may contain up to 4K

16-bit words. Memory M1 is the display list memory and contains the actual commands which control the display sequence. The display list data may be interpreted in one of three modes: control, short vector or character. There are 16 control mode commands. Each command consists of a 4-bit opcode and 12 bits of data. The formats are as follows:

OPCODE	DATA	
00	0	escape to character mode
01	jump address	jump and sync to 60 Hz.
02	jump address	jump immediate
03	0	goto short vector mode
04	+/- delta X (invisible)	manhattan vectors
05	+/- delta Y (invisible)	
06	+/- delta X (visible)	
07	+/- delta Y (visible)	
10	X (invisible)	load registers absolute
11	Y (invisible)	
12	unused	
13	Y (visible)	
14	brightness, scale, blink	set parameter register
15	wait (invisible)	wait 250ns per bit
16	wait (visible)	
17	unused	

In short vector mode the 16 bits in a word have the following meaning (from least significant bit to most significant bit):

0-5	delta Y
6	+/- (Y)
7-12	delta X
13	+/- (X)
14	visible/invisible
15	escape back to control mode

In character mode the 16-bit word consists of two 8-bit characters. The 8 bits are used as an address pointer in memory M2 to fetch and display the character. One character, DC1 (021), has been defined to go to M1 control mode.

GLANCE also has a writeable character generator memory containing up to 4K 16-bit words. A character look-up table is stored at addresses 0 to 377 (octal). This table contains a function word for each character. The function word consists of a 4-bit opcode and 12 bits of data as defined below:

OPCODE	DATA
16	pointer to character set
00	0 null, fetch next ascii character
01	0 goto M1 control mode
17	pointer to control set function, goto M2 control

The character set consists of 2-bit GLANCE code for displaying the characters in an incremental mode (8),(9). The control set consists of control commands of much the same format as the control commands in the display list in memory M1 (see reference 9 for further details).

GPLOT Description

The availability of the GLANCE graphical terminals has added a whole new dimension to the possibilities for plotting data sets. One can now plot data in an interactive manner. A complete software package has been coded to run on the 516 time-sharing system to display a user's data on the GLANCE terminal. This program, called GPLOT, takes its input from a file. The file may contain any number of data sets and must be in the same format as that required for GEPlot in order to guarantee that a user may plot his data on STARE (batch mode) or on a GLANCE terminal (516 time-sharing mode). For ease of use GPLOT is interfaced with both the FSNAP executive and the system executive. It is also callable from within an FSNAP program.

An attempt was made to make the output of GPLOT identical to that produced by TPlot so as to give the user the option of displaying his data on STARE or GLANCE. For this reason the file formats for GEPlot and GPLOT were kept compatible. Nearly all of the features provided by TPlot are also provided by GPLOT. In

fact, in some cases (to be discussed later) more features can be provided for the user by GPLOT than by TPLOT, since the user has control over the character generator in GLANCE. Some of the features provided by GPLOT include:

- choice of linear or log scales for x and/or y
- automatic or specified selection of x and y scale factors
- automatic selection of grid lines
- choice of grid lines or grid ticks
- ability to inhibit grid lines and specify one's own
- automatic labeling of grid lines
- choice of rectangular frame or polar graph frame.
- controllable plot size in horiz. and vert. directions
- control over directions of positive X and positive Y
- automatic centering of titles and labels
- plotting of multiple curves with identification
- character or dashed-line drawing
- ability to plot an arbitrary object at any data point
- ability to execute user subroutine at each data point
- ability to place a legend below graph
- ability to place labels at any point on graph.

Although the input file format for GPLOT is compatible to that required for GEPLLOT, some added options are required to specify the added features desired of GPLOT. These options

appear as 4 more option parameters on the end of the first "card" of the input file. The options card now appears as:

LLX,LLY,NGL,ARX,ARY,YREF,LABOP,KO,XMIN,XMAX,YMIN,YMAX,KX,KY,
ITYCUR,NTT,USEROPT,CFL,URSUBR,LFL (all on one line).

All other card formats remain the same. The value of USEROPT (if it appears) specifies whether the character file "CFL", the user subroutine "URSUBR" or the label file "LFL" are to be used to display the data set. These options are explained in further detail later on. First, the new features which may be specified by means of giving the first 16 option parameters other values than those possible for GEPlot are described.

The unique features of the GLANCE scope terminals allow one to implement options other than those provided by the TPlot package on the central computer (HIS-6000). Only the features which have been implemented that are different than those provided by TPlot are described here. The reader is referred to the TPlot manual for features which are provided by both TPlot and GPlot. Two extra features are provided by the NGL option. NGL = 6 will display a picture with no frame, grid lines, or labels. NGL = 7 draws X and Y axes if they appear on the plotting area, and puts grid ticks and labels on the axes. The LABOP option values of 3, 4 and 5 are treated the same in GPlot as in TPlot with the added feature that GPlot will look in the label file "LFL" (if specified) to see if the user specified any corresponding X or Y

labels. This gives the user the capability to put his own labels on the axes if so desired. The value of the parameter ITYCUR gives the user detailed control over how his curve(s) is(are) to be drawn. GPLOT allows 9 possible values of this parameter:

- (1) Data points are connected consecutively by straight lines to form a continuous curve.
- (2) Same as (1) except that an identifying letter is placed to the right of the last plotted point. The character will be A, B, C ... corresponding to the curve number.
- (3) Same as (2) except that the curve is labelled with the character in CHAR.
- (4) No vectors are drawn. Instead the character in CHAR will be plotted at each point.
- (5) Data is connected by straight lines in pairs to give the dashed line effect.
- (6) This value specifies the general dashed line option. The connectivity pattern is specified by the first number in CHAR and the number of points to be repeated in the pattern is specified by the second number (following CHAR on same line of input file). Examples are shown in the GPLOT manual (10).
- (7) No vectors are drawn. This value is particularly useful and very powerful when one wishes to execute a user specified subroutine at each data point.

(8) No vectors are drawn but CHAR is read in and may be used in the execution of a user subroutine at each data point.

(9) All vectors are drawn in and CHAR is read in and may be used in the execution of a user subroutine at each data point.

The use of the option parameter USEROPT adds some very powerful features to the GPLOT program. One may specify a character file, a user subroutine and a label file, each of which may be used to enhance the appearance of a user's plotted data set(s).

The contents of the character file "CFL" specify which characters in the character set the user wishes to define so that when one invokes a plot with ITYCUR = 4 the user specified characters may be plotted at each data point. The character generator file "CFL" contains definitions of characters which the user wishes to re-define different from the standard character set. These character definitions are put into the character generator memory. The routine which writes the character memory has been interfaced both with the system executive and the FSNAP executive as well as being callable from an FSNAP program. This allows one to print special characters on the scope screen using the FSNAP "TYPE" statement. The reader is referred to the GPLOT manual (ref. 10) for details of the character generator.

The user subroutine (URSUBR) is a program written in the 516 segmented assembler language and is called at each data point if the user specifies this option. This gives the user great flexibility in plotting his data set(s). Eight different subroutines have been written to interface to GPLOT.

(1) BARPLT - enables a user to construct bar graphs. This subroutine is normally used with ITYCUR = 7, but interesting results may be obtained by setting ITYCUR = 4 and plotting a character at each data point as well.

(2) HISPLT - enables a user to construct histograms. Again this subroutine may be invoked with ITYCUR = 4 or 7.

(3) MIXCHR - enables a user to draw mixed character plots. A label is placed below each data point, consisting of the character currently in CHAR and a number corresponding to the number of the data point.

(4) PHIPLT - enables a user to generate "phi" symbols at each one of his data points. The user must have three curves specifying the limits of the "phi" symbol and the actual data points.

(5) SHDBAR - enables a user to generate shaded bar graphs.

(6) AROPLT - enables a user to place directional arrows on his data points.

(7) LINPLT - enables a user to construct vertical bars from his data points to the minimum Y value present in the data.

(8) VARCHR - enables a user to plot different characters at his data points. This subroutine obtains its characters from the legend file specified by the user.

Other user subroutines may be written as well, as the need arises. One is referred to the GPLOT manual (10) for the details of writing such a subroutine.

The legend file provided by the user gives him flexibility in labelling his curves and in displaying other text at any number of points on his graph. The user may place labels on the X and Y axes, thus enabling him to draw and label grid lines or ticks wherever he chooses. The choice of grid ticks or grid lines is still made by NGL. One also is given the capability to position labels at arbitrary X,Y coordinates. Legends, consisting of one or more lines of text, may be written at any X,Y coordinates as well as at the default position, i.e., the lower left hand corner of the viewing area.

In preparing his input data file to be plotted the user is given some aid by a diagnostic package which dumps out the values of his variables if an error is detected in the input file format. The values of these variables are usually adequate to tell the user where his input file is in error. This interactive feature of GPLOT allows one to debug his plots easily without going to the expense of submitting a remote job to the central

computer and waiting for the results. This technique has proven to be a real time saver in preparing graphs to be plotted remotely on the STARE facility.

GPLOT Hardcopy Features

Obtaining a picture on a GLANCE screen is in itself not sufficient. Therefore a hardcopy feature has been added by means of the 201 Dataphone GERTS connection with the HIS-6000 computer. To make this possible some powerful interactive features were added to GPLOT and some auxiliary programs were written. These interactive features and the auxiliary programs are discussed first. Then the instructions for actually obtaining the hard copies are explained.

One may invoke GPLOT from either the system level, the FSNAP level or by a direct CALL from an FSNAP program itself, by means of:

```
GPLOT,IFILE,OFILE(optional).
```

The input file "IFILE" may contain data sets for any number of graphs. Upon displaying the first (and subsequent) plots on the scope screen, five buttons directly below the plot are labelled as:

```
DEBUG REWIND NEXT DONE STARE
```

By activating these buttons, the following things will occur. The DEBUG button initiates a display of all of the user specified

options and other parameters to enable him to "debug" his plot, i.e., to determine why his plot did not turn out the way he expected it. By pushing the NEXT button, the next graph will be displayed if he has more data in his input file. If not, GPLOT will quit. The DONE button will automatically terminate the plotting of the user's data sets. By hitting the REWIND button, the first plot of the user's data will be displayed again. To obtain a hardcopy of any one of his plots, the user may hit the STARE button. This will cause the contents of both GLANCE memories to be written into a file. Upon hitting the DONE button, all of the user-requested hardcopy plots are sent to the HIS machine to be output on the STARE facility. The actual job submitted to the HIS-6000 computer is as follows:

```
SNUMB  xxxxxx
SGRADE  1
IDENT   M0000,M000xxxxxxxx
REMOTE  **,ONL
OPTION  FORTRAN,NOMAP
USE     .....
LIBRARY JC,GS
EXECUTE
PRMFL   JC,R,R,GEDISK/STARE
DATA    05,NCKSUM
```

data

```
SELECT CC/GRAPHB  
ENDJOB
```

An optional output file "OFILE" may be specified if one wishes to write the display list generated into a file simultaneously with writing them in the GLANCE display list. This allows one to come back later and glance at the output plots by means of:

```
GLANCE,OFILE
```

without having to go through the calculations to produce the display list again. One may append more plots to "OFILE" at any time. The GLANCE program displays one plot at a time and gives the user the same control as in GPLOT by means of the labelled buttons on the bottom of the scope screen. Here display of the next plot is almost instantaneous. One can "glance" at plots quickly to observe differences between adjacent plots in the "OFILE" file. Again one may hit the STARE button to obtain selective hard copies.

As mentioned before, hard copy plots are obtained by reading both GLANCE memories into a file each time the STARE button is pushed. Then when the DONE button is hit, the file is sent as the data part of a remote batch job to the HIS-6000 machine. The data file includes some option specifications which are a

function of the particular GLANCE terminal from which the plot is sent. These options include the sizes of the GLANCE memories and the order in which the characters are displayed in a word (i.e. high order byte first or low order byte first). The HIS program which receives this data will produce the appropriate commands to drive the STARE facility by simulating the display as defined by the contents of the display list in memory one (M1). Each vector in memory one is simulated by means of a call to the DRVECT subroutine in the software package available to drive the STARE facility (8). Each character in the display list is drawn by simulating the character definition as written in the character memory (M2). A header with the appropriate SNUMB and BOX number are put in the top left hand corner of each graph. The Appendix contains some sample plots produced by GPLOT.

It is possible to generate displays on the scope screen other than those produced by GPLOT. In order to obtain hard copies of these pictures, one may invoke the STARE program from another terminal to produce a hard copy on the central STARE facility. For instance one may wish to generate arbitrarily complex pictures using the character generator, pictures which cannot easily be produced by TPLOT. This allows one to get hard copies of any display on the scope screen.

Conclusions

We have described a particular solution for plotting one's data sets produced on a mini-computer. In summary, three basic methods are available for plotting one's data:

(1) If one has a mini-computer without any connection to the HIS machine, one may submit a batch job over the counter containing the data sets to be plotted in a format compatible with that required by GEPlot.

(2) If one has a mini-computer with a connection to the HIS machine, one can submit a remote job to the HIS machine, again containing the data sets in a format compatible with that required by GEPlot. In both of these cases, however, one is limited to hardcopy plots and to the constraints imposed by TPlot and the STARE facility.

(3) The ideal solution is to have a general Graphics scope terminal interfaced with the mini-computer. This enables one to obtain plots in an interactive manner directly at the terminal and without the limitations imposed by another software package. At the same time with a connection to the HIS machine it is possible to obtain hard copies using STARE.

Currently there are three 516 TSS systems at Bell Labs, each with GLANCE terminals. Dept. 1352 has four GLANCE terminals on its

516 TSS system. This has proven to be a viable solution for plotting the data generated on the 516 mini-computer time-sharing system.

Recently an I/O loop has been designed for the PDP-11 family of computers. A GLANCE terminal has been put on the loop and programmed to run as a general login terminal. A GPLOT package similar to the one described above is currently being written to run on the PDP-11/45 computer under the UNIX operating system.

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The coding of GPLOT was done by J.E. Steinhart, an employee during the summer of 1973. J.H. Condon wrote the HIS software package to convert GLANCE vectors to STARE output. The assistance of E.J. Sitar in interfacing with the HIS software packages is gratefully acknowledged. The users of the 516 time-sharing system have provided some very useful feedback in designing the plotting packages for the 516 TSS.

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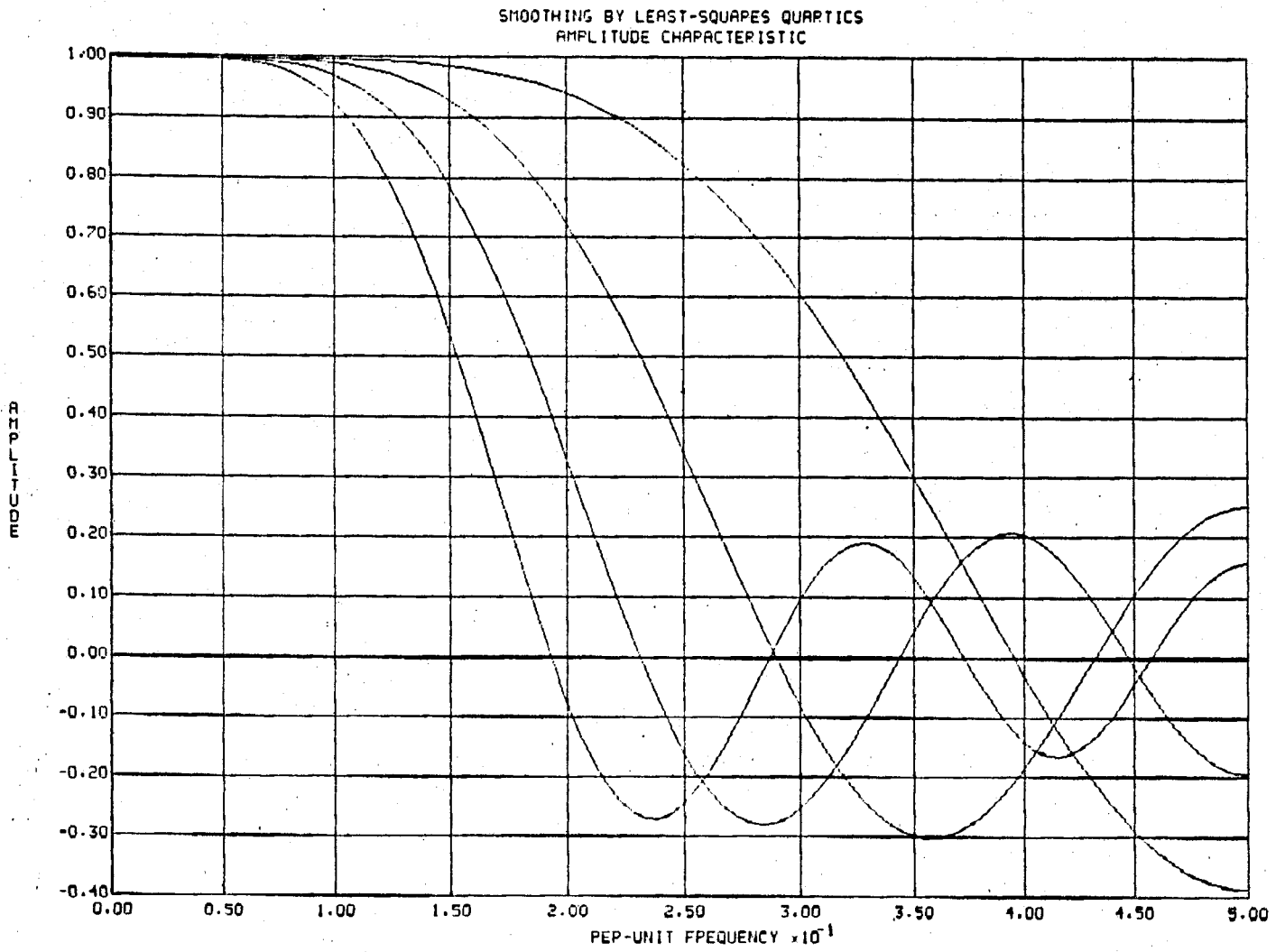


Figure 1

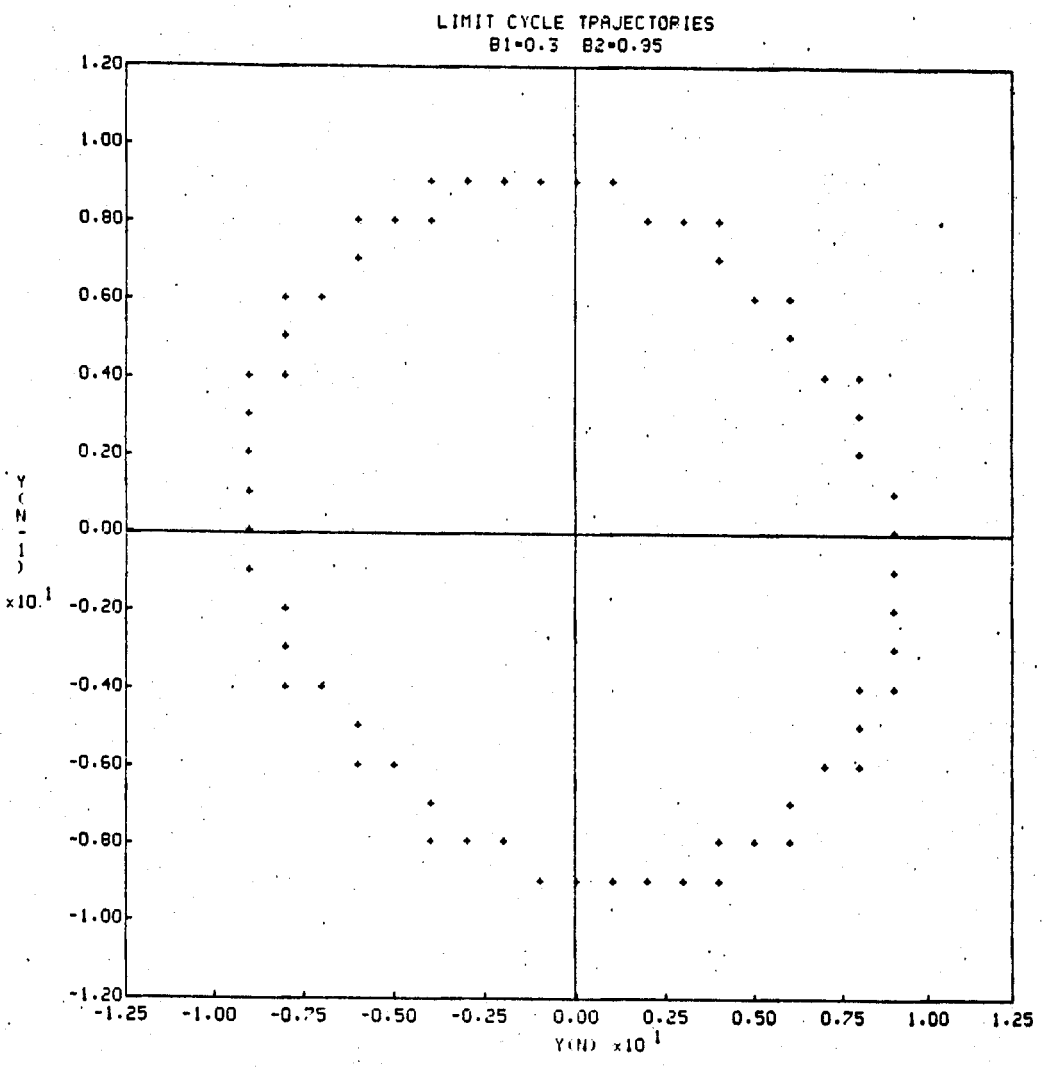


Figure 2

PENDING NEXT DONE STAGE

PLOT 5

DELTA MOD RESPONSE R1= 68.0 K R2= 1.8 K
C1= 150.0 NF C2= 15.0 NF C3= 1.0 NF

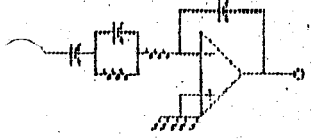
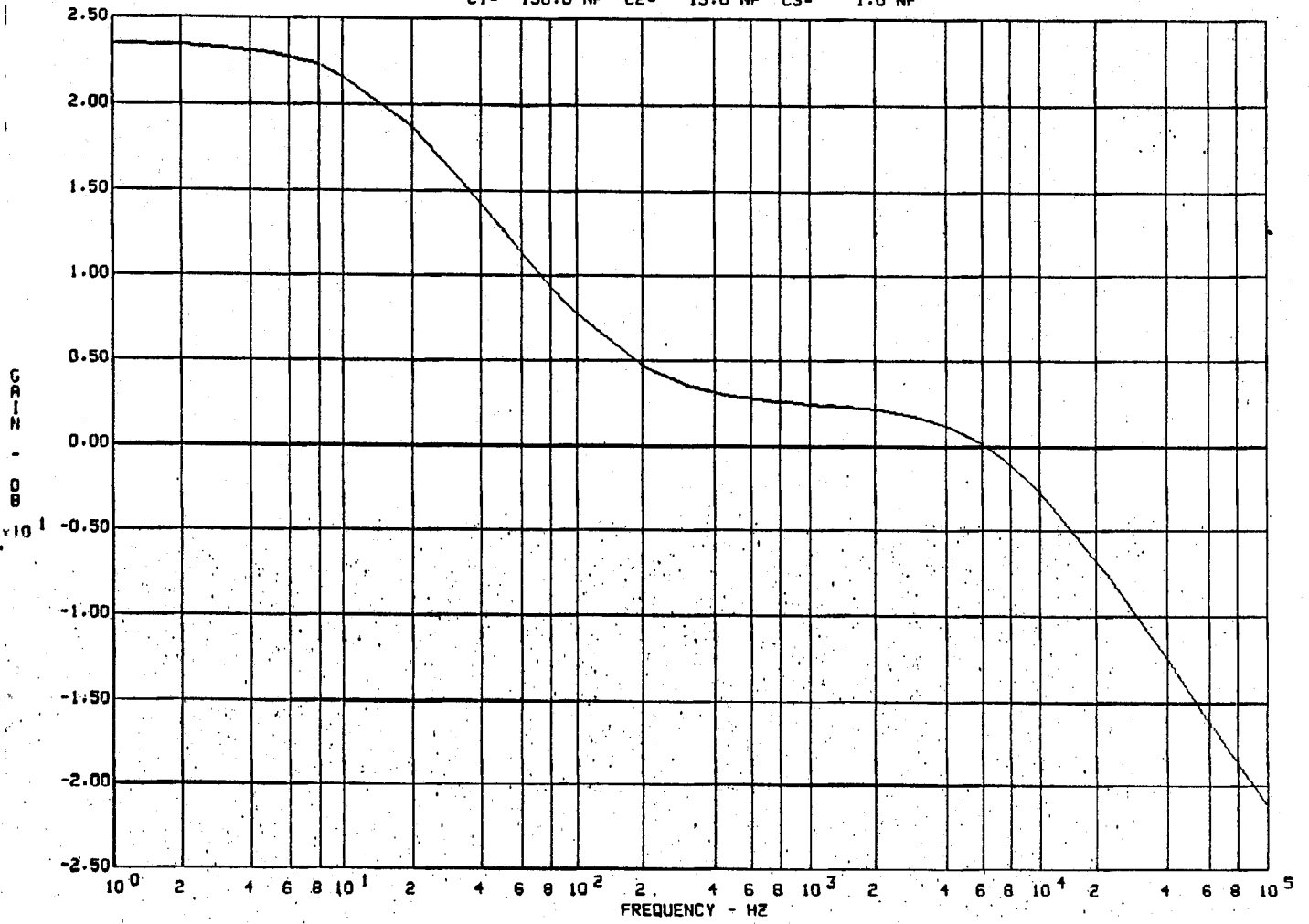


Figure 3

PLOT 1'

DEBUG REWIND NEXT DONE STARE

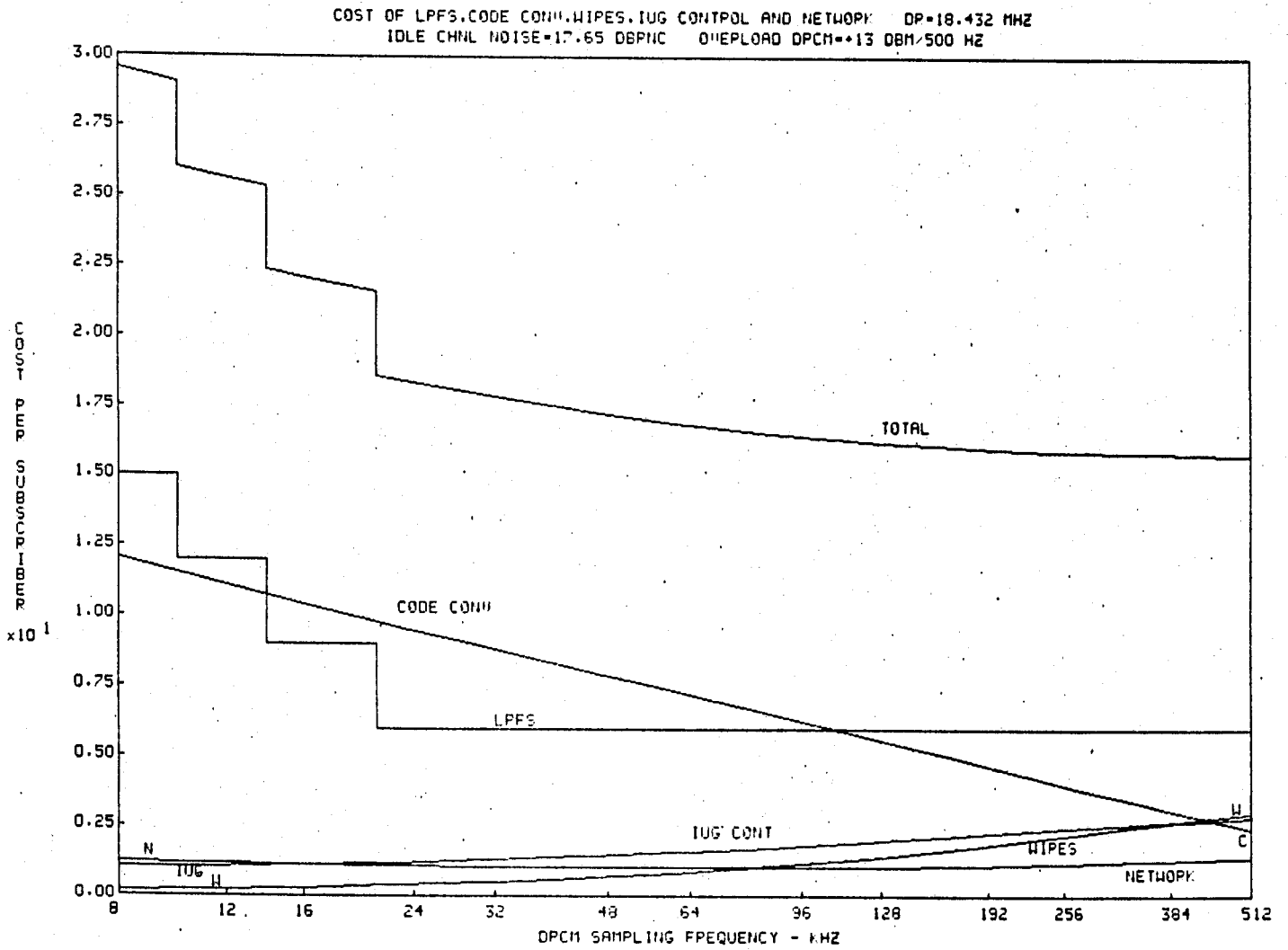


Figure 4

DEBUG RETURN NEXT DONE STAPE

PLOT 1

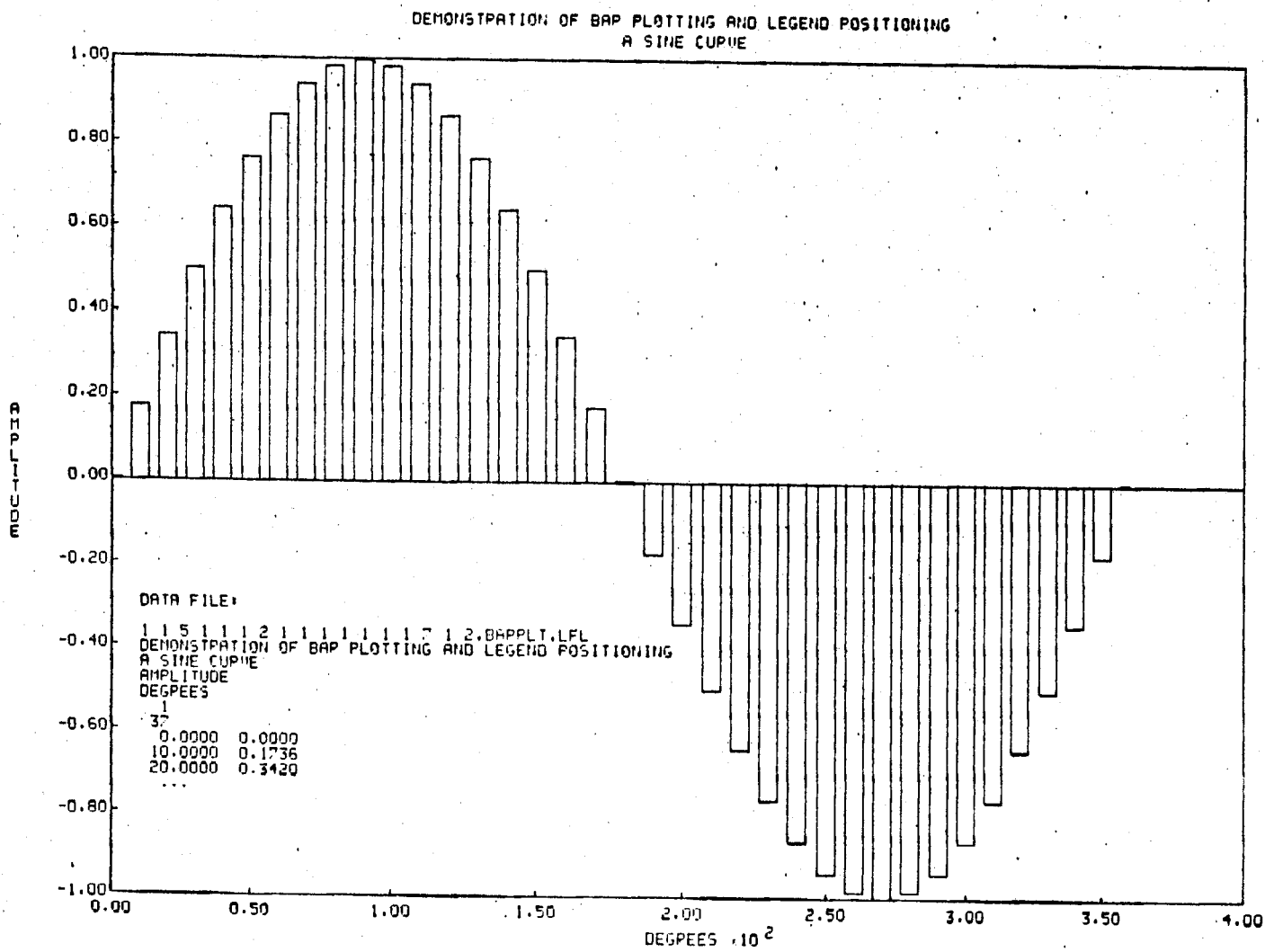


Figure 5

PLOT 1

DEBUG

PELIND

HEAT

ONE

STAPE