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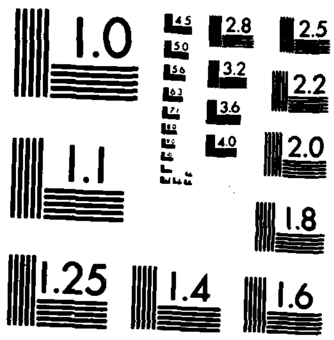

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REPORT SD-TR-84-06, Vol. II

AD-A141 145

LCAP2 - Linear Control Analysis Program

Volume II: Interactive LCAP2 User's Guide

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Final Report

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This report has been reviewed by the Public Affairs Office (PAS) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

William J. Cooper
Project Officer

Joseph Hess
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West Coast Office, Air Force
Space Technology Center

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The computer program LCAP2 (Linear Controls Analysis Program) provides the analyst with the capability to numerically perform classical linear control analysis techniques such as transfer function manipulation, transfer function evaluation, frequency response, root locus, time response and sampled-data transforms. It is able to deal with continuous and sampled-data systems, including multiloop multirate digital systems, using s, z and w transforms.

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20. ABSTRACT (Continued)

Primary considerations in the development of this program were ease of use and computational accuracy. Transfer function and polynomial arrays are defined to be referenced with indices so that they may be easily addressed by the operators. The combination of this set of LCAP2 operators and the form of the data structure provides a very flexible and easy to use program.

Since each LCAP2 operator is coded as a FORTRAN subroutine, the batch version of LCAP2 allows the user to easily develop code to automate, for example, a complete stability analysis task beginning with the input of raw data to the generation of the stability plots. An interactive version of LCAP2 is also available.

The LCAP2 report is organized in three volumes: batch user's guide (I), interactive user's guide (II), and source code description (III).

PREFACE

This is the first formal issue of the user's guide for Interactive LCAP2. Numerous examples describing the more common LCAP2 operators are presented.

The author would like to acknowledge the following individuals for their support in the development of this program: Floyd Fernandez for (1) the initial formulation of the tree structure utilized for segmentation of this program and (2) the development of the prompting routines for loading polynomial and transfer function data; Cindy Wong for (1) the development of routines associated with the restart capability and (2) the initial development of procedures used to automate handling of data and plot files; and Diane Troth for development of the preprocessor which will be used later when the advanced user mode described in Appendix B is implemented.

A-1

CONTENTS

1.0 INTRODUCTION

Interactive LCAP2 (Linear Controls Analysis Program) is a CDC INTERCOM program which provides the control analyst with the capability to numerically perform classical linear control analysis techniques such as transfer function manipulation, transfer function evaluation, frequency response, root locus, inverse time response and sampled-data transforms. It is able to deal with continuous and sampled-data systems, including multiloop multirate digital systems, using s, z and w transforms. This program is an interactive version of the batch LCAP2 program, Ref. 1. Development of this interactive program was started in 1980 to provide a quick response capability for project support, proposal evaluation and design iteration. Most of the initial design objectives of this program have been completed and are documented herein. Effort will continue on the completion of the remaining design objectives and on the upgrading of the user interface. As new video and/or graphics terminals are made available for use as INTERCOM terminals, the user interface will be improved by incorporating new features of these terminals. This interactive program will eventually provide all of the desirable features of the batch version which are suitable for interactive use. The batch version will continue to be used for the analysis of large complex systems which cannot be efficiently modeled in the interactive version.

2.0 DESCRIPTION

This interactive program, like the batch version was designed to provide the control system analyst with most of the classical analysis tools needed for analyzing continuous and sampled-data systems by transform techniques. A set of transfer function and polynomial operators has been defined in a fashion similar to the instruction set of a computer. Transfer function and polynomial arrays are defined to be referenced with indices so that they may be easily addressed by the operators. The combination of this set of LCAP2 operators and the form of the data structure provides a very flexible and easy to use program.

The data structure of the program includes (1) s, z and w plane transfer functions designated as SPTFi, i=1,2..., ZPTFi, i=1,2..., WPTFi i=1,2..., respectively, and (2) polynomials designated as POLYi ,i=1,2... Operations on these transfer functions or polynomials are specified by references to their indices. An arbitrarily large number of transfer functions and polynomials are available to the user since disk storage is utilized when the number becomes too large.

The transfer functions are represented as ratios of polynomials. The user can load data into a transfer function using either the coefficient or the root form representation. Data structure used for the transfer functions and polynomials require that the order of the polynomials be less than fifty.

In the batch version each of the LCAP2 operators is implemented as a FORTRAN subroutine with a minimal number of arguments used to specify the transfer functions or polynomials involved. For example, to add SPTF1 to SPTF2 and store the results into SPTF3, the FORTRAN statement is CALL SPADD(3,1,2). If this example were to be done interactively and if as much commonality between the batch and interactive versions were to be maintained, the user response to the prompt for an operation would be SPADD(3,1,2). At the present, interactive LCAP2 does not have the capability to allow the user to specify the arguments on the same line. Instead, the program will prompt the user for all the arguments and parameters required for implementing the operation. For the experienced user this prompting may yield more output than desired. Appendix B describes a proposed advanced user mode which will reduce the amount of output. This description is included in this report so that users can see what the new advanced user mode will be, and more importantly, to solicit from the users other ideas to improve the user interface.

This program was developed with the intent of not requiring the use of a user's manual. Although this is possible with the liberal amount of prompts incorporated into this program, the approach herein to provide numerous examples is a more effective method for describing the utility of this program.

3.0 LANGUAGE AND HOST COMPUTER

The program is written entirely in CDC FORTRAN EXTENDED 4 with the exception of one subroutine which is written in COMPASS assembly language. This interactive version of LCAP2 runs on the CDC 835 computer under the INTERCOM Version 5.0 system and the NOS 1 operating system. Description of the code for this program is given in Ref. 2.

Since the total length of the compiled subroutines of LCAP2 is much larger than the 120K octal words available to the user on the CDC 835, segment loading is utilized. This loader will dynamically load the the appropriate routines into memory as they are needed. Use of this loader requires the formulation of a tree structure which will enable the program to load within the available memory.

4.0 LOGON PROCEDURE

After logging in on a CDC INTERCOM terminal, before attaching and loading the LCAP2 program, the user should change the default SCREEN value from 76 columns to either 80 or 132 columns. For normal usage, select the 80 column format by typing the command

```
screen,80
```

Selection of the 132 column format, assuming that the terminal in use can support this larger width, will allow LCAP2 to optionally produce a higher resolution printer plots utilizing this wider format.

The next two commands for the logon procedure for interactive LCAP2 are

```
attach(lcap2,8intlcap2,id=9487)
lcap2.
```

The program will then respond by asking the user

```
WOULD YOU LIKE TO RETRIEVE DATA FROM A PREVIOUS SESSION?
TYPE (Y OR N):
```

This option allows the user to restore data saved from a previous interactive LCAP2 session or LCAP2 batch job. If the user types n the program will respond with

```
WELCOME TO INTERACTIVE LCAP2
```

This finishes the logon procedure for interactive LCAP2.

If the user had typed y instead in response to the prompt, the program would have responded with

```
HAVE YOU ATTACHED THE PERMANENT FILE CONTAINING YOUR DATA?
TYPE (Y OR N):
```

If the user then types n, the program will respond with

```
GO ATTACH THE PERMANENT FILE USING TAPE30 AS THE LOCAL
FILE NAME, THEN START OVER BY TYPING LCAP2.
```

The user should then type in the following

```
attach(tape30,lfn,id=.....)
lcap2.
```

where lfn is the name of the file cataloged from a previous interactive session or batch job.

The above logon procedure checks to see if the user has attached TAPE30 before continuing with LCAP2. If the user has not attached this file yet, the program exits to the INTERCOM COMMAND mode to allow the user to attach the file. A more straight forward method for logging on when old data is to be retrieved first is

```
attach(tape30,lfn,id=.....)
attach(lcap2,8intlcap2,id=9487)
lcap2.
```

5.0 SELECTION OF 80 OR 132 COLUMN FORMAT FOR PRINTER PLOT

After completion of the logon procedure the program will prompt the user with

```
PRINTER PLOTS WILL BE FORMATTED FOR 80 COLUMNS.
DO YOU WANT TO CHANGE IT TO 132 COLUMNS? (Y OR N):
```

For normal usage, respond by typing n. If the 132 column format were selected instead, the INTERCOM SCREEN command should also have been set to 132 columns before loading the LCAP2 program. If not, portions of the right side of the plots would wrap around onto new continuation lines.

After selecting the format for the printer plots, the program will prompt the user with

```
ENTER OPERATION (TYPE H IF HELP NEEDED):
```

6.0 LOGOFF PROCEDURE

Interactive LCAP2 can be terminated by the LCAP2 operator END. If the user did not used the LCAP2 operator STORE nor requested that a hardcopy plot be generated, the program will exit to the INTERCOM COMMAND mode.

If the LCAP2 operator STORE was used, before the LCAP2 interactive session is completed, the program will automatically catalog the LCAP2 data file for you. It will prompt you for a 7 character name to be used to identify the file. Be sure that the first character is an alphabet and that there are no imbedded blanks. As a reminder, the program will also printout the INTERCOM command to be used to attach this data file when logging on at a later time.

If hardcopy plots are requested, interactive LCAP2 would have written hardcopy files to file PLOT. Since the HARDCPY program, which processes the PLOT file, resides on the CDC 176, the file PLOT must first be cataloged on the host computer for INTERCOM and then a separate batch job sent to the CDC 176 to execute the HARDCPY program. These two operations are all performed automatically by the interactive LCAP2 program. The program will prompt the user for a 7 character name to be used to identify the plot file. Also, the user will be prompted to designate where the plots and the dayfile are to be returned.

7.0 LIST OF LCAP2 OPERATORS

The following is a list of the LCAP2 operators grouped by type of operations. A brief description of each operation is included. A more detailed description of each operator is included in Appendix A.

POLYNOMIAL OPERATORS

PADD - Polynomial Add
PCNGC - Change Coefficients Of Polynomial
PCNGR - Change Roots of Polynomial
PEQU - Polynomial Equal
PLDC - Polynomial Load, Coefficient Form
PLDR - Polynomial Load, Root Form
PMPY - Polynomial Multiply
PPRN - Polynomial Print
PRTS - Find Roots Of Polynomial
PSUB - Polynomial Subtract

S-PLANE OPERATORS

CPYPS - Copy Polynomials Into S-Plane Transfer Function
CPYSP - Copy S-Plane Transfer Function Into Polynomials
SELCR - Eliminate Common Roots From S-Plane Transfer Function
SFREQ - S-Plane Frequency Response
SLOCI - S-Plane Root Locus
SNORM - Normalize S-Plane Transfer Function
SPADD - S-Plane Transfer Function Add
SPCNGC - Change Coefficients of S-Plane Transfer Function
SPCNGR - Change Roots of S-Plane Transfer Function
SPDIV - S-Plane Transfer Function Divide
SPEQU - S-Plane Transfer Function Equal
SPLDC - S-Plane Transfer Function Load, Coefficient Form
SPLDR - S-Plane Transfer Function Load, Root Form
SPMPY - S-Plane Transfer Function Multiply
SPPRN - S-Plane Transfer Function Print
SPRTS - Find Roots Of S-Plane Transfer Function
SPSUB - S-Plane Transfer Function Subtract
STIME - Inverse Laplace Transform and Time Response
SWMRX - S-to-W Plane Multirate Transform (slow-to-fast sampler)
SWXFM - S-to-W Plane Transform
SZMRX - S-to-Z Plane Multirate Transform (slow-to-fast sampler)
SZXFM - S-to-Z Plane Transform

Z-PLANE OPERATORS

CPYPZ - Copy Polynomials Into Z-Plane Transfer Function
CPYZP - Copy Z-Plane Transfer Function Into Polynomials
ZELCR - Eliminate Common Roots From Z-Plane Transfer Function
ZFREQ - Z-Plane Frequency Response
ZLOCI - Z-Plane Root Locus
ZNORM - Normalize Z-Plane Transfer Function
ZMRFQ - Z-Plane Multirate Frequency Response

ZMRXFM - Z-Plane Multirate Transform By Frequency Decomposition (fast-to-slow sampler)
ZPADD - Z-Plane Transfer Function Add
ZPCNGC - Change Coefficients Of Z-Plane Transfer Function
ZPCNGR - Change Roots Of Z-Plane Transfer Function
ZPDIV - Z-Plane Transfer Function Divide
ZPEQU - Z-Plane Transfer Function Equal
ZPLDC - Z-Plane Transfer Function Load, Coefficient Form
ZPLDR - Z-Plane Transfer Function Load, Root Form
ZPMPY - Z-Plane Transfer Function Multiply
ZPPRN - Z-Plane Transfer Function Print
ZPRTS - Find Roots Of Z-Plane Transfer Function
ZPSUB - Z-Plane Transfer Function Subtract
ZSXFM - Z-to-S Root Transformation
ZTIME - Inverse Z-Transform and Time Response
ZVCNG - Z-to-ZN Transform
ZWXFM - Z-to-W Plane Transform

W-PLANE OPERATORS

CPYPW - Copy Polynomials Into W-Plane Transfer Function
CPYWP - Copy W-Plane Transfer Function Into Polynomials
WELCR - Eliminate Common Roots From W-Plane Transfer Function
WFREQ - W-Plane Frequency Response
WLOCI - W-Plane Root Locus
WMRFQ - W-Plane Multirate Frequency Response
WMRXFM - W-Plane Multirate Transform By Frequency Decomposition (fast-to-slow sampler)
WNORM - Normalize W-Plane Transfer Function
WPADD - W-Plane Transfer Function Add
WPCNGC - Change Coefficients Of W-Plane Transfer Function
WPCNGR - Change Roots Of W-Plane Transfer Function
WPDIV - W-Plane Transfer Function Divide
WPEQU - W-Plane Transfer Function Equal
WPLDC - W-Plane Transfer Function Load, Coefficient Form
WPLDR - W-Plane Transfer Function Load, Root Form
WPMPY - W-Plane Transfer Function Multiply
WPPRN - W-Plane Transfer Function Print
WPRTS - Find Roots Of W-Plane Transfer Function
WPSUB - W-Plane Transfer Function Subtract
WSXFM - W-to-S Root Transformation
WZXFM - W-to-Z Plane Transform

MISCELLANEOUS OPERATORS

END - Terminates Prompting Of LCAP2 Operators
DTERM - Determinant Of Matrix M(s) With Substitution Of Vector B For Use In Transfer Function Evaluation Via Cramer's Method

DETRM - Old Version Of Operator DTERM
(No Substitution Of B Vector)
STORE - Store Data From Current Interactive Session
RESTORE - Restore Data From Old Interactive Session Or Batch Job

8.0 EXAMPLES

Examples are presented to demonstrate the utility of typical LCAP2 operators. Examples 1 through 14 were prepared to be executed sequentially to demonstrate a typical interactive session. These examples include the demonstration of the logon and logoff procedures, the hardcopy plotting procedures and the STORE operator used to save transfer function, polynomial and matrix data for a restart capability. Example 15 demonstrates the RESTORE operator which restores data stored from a previous interactive session. Examples 16 and 17 demonstrates operators used to change coefficients and roots of transfer functions previously loaded or computed.

Each of the examples begins with a statement of the problem and is followed by a terminal dialog which includes program output and user input. To differentiate between program output and user input, program output is in upper case and user input is in lower case. User input is always preceded by a prompt. The prompt is always terminated by a colon,:, as in the following example

IS THIS TRANSFER FUNCTION NEW OR OLD (Y OR N):

The user is prompted for assignment of polynomial and transfer function indices or identifiers. In Examples 2 through 13 the assignment is arbitrarily made in sequential order.

As described earlier, the generation of hardcopy plots is not completely automated. In Examples 2,6,7,8,10 and 11 which have requests for both printer and hardcopy plots, only the printer plots are shown. The hardcopy plot files generated by these examples are cataloged in Example 14 as part of the logoff procedure. A separate batch job is then sent automatically to the CDC 176 which then processes the hardcopy plots. The hardcopy plots from these examples are presented in Appendix D.

The examples presented are essentially the same as those in Section 8 of the Batch LCAP2 User's Guide, Ref. 1, so that differences in usage between both versions of LCAP2 can be compared. It should be noted that Interactive LCAP2 accepts only numeric and simple alphanumeric data while Batch LCAP2 can include FORTRAN expressions as part of the data entry, although the examples in Ref. 1 did not use them.

EXAMPLE 1 TYPICAL LOGON PROCEDURE

Problem: Logon so that Examples 2 through 12 can be executed sequentially in a single interactive session after this example. The 80 column format for printer plots will be used.

After logging on the CDC INTERCOM, the terminal dialog[1] is:

```
screen,80
attach(lcap2,8intlcap2,id=9487)
lcap2.

WOULD YOU LIKE TO RETRIEVE DATA FROM A PREVIOUS SESSION?
TYPE (Y OR N):n

WELCOME TO INTERACTIVE LCAP2

PRINTER PLOTS WILL BE FORMATTED FOR 80 COLUMNS.
DO YOU WANT TO CHANGE IT TO 132 COLUMNS? (Y OR N):n
```

The next prompt will ask the user for an LCAP2 operator. This prompt appears in the terminal dialog of the next example.

[1] To differentiate between program output and user input, program output is in upper case and user input is in lower case.

EXAMPLE 2 S-PLANE FREQUENCY RESPONSE

Problem: Compute frequency response of

$$\frac{25}{s^2 + 5s + 25}$$

between .10 to 100. rad/sec.

User will load transfer function data in coefficient form. Program will automatically assign this data into s-plane transfer function SPTF1.

The terminal dialog for this example is:

```
ENTER OPERATION (TYPE H IF HELP NEEDED):sfreq
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER THE DEGREE OF THE NUMERATOR:0
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER:25
ENTER THE DEGREE OF THE DENOMINATOR:2
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:25 5 1
THE DEGREE OF THE NUMERATOR IS 0
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
25.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS 2
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
25. 5. 1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTIONS IS TO BE STORED:1

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION 1

---> SFREQ - FREQUENCY RESPONSE OF S-PLANE TRANSFER
            FUNCTION 1

IS THE FREQUENCY IN RAD/SEC OR HZ? (R OR H):r
DO YOU WANT TRANSPORT DELAY INCLUDED IN THE RESPONSE? (Y OR N):n
DO YOU WANT COMPUTER TO AUTOMATICALLY DETERMINE FREQUENCY VALUES
TO BE USED IN EVALUATING THE FREQUENCY RESPONSE ? (Y OR N):y
```

WILL ASK YOU FOR SPECIFIC FREQUENCY VALUES TO BE USED IN EVALUATING FREQUENCY RESPONSE. COMPUTER WILL THEN AUTOMATICALLY CHOOSE ADDITIONAL FREQUENCY VALUES TO PROVIDE DETAILED RESPONSE.

INPUT NUMBER OF SPECIFIC FREQUENCY VALUES YOU INTEND TO ENTER.
(ENTER A VALUE BETWEEN 2-20, IF NOT SURE, TRY 2):2
ENTER 2 FREQUENCY VALUES IN ASCENDING ORDER:.1 100
DO YOU WANT TO SUPPRESS TABULAR OUTPUT OF THE RESPONSE? (Y OR N):n

OMEGA RAD/SEC	REAL	IMAGINARY	DB	PHASE	PHASE MARGIN
.1000	.100E+01	-.200E-01	.002	-1.15	178.85
.1200	.100E+01	-.240E-01	.003	-1.38	178.62
.1400	.100E+01	-.288E-01	.004	-1.65	178.35
.1728	.100E+01	-.346E-01	.005	-1.98	178.02
.2074	.100E+01	-.415E-01	.007	-2.38	178.62
.2488	.100E+01	-.499E-01	.011	-2.86	177.14
.2986	.100E+01	-.599E-01	.015	-3.43	176.57
.3583	.100E+01	-.720E-01	.022	-4.12	175.88
.4300	.100E+01	-.866E-01	.032	-4.95	175.05
.5160	.100E+01	-.104E+00	.046	-5.95	174.05
.6192	.100E+01	-.126E+00	.066	-7.17	172.83
.7430	.100E+01	-.152E+00	.095	-8.64	171.36
.8916	.999E+00	-.184E+00	.136	-10.44	169.56
1.070	.998E+00	-.224E+00	.194	-12.64	167.36
1.284	.995E+00	-.274E+00	.276	-15.37	164.63
2.084	.965E+00	-.487E+00	.673	-26.77	153.23
2.724	.889E+00	-.688E+00	1.017	-37.77	142.23
3.364	.728E+00	-.894E+00	1.236	-50.87	129.13
3.844	.539E+00	-.101E+01	1.202	-61.99	118.01
4.324	.311E+00	-.107E+01	.907	-73.74	106.26
4.804	.828E-01	-.103E+01	.320	-85.42	94.58
5.000	.225E-04	-.100E+01	.000	-90.00	90.00
5.480	-.162E+00	-.883E+00	-.940	-100.40	79.60
6.120	-.285E+00	-.701E+00	-2.421	-112.15	67.85
6.920	-.332E+00	-.503E+00	-4.399	-123.48	56.52
7.880	-.317E+00	-.336E+00	-6.707	-133.27	46.73
8.840	-.273E+00	-.231E+00	-8.834	-140.25	39.75
10.12	-.226E+00	-.148E+00	-11.362	-146.83	33.17
11.40	-.184E+00	-.999E-01	-13.584	-151.50	28.57
13.00	-.144E+00	-.651E-01	-16.014	-155.71	24.29
14.92	-.111E-00	-.418E-01	-18.536	-159.32	20.68
16.84	-.874E-01	-.285E-01	-20.731	-161.96	18.04
19.40	-.661E-01	-.183E-01	-23.275	-164.57	15.43
21.96	-.517E-01	-.124E-01	-25.488	-166.50	13.50
25.16	-.394E-01	-.816E-02	-27.902	-168.31	11.69
29.00	-.297E-01	-.528E-02	-30.410	-169.92	10.08
32.84	-.232E-01	-.361E-02	-32.598	-171.14	8.86
37.96	-.173E-01	-.232E-02	-35.140	-172.37	7.63

43.08	-.135E-01	-.158E-02	-37.354	-173.29	6.71
49.48	-.102E-01	-.104E-02	-39.774	-174.17	5.83
57.16	-.765E-02	-.674E-02	-42.292	-174.96	5.04
64.84	-.595E-02	-.461E-03	-44.489	-175.56	4.44
75.08	-.443E-02	-.297E-03	-47.043	-176.17	3.83
85.32	-.343E-02	-.202E-03	-49.268	-176.63	3.37
98.12	-.260E-02	-.133E-03	-51.700	-177.08	2.92
100.0	-.250E-02	-.125E-03	-52.030	-177.13	2.87

```
DO YOU WANT A NICHOLS PLOT? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N; IF NO, PREVIOUS TITLE USED):y
TYPE IN TITLE TO APPEAR ON PLOT (.LE.70 CHARACTERS) AND RETURN:
example 1 s-plane frequency response
THE TITLE ENTERED IS:
EXAMPLE 1 S-PLANE FREQUENCY RESPONSE
IS THE TITLE CORRECT? (Y OR N):y
DO YOU WANT AUTOMATIC SCALING FOR THE MAGNITUDE RESPONSE? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y
```

```
   NICHOLS PLOT (MAGN. VS PHASE)                                   10/31/83
   EXAMPLE 2 S-PLANE FREQUENCY RESPONSE

   6.00                                                                 I
   3.00                                                                 I
   0.       -------------------------------------------XXXXXXXXXXXXXXXXXX
  -3.00                                            XXXX                 I
  -6.00                                          XXX                    I
  -9.00                                         XX                      I
  -12.0                                        XX                       I
  -15.0                                       XX                        I
  -18.0                                      XX                         I
  -21.0                                      X                          I
  -24.0                                     XX                          I
  -27.0                                     X                           I
  -30.0                                     X                           I
  -33.0                                    XX                           I
  -36.0                                    X                            I
  -39.0                                    X                            I
  -42.0                                    X                            I
  -45.0                                    X                            I
  -48.0                                    X                            I
  -51.0                                   XX                            I
  -54.0                                                                 I
            I     I     I     I     I     I     I     I     I     I     I
        -360.000    -288.000    -216.000    -144.000     -72.000       0.000
```

```
WOULD YOU LIKE TO CHANGE FREQUENCY RANGE AND RECOMPUTE RESPONSE? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N): y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
DO YOU WANT A BODE PLOT? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N; IF NO, PREVIOUS TITLE USED):n
DO YOU WANT AUTOMATIC SCALING FOR THE MAGNITUDE RESPONSE? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y


   BODE PLOT (MAGN. VS FREQ.)                                        10/31/83
   EXAMPLE 2 S-PLANE FREQUENCY RESPONSE

   6.00     I
   3.00     I
   0.       XX-XX-XX-XXX-XX-XX-XXXXXXXXXXXXX--------------------------
  -3.00     I                               XX
  -6.00     I                                XX
  -9.00     I                                  XX
  -12.0     I                                   XX
  -15.0     I                                    XX
  -18.0     I                                     XX
  -21.0     I                                       XX
  -24.0     I                                        XX
  -27.0     I                                         XX
  -30.0     I                                           XX
  -33.0     I                                            XX
  -36.0     I                                             XX
  -39.0     I                                               X
  -42.0     I                                                XX
  -45.0     I                                                 XX
  -48.0     I                                                   XX
  -51.0     I                                                    XX
  -54.0     I
            I     I     I     I     I     I     I     I     I     I     I
          .100E+00         1.00              10.0              100.
```

BODE PLOT (PHASE VS FREQ.)   10/31/83
EXAMPLE 2 S-PLANE FREQUENCY RESPONSE

```
 20.0     I
0.        I
-20.0     XX-XX-XX-XXX-XX-X-------------------------------------------
-40.0     I                X XXXXXX
-60.0     I                        XXX
-80.0     I                          XXX
-100.     I                            XXX
-120.     I                              XX
-140.     I                               XX
-160.     I                                 XXXX
-180.     I                                    XXXXXXXX
-200.     I                                            XXXXXXXXXX
-220.     I
-240.     I
-260.     I
-280.     I
-300.     I
-320.     I
-340.     I
-360.     I
-380.     I
          I     I     I     I     I     I     I     I     I     I     I
        .100E+00          1.00              10.0              100.
```

WOULD YOU LIKE TO CHANGE FREQUENCY RANGE AND RECOMPUTE RESPONSE? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N):y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
DO YOU WANT A NYQUIST PLOT? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N; IF NO, PREVIOUS TITLE USED):n
DO YOU WANT AUTOMATIC SCALING FOR THE MAGNITUDE RESPONSE? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y

```
   NYQUIST PLOT                                                    10/31/83
   EXAMPLE 2 S-PLANE FREQUENCY RESPONSE

   2.00                                   I
   1.80                                   I
   1.60                                   I
   1.40                                   I
   1.20                                   I
   1.00                                   I
   .800                                   I
   .600                                   I
   .400                                   I
   .200                                   I
  0.        --------------------------XXXXX-----------------------X-----
  -.200                            XXX    I                       X
  -.400                           X       I                      XX
  -.600                           XX      I                    XXX
  -.800                            XXXX   I                X XXX
  -1.00                                X XX X X XX X X X XX
  -1.20                                   I
  -1.40                                   I
  -1.60                                   I
  -1.80                                   I
  -2.00                                   I
            I     I     I     I     I     I     I     I     I     I     I
         -1.25 -1.00  -.75  -.50  -.25   .00   .25   .50   .75  1.00  1.25

WOULD YOU LIKE TO CHANGE FREQUENCY RANGE AND RECOMPUTE RESPONSE? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N):y
DO YOU WANT A HARDCOPY PLOT TO BE IN DB SCALES? (Y OR N):y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
------------------------------------------------------------------------------
```

EXAMPLE 3 ROOTS OF A POLYNOMIAL

Problem: Compute the roots of the polynomial

$$x^3 + 13x^2 + 38x^1 + 34$$

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:prts
IS THIS POLYNOMIAL NEW OR OLD? (N OR O):n
ENTER THE DEGREE OF POLYNOMIAL:3
ENTER POLYNOMIAL COEFFICIENTS IN ASCENDING ORDER:34 38 13 1
THE DEGREE OF THE POLYNOMIAL IS   3
POLYNOMIAL COEFFICIENTS IN ASCENDING ORDER ARE
34. 38. 13. 1
IS THE POLYNOMIAL DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE POLYNOMIAL IS TO BE STORED:1

---> DATA IS LOADED INTO POLYNOMIAL  1

DEGREE OF POLY1  IS  3          (COEFFICIENTS IN ASCENDING ORDER)
34. 38. 13. 1.

--->  PRTS - FIND ROOTS OF POLY1

                               THE ROOTS OF ROOT1  ARE

NO.        REAL            IMAG.             OMEGA            ZETA

 1      -1.8445105      -.49938380       1.9109168        .96524896
 2      -1.8445105       .49938380       1.9109168        .96524896
 3      -9.3109790      0.

DEGREE OF POLY1  IS  3          (COEFFICIENTS IN ASCENDING ORDER)
34. 38. 13. 1.
```

EXAMPLE 4 MULTIPLY TWO S-PLANE TRANSFER FUNCTIONS

Problem: Multiply the following two s-plane transfer functions

$$\frac{25}{s^2 + 5s + 25} \quad \text{and} \quad \frac{30\left(\frac{s}{10} + 1\right)}{70(s)\left(\frac{s}{7} + 1\right)\left(\frac{s}{1 + j2} + 1\right)\left(\frac{s}{1 - j2} + 1\right)}$$

The first transfer function is the same as SPTF1 from Example 2. The second transfer function is given in root form. When transfer function data is expressed in root form, gains associated with the numerator and denominator must be specified to uniquely define the transfer function. The gains used by LCAP2 correspond to the low order non-zero coefficient of the numerator and denominator polynomials if the root form were expanded out. For this example, these two gains would be 30 and 70. (A distinction is made for the low order non-zero coefficient since the low order coefficient can be zero as is that of the denominator in this example.)

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:spmpy
IS THE FIRST TRANSFER FUNCTION NEW OR OLD (N OR O):o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:1
IS THE SECOND TRANSFER FUNCTION NEW OR OLD? (N OR O): n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):r

TO SIMPLIFY ENTRY OF COMPLEX ROOTS ONLY DATA FOR ONE HALF OF
A COMPLEX PAIR ARE TO BE ENTERED. LCAP2 WILL ENTER ITS
CONJUGATE AUTOMATICALLY. WHEN PROMPTED FOR NUMBER OF ROOT
VALUES TO BE ENTERED, EACH COMPLEX ROOT PAIR IS COUNTED AS
ONE ROOT VALUE. WOULD YOU LIKE AN EXAMPLE? (Y OR N):y

IF THE ROOTS (0.,0.) (-1.,0.) (-2.,3.) (-2.,-3.) ARE TO
ENTERED, THE NUMBER OF ROOT VALUES TO BE ENTERED IS 3. WHEN
PROMPTED FOR THE 3 ROOT VALUES, ENTER (0.,0.) (-1.,0.) (-2.,3.).
IF ROOT VALUES CANNOT ALL BE ENTERED ON THE SAME LINE, ENTER
WHATEVER YOU CAN, TYPE RETURN AND CONTINUE ON THE NEXT LINE.

IN ADDITION TO SPECIFYING THE ROOTS OF A POLYNOMIAL, A GAIN
MUST BE SPECIFIED TO COMPLETELY CHARACTERIZE THE POLYNOMIAL.
THE VALUE UTILIZED TO SPECIFY THIS GAIN IS THE LOW ORDER NON-
ZERO COEFFICIENT OF THE POLYNOMIAL.
```

```
INPUT NUMBER OF ROOT VALUES YOU INTEND TO ENTER FOR THE
NUMERATOR (REMEMBER THAT EACH COMPLEX PAIR IS CONSIDERED
AS ONE ROOT VALUE):1
ENTER   1 ROOT VALUES USING THE FORMAT (A,B) (C,D) ETC:(-10.,0.)
ENTER LOW ORDER NON-ZERO COEFFICIENT FOR THE NUMERATOR:30
INPUT NUMBER OF ROOT VALUES YOU INTEND TO ENTER FOR THE
DENOMINATOR (REMEMBER THAT EACH COMPLEX PAIR IS CONSIDERED
AS ONE ROOT VALUE):3
ENTER  3 ROOT VALUES USING THE FORMAT (A,B) (C,D) ETC:(0,0) (-7.,0.)
(-1.,2.)
ENTER LOW ORDER NON-ZERO COEFFICIENT FOR THE DENOMINATOR:70
THE NUMERATOR ROOT VALUES ENTERED ARE

   ROOT ID.             ROOT VALUES
      1        -10.000000       0.

LOW ORDER COEFFICIENT OF THE NUMERATOR IS    30.000000
IS THE DATA CORRECT? (Y OR N):y
THE DENOMINATOR ROOT VALUES ENTERED ARE

   ROOT ID.             ROOT VALUES
      1        0.               0.
      2        -7.0000000       0.
      3        -1.0000000         2.0000000

LOW ORDER COEFFICIENT OF THE DENOMINATOR IS    70.000000
IS THE DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO STORED:2

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION  2

ENTER NUMBER WHERE OUTPUT FROM SPMPY IS TO BE STORED:3

--->    SPTF3  =     SPTF1      *    SPTF2

DEGREE OF NUMERATOR OF SPTF3  IS  1    (COEFFICIENTS IN ASCENDING ORDER)
750. 75.

DEGREE OF DENOMINATOR OF SPTF3  IS  6  (COEFFICIENTS IN ASCENDING ORDER)
0. 1750. 1300. 710. 178. 28. 2.

BODE GAIN =    .42857143
-------------------------------------------------------------------------------
```

Note that if the second transfer function were expressed in a different form, the numerator and denominator non-zero coefficients would not necessarily appear explicitly. For example, if the root locus representation were used, i.e.,

$$\frac{3(s + 10)}{2(s + 7)(s + 1 + j2)(s + 1 - j2)}$$

then:

numerator low order non-zero coefficient = (3)(10) = 30
denominator low order non-zero coefficient = (2)(7)(1+j2)(1-j2) = 70

EXAMPLE 5 CLOSED LOOP S-PLANE TRANSFER FUNCTION

Problem: Given open loop transfer function G(s) and feedback transfer H(s) where

$$G(s) = \frac{15}{s^3 + 6s^2 + 5s}$$

$$H(s) = \frac{s + 1.5}{s + 15}$$

compute the closed loop transfer function F(s) where

$$F(s) = \frac{G(s)}{1 + G(s)H(s)}$$

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:spmpy
IS THE FIRST TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER THE DEGREE OF THE NUMERATOR:0
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER:15
ENTER THE DEGREE OF THE DENOMINATOR:3
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:0 5 6 1
THE DEGREE OF THE NUMERATOR IS 0
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
15.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS 3
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
0. 5. 6. 1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:4

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION  4

IS THE SECOND TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER THE DEGREE OF THE NUMERATOR:1
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER: 1.5 1
ENTER THE DEGREE OF THE DENOMINATOR:1
```

```
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:15 1
THE DEGREE OF THE NUMERATOR IS 1
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
1.5 1.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS 1
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
15. 1
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:5

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION 5

ENTER NUMBER WHERE OUTPUT FROM SPMPY IS TO STORED:6

--->   SPTF6  =     SPTF4      *    SPTF5

DEGREE OF NUMERATOR OF SPTF6  IS  1    (COEFFICIENTS IN ASCENDING ORDER
22.5 15.
DEGREE OF DENOMINATOR OF SPTF6  IS  4  (COEFFICIENTS IN ASCENDING ORDER
0. 75. 95. 21. 1.

BODE GAIN =    .30000000

----------------------------------------------------------------------

ENTER NEXT OPERATION:spadd
IS THE FIRST TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER THE DEGREE OF THE NUMERATOR:0
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER: 1
ENTER THE DEGREE OF THE DENOMINATOR:0
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:1
THE DEGREE OF THE NUMERATOR IS 0
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
1.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS 0
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:7

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION  7

IS THE SECOND TRANSFER FUNCTION NEW OR OLD? (N OR O):o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:6

ENTER NUMBER WHERE OUTPUT FROM SPADD IS TO STORED:8
```

```
--->    SPTF8  =     SPTF7      +    SPTF6

DEGREE OF NUMERATOR SPTF8  IS  4       (COEFFICIENTS IN ASCENDING ORDER)
22.5 90. 95. 21. 1.

DEGREE OF DENOMINATOR SPTF8  IS  4     (COEFFICIENTS IN ASCENDING ORDER)
0. 75. 95. 21. 1.

BODE GAIN =        .30000000

------------------------------------------------------------------------------

ENTER NEXT OPERATION:spdiv
IS THE FIRST TRANSFER FUNCTION NEW OR OLD (N OR O):o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:4
IS THE SECOND TRANSFER FUNCTION NEW OR OLD? (N OR O): o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:8

ENTER NUMBER WHERE OUTPUT FROM SPDIV IS TO BE STORED:9

--->    SPTF9  =     SPTF4      /    SPTF8

DEGREE OF NUMERATOR OF SPTF9  IS  4    (COEFFICIENTS IN ASCENDING ORDER)
0. 1125. 1425. 315. 15.

DEGREE OF DENOMINATOR OF SPTF9  IS  7  (COEFFICIENTS IN ASCENDING ORDER)
0. 112.5 585. 1037.5 765. 226. 27. 1.

BODE GAIN =    10.000000

------------------------------------------------------------------------------

ENTER NEXT OPERATION:selcr
IS THE TRANSFER FUNCTION NEW OR OLD? (N OR O):o
ENTER NUMBER OF TRANSFER FUNCTION:9

--->   SELCR - ELIMINATE COMMON ROOTS OF S-PLANE
               TRANSFER FUNCTION 9

                      THE COMMON ROOTS ELIMINATED ARE

NO.        REAL             IMAG.              OMEGA             ZETA

 1      -1.0000000       0.
 2      -5.0000000       0.
 3      0.               0.

--->    SPTF9  =PSYNTH(SROOT9 )
```

THE NUMERATOR ROOTS OF SROOT9 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-15.0000000	0.		

LOW ORDER NON ZERO COEFFICIENT = 1125.0000

THE DENOMINATOR ROOTS OF SROOT9 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-.75554143	0.		
2	-.41685761	0.		
3	-4.7326564	0.		
4	-15.09494	0.		

LOW ORDER NON ZERO COEFFICIENT = 112.50000

DEGREE OF NUMERATOR OF SPTF9 IS (COEFFICIENTS IN ASCENDING ORDER)
1125. 75.

DEGREE OF DENOMINATOR OF SPTF9 IS (COEFFICIENTS IN ASCENDING ORDER)
112.5 450. 475. 105. 5.

BODE GAIN = 10.000000

EXAMPLE 6 S-PLANE ROOT LOCUS

Problem: Compute the root locus for the following transfer function

$$\frac{1.8\left(\frac{s}{1}+1\right)}{s\left(\frac{s}{2}+1\right)\left(\frac{s}{3}+1\right)\left(\frac{s}{5-j1}+1\right)\left(\frac{s}{5+j1}+1\right)}$$

by varying the nominal gain from .125 to 2.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:sloci
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):r

GENERAL DESCRIPTION ON INPUT OF COMPLEX ROOTS WAS PRESENTED
EARLIER. DO YOU WANT IT REPEATED AGAIN? (Y OR N):n

INPUT NUMBER OF ROOT VALUES YOU INTEND TO ENTER FOR THE
NUMERATOR (REMEMBER THAT EACH COMPLEX PAIR IS CONSIDERED
AS ONE ROOT VALUE):1
ENTER  1 ROOT VALUE USING THE FORMAT (A,B) (D,E) ETC:(-1.0,0.)
ENTER LOW ORDER NON-ZERO COEFFICIENT FOR THE NUMERATOR:1.8
INPUT NUMBER OF ROOT VALUES YOU INTEND TO ENTER FOR THE
DENOMINATOR (REMEMBER THAT EACH COMPLEX PAIR IS CONSIDERED
AS ONE ROOT VALUE):4
ENTER  4 ROOT VALUES USING THE FORMAT (A,B) (D,E) ETC:(0,0) (-2.,0.)
(-3.,0.) (-5.,1.)
ENTER LOW ORDER NON-ZERO COEFFICIENT FOR THE DENOMINATOR:1
THE NUMERATOR ROOT VALUES ENTERED ARE

   ROOT ID.             ROOT VALUES
      1        -1.0000000       0.

LOW ORDER NON-ZERO COEFFICIENT OF THE NUMERATOR IS    1.8000000
IS THE DATA CORRECT? (Y OR N):y
THE DENOMINATOR ROOT VALUES ENTERED ARE

   ROOT ID.             ROOT VALUES
      1        0.               0.
      2        -2.0000000       0.
      3        -3.0000000       0.
      4        -5.0000000        1.0000000
```

```
LOW ORDER NON ZERO COEFFICIENT OF THE DENOMINATOR IS    1.0000000
IS THE DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:10

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION 10

--->  SLOCI - ROOT LOCUS OF S-PLANE TRANSFER
              FUNCTION 10

                           THE OPEN LOOP ZEROES ARE

NO.        REAL            IMAG.             OMEGA            ZETA

 1      -1.000000        0.

                           THE OPEN LOOP POLES ARE

NO.        REAL            IMAG.             OMEGA            ZETA

 1      -5.0000000      -1.0000000        5.0990195        .98058068
 2      -5.0000000       1.0000000        5.0990195        .98058068
 3      -2.0000000       0.
 4      -3.0000000       0.
 5      0.               0.

WILL ASK YOU FOR SPECIFIC GAIN VALUES TO BE USED TO COMPUTE ROOT LOCI.
FIRST VALUE WILL BE STARTING GAIN VALUE. THE LAST VALUE WILL BE
THE LAST GAIN VALUE. OPTION WILL FOLLOW WHICH WILL ALLOW COMPUTER
TO CHOOSE ADDITIONAL GAINS BETWEEN USER SUPPLIED GAIN VALUES.

INPUT NUMBER OF SPECIFIC GAIN VALUES YOU INTEND TO ENTER.
ENTER A VALUE BETWEEN 2-25, IF NOT SURE, TRY 2): 2
ENTER  2 GAIN VALUES IN ASCENDING ORDER:.125 2
CHOOSE ADDITIONAL GAINS BY (A) ADDING A CONSTANT TO PREVIOUS VALUE OR BY
(M) MULTIPLYING PREVIOUS VALUE BY A CONSTANT? (A OR M):m
ENTER THE VALUE OF THE CONSTANT TO BE USED:2
THE DATA JUST ENTERED WILL PRODUCE  5 ROOT LOCUS GAIN VALUES TO BE
USED. WOULD YOU LIKE TO HAVE THEM LISTED FIRST BEFORE PROCEEDING
FURTHER? (Y OR N):y
.125 .25 .5 1. 2.
ARE THESE THE GAIN VALUES YOU WANT? (Y OR N), IF N YOU MAY
REENTER DATA):y
DO YOU WANT TO SUPPRESS TABULAR PRINTOUT OF THE ROOTS? (Y OR N):n
```

CLOSED LOOP POLES FOR GAIN = .1250000 (GAIN NO. 1) ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-1.7947341	-1.1077310	2.1090611	.85096357
2	-1.7947341	1.1077310	2.1090611	.85096357
3	-5.5892217	1.6614254	5.8309290	.95854737
4	-5.5892217	-1.6614254	5.8309290	.95854737
5	-.23208832	0.		

CLOSED LOOP POLES FOR GAIN = .2500000 (GAIN NO. 2) ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-1.4171985	-1.4418858	2.0217532	.70097500
2	-1.4171985	1.4418858	2.0217532	.70097500
3	-5.8577544	1.9606112	6.1771582	.94829277
4	-5.8577544	-1.9606112	6.1771582	.94829277
5	-.45009415	0.		

CLOSED LOOP POLES FOR GAIN = .5000000 (GAIN NO. 3) ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-.94735061	-1.9000842	2.1231564	.44619915
2	-.94735061	1.9000842	2.1231564	.44619915
3	-6.1975818	-2.3343777	6.6226384	.93581763
4	-6.1975818	2.3343777	6.6226384	.93581763
5	-.71013518	0.		

CLOSED LOOP POLES FOR GAIN = 1.0000000 (GAIN NO. 4) ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-.44922549	-2.4680974	2.5086468	.17907084
2	-.44922549	2.4680974	2.5086468	.17907084
3	-6.6183282	-2.7904455	7.1825382	.92144699
4	-6.6183282	2.7904455	7.1825382	.92144699
5	-.86489263	0.		

```
CLOSED LOOP POLES FOR GAIN =   2.0000000      (GAIN NO.  5) ARE

NO.         REAL              IMAG.            OMEGA            ZETA

 1      .10025104       -3.1088677        3.1104837       -.32230049E-01
 2      .10025104        3.1088677        3.1104837       -.32230049E-01
 3    -7.1323100       -3.3395771        7.8754442        .90563907
 4    -7.1323100        3.3395771        7.8754442        .90563907
 5     -.93588209       0.

     ---------------------------------------------------------------

DO YOU WANT TO CHANGE ROOT LOCUS GAINS AND RECOMPUTE THE RESULTS? (Y OR N):n
DO YOU WANT A PLOT? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N; IF NO, PREVIOUS TITLE USED):y
TYPE IN TITLE TO APPEAR ON PLOT (.LE.70 CHARACTERS) AND RETURN:
example 6 s-plane root locus
THE TITLE ENTERED IS:
EXAMPLE 6 S-PLANE ROOT LOCUS
IS THE TITLE CORRECT (Y OR N):y
DO YOU WANT AUTOMATIC PLOT SCALING? (Y OR N):n
ENTER MIN AND MAX X-AXIS VALUES (ENTER 2 VALUES):-9 1
ENTER MIN AND MAX Y-AXIS VALUES (ENTER 2 VALUES):-1 9
MIN X-AXIS =    -9.0000        MAX X-AXIS =     1.0000
MIN Y-AXIS =    -1.0000        MAX Y-AXIS =     9.0000
IS THE DATA CORRECT? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y
```

ROOT LOCUS 10/31/83
EXAMPLE 6 S-PLANE ROOT LOCUS

```
 9.00                                                           I
 8.50                                                           I
 8.00                                                           I
 7.50                                                           I
 7.00                                                           I
 6.50                                                           I
 6.00                                                           I
 5.50                                                           I
 5.00                                                           I
 4.50                                                           I
 4.00                                                           I
 3.50                *                                          I
 3.00                   *                                       I*
 2.50                      *                                 *  I
 2.00                        *                            *     I
 1.50                         *                        *        I
 1.00                                                *          I
 .500                                                           I
0.        ------------------------------------------------****-*I------
-.500                                                           I
-1.00                                                           I
          I     I     I     I     I     I     I     I     I     I     I
       -9.00 -8.00 -7.00 -6.00 -5.00 -4.00 -3.00 -2.00 -1.00  0.00  1.00
```

DO YOU WANT TO CHANGE PLOT SCALES AND REPLOT? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N): y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT

EXAMPLE 7 INVERSE LAPLACE TRANSFORM AND TIME RESPONSE

Problem: Find the inverse Laplace transform and the step response of the following transfer function

$$\frac{432s + 4320}{s^4 + 35s^3 + 345s^2 + 1008s + 2160}$$

Plot the response in increments of .05 seconds from 0 to 5 seconds.

The inverse Laplace transform is computed by the partial fraction expansion method. The algorithm used to compute the partial fraction expansion requires that (1) there are no multiple poles other than those at the origin and (2) the degree of the numerator must not be greater than the number of non-zero poles of the denominator. Up to 5 poles at the origin are allowed.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:stime
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER THE DEGREE OF NUMERATOR:1
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER: 4320 432
ENTER THE DEGREE OF DENOMINATOR:4
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:2160 1008 345 35 1
THE DEGREE OF THE NUMERATOR IS  1
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
4320. 432.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS 4
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
2160. 1008. 345. 35. 1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:11

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION 11

--->  STIME - TIME RESPONSE OF S-PLANE TRANSFER
              FUNCTION 11

IS THIS AN IMPULSE OR A STEP RESPONSE? (I OR S):s
ENTER MAGNITUDE OF THE IMPULSE OR STEP:1.
ENTER BEGINNING PLOT TIME:0
ENTER FINAL PLOT TIME:5
ENTER DELTA PLOT TIME:.05
DO YOU WANT TO SUPPRESS TABULAR OUTPUT OF THE RESPONSE (Y OR N):n
```

NO.	ROOT		PARTIAL FRACTION COEFFICIENT	
1	-1.5000000	-2.5980762	-.99977959	-.69735056
2	-1.5000000	2.5980762	-.99977959	.69735056
3	-12.000000	0.	.76923077E-01	0.
4	-20.000000	0.	-.76923077E-01	0.
5	0.	0.	2.0000000	0.

ANALYTICAL SOLUTION IS THE SUMMATION OF THE FOLLOWING 4 TERMS

```
                                          (  2.0000    ) * T** 0
((-2.000    )*(cos( 2.60    *T))+(-1.395    )*(sin( 2.60    *T)))*E**(-1.500   *T)
                                 (  .76923E-01) * E**( -12.000     * T)
                                 ( -.77364E-01) * E**( -20.000     * T)
```

*** TIME RESPONSE ***

TIME	VALUE	TIME	VALUE	TIME	VALUE
0.	0.	1.7000	2.1497	3.4000	2.0054
.50000E-01	.66945E-02	1.7500	2.1235	3.4500	2.0066
.10000	.44037E-01	1.8000	2.0985	3.5000	2.0075
.15000	.10879	1.8500	2.0749	3.5500	2.0082
.20000	.20673	1.9000	2.0530	3.6000	2.0086
.25000	.32913	1.9500	2.0330	3.6500	2.0087
.30000	.46993	2.0000	2.0152	3.7000	2.0086
.35000	.62345	2.0500	1.9995	3.7500	2.0084
.40000	.78455	2.1000	1.9860	3.8000	2.0084
.45000	.94871	2.1500	1.9747	3.8500	2.0076
.50000	1.1120	2.2000	1.9655	3.9000	2.0070
.55000	1.2711	2.2500	1.9582	3.9500	2.0063
.60000	1.4233	2.3000	1.9529	4.0000	2.0057
.65000	1.5664	2.3500	1.9493	4.0500	2.0050
.70000	1.6985	2.4000	1.9472	4.1000	2.0042
.75000	1.8186	2.4500	1.9466	4.1500	2.0035
.80000	1.9257	2.5000	1.9471	4.2000	2.0029
.85000	2.0194	2.5500	1.9487	4.2500	2.0022
.90000	2.0997	2.6000	1.9511	4.3000	2.0016
.95000	2.1667	2.6500	1.9542	4.3500	2.0011
1.0000	2.2209	2.7000	1.9578	4.4000	2.0006
1.0500	2.2209	2.7500	1.9618	4.4500	2.0001
1.1000	2.2937	2.8000	1.9661	4.5000	1.9998
1.1500	2.3140	2.8500	1.9704	4.5500	1.9994
1.2000	2.3249	2.9000	1.9748	4.6000	1.9992
1.2500	2.3276	2.9500	1.9791	4.6500	1.9990
1.3000	2.3230	3.0000	1.9832	4.7000	1.9988
1.3500	2.3123	3.0500	1.9871	4.7500	1.9987
1.4000	2.2966	3.1000	1.9907	4.8000	1.9986

1.4500	2.2769	3.1500	1.9940	4.8500	1.9986
1.5000	2.2542	3.2000	1.9970	4.9000	1.9986
1.5500	2.2293	3.2500	1.9996	4.9500	1.9986
1.6000	2.2032	3.3000	2.0019	5.0000	1.9987
1.6500	2.1764	3.3500	2.0038		

```
DO YOU WANT TO CHANGE PLOT TIMES AND RECOMPUTE THE RESPONSE? (Y OR N):n
DO YOU WANT TO PLOT THE RESPONSE? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N); IF NO, PREVIOUS TITLE USED):y
TYPE IN TITLE TO APPEAR ON PLOT (.LE.70 CHARACTERS) AND RETURN:
example 7 inverse laplace transform and time response
THE TITLE ENTERED IS:
EXAMPLE 7 INVERSE LAPLACE TRANSFORM AND TIME RESPONSE
IS THE TITLE CORRECT? (Y OR N):y
DO YOU WANT AUTOMATIC PLOT SCALING? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y

   TIME RESPONSE                                                   10/31/83
   EXAMPLE 7 INVERSE LAPLACE TRANSFORM AND TIME RESPONSE

   3.20     I
   3.00     I
   2.80     I
   2.60     I
   2.40     I             ***
   2.20     I          ***   *****
   2.00     I         **          ****************************************
   1.80     I        *
   1.60     I       *
   1.40     I      *
   1.20     I     **
   1.00     I    *
    .800    I    *
    .600    I   *
    .400    I  **
    .200    I *
  0.        **------------------------------------------------------------
  -.200     I
  -.400     I
  -.600     I
  -.800     I
            I     I     I     I     I     I     I     I     I     I     I
          0.00   .50  1.00  1.50  2.00  2.50  3.00  3.50  4.00  4.50  5.00

DO YOU WANT TO CHANGE PLOT PARAMETERS AND REPLOT THE RESULTS? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N): y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
```

EXAMPLE 8 INVERSE Z-TRANSFORM BY POWER SERIES METHOD

Problem: Find the inverse z transform and the step response of the following transfer function

$$\frac{a_4 z^4 + a_3 z^3 + a_2 z^2 + a_1 z + a_0}{b_4 z^4 + b_3 z^3 + b_2 z^2 + b_1 z + b_0}$$

where a_0 = -1.96474786E-4 b_0 = 0.243334776

a_1 = -3.87975526E-4 b_1 = -1.58617798

a_2 = 1.49221356E-5 b_2 = 3.43416283

a_3 = 4.07871707E-4 b_3 = -3.09127983

a_4 = 2.01448831E-4 b_4 = 1.0

and the sampling period is .04 seconds.

Although the power series method for computing the inverse z transform is not as accurate as the partial fraction method, the results for typical transfer functions are very good. To provide a measure of the accuracy of the response, the results are computed in both single and double precision and compared.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:ztime
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER THE DEGREE OF NUMERATOR:4
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER: -1.96474786E-4
-3.87975526E-4 1.49221356E-5 4.07871707E-4 2.01448831E-4
ENTER THE DEGREE OF DENOMINATOR:4
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:.243334776
-1.58617798 3.43416283 -3.09127983 1
```

```
THE DEGREE OF THE NUMERATOR IS  4
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
-.000196474786 -.000387975526 .0000149221356 .000407871707
.000201448831
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS  4
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
.243334776 -1.58617798 3.43416283 -3.09127983 1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:1

---> DATA IS LOADED INTO Z-PLANE TRANSFER FUNCTION  1

--->  ZTIME - TIME RESPONSE OF Z - PLANE TRANSFER
             FUNCTION 1

ENTER SAMPLING PERIOD:.04
IS THIS AN IMPULSE OR A STEP RESPONSE? (I OR S):s
ENTER MAGNITUDE OF THE IMPULSE OR STEP:1
ENTER FINAL PLOT TIME:2.0

             FINAL VALUE =    .999908
```

*** TIME RESPONSE ***

TIME	VALUE	TIME	VALUE	TIME	VALUE
0.	.20135E-03	.68000	.13117	1.3600	.25310
.40000E-01	.12321E-02	.72000	.14013	1.4000	.25856
.80000E-01	.37411E-02	.76000	.14886	1.4400	.26388
.12000	.78894E-02	.80000	.15736	1.4800	.26907
.16000	.13486E-01	.84000	.16562	1.5200	.27413
.20000	.20269E-01	.88000	.17364	1.5600	.27907
.24000	.27989E-01	.92000	.18142	1.6000	.28391
.28000	.36424E-01	.96000	.18897	1.6400	.28864
.32000	.45388E-01	1.0000	.19629	1.6800	.22927
.36000	.54723E-01	1.0400	.20339	1.7200	.29781
.40000	.64299E-01	1.0800	.21027	1.7600	.30227
.44000	.74009E-01	1.1200	.21695	1.8000	.30664
.48000	.83764E-01	1.1600	.22342	1.8400	.31093
.52000	.93493E-01	1.2000	.22970	1.8800	.31516
.56000	.10314	1.2400	.23581	1.9200	.31931
.60000	.11266	1.2800	.24173	1.9600	.32340
.64000	.12201	1.3200	.24750	2.0000	.32743

```
    AT THE LAST TIME POINT THE SINGLE PRECISION VALUE DIFFERS FROM THE
         DOUBLE PRECISION VALUE BY    .55E-09 PERCENT.

DO YOU WANT TO CHANGE PLOT TIMES AND RECOMPUTE THE RESPONSE? (Y OR N):n
DO YOU WANT TO PLOT THE RESPONSE? (Y OR N):y
```

```
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N) (IF NO, PREVIOUS TITLE USED):y
TYPE IN TITLE TO APPEAR ON PLOT (.LE.70 CHARACTERS) AND RETURN:
example 8 inverse z-transform by power series method
THE TITLE ENTERED IS:
EXAMPLE 8 INVERSE Z-TRANSFORM BY POWER SERIES METHOD
IS THE TITLE CORRECT? (Y OR N):y
DO YOU WANT AUTOMATIC PLOT SCALING? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y


    TIME RESPONSE                                                  10/31/83
    EXAMPLE 8 INVERSE Z-TRANSFORM BY POWER SERIES METHOD

   .360      I
   .340      I
   .320      I                                                      ** ***
   .300      I                                                 * ***
   .280      I                                             ****
   .260      I                                        ****
   .240      I                                    ** *
   .220      I                               * ***
   .200      I                             **
   .180      I                         * **
   .160      I                       **
   .140      I                   * **
   .120      I                 **
   .100E+00 I               **
   .800E-01 I            **
   .600E-01 I          **
   .400E-01 I       * *
   .200E-01 I    ***
  0.        ***-*---------------------------------------------------------
  -.200E-01 I
  -.400E-01 I
            I     I     I     I     I     I     I     I     I     I     I
          0.00   .20   .40   .60   .80  1.00  1.20  1.40  1.60  1.80  2.00

DO YOU WANT TO CHANGE PLOT PARAMETERS AND REPLOT THE RESULTS? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N): y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT

------------------------------------------------------------------------------
```

EXAMPLE 9 Z TRANSFORM OF AN S-PLANE TRANSFER FUNCTION

Problem: Compute the z transform of the following transfer function with order hold and a delay of .008 seconds. The sampling period is .0 onds.

$$\frac{2900s + 2900}{s^5 + 4s^4 + 124s^3 + 363s^2}$$

The partial fraction expansion method is used to compute the z transform algorithm used to computed the partial fraction expansion requires th there are no multiple poles other than those at the origin and (2) the deg the numerator must not be greater than the number of non-zero poles denominator. Up to 5 poles at the origin are allowed (this includes the on the zero order hold if applicable).

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:szxfm
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):n
IS DATA TO BE ENTERED IN ROOT OR COEFFICIENT FORM? (R OR C):c
ENTER DEGREE OF THE NUMERATOR:1
ENTER NUMERATOR COEFFICIENTS IN ASCENDING ORDER: 2900 2900
ENTER DEGREE OF THE DENOMINATOR:5
ENTER DENOMINATOR COEFFICIENTS IN ASCENDING ORDER:0 0 363 124 4 1
THE DEGREE OF THE NUMERATOR IS 1
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
2900. 2900.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS 5
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
0. 0. 363. 124. 1
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y
ENTER NUMBER WHERE TRANSFER FUNCTION IS TO BE STORED:12

---> DATA IS LOADED INTO S-PLANE TRANSFER FUNCTION 12

ENTER THE SAMPLING PERIOD:.08
ENTER THE DELAY TIME IN SECONDS:.008
INCLUDE THE A ZERO ORDER HOLD (Y OR N):y

ENTER NUMBER WHERE OUTPUT FROM SZXFM IS TO BE STORED:2

---> ZROOT2  =    SZXFM OF       SROOT12
```

---> ZPTF2 = SZXFM OF SPTF12

NO.	ROOT		PARTIAL FRACTION EXPANSION COEFFICIENT	
1	-.50000000	-10.988630	.96684606E-01	-.40456452E-02
2	-.50000000	10.988630	-.96684606E-01	.40456452E-02
3	-3.0000000	0.	1.6914552	0.
4	0.		-1.8848244	0.
5	0.	0.	5.2599625	0.
6	0.	0.	7.9889807	0.

THE NUMERATOR ROOTS OF ZROOT2 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-12.268933	0.		
2	-.67135130E-04	0.		
3	.92311634	0.		
4	-.13469859	0.		
5	-1.1567519	0.		

LOW ORDER NON ZERO COEFFICIENT = -.23106189E-04

THE DENOMINATOR ROOTS OF ZROOT2 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	.61284138	-.73996066	.96078944	-.63785191
2	.61284138	.73996006	.96078944	-.63785191
3	.78662786	0.		
4	1.00000000	0.		
5	1.00000000	0.		
6	0.	0.		

LOW ORDER NON ZERO COEFFICIENT = -46.473538

DEGREE OF NUMERATOR OF ZPTF2 IS 5 (COEFFICIENTS IN ASCENDING ORDER)
-.00002310618894132 -.3443427037346 -2.507846683653 .6794170629569
2.464719122914 .1950347342772

DEGREE OF DENOMINATOR OF ZPTF2 IS 6 (COEFFICIENTS IN ASCENDING ORDER)
0. -46.47353837271 213.7325205421 -416.8323061287 442.3612041218
-256.7878801625 64.

EXAMPLE 10 MULTIRATE FREQUENCY RESPONSE BY FREQUENCY DECOMPOSITION

Problem: Compute the frequency response of the following function

$$\frac{1}{n}\sum_{k=1}^{n-1} G_n^{T/n}\left(z\, e^{j2*pi*k/n}\right)$$

where T=.24 seconds, n=3 and $G_n^{T/n}(z)$ is the z-transform computed in Example 9.

The above function is Sklansky's frequency decomposition method for expressing the output transform of a fast to slow sampler in terms of the faster input transfer function. An example of how this frequency decomposition method can be applied to the stability analysis of a multiloop multirate control system is given in Example 2 of Ref. 3. The above function can represent the open loop transfer function of Eq (6.6) in Ref. 3.

The operator ZMRFQ evaluates the frequency response of the above function by using only the transform of the faster sampled signal $G_n^{T/n}(z)$. The response is computed by the indicated summation with shifted values of z_n. This operation yields only the multirate frequency response of $G_n^{T/n}(z)$. No z-transform at the slower sampling rate is computed. In the next example though, an explicit form for the implementing the frequency decomposition method is described.

Since one-half of the sampling frequency of the slower output sampler is 13.09 rad/sec, the frequency range to be used for this example will be 1.0 to 13.0 rad/sec.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:zmrfq
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:2

---> ZMRFQ - MULTIRATE FREQUENCY RESPONSE (BY
            FREQUENCY DECOMPOSITION) OF ZPTF2

IS THE FREQUENCY IN RAD/SEC OR HZ? (R OR H):r
ENTER SAMPLING PERIOD OF THE SLOWER SAMPLER:.24
```

```
ENTER INTEGER RATIO OF OUTPUT/INPUT SAMPLING PERIODS:3
DO YOU WANT COMPUTER TO AUTOMATICALLY DETERMINE FREQUENCY VALUES
TO BE USED IN EVALUATING THE FREQUENCY RESPONSE? (Y OR N): y

WILL ASK YOU FOR SPECIFIC FREQUENCY VALUES TO BE USED IN EVALUATING
FREQUENCY RESPONSE. COMPUTER WILL THEN AUTOMATICALLY CHOOSE
ADDITIONAL FREQUENCY VALUES TO PROVIDE DETAILED RESPONSE.

INPUT NUMBER OF SPECIFIC FREQUENCY VALUES YOU INTEND TO ENTER.
(ENTER A VALUE BETWEEN 2-20, IF NOT SURE, TRY 2):2
ENTER  2 FREQUENCY VALUES IN ASCENDING ORDER:1 13
DO YOU WANT TO SUPPRESS TABULAR OUTPUT OF THE RESPONSE? (Y OR N):n
```

OMEGA RAD/SEC	ZREAL	ZIMAG	REAL	IMAGINARY	DB	PHASE	PHASE MARGIN
1.000	.997	.080	-.331E+01	-.143E+01	11.125	-156.66	23.34
1.200	.995	.096	-.247E+01	-.113E+01	8.664	-155.48	24.52
1.400	.994	.112	-.195E+01	-.906E+00	6.648	-155.08	24.92
1.700	.991	.136	-.147E+01	-.670E+00	4.171	-155.51	24.49
2.000	.987	.159	-.117E+01	-.504E+00	2.125	-156.75	23.25
2.369	.982	.188	-.933E+00	-.360E+00	-.000	-158.91	21.09
2.869	.974	.220	-.722E+00	-.230E+00	-2.411	-162.36	17.64
3.469	.962	.274	-.560E+00	-.132E+00	-4.805	-166.75	13.25
4.269	.942	.335	-.423E+00	-.556E-01	-7.377	-172.53	7.47
5.069	.919	.394	-.339E+00	-.112E-01	-9.387	-178.11	1.89
5.346	.910	.415	-.317E+00	.458E-07	-9.966	-180.00	-.00
6.946	.850	.528	-.241E+00	.467E-01	-12.206	-190.98	-10.98
8.546	.775	.632	-.225E+00	.989E-01	-12.202	-203.76	-23.76
9.546	.722	.692	-.250E+00	.181E+00	-10.213	-215.89	-35.39
10.05	.694	.720	-.270E+00	.286E+00	-8.096	-226.62	-46.62
10.35	.677	.736	-.262E+00	.409E+00	-6.287	-237.50	-57.50
10.55	.655	.747	-.208E+00	.530E+00	-4.893	-248.60	-68.60
10.70	.656	.755	-.110E+00	.630E+00	-3.887	-260.08	-80.08
10.82	.648	.762	.250E-01	.688E+00	-3.247	-272.08	-92.08
10.92	.642	.767	.160E+00	.690E+00	-2.994	-283.03	-103.03
11.02	.636	.772	.292E+00	.640E+00	-3.054	-294.53	-114.53
11.12	.630	.777	.393E+00	.546E+00	-3.442	-305.70	-125.70
11.22	.623	.782	.447E+00	.435E+00	-4.097	-315.81	-135.81
11.37	.614	.789	.458E+00	.283E+00	-5.376	-328.22	-148.22
11.57	.601	.799	.409E+00	.150E+00	-7.222	-339.91	-159.91
11.82	.585	.811	.335E+00	.654E-01	-9.326	-348.97	-168.97
12.12	.566	.825	.270E+00	.236E-01	-11.343	-355.00	-175.00
12.62	.532	.847	.212E+00	.339E-02	-13.460	-359.09	-179.09
13.00	.506	.862	.198E+00	.333E-03	-14.077	-359.90	-179.90

```
DO YOU WANT A NICHOLS PLOT? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N; IF NO, PREVIOUS TITLE USED):y
```

```
TYPE IN TITLE TO APPEAR ON PLOT (.LE.70 CHARACTERS) AND RETURN:
example 10 multirate frequency response by frequency decomposition
THE TITLE ENTERED IS:
EXAMPLE 10 MULTIRATE FREQUENCY RESPONSE BY FREQUENCY DECOMPOSITION
IS THE TITLE CORRECT? (Y OR N):y
DO YOU WANT AUTOMATIC SCALING FOR THE MAGNITUDE RESPONSE? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y


 NICHOLS PLOT (MAGN. VS PHASE)                                    10/31/83
 EXAMPLE 10 MULTIRATE FREQUENCY RESPONSE BY FREQUENCY DECOMPOSITION

 18.0                                                                  I
 16.0                                                                  I
 14.0                                                                  I
 12.0                                        *                         I
 10.0                                        *                         I
 8.00                                        *                         I
 6.00                                        *                         I
 4.00                                        *                         I
 2.00                                        *                         I
0.        ----------------------------------**-------------------------I
-2.00                 **                    *                          I
-4.00           ****** *******             **                          I
-6.00         **             ***          **                           I
-8.00       **                  **        *                            I
-10.0      **                    ***     *                             I
-12.0     **                       *****                               I
-14.0     *                                                            I
-16.0                                                                  I
-18.0                                                                  I
-20.0                                                                  I
-22.0                                                                  I
          I     I     I     I     I     I     I     I     I     I     I
      -360.000    -288.000    -216.000     -144.000     -72.000       0.000

WOULD YOU LIKE TO CHANGE FREQUENCY RANGE AND RECOMPUTE RESPONSE? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N): y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
DO YOU WANT A BODE PLOT? (Y OR N):n
DO YOU WANT A NYQUIST PLOT? (Y OR N):n
```

The z-plane frequencies in the tabulation of the response are at the faster sampling rate. Note that at 13.0 rad/sec the z-plane frequency is (.506 + j.852) or approximately 60 degrees on the unit circle. At the slower sampling rate this point would be at approximately the (-1. + j 0.) point, which is 3 times 60 degrees on the unit circle.

EXAMPLE 11 RATIONAL REPRESENTATION OF FREQUENCY DECOMPOSITION METHOD

Problem: Compute the frequency response of the function

$$\frac{1}{n} \sum_{k=1}^{n-1} G_n^{T/n}\left(z\, e^{j2*pi*k/n}\right)$$

using the explicit form of Sklansky's frequency decomposition method where T=.24 seconds, n=3 and $G_n^{T/n}(z)$ is the z-transform computed in Example 9.

In Example 10 the frequency response was computed using the operator ZMRFQ which numerically evaluated the function over a range of frequencies for z_n.

Until recently, this was the only means in LCAP2 of applying the frequency decomposition method. A new operator, ZMRXFM, has been implemented which will yield a rational representation of this frequency decomposition method. This operator computes the output transform of a fast to slow sampler. This output transform is a transfer function represented in rational form at the slower sampling rate. After this transfer function has been computed, the single rate z-plane frequency response operator, ZFREQ, can be used to evaluate the response.

The numerical technique for computing the rational form of the frequency decomposition method will be documented in the near future.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:zmrxfm
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:2
ENTER SAMPLING PERIOD OF SLOWER OUTPUT SAMPLER IN SECONDS:.24
ENTER RATIO OF OUTPUT/INPUT SAMPLING PERIODS:3

ENTER NUMBER WHERE OUTPUT FROM ZMRXFM IS TO STORED:3

--->  ZROOT3  =   ZMRXFM OF       ZROOT2

--->   ZPTF3  =PSYNTH(ZROOT3)
```

THE NUMERATOR ROOTS OF ZROOT3 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-.10647750E-01	0.		
2	-.59161620	0.		
3	.78658382	0.		
4	-2.9655282	0.		

LOW ORDER NON ZERO COEFFICIENT = -.18162533

THE DENOMINATOR ROOTS OF ZROOT3 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-.77650116	-.42857182	.88692044	.87550262
2	-.77650116	.42857182	.88692044	.87550262
3	.48675226	0.		
4	1.00000000	0.		
5	1.00000000	0.		

LOW ORDER NON ZERO COEFFICIENT = -24.505145

```
DEGREE OF NUMERATOR OF ZPTF3  IS  4    (COEFFICIENTS IN ASCENDING ORDER)
-.1816253320627 -17.19496629374 -12.53387821671 34.37676332934
12.3603697263

DEGREE OF DENOMINATOR OF ZPTF3  IS  5  (COEFFICIENTS IN ASCENDING ORDER)
-24.5051447024 50.97511989617 39.80519865903 -70.51517819695
-59.75999565584 64.

-------------------------------------------------------------------------------

ENTER NEXT OPERATION:zfreq
IS THIS TRANSFER FUNCTION NEW OR OLD? (N OR O):o
ENTER THE NUMBER OF THE TRANSFER FUNCTION:3

--->  ZFREQ - FREQUENCY RESPONSE OF Z-PLANE TRANSFER
              FUNCTION  3

IS THE FREQUENCY IN RAD/SEC OR HZ? (R OR H):r
ENTER SAMPLING PERIOD OF THE SLOWER SAMPLER:.24
DO YOU WANT COMPUTER TO AUTOMATICALLY DETERMINE FREQUENCY VALUES
TO BE USED IN EVALUATING THE FREQUENCY RESPONSE? (Y OR N): y

WILL ASK YOU FOR SPECIFIC FREQUENCY VALUES TO BE USED IN EVALUATING
FREQUENCY RESPONSE. COMPUTER WILL THEN AUTOMATICALLY CHOOSE
ADDITIONAL FREQUENCY VALUES TO PROVIDE DETAILED RESPONSE.
```

INPUT NUMBER OF SPECIFIC FREQUENCY VALUES YOU INTEND TO ENTER.
(ENTER A VALUE BETWEEN 2-20, IF NOT SURE, TRY 2):2
ENTER 2 FREQUENCY VALUES IN ASCENDING ORDER:1 13
DO YOU WANT TO SUPPRESS TABULAR OUTPUT OF THE RESPONSE? (Y OR N):n

OMEGA RAD/SEC	ZREAL	ZIMAG	REAL	IMAGINARY	DB	PHASE	PHASE MARGIN
1.000	.971	.238	-.331E+01	-.143E+01	11.125	-156.66	23.34
1.200	.959	.284	-.247E+01	-.113E+01	8.664	-155.48	24.52
1.400	.944	.330	-.195E+01	-.906E+00	6.648	-155.08	24.92
1.700	.918	.397	-.147E+01	-.670E+00	4.171	-155.51	24.49
2.000	.887	.462	-.117E+01	-.504E+00	2.125	-156.75	23.25
2.369	.843	.538	-.933E+00	-.360E+00	-.000	-158.91	21.09
2.869	.772	.635	-.722E+00	-.230E+00	-2.411	-162.36	17.64
3.469	.673	.740	-.560E+00	-.132E+00	-4.805	-166.75	13.25
4.269	.519	.854	-.423E+00	-.556E-01	-7.377	-172.53	7.47
5.069	.347	.938	-.339E+00	-.112E-01	-9.387	-178.11	1.89
5.346	.284	.959	-.317E+00	.458E-07	-9.966	-180.00	-.00
6.946	-.096	.995	-.241E+00	.467E-01	-12.206	-190.98	-10.98
8.546	-.462	.887	-.225E+00	.989E-01	-12.202	-203.76	-23.76
9.546	-.660	.752	-.250E+00	.181E+00	-10.213	-215.89	-35.39
10.05	-.745	.667	-.270E+00	.286E+00	-8.096	-226.62	-46.62
10.35	-.791	.612	-.262E+00	.409E+00	-6.287	-237.50	-57.50
10.55	-.819	.573	-.208E+00	.530E+00	-4.893	-248.60	-68.60
10.70	-.839	.544	-.110E+00	.630E+00	-3.887	-260.08	-80.08
10.82	-.855	.518	.250E-01	.688E+00	-3.247	-272.08	-92.08
10.92	-.868	.497	.160E+00	.690E+00	-2.994	-283.03	-103.03
11.02	-.879	.476	.292E+00	.640E+00	-3.054	-294.53	-114.53
11.12	-.890	.455	.393E+00	.546E+00	-3.442	-305.70	-125.70
11.22	-.901	.434	.447E+00	.435E+00	-4.097	-315.81	-135.81
11.37	-.916	.401	.458E+00	.283E+00	-5.376	-328.22	-148.22
11.57	-.934	.357	.409E+00	.150E+00	-7.222	-339.91	-159.91
11.82	-.954	.300	.335E+00	.654E-01	-9.326	-348.97	-168.97
12.12	-.973	.231	.270E+00	.236E-01	-11.343	-355.00	-175.00
12.62	-.994	.112	.212E+00	.339E-02	-13.460	-359.09	-179.09
13.00	-1.000	.022	.198E+00	.333E-03	-14.077	-359.90	-179.90

DO YOU WANT A NICHOLS PLOT? (Y OR N):y
DO YOU WANT TO ENTER TITLE FOR PLOT?
(Y OR N; IF NO, PREVIOUS TITLE USED):y
TYPE IN TITLE TO APPEAR ON PLOT (.LE.70 CHARACTERS) AND RETURN:
example 11 rational representation of frequency decomposition method
THE TITLE ENTERED IS:
EXAMPLE 11 RATIONAL REPRESENTATION OF FREQUENCY DECOMPOSITION METHOD
IS THE TITLE CORRECT? (Y OR N):y
DO YOU WANT AUTOMATIC SCALING FOR THE MAGNITUDE RESPONSE? (Y OR N):y
DO YOU WANT A PRINTER PLOT? (Y OR N):y

```
 NICHOLS PLOT (MAGN. VS PHASE)                                   10/31/83
 EXAMPLE 11 RATIONAL REPRESENTATION OF FREQUENCY DECOMPOSITION METHOD

 18.0                                                                 I
 16.0                                                                 I
 14.0                                                                 I
 12.0                                       *                         I
 10.0                                       *                         I
 8.00                                       *                         I
 6.00                                       *                         I
 4.00                                       *                         I
 2.00                                       *                         I
0.        ---------------------------------**-------------------------I
-2.00                 **                   *                          I
-4.00           ****** *******            **                          I
-6.00         **             ***         **                           I
-8.00       **                **         *                            I
-10.0      **                  ***      *                             I
-12.0     **                       *****                              I
-14.0     *                                                           I
-16.0                                                                 I
-18.0                                                                 I
-20.0                                                                 I
-22.0                                                                 I
          I     I     I     I     I     I     I     I     I     I     I
      -360.000    -288.000    -216.000    -144.000     -72.000       0.000

WOULD YOU LIKE TO CHANGE FREQUENCY RANGE AND RECOMPUTE RESPONSE? (Y OR N):n
DO YOU WANT A HARDCOPY PLOT? (Y OR N): y
DATA FOR HARDCOPY PLOT WRITTEN TO FILE - PLOT
DO YOU WANT A BODE PLOT? (Y OR N):n
DO YOU WANT A NYQUIST PLOT? (Y OR N):n
```

Note that the frequency response is identical to the response computed in Example 10. In the tabulation of the response, the z-plane frequencies are at the slower sampling rate.

EXAMPLE 12 TRANSFER FUNCTION EVALUATION BY CRAMER'S METHOD

Problem: Given

$$\underline{M}(s) = \begin{vmatrix} s + 2 & -(s + 3) \\ 0 & .01 s^2 + .15 s + 1 \end{vmatrix}$$

$$\underline{B}(s) = \begin{vmatrix} 0 \\ 1 \end{vmatrix} \quad \text{and } \underline{X}(s) = \begin{vmatrix} x_1(s) \\ x_2(s) \end{vmatrix}$$

find the transfer function $x_1(s)/u(s)$ by application of Cramer's method.

$$\frac{x_1(s)}{u(s)} = \frac{\det \underline{M}_1(s)}{\det \underline{M}(s)}$$

where $\underline{M}_1(s)$ is equal to $\underline{M}(s)$ with column 1 replaced by $\underline{B}(s)$.

Three operations are required for this example. The first two compute the determinants and store the results into polynomials and the last one copies the polynomials into an s-plane transfer function.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:dterm
IS THE MATRIX NEW OR OLD? (N OR O):n

ENTER DIMENSION OF MATRIX (30 IS THE MAXIMUM):2
THE HIGHEST POSSIBLE ORDER OF ANY POLYNOMIAL OF THE MATRIX IS 4

ENTER MATRIX DATA. ONE COEFFICIENT PER LINE WITH
FORMAT: DEGREE (I,J) VALUE
(NEGATIVE VALUE FOR DEGREE WILL TERMINATE DATA ENTRY. 2ND & 3RD
FIELDS MUST BE ENTERED BUT WILL BE IGNORED)
```

```
0 (1,1) 2
0 (1,2) -3
0 (2,2) 1
1 (1,1) 1
1 (1,2) -1
1 (2,2) .15
2 (2,2) .01
-1 (1,1) 0

DO YOU WANT MATRIX DATA PRINTED OUT? (Y OR N):y

                        0                  1                  2                  3
ROW  COL               S                  S                  S                  S

 1    1       .20000000E+01    .10000000E+01
 1    2      -.30000000E+01   -.10000000E+01
 2    2       .10000000E+01    .15000000E+00    .10000000E-01

DO YOU WANT TO CORRECT MATRIX DATA? (Y OR N):n
DO YOU WANT TO SUBSTITUTE B VECTOR INTO THE MATRIX? (Y OR N):n
ENTER NUMBER WHERE DETERMINANT IS TO BE STORED:2

--->    ROOT2  = ROOTS OF DETERMINANT

                              THE ROOTS OF ROOT2 ARE

NO.        REAL           IMAG.           OMEGA            ZETA

 1     -7.5000000      6.61437828      10.0000000       .750000000
 2     -7.5000000     -6.61437828      10.0000000        750000000
 3     -2.0000000      0.

                     LOW ORDER NON ZERO COEFFICIENT =   2.0000000

--->   POLY2  = PSYNTH(ROOT2 )

DEGREE OF POLY2  IS  3          (COEFFICIENTS IN ASCENDING ORDER)
2. 1.3 .17 .01

------------------------------------------------------------------------------

ENTER NEXT OPERATION:dterm
IS THE MATRIX NEW OR OLD? (N OR O):o

DO YOU WANT MATRIX DATA PRINTED OUT? (Y OR N):n
DO YOU WANT TO CORRCT MATRIX DATA? (Y OR N):n
DO YOU WANT TO SUBSTITUTE B VECTOR INTO THE MATRIX? (Y OR N):y
IS THE B VECTOR NEW OR OLD? (N OR O):n
```

```
ENTER B VECTOR. ONE COEFFICIENT PER LINE WITH
FORMAT: DEGREE  ROW NO.  VALUE
(NEGATIVE VALUE FOR DEGREE WILL TERMINATE DATA ENTRY. 2ND & 3RD
FIELDS MUST BE ENTERED BUT WILL BE IGNORED)

0 2 1
-1 0 0

DO YOU WANT B VECTOR PRINTED OUT? (Y OR N):y

                 0                 1                2                3
ROW             S                 S                S                S

 2       .10000000E+01

DO YOU WANT TO CORRECT THE B VECTOR? (Y OR N):n
ENTER COLUMN NUMBER WHERE B VECTOR IS TO SUBSTITUTED:1
ENTER NUMBER WHERE DETERMINANT IS TO BE STORED:3

--->    ROOT3  = ROOTS OF DETERMINANT

                           THE ROOTS OF ROOT3 ARE

NO.        REAL              IMAG.             OMEGA              ZETA

 1     -3.0000000       0.

                    LOW ORDER NON ZERO COEFFICIENT =   3.0000000

--->   POLY3  = PSYNTH(ROOT3 )

DEGREE OF POLY3  IS  1          (COEFFICIENTS IN ASCENDING ORDER)
3. 1.

------------------------------------------------------------------------------
ENTER NEXT OPERATION:cpyps
(NUM. IS 1ST POLY., DENOM. IS 2ND POLY.)
IS THE FIRST POLYNOMIAL NEW OR OLD? (N OR O):o
ENTER THE NUMBER OF THE POLYNOMIAL:3
IS THE SECOND POLYNOMIAL NEW OR OLD? (N OR O):o
ENTER THE NUMBER OF THE POLYNOMIAL:2

                          THE ROOTS OF ROOT3 ARE

NO.        REAL              IMAG.             OMEGA              ZETA

 1     -3.0000000       0.
```

DEGREE OF POLY3 IS 3 (COEFFICIENTS IN ASCENDING ORDER)

3. 1.

THE ROOTS OF ROOT2 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-7.5000000	6.61437828	10.0000000	.750000000
2	-7.5000000	-6.61437828	10.0000000	750000000
3	-2.0000000	0.		

DEGREE OF POLY2 IS 1 (COEFFICIENTS IN ASCENDING ORDER)
2. 1.3 .17 .01

ENTER NUMBER WHERE OUTPUT FROM CPYSP IS TO BE STORED:13

---> SROOT13 = ROOT3 / ROOT2

---> SPTF13 = POLY3 / POLY2

THE NUMERATOR ROOTS OF SROOT13 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-3.0000000	0.		

LOW ORDER NON ZERO COEFFICIENT = 3.0000000

THE DENOMINATOR ROOTS OF SROOT13 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-7.5000000	6.61437828	10.0000000	.750000000
2	-7.5000000	-6.61437828	10.0000000	750000000
3	-2.0000000	0.		

LOW ORDER NON ZERO COEFFICIENT = 2.0000000

DEGREE OF NUMERATOR OF SPTF13 IS 1 (COEFFICIENTS IN ASCENDING ORDER)
3. 1.

DEGREE OF DENOMINATOR OF SPTF13 is 3 (COEFFICIENTS IN ASCENDING ORDER)
2. 1.3 .17 .01

EXAMPLE 13 STORE DATA FROM CURRENT INTERACTIVE SESSION FOR LATER USE

Problem: Store all polynomial, transfer function and matrix data so that it can be used in a subsequent interactive LCAP2 session or batch LCAP2 job.

The terminal dialog for this example is[1] :

```
ENTER NEXT OPERATION:store

---> STORE POLYNOMIALS, TRANSFER FUNCTIONS AND MATRIX DATA OF THIS
     INTERACTIVE SESSION ON TAPE31

ENTER ONE LINE OF MESSAGE FOR IDENTIFYING THE DATA FILE (.LE.70 CHAR.):
examples for lcap2 users manual

DO YOU WANT PRINTOUT OF DATA TO BE SAVED? (Y OR N):y

                                THE ROOTS OF ROOT1   ARE

NO.          REAL             IMAG.             OMEGA             ZETA
 1       -1.8445105        -.49938380         1.9109168         .96524896
 2       -1.8445105         .49938380         1.9109168         .96524896
 3       -9.3109790        0.

DEGREE OF POLY1   IS   3           (COEFFICIENTS IN ASCENDING ORDER)
34. 38. 13. 1.
                                THE ROOTS OF ROOT2   ARE

NO.          REAL             IMAG.             OMEGA             ZETA

 1       -7.5000000         6.6143783         10.000000         .75000000
 2       -7.5000000        -6.6143783         10.000000         .75000000
 3       -2.0000000        0.

DEGREE OF POLY2   IS   3           (COEFFICIENTS IN ASCENDING ORDER)
2. 1.3 .17 .01
                                    .
                          (data for polynomial 3)
                                    .
                                    .
                (data for s-plane transfer functions 1,...,5)
                                    .
                                    .
```

[1] Since the interactive session represented by Examples 1 through 13 generated nineteen different data sets, for brevity only a representative sample of the output for this example is given here.

(data for z-plane transfer functions 1,2,3)

.

.

(data for s-plane transfer functions 6,...,13)

.

.

MXM = 2
MDEG = 2

MATRIX M(S) IS

ROW	COL	S^0	S^1	S^2	S^3
1	2	-.30000000E+01	-.10000000E+01		
2	1	.10000000E+01			
2	2	.10000000E+01	.15000000E+00	.10000000E-01	

B VECTOR IS

ROW	S^0	S^1	S^2	S^3
2	.10000000E+01			

Note that the s-plane transfer functions are not listed continuously f through 13. This is due to the method in which polynomials and transfer tions are stored in the program. All polynomials and transfer functions indices 1 through 5 are saved in SCM (small core memory). All polynomial transfer functions with indices greater than 5 are saved on disk storag printing out the data stored by the STORE operator, the data which is sav SCM is printed out before the data which is saved on disk storage.

EXAMPLE 14 END OPERATION AND CATALOGING OF DATA AND PLOT FILES

Problem: An END operation will terminate the current interactive LCAP2 session. If hardcopy plots were requested or the STORE operation was executed during the interactive session, the program will automatically catalog these files for the user. Since the assumption was made that the first thirteen examples were executed during the same session, both a plot file and a data file will be cataloged in this example.

The terminal dialog for this example is:

```
-----------------------------------------------------------------------------

ENTER NEXT OPERATION:end

DATA FILE CREATED BY OPERATION STORE WILL BE CATALOGED
FOR YOU. ENTER 7 CHARACTER WORD TO BE USED AS FILE NAME:dataxxx

ENTER 7 CHARACTER WORD TO BE USED TO CATALOG PLOT FILE:plotxxx

ENTER LETTER TO DESIGNATE WHERE PLOT JOB WILL BE ROUTED TO
(D)D-8 ,(F)A3 ,(J)BLDG 120 ,(K)BLDG A6, (N)BLDG D5
TYPE (D,F,J,K OR N):d

DO YOU WANT THE HARDCOPY PLOTS TO BE PRODUCED IN D8 INSTEAD OF A3? (Y OR N):y

DATA FILE HAS BEEN CATALOGED. TO USE THIS DATA FOR A
FUTURE JOB, ATTACH THIS DATA FILE PRIOR TO USING
INTERACTIVE LCAP2 AGAIN. THE ATTACH COMMAND WILL BE

**************************************
*  ATTACH,TAPE30,8DATAXXX,ID=9487.  *
**************************************

PLOT FILE CATALOGED ON CDC 835 AS 8PLOTXXX,ID=9487
(THIS FILE WILL BE PURGED UPON COMPLETION OF HARDCOPY PLOTS)

D3050JI HAS BEEN SUBMITTED TO THE SYSTEM
-----------------------------------------------------------------------------
```

EXAMPLE 15 RESTORE DATA FROM A PREVIOUS INTERACTIVE LCAP2 SESSION

Problem: Logon and restore data stored in Example 13 from a previous interactive session.

After logging on the CDC INTERCOM, the terminal dialog is[1] :

```
screen,80
attach(tape30,8dataxxx,id=9487)
attach(lcap2,8intlcap2,id=9487)
lcap2.

WOULD YOU LIKE TO RETRIEVE DATA FROM A PREVIOUS SESSION?
TYPE (Y OR N):y

HAVE YOU ATTACHED THE PERMANENT FILE CONTAINING YOUR DATA?
TYPE (Y OR N):y

WELCOME TO INTERACTIVE LCAP2

PRINTER PLOTS WILL BE FORMATTED FOR 80 COLUMNS.
DO YOU WANT TO CHANGE IT TO 132 COLUMNS? (Y OR N):n

ENTER OPERATION (TYPE H IF HELP IS NEEDED):restore

---> RESTORE POLYNOMIALS, TRANSFER FUNCTIONS AND MATRIX DATA
     FROM A PREVIOUS JOB

TAPE30 IDENTIFIER IS
EXAMPLES FOR INTERACTIVE LCAP2 USERS MANUAL

DO YOU WANT THE RESTORED DATA PRINTED OUT? (Y OR N):y

                             THE ROOTS OF ROOT1   ARE

NO.         REAL          IMAG.           OMEGA          ZETA
 1      -1.8445105     -.49938380       1.9109168      .96524896
 2      -1.8445105      .49938380       1.9109168      .96524896
 3      -9.3109790     0.

DEGREE OF POLY1  IS  3          (COEFFICIENTS IN ASCENDING ORDER)
34. 38. 13. 1.
```

[1] Since the interactive session represented by Examples 1 through 13 generated nineteen different data sets, for brevity only a representative sample of the output for this example is given here.

THE ROOTS OF ROOT2 ARE

NO.	REAL	IMAG.	OMEGA	ZETA
1	-7.5000000	6.6143783	10.000000	.75000000
2	-7.5000000	-6.6143783	10.000000	.75000000
3	-2.0000000	0.		

DEGREE OF POLY2 IS 3 (COEFFICIENTS IN ASCENDING ORDER)
2. 1.3 .17 .01

.

(data for polynomial 3)

.

.

(data for s-plane transfer functions 1,...,5)

.

.

(data for z-plane transfer functions 1,2,3)

.

.

(data for s-plane transfer functions 6,...,13)

.

.

MXM = 2
MDEG = 2

MATRIX M(S) IS

ROW	COL	S^0	S^1	S^2	S^3
1	2	-.30000000E+01	-.10000000E+01		
2	1	.10000000E+01			
2	2	.10000000E+01	.15000000E+00	.10000000E-01	

B VECTOR IS

ROW	S^0	S^1	S^2	S^3
2	.10000000E+01			

EXAMPLE 16 CHANGE COEFFICIENTS OF AN S-PLANE TRANSFER FUNCTION

Problem: Change the coefficients of SPTF11 from Example 7 to the following

$$\frac{432s + 5000}{s^4 + 35s^3 + 345s^2 + 1008s + 2500}$$

which differ only in the coefficient of the s**0 terms of the numerator and denominator.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:spcngc
ENTER THE NUMBER OF THE TRANSFER FUNCTION:11
THE DEGREE OF THE NUMERATOR IS  1
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
4320. 432.
IS THE NUMERATOR DATA CORRECT? (Y OR N):n
TYPE (D) TO CHANGE DEGREE,(C) TO CHANGE  COEFFICIENTS:c
ENTER THE NUMBER OF INCORRECT COEFFICIENTS:1
ENTER THE DEGREES OF THE TERMS WITH INCORRECT COEFFICIENTS:0
ENTER THE  1 CORRECT NUMERATOR COEFFICIENTS:5000
THE DEGREE OF THE NUMERATOR IS  1
NUMERATOR COEFFICIENTS IN ASCENDING ORDER ARE
5000. 432.
IS THE NUMERATOR DATA CORRECT? (Y OR N):y
THE DEGREE OF THE DENOMINATOR IS  4
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
2160. 1008. 345. 35. 1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):n
TYPE (D) TO CHANGE DEGREE,(C) TO CHANGE  COEFFICIENTS:c
ENTER THE NUMBER OF INCORRECT COEFFICIENTS:1
ENTER THE DEGREES OF THE TERMS WITH INCORRECT COEFFICIENTS:0
ENTER THE  1 CORRECT DENOMINATOR COEFFICIENTS:2500
THE DEGREE OF THE DENOMINATOR IS  4
DENOMINATOR COEFFICIENTS IN ASCENDING ORDER ARE
2500. 1008. 345. 35. 1.
IS THE DENOMINATOR DATA CORRECT? (Y OR N):y

--->   CHANGE COEFFICIENTS OF SPTF11
```

EXAMPLE 17 CHANGE ROOTS OF AN S-PLANE TRANSFER FUNCTION

Problem: Change the roots of SPTF2 from Example 4 to the following

$$\frac{30\left(\dfrac{s}{12}+1\right)}{60(s)\left(\dfrac{s}{8}+1\right)\left(\dfrac{s}{1+j2}+1\right)\left(\dfrac{s}{1-j2}+1\right)}$$

which differ only in the location of the numerator root, one of the denominator roots, and the denominator gain.

The terminal dialog for this example is:

```
ENTER NEXT OPERATION:spcngr
ENTER THE NUMBER OF THE TRANSFER FUNCTION:2
THE NUMERATOR ROOT VALUES ENTERED ARE

   ROOT ID.              ROOT VALUES
      1        -10.000000        0.

LOW ORDER NON-ZERO COEFFICIENT OF THE NUMERATOR IS    30.000000
IS THE DATA CORRECT? (Y OR N):n
TYPE (A) TO ADD ROOT VALUES, (D) TO DELETE ROOT VALUES, (C) TO CHANGE
ROOT VALUES OR (G) TO CHANGE GAIN VALUE FOR THE NUMERATOR:c
ENTER THE NUMBER OF INCORRECT ROOT VALUES:1
ENTER THE  1 ROOT VALUES (ID. NUMBER ONLY) TO BE CHANGED:1
ENTER THE  1 CORRECT ROOT VALUES:(-12.,0.)

THE NUMERATOR ROOT VALUES ENTERED ARE

   ROOT ID.              ROOT VALUES
      1        -12.000000        0.

LOW ORDER NON-ZERO COEFFICIENT OF THE NUMERATOR IS    30.000000
IS THE DATA CORRECT? (Y OR N):y
THE DENOMINATOR ROOT VALUES ENTERED ARE

   ROOT ID.              ROOT VALUES
      1        -1.0000000        2.0000000
      2        -7.0000000        0.
      3        0.                0.
```

```
LOW ORDER NON-ZERO COEFFICIENT OF THE NUMERATOR IS    70.000000
IS THE DATA CORRECT? (Y OR N):n
TYPE (A) TO ADD ROOT VALUES, (D) TO DELETE ROOT VALUES, (C) TO CHANGE
ROOT VALUES OR (G) TO CHANGE GAIN VALUE FOR THE NUMERATOR:c
ENTER THE NUMBER OF INCORRECT ROOT VALUES:1
ENTER THE  1 ROOT VALUES (ID. NUMBER ONLY) TO BE CHANGED:2
ENTER THE  1 CORRECT ROOT VALUES:(-8.,0.)
THE DENOMINATOR ROOT VALUES ENTERED ARE

   ROOT ID.            ROOT VALUES
      1        -1.0000000       2.0000000
      2        -8.0000000      0.
      3        0.              0.

LOW ORDER NON-ZERO COEFFICIENT OF THE NUMERATOR IS    70.000000
IS THE DATA CORRECT? (Y OR N):n
TYPE (A) TO ADD ROOT VALUES, (D) TO DELETE ROOT VALUES, (C) TO CHANGE
ROOT VALUES OR (G) TO CHANGE GAIN VALUE FOR THE NUMERATOR:g
ENTER LOW ORDER NON-ZERO COEFFICIENT FOR THE DENOMINATOR:60
THE DENOMINATOR ROOT VALUES ENTERED ARE

   ROOT ID.            ROOT VALUES
      1        -1.0000000       2.0000000
      2        -8.0000000      0.
      3        0.              0.

LOW ORDER NON-ZERO COEFFICIENT OF THE NUMERATOR IS    60.000000
IS THE DATA CORRECT? (Y OR N):y

--->   CHANGE ROOTS OF SROOT2

--->   SPTF2   = PSYNTH(SROOT2 )

------------------------------------------------------------------------------
```

REFERENCES

1. E. A. Lee, "LCAP2 - Linear Controls Analysis Program, Vol I: Batch LCAP2 User's Guide," Aerospace Corporation, TR - 0084(9975)-1 Vol I, 15 November 1983

2. E. A. Lee, "LCAP2 - Linear Controls Analysis Program, Vol III: Source Code Description," Aerospace Corporation, TR - 0084(9975)-1 Vol III, 15 November 1983

3. E. A. Lee, "LCAP2-Linear Controls Analysis Program," IEEE Control Systems Magazine, December 1982, pp. 15-18.

APPENDIX A. DESCRIPTION OF OPERATORS

Detailed description of the LCAP2 operators is given in Ref. 2. An abbreviated description for each of these operators are given below:

POLYNOMIAL OPERATORS

PADD - Polynomial Add
POLYi = POLYj + POLYk

PCNGC - Change Coefficients Of Polynomial POLYi

PCNGR - Change Roots Of Polynomial POLYi

PEQU - Polynomial Equal
POLYi = POLYj

PLDC - Polynomial Load, Coefficient Form
POLYi = POLY

PLDR - Polynomial Load, Root Form
ROOTi = ROOT, POLYi = PSYNTH(ROOTi)

PMPY - Polynomial Multiply
POLYi = POLYj * POLYk

PPRN - Polynomial Print
Print out POLYi

PRTS - Find Roots Of Polynomial
ROOTi = Roots of POLYi

PSUB - Polynomial Subtract
POLYi = POLYj - POLYk

S-PLANE OPERATORS

CPYPS - Copy Polynomials Into S-Plane Transfer Function
SPTFi = POLYj / POLYk

CPYSP - Copy S-Plane Transfer Function Into Polynomials
POLYj = numerator of SPTFi
POLYk = denominator of SPTFi

SELCR - Eliminate Common Roots From S-Plane Transfer Function
SPTFi = SPTFi with common roots eliminated

SFREQ - S-Plane Frequency Response
Compute frequency response of SPTFi

SLOCI - S-Plane Root Locus
Compute root locus of SPTFi

SNORM - Normalize S-Plane Transfer Function
SPTFi = SPTFi with coefficients normalized

SPADD - S-Plane Transfer Function Add
SPTFi = SPTFj + SPTFk

SPCNGC - Change Coefficients Of S-Plane Transfer Function SPTFi

SPCNGR - Change Roots Of S-Plane Transfer Function SPTFi

SPDIV - S-Plane Transfer Function Divide
SPTFi = SPTFj / SPTFk

SPEQU - S-Plane Transfer Function Equal
SPTFi = SPTFj

SPLDC - S-Plane Transfer Function Load, Coefficient Form
SPTFi = POLYN / POLYD

SPLDR - S-Plane Transfer Function Load, Root Form
SROOTi = ROOTN / ROOTD , SPTFi = PSYNTH(SROOTi)

SPMPY - S-Plane Transfer Function Multiply
SPFTi = SPTFj * SPTFk

SPPRN - S-Plane Transfer Function Print
Print out SPTFi

SPRTS - Find Roots Of S-Plane Transfer Function
SROOTi = Roots of SPTFi

SPSUB - S-Plane Transfer Function Subtract
SPTFi = SPTFj - SPTFk

STIME - Inverse Laplace Transform and Time Response
Compute time response of SPTFi by partial fraction expansion

SWMRX - S-to-W Plane Multirate Transform (slow-to-fast sampler)
WPTFi = w plane multirate transform of SPTFj

SWXFM - S-to-W Plane Transform
WPTFi = w plane transform of SPTFj

SZMRX - S-to-Z Plane Multirate Transform (slow-to-fast sampler)
ZPTFi = z plane multirate transform of SPTFj

SZXFM - Z-to-Z Plane Transform
ZPTFi = z plane transfrom of SPTFj

Z-PLANE OPERATORS

CPYPZ - Copy Polynomials Into Z-Plane Transfer Function
ZPTFi = POLYj / POLYk

CPYZP - Copy Z-Plane Transfer Function Into Polynomials
POLYj = numerator of ZPTFi
POLYk = denominator of ZPTFi

ZELCR - Eliminate Common Roots From Z-Plane Transfer Function
ZPTFi = ZPTFi with common roots eliminated

ZFREQ - Z-Plane Frequency Response
Compute frequency response of ZPTFi

ZLOCI - Z-Plane Root Locus
Compute root locus of ZPTFi

ZMRFQ - Z-Plane Multirate Frequency Response
Compute multirate rate frequency response of ZPTFi
by application of frequency decomposition method

ZMRXFM - Z-Plane Multirate Transform By Frequency Decomposition
(fast-to-slow sampler)
ZPTFi = Multirate transform of ZPTFj by application
of frequency decomposition method.

ZNORM - Normalize Z-Plane Transfer Function
ZPTFi = ZPTFj with coefficients normalized

ZPADD - Z-Plane Transfer Function Add
ZPTFi = ZPTFj + ZPTFk

ZPCNGC - Change Coefficients Of Z-Plane Transfer Function ZPTFi

ZPCNGR - Change Roots Of Z-Plane Transfer Function ZPTFi

ZPDIV - Z-Plane Transfer Function Divide
ZPTFi = ZPTFj / ZPTFk

ZPEQU - Z-Plane Transfer Function Equal
ZPTFi = ZPTFj

ZPLDC - Z-Plane Transfer Function Load, Coefficient Form
ZPTFi = POLYN / POLYD

ZPLDR - Z-Plane Transfer Function Load, Root Form
ZROOTi = ROOTN/ ROOTD, ZPTFi = PSYNTH(ZROOTi)

ZPMPY - Z-Plane Transfer Function Multiply
ZPTFi = ZPTFj * ZPTFk

ZPPRN - Z-Plane Transfer Function Print
Print out ZPTFi

ZPRTS - Find Roots Of Z-Plane Transfer Function
ZROOTi = Roots of ZPTFi

ZPSUB - Z-Plane Transfer Function Subtract
ZPTFi = ZPTFj - ZPTFk

ZSXFM - Z-to-S Root Transformation
Compute "s plane equivalent" of roots of ZPTFi

ZTIME - Inverse Z-Transform and Time Response
Compute time response of ZPTFi by power series

ZVCNG - Z-to-ZN Transform
ZPTFi = ZPTFj with z replaced with z**n

ZWXFM - Z-to-W Plane Transform
WPTFi = Bilinear transform of ZPTFi

W-PLANE OPERATORS

CPYPW - Copy Polynomials Into W-Plane Transfer Function
WPTFi = POLYj / POLYk

CPYWP - Copy W-Plane Transfer Function Into Polynomials
POLYj = numerator of WPTFi
POLYk = denominator of WPTFi

WELCR - Eliminate Common Roots From W-Plane Transfer Function
WPTFi = WPTFi with common roots eliminated

WFREQ - W-Plane Frequency Response
Compute frequency response of WPTFi

WLOCI - W-Plane Root Locus
Compute root locus of WPTFi

WMRFQ - W-Plane Multirate Frequency Response
Compute multirate frequency response of WPTFi by application of frequency decomposition method

WMRXFM - W-Plane Multirate Transform By Frequency Decomposition (fast-to-slow sampler)
WPTFi = Multirate transform of WPTFj by application frequency decomposition method

WNORM - Normalize W-Plane Transfer Function
WPTFi = WPTFi with coefficients normalized

WPADD - W-Plane Transfer Function Add
WPTFi = WPTFj + WPTFk

WPCNGC - Change Coefficients Of W-Plane Transfer Function WPTFi

WPCNGR - Change Roots Of W-Plane Transfer Function WPTFi

WPDIV - W-Plane Transfer Function Divide
WPTFi = WPTFj / WPTFk

WPEQU - W-Plane Transfer Function Equal
WPTFi = WPTFj

WPLDC - W-Plane Transfer Function Load, Coefficient Form
WPTFi = POLYN / POLYD

WPLDR - W-Plane Transfer Function Load, Root Form
WROOTi = ROOTN / ROOTD, WPTFi = PSYNTH(WROOTi)

WPMPY - W-Plane Transfer Function Multiply
WPTFi = WPTFj * WPTFk

WPPRN - W-Plane Transfer Function Print
Print out WPTFi

WPRTS - Find Roots Of W-Plane Transfer Function
WROOTi = Roots of WPTFi

WPSUB - W-Plane Transfer Function Subtract
WPTFi = WPTFj - WPTFk

WSXFM - W-to-S Root Transformation
Find "s plane equivalent" of roots of WPTFi

```
WZXFM   - W-to-Z Plane Transform
          ZPTFi = Bilinear transform of WPTFj
```

MISCELLANEOUS OPERATORS

```
DTERM   - Determinant Of Matrix M(s) With Substitution Of Vector B(s)
          For Use In Transfer Function Evaluation Via Cramer's Method
          POLYi = det M(s) with column j replaced with vector B(s)
                  (j=0 interpreted to mean no column substitution)

DETRM   - Old Version Of Operator DTERM
          (No Substitution Of B Vector)

STORE   - Store Data From Current Interactive Job
          Data stored on file TAPE31

RESTORE - Restore Data From Old Interactive Or Batch Job
          Data read from file TAPE30
```

APPENDIX B. DESCRIPTION OF PROPOSED ADVANCED USER MODE

Although the program produces a very detailed set of prompts to enable a new user to easily use the program, the experienced user will find that some of the prompts are excessively long. To eliminate some of these prompts, an advanced user mode will be implemented in the near future.

The proposed advanced user mode is invoked by including arguments with the LCAP2 operators. The general form of the operators will be

$$\text{OPERAT}(p_1, p_2, \ldots\ldots, p_n)$$

where OPERAT is an LCAP2 operator and the p_i's are optional[1] parameters.

The parameters can be constants use for specifying identifiers for the polynomials and transfer functions or they can be simple expressions used for specifying the value of a variable. For example, the operator

```
szxfm(3,2,sampt=.05,delay=.01,zoh=1)
```

will compute the z-transform of *s-plane transfer* function 2 and store the results into z-plane transfer function 3 using the values entered for the variables sampt, delay and zoh. These three variables are the name of the FORTRAN variable used in the batch version of LCAP2.

To maintain as much commonality with the batch version, the left-most arguments of the interactive operator will be identical to those used by the batch version. In general, these arguments are used to specify the indices or identifiers of the polynomials or transfer functions involved. Furthermore, there is a constraint that the number of these integer arguments must be equal to the same number arguments for the batch version.

If a value of 0 is entered where the indice of the operand is expected, as in

```
szxfm(3,0,sampt=.05,delay=.01,zoh=1)
```

the program will prompt the user to enter data for the s-plane transfer function. If a value of 0 is entered where the indice of the resultant transfer function is expected, as in

[1] There are constraints on the first few parameters if the argument form is used. This is described on the following pages.

```
szxfm(0,2,sampt=.05,delay=.01,zoh=1)
```

the program will automatically assign an unused index to the resultant z-plane transfer function.

After the integer constants, the remaining arguments are optional and must be expressions. These expressions are used to assign values to the same FORTRAN variables used by the batch version of LCAP2. If the user enters a value for a required variable, the program will not prompt the user for this variable. All required variables not set by the user will be prompted by the program.

The arguments form for all the LCAP2 operators is given below. The argument names are the same as those used in the batch version.

ARGUMENT FORM OF THE POLYNOMIAL OPERATORS

```
PADD(i,j,k)
PCNGC(i)
PCNGR(i)
PEQU(i,j)
PLDC(i)
PLDR(i)
PMPY(i,j,k)
PPRN(i)
PRTS(i)
PSUB(i,j,k)
```

ARGUMENT FORM OF THE S-PLANE OPERATORS

```
CPYPS(i,j,k)
CPYSP(i,j,k)
SELCR(i)
SFREQ(i,rad= ,fdelay= ,fauto= ,nomeg= )
SLOCI(i,nloci= ,kflg= ,kdelt= )
SNORM(i,nrmfg= ,knorm= )
SPADD(i,j,k)
SPCNGC(i)
SPCNGR(i)
SPDIV(i,j,k)
SPEQU(i,j)
SPLDC(i)
SPLDR(i)
SPMPY(i,j,k)
SPPRN(i)
SPRTS(i)
SPSUB(i,j,k)
STIME(i,tzero= ,tend= ,tdelt= ,tmagn= ,step= )
SWMRX(i,j,sampt= ,delay= ,zoh=, ntger= )
SWXFM(i,j,sampt= ,delay= ,zoh= )
SZXFM(i,j,sampt= ,delay= ,zoh= ,ntger= )
SZXFM(i,j,sampt= ,delay= ,zoh= )
```

ARGUMENT FORM OF THE Z-PLANE OPERATORS

```
CPYPZ(i,j,k)
CPYZP(i,j,k)
ZELCR(i)
ZFREQ(i,rad= ,fdelay= ,sampt= ,fauto= ,nomeg= )
ZLOCI(i,nloci= ,kflg= ,kdelt= )
ZNORM(i,nrmfg= ,knorm= )
ZMRFQ(i,rad= ,fauto= ,nomeg= ,sampt= ,mtger= )
ZMRXFM(i,j,sampt= ,ntger= )
ZPADD(i,j,k)
ZPCNGC(i)
ZPCNGR(i)
ZPDIV(i,j,k)
ZPEQU(i,j)
ZPLDC(i)
ZPLDR(i)
ZPMPY(i,j,k)
ZPPRN(i)
ZPRTS(i)
ZPSUB(i,j,k)
ZSXFM(i,j,sampt= ,zoh= )
ZTIME(i,sampt= ,tend= ,tmagn= ,tstep= )
ZVCNG(i,j,ntger= )
ZWXFM(i,j,sampt= )
```

ARGUMENT FORM OF THE W-PLANE OPERATORS

```
CPYPW(i,j,k)
CPYWP(i,j,k)
WELCR(i)
WFREQ(i,rad= ,fauto= ,nomeg=,)
WLOCI(i)
WMRFQ(i,rad= ,fauto= ,nomeg= ,sampt= ,ntger= )
WMRXFM(i,j,sampt= ,ntger= )
WNORM(i,nrmfg= ,knorm= )
WPADD(i,j,k)
WPCNGC(i)
WPCNGR(i)
WPDIV(i,j,k)
WPEQU(i,j)
WPLDC(i)
WPLDR(i)
WPPRN(i)
WPMPY(i,j,k)
WPRTS(i)
WPSUB(i,j,k)
WSXFM(i,sampt= )
WZXFM(i,j,sampt= )
```

ARGUMENT FORM OF THE MISCELLANEOUS OPERATORS

```
END
DTERM(i,j)
DETRM(i)
STORE
RESTORE
```

DEFINITION OF LCAP2 ARGUMENTS

DELAY - Delay Time For Sampled-data Transform
FAUTO - .NE.0 For Automatic Selection Of Frequency Values Used In Evaluating Frequency Response
FDLAY - Time Delay For S-plane Frequency Response
KDELT - Incremental Value For Root Locus Gain Selection
KFLG - Flag For Computing Root Locus Gains
.EQ.0 For Computing Gains By Ratio KDELT
.NE.0 For Computing Gains By Increment KDELT
KNORM - Gain Used For Normalizing Polynomial Or Transfer Function
MTGER - Integer M For Multirate Configuration
NLOCI - Number of Gain Values To Be Used With Root Locus Gain Calculation
NOMEG - Number of Frequency Values To Be Used With Automatic Frequency Point Selection
NRMFG - Polynomial And Transfer Function Normalization Flag
.EQ.0, Low Order Non-zero Coefficient Of Numerator Set To KNORM And All Other Coefficients Normalized To This Value (Bode Form)
.NE.0, High Order Coefficient Of Numerator Set To KNORM And All Other Coefficients Normalized To This Value (Root Locus Form)
NTGER - Integer N For Multirate Configuration
RAD - .NE.0 For frequency in rad/sec
.EQ.0 For frequency in Hz
SAMPT - Sampling Period
STEP - .NE.0 For Step Response When Computing Time Response
.EQ.0 For Impulse Response When Computing Time Response
TDELT - Incremental Time For S-plane Time Response
TEND - End Time For Time Response Calculation
TMAGN - Magnitude Of Input For Time Response Calculation
TZERO - Start Time For S-plane Time Response Calculation
ZOH - .NE.0, Include Zero Order Hold In Computation Of Sampled-Data Transform
.EQ.0, Do Not Include Zero Order Hold

Preprocessor routines have been written to 'crack' or decipher the argument form of the LCAP2 operators. Before implementation of the proposed advanced user mode, suggestions for improvements from users would be appreciated.

APPENDIX C. PROGRAM AVAILABILITY

The source code for this program is available to agencies supporting DOD projects and studies. The requester, however, should be aware that some non-ANSI FORTRAN code and one assembly language subroutine are utilized. If the program is be be run on a CDC 835 computer under the INTERCOM system and NOS 1 operating system, no problems should be encountered. If the program is to be run on any other computer, modifications to the program most likely will have to be made. The following facts will be of interest if modifications are to be made:

(a) A FORTRAN version of CXMTX1, which is written in assembly language, is available.

(b) Non-ANSI CDC FORTRAN 4 ENCODE and DECODE statements must be replaced with ANSI standard internal write and read statements. Even if the target computer and operating system supports the ENCODE and DECODE statements modifications might still be necessary since the ENCODE statements used in LCAP2 makes use of the fact that the CDC word length is 60 bits long.

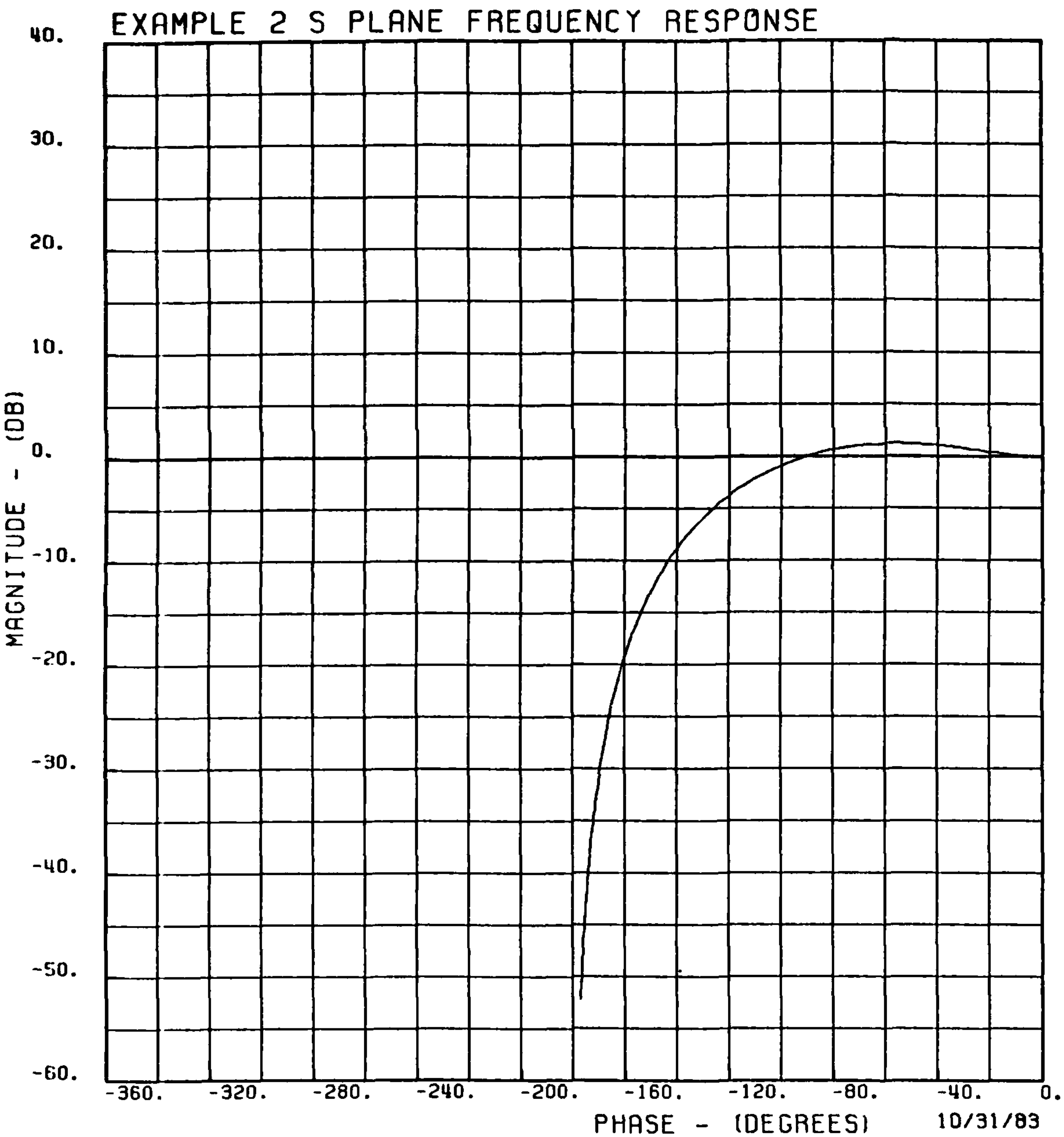
(c) Work has been initiated to convert this program to FORTRAN 5 and have it operational for the IBM 3033 computer as well.

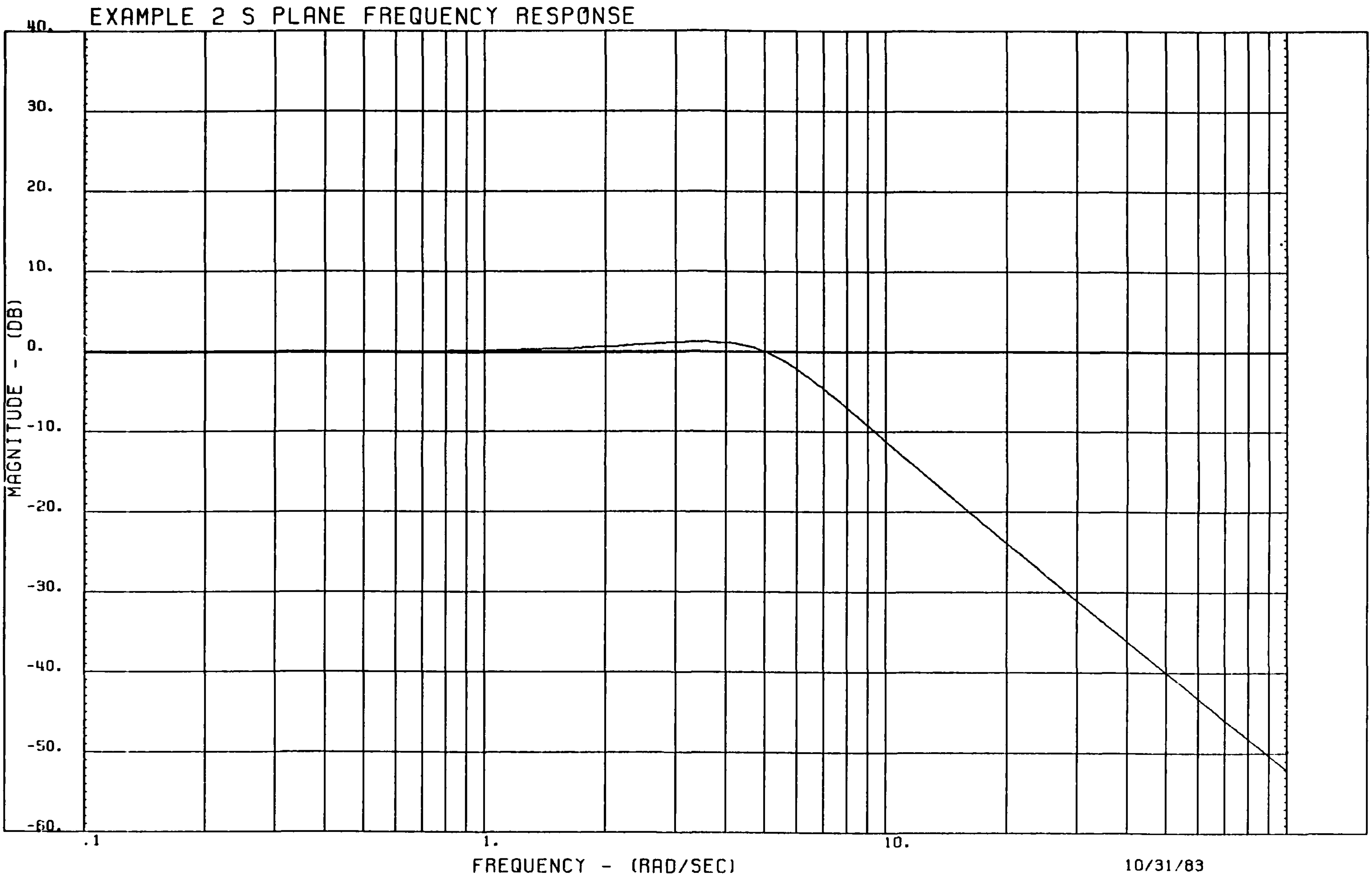
This program as well as this user's guide is in a continuous process of evolution and development. For these reasons, this program and related materials will be made available under the understanding that no warranty, express or implied, is made by the Aerospace Corporation as to the accuracy and functioning of the program and related materials and that no responsibility for program maintenance is implied.

The current reproduction and handling fee is $220.00. Request for a copy of this program, which also includes the Batch version of LCAP2 as well, should be addressed to:

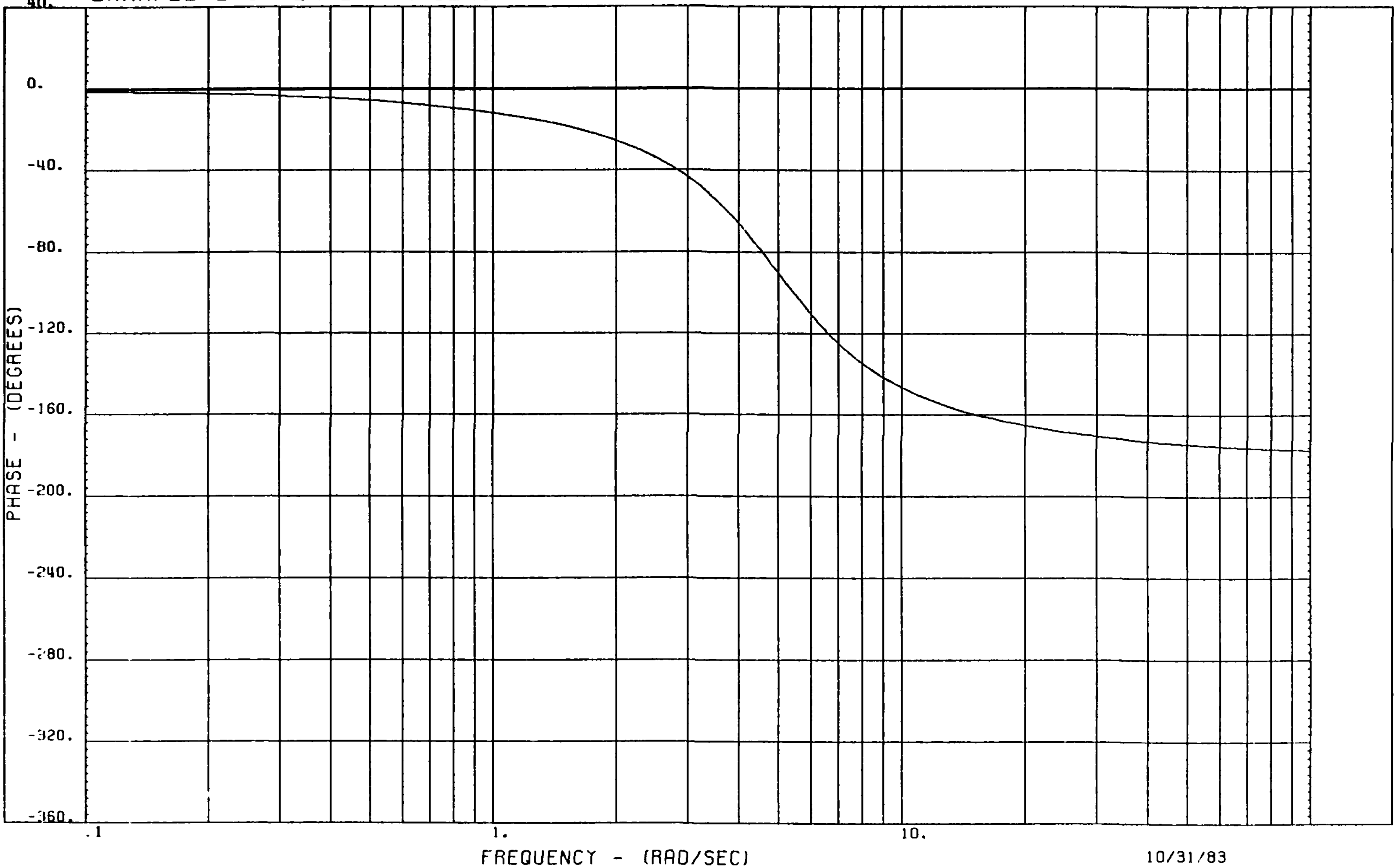
Administrator
Information Processing Division
The Aerospace Corporation
2350 E. El Segundo Blvd.
El Segundo, California 90245

APPENDIX D. HARDCOPY PLOTS FROM EXAMPLES 2,6,7,8,10 AND 11

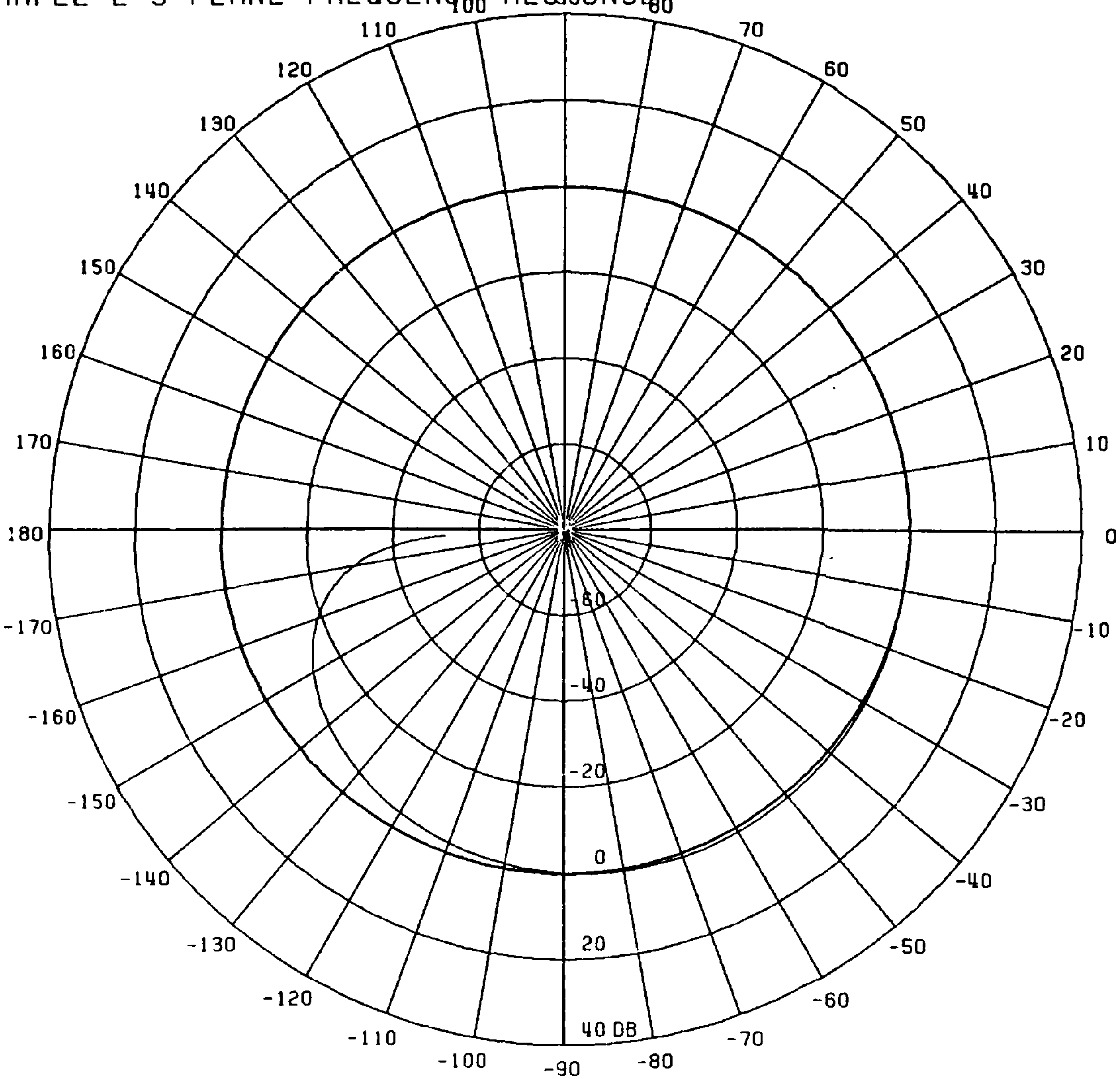

EXAMPLE 2 S PLANE FREQUENCY RESPONSE
40.
30.
20.
10.
0.
-10.
-20.
-30.
-40.
-50.
-60.
MAGNITUDE - (DB)
-360.
-320.
-280.
-240.
-200.
-160.
-120.
-80.
-40.
0.
PHASE - (DEGREES)
10/31/83


EXAMPLE 2 S PLANE FREQUENCY RESPONSE
40.
30.
20.
10.
0.
-10.
-20.
-30.
-40.
-50.
-60.
MAGNITUDE - (DB)
.1
1.
10.
FREQUENCY - (RAD/SEC)
10/31/83

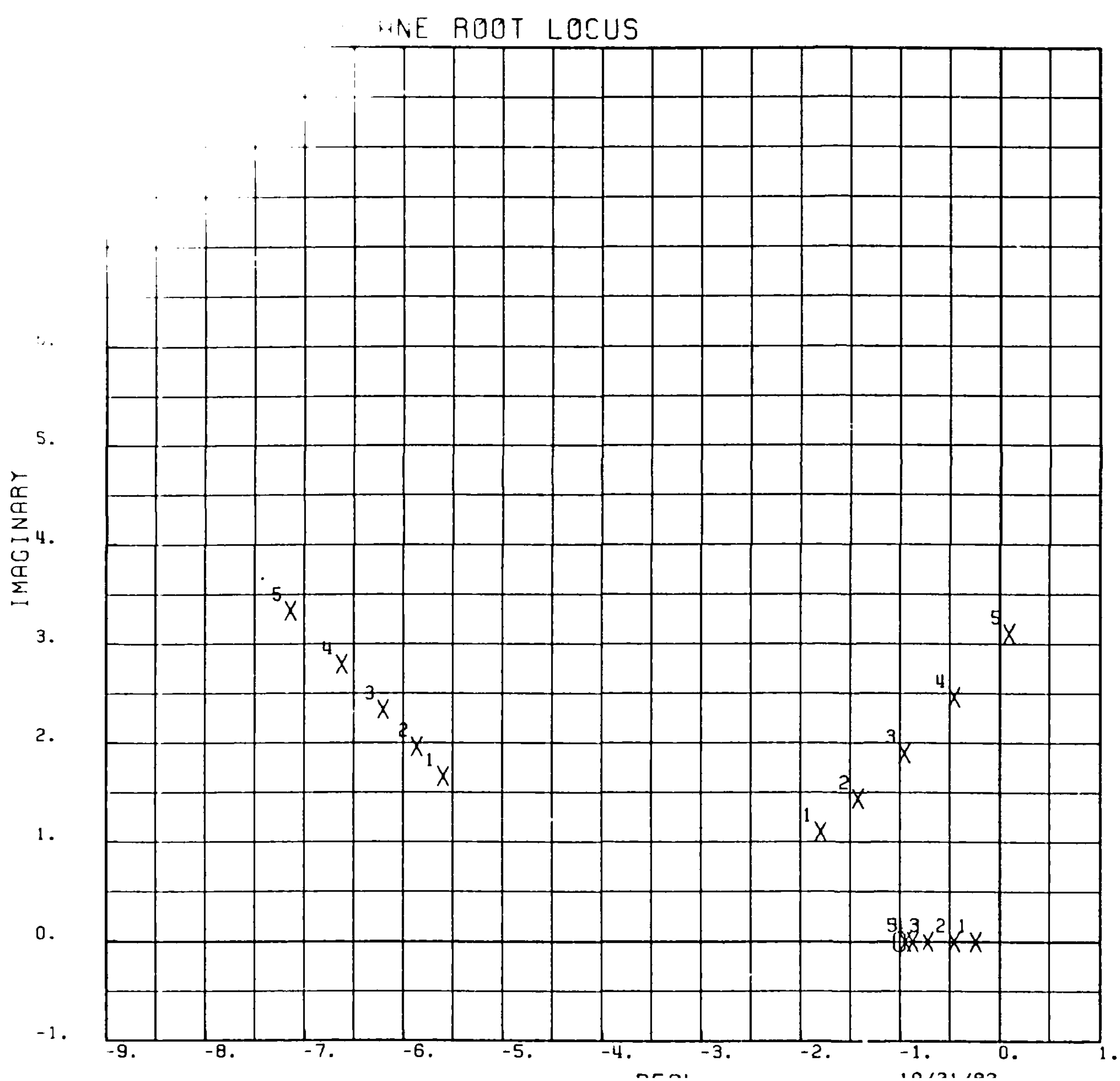
EXAMPLE 2 S PLANE FREQUENCY RESPONSE



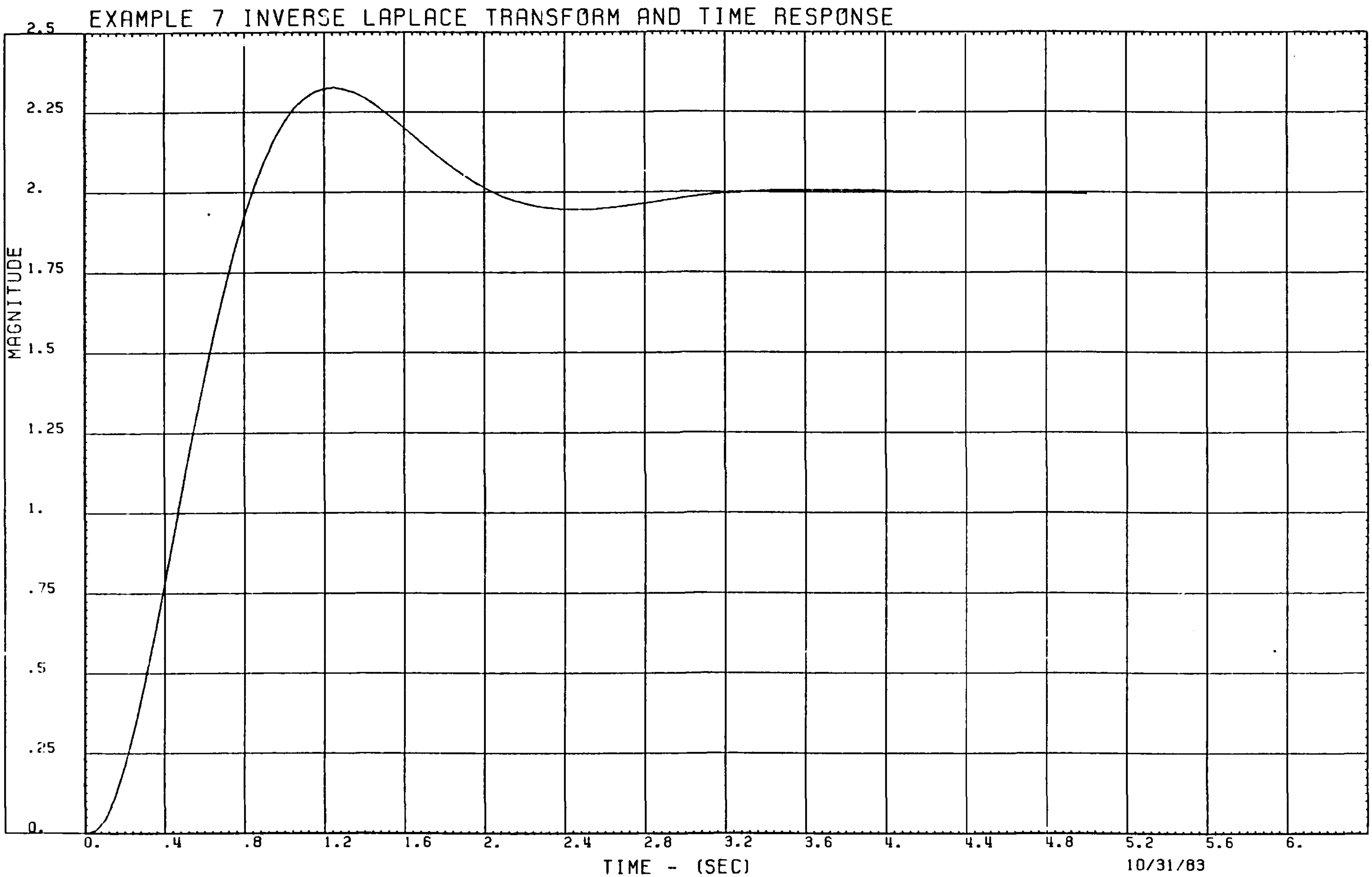
EXAMPLE 2 S PLANE FREQUENCY RESPONSE



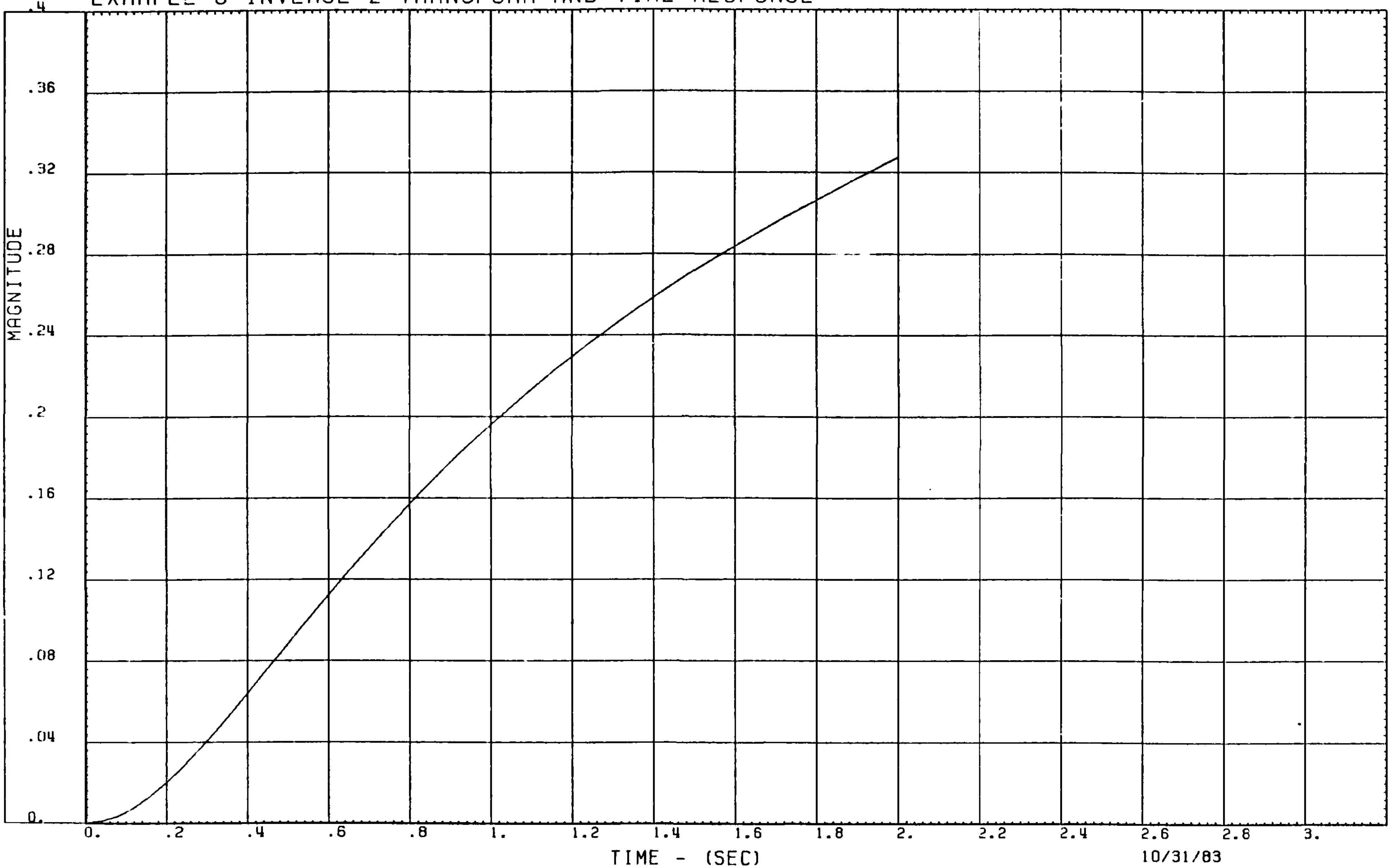
10/31/83

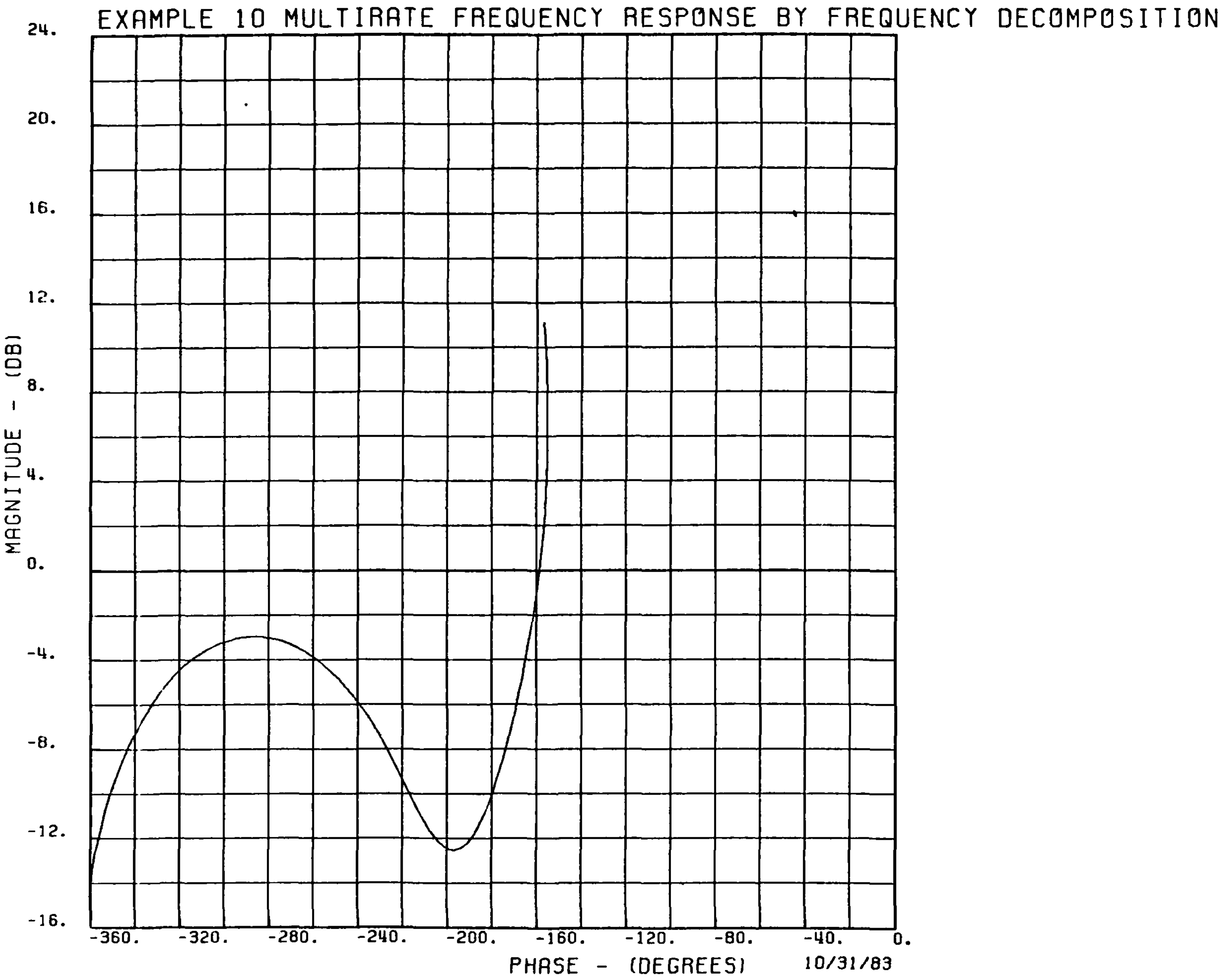


GAIN NO.	GAIN
1	.12500000
2	.25000000
3	.50000000
4	1.0000000
5	2.0000000


EXAMPLE 7 INVERSE LAPLACE TRANSFORM AND TIME RESPONSE
MAGNITUDE
2.5
2.25
2.
1.75
1.5
1.25
1.
.75
.5
.25
0.
0.
.4
.8
1.2
1.6
2.
2.4
2.8
3.2
3.6
4.
4.4
4.8
5.2
5.6
6.
TIME - (SEC)
10/31/83

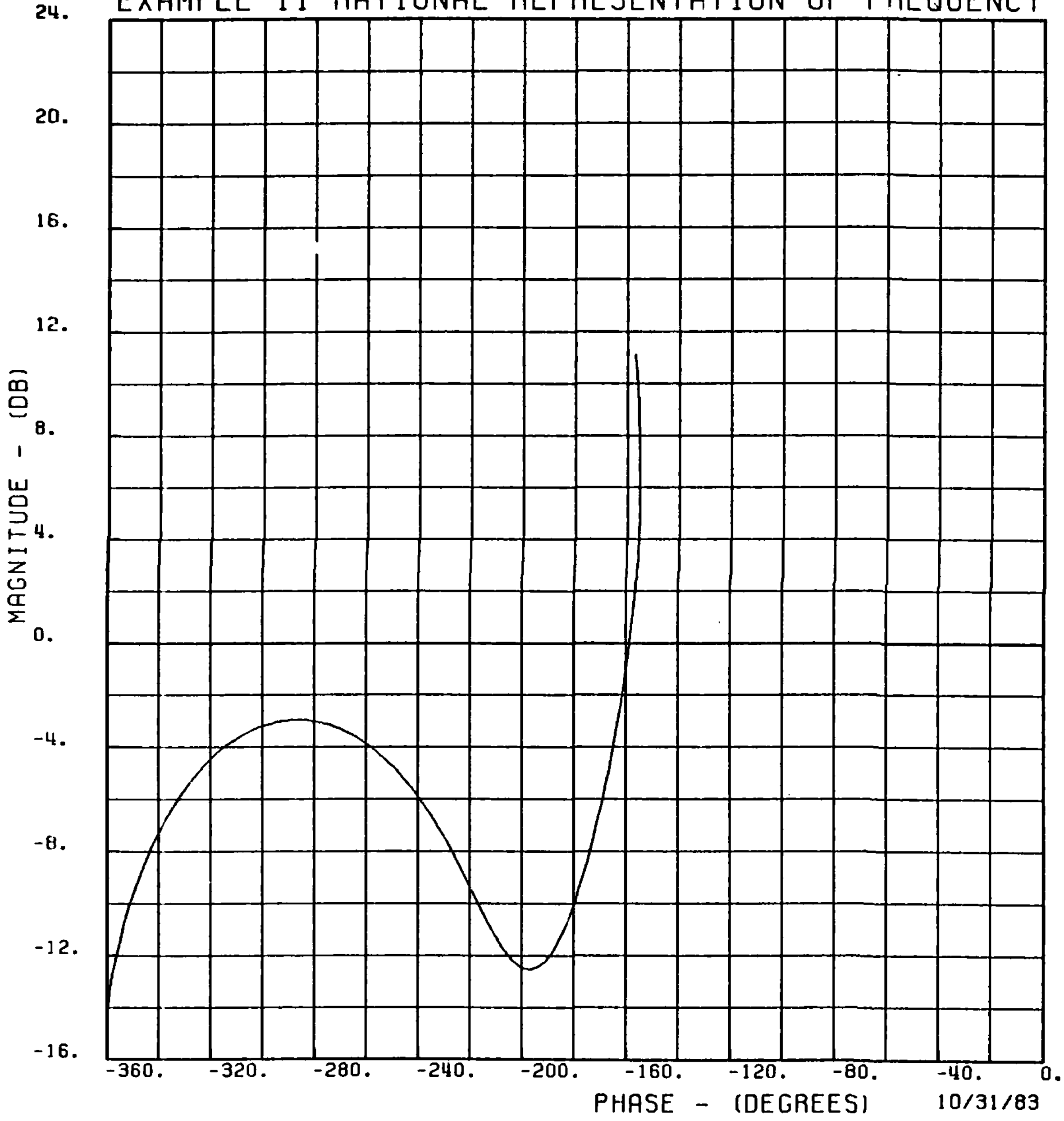
EXAMPLE 8 INVERSE Z TRANSFORM AND TIME RESPONSE





EXAMPLE 10 MULTIRATE FREQUENCY RESPONSE BY FREQUENCY DECOMPOSITION
24.
20.
16.
12.
8.
4.
0.
-4.
-8.
-12.
-16.
MAGNITUDE - (DB)
-360.
-320.
-280.
-240.
-200.
-160.
-120.
-80.
-40.
0.
PHASE - (DEGREES)
10/31/83

EXAMPLE 11 RATIONAL REPRESENTATION OF FREQUENCY DECOMPOSITION METHOD



END

FILMED