DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1973/31

PROGRAM MANYPLOT - COMPUTER CALCULATED INVERSE LAPLACE TRANSFORMS FOR PREDICTION OF CIRCUIT BEHAVIOUR

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CONTENTS

SUMMARY

Programs Manyplot and Merry were written specifically to aid the Design & Development Group in complex circuit analysis of passive and active filter circuits. The use of numerically calculated inverse Laplace transforms allows previously impossible analysis to be carried out rapidly. These programs should be of use in determining accurate response and system curves for magnetotelluric and other geophysical electronic measuring equipment.

1. INTRODUCTION

1.0 In analogue electronics, frequent use is made of the 'pole-zero' method of describing a circuit transfer function by its complex singularities. Specification of these singularities and a gain factor is sufficient to describe the behaviour of a circuit's output in response to any input. The program described here will, given these singularities and a gain factor, calculate amplitude and phase information for sinusoidal input and will calculate system response to a delta function, unit step, or unit ramp function using numerically calculated inverse Laplace transforms.

1.1 The program, called MANYPLOT, produces line printer and drum plotter output of phase and amplitude for sinusoidal inputs. For the other three types of imput only line printer outputs are produced, as very large output values may be generated with lightly damped systems. Selection of plotter scale is automatically optimized, and suitable logarithmic intervals are automatically selected for frequency intervals.

1.2 MANYPLOT is usually used as a relocatable binary deck generated from a Fortran source deck. An interactive program (MERRY) is available to pass data to MANYPLOT and control its break-in or execution. MERRY is a binary program generated by the assembly language program MERRYGEN and may be entered from a remote terminal to the CSIRO's CDC 3600 computer in Canberra.

1.3 MANYPLOT should have immediate application as an electronic design aid and perhaps in the field of mechanical engineering.

2. THEORY

2.0 Every linear passive electronic circuit can be reduced to an equivalent circuit of resistors, capacitors, and inductors. (The arguments to be used will also apply to circuits containing active elements). This equivalent circuit may be further reduced by considering capacitors and inductors as reactances, having a certain impedance and associated phase angle. Thus every circuit may be reduced to an equivalent arrangement of resistors and reactances. It is then fairly simple to write down, for such a circuit, the output voltage as a function of any impressed input voltage and of the resistances and reactances in the circuit.

2.1 We may write the generalized reactances as functions of a complex differential operator which we will call 's'. Then the generalized inductive reactance may be written as sL and the generalized capacitive reactance as 1/sC. Thus the original equivalent circuit mentioned may be expressed as a function of constants and s. This representation, being equivalent to the original circuit, will of necessity contain all useful information on the system; we can, then, put all knowledge of the circuit's behaviour into the ratio of two polynomials in s. This ratio of polynomials is known as the transfer function for the circuit and may be conventionally written as H(s).

i.e. $$H(s) = \frac{V\ out(s)}{V\ in(s)} = \frac{a_n s^n + a_{n-1} s^{n-1} + \ldots + a_o}{b_m s^m + b_{m-1} s^{m-1} + \ldots + b_o}$$

This ratio of polynomials may be factored into a quotient of products of single-order terms as follows:

$$H(s) = K \cdot \frac{(s-z_o)\ (s-z_1)\ (s-z_2)\ \ldots\ (s-z_n)}{(s-p_o)\ (s-p_1)\ (s-p_2)\ \ldots\ (s-p_m)}$$

where for $s = z_o, z_1, z_2 \ldots z_n$, $H(s) = 0$;

these $z_o, z_1, z_2 \ldots z_n$ are the zeros of the transfer function H(s)

and for $s \rightarrow p_o, p_1, p_2 \ldots p_n$, $H(s) \rightarrow \infty$;

these $p_o, p_1, p_2 \ldots p_n$ are then the poles of the transfer function.

2.2 Thus our knowledge of the original circuit reduces to a knowledge of the constant 'K' plus the poles and zeros for the circuit. In theory, it is a comparatively simple matter to find K and the poles and zeros of a circuit. It remains for the circuit designer to be able to predict the circuit behaviour from knowledge of K and the poles and zeros; or, knowing that a certain number of poles and zeros gives him the response function he desires, to find the values of the poles and zeros and then work back and synthesize a circuit from them.

2.3 One of the simplest forcing functions used is the sine wave; for this we write $s = jw$ ($j = \sqrt{-1}$ and w = angular frequency in radians per second) and consider the complex function:

$$H(jw) = K \cdot \frac{(jw-z_o)(jw-z_1) \ldots (jw-z_n)}{(jw-p_o)(jw-p_1) \ldots (jw-p_m)} = \frac{V\ out\ (jw)}{V\ in\ (jw)}$$

This completely determines the output in terms of the input multiplied by a complex function containing phase and amplitude information. This information may be extracted as phase and amplitude information:

for amplitude, $\frac{V\ out}{V\ in} = K \cdot \sqrt{Re^2 + Im^2}$ where Re and Im are the respective real and imaginary parts of H(jw)/K.

Arctan (Im/Re) gives the desired phase relation from output to imput. Thus, all that is necessary for the extraction of the phase and amplitude from the poles and zeros is the finding of the real and imaginary parts of H(s) with s = jw. This is a tedious job if there are many poles and zeros and if many frequencies ($w = 2\pi f$) are to be considered; the task is therefore ideally suited to computer solution. Just how this is done may be seen from the flow chart provided (cf. Chapter 3 and Appendix 2).

2.4 A knowledge of the phase and amplitude response of a circuit to sine wave excitation is unfortunately not enough for the electronics designer. He usually wants to know also how the circuit reacts to ramp-type functions, delta functions (unit impulse functions), and step functions. This is not as easy a problem as that of phase and amplitude. It becomes necessary to introduce the notion of the Laplace Transform, which is a generalization of the Fourier Transform. The Laplace Transform enables transformation from the time domain to the complex frequency domain and back again using the inverse transform. The Laplace Transform is defined as:

$$L(F(t)) = f(s) = \int_0^{\infty} e^{-st} F(t).dt$$

and the inverse transform may be written:

$$F(t) = L^{-1}(f(s)) = \frac{1}{2\pi j} \int_{\sigma_1 - j\infty}^{\sigma_1 + j\infty} f(s)\, e^{st}\, .ds$$

where we assume F(t) = 0 if $t < 0$ and $s = \sigma + jw$ with $0 < \sigma_1 > \sigma$ for all σ

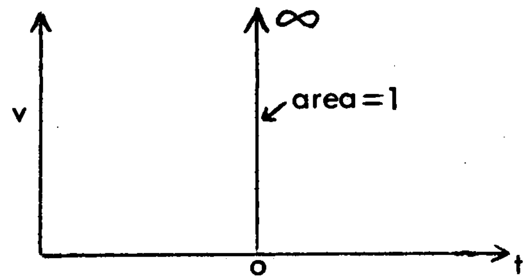
2.5 In electronics, one is most frequently interested in transformations from the complex frequency (s) domain to the time (t) domain. One is therefore concerned with the inverse transforms of H(s) functions. For polynomials up to third or fourth order, it is reasonably easy to calculate the functional form of the inverse transform, but for higher-order ratios of polynomials the task becomes increasingly difficult without machine aid. The program to be described successfully carries out the inverse Laplace Transform for ratios of two polynomials and produces unit impulse, unit step, and unit ramp information from the values of poles and zeros fed into it. The program accepts any combination of up to 24 poles and 24 zeros, which may be either real or complex. There must be more poles than zeros.

2.6 Let us consider $H(S) = \dfrac{E\ out\ (s)}{E\ \ in\ (s)}$ where E out (s) is the Laplace

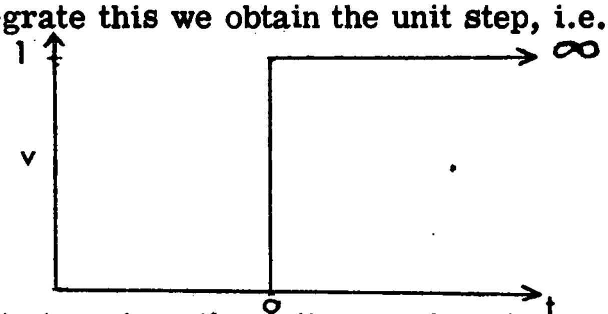
Transform of the output $e_{out}(t)$ and $E_{in}(s)$ is the Laplace Transform of the input $e_{in}(t)$. But if $e_{in}(t)$ is a delta function, $E_{in}(s) = 1$ and thus $H(s) = E_{out}(s)$. Therefore $h(t) = L^{-1}\ H(S)$ or $e_{out}(t) = L^{-1}\ H(S)$.

i.e., the impulsive response of the transfer function H(S) is simply the inverse Laplace Transform of the transfer function.

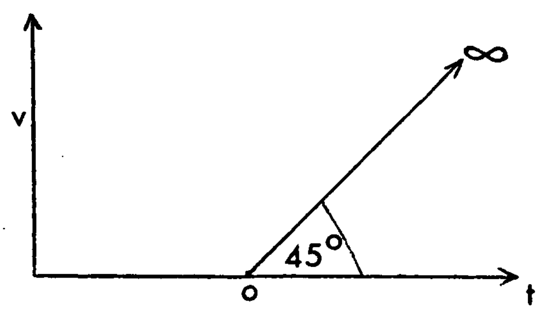
The unit impulse function looks like this:



If we integrate this we obtain the unit step, i.e.:



Integrating the unit step gives the unit ramp function:



2.7 As it stands, the definition of the inverse transform is awkward to use in machine oriented calculations. However, by manipulating the definition, it is possible to derive an expression for polynomial ratios, known as the Heaviside expansion formula. This is:

$$L^{-1}\left[\frac{P(S)}{Q(S)}\right] = \sum_{k-1}^{n} \frac{P(\alpha k)e^{\alpha kt}}{Q'(\alpha k)}$$

where P(s) and Q(s) are the two polynomials; the roots (and hence the poles) of Q(s) are $\alpha_1, \alpha_2, \alpha_3, \ldots \alpha_n$. P(s) is of degree less than n and the roots of Q(s) are to be all distinct. $Q'(\alpha_k)$ is the derivative of Q(s) with respect to s at the point $s = \alpha_k$.

2.8 It can be seen that for large n, any sort of hand calculations using the above formula would be extremely long and tedious and would rely on a high calculation accuracy from step to step. The problem thus lends itself well to computer calculation. The method of integration of the transfer function for unit step and unit ramp is simple, as integration is equivalent to multiplication by a 1/s term or equivalently putting an extra pole into the system at s = zero. This increases the order of polynomial Q(s) by 1.

2.9 There are only two restrictions in the Heaviside expansion formula. Multiple roots of Q(s) are forbidden and the order of P(s) must be less than that of Q(s). The multiple roots problem can be overcome quite simply in computer applications by making identical roots slightly different to machine accuracy (10 figures) but not sufficiently different to affect the desired accuracy of the final result (seldom any more than four to six significant figures). Unfortunately, at this stage, the one remaining restriction - that the order of P(s) be less than that of Q(s) - has not been overcome for the transient analysis part of the program but ramp and step response is slightly less restricted than unit impulse, owing to the addition of the poles at zero.

2.10 Numeric differentiation of polynomial Q(s) cannot easily be carried out with accuracy, so the differentiation is reduced to an algebraic manipulation in the following manner:

Consider $Q(s) = (s-a_1)(s-a_2)(s-a_3) \ldots (s-a_n)$

Differentiating gives $Q'(s) = -a_1 (s-a_2) \ldots (s-a_n - a_2 (s-a_1)(s-a_3) \ldots$

$\ldots (s-a_n)$ etc.

i.e. $$Q'(s) = \sum_{k=1}^{n} \left\{ -a_k \left[\prod_{\substack{m=1 \\ m \neq k}}^{n} (s-a_m) \right] \right\}$$

This then is an exact algebraic expression for the differentiation of Q(s), and has been used in the program.

2.11 As MANYPLOT is completely general, except for the restriction on the order of the zero polynomial (this is only a minor limitation), it would appear that the program could be used for calculating inverse Laplace Transforms of virtually any mathematical function - all functions being reducible to the ratio of two polynomials.

3. PROGRAM MANYPLOT

3.0 MANYPLOT was written in Fortran IV for the CDC 3600 computer. A flow chart may be seen in Appendix 2, and program listings in Appendix 1. Memory requirements for MANYPLOT and LAPLACE are 12 000 words (decimal), and execution times are roughly 30 seconds for a steady-state analysis and between ½ and 2 minutes for a transient analysis, depending upon the number of poles and zeros. MANYPLOT reads its data from a drum document called MANYDRUM, which is lost after MANYPLOT is executed. MANYDRUM is created and saved by MERRY (Chapter 5).

MANYPLOT:

(a) Reads all necessary data

(b) Formats all output for printing and/or plotting.

(c) Performs steady-state analysis as per (2.3) or

(d) Calls function LAPLACE (Chapter 4) which calculates the inverse Laplace Transforms and integrated transforms as per paragraphs 2.7 and 2.10.

3.1 As Manyplot chooses its own scales etc., all that is required in the form of data is as follows:

	Transient Analysis	Steady-state Analysis
(a)	Whether transient or steady state	Whether the transient or steady state
(b)	Poles and zeros	Poles and zeros
(c)	Gain factor	Gain factor
(d)	Transient time in seconds	Start frequency and stop frequency
(e)	Title for printouts	Title for plots and printouts

3.2 MANYPLOT can handle any number of poles and zeros. The only restriction lies in the dimensioning of arrays (complex), "Pole" and "Zero". These dimensions are nominally set to 24 each. Present input formating allows up to 9 poles/zeros.

3.3 Scales. Horizontal scales (i.e. frequency) on the plots are chosen to be 10 inch logarithmic intervals between the stipulated frequency limits. On the phase plot, the most suitable vertical scale in the following range is chosen (the scale is 10 inches high).

(a) $\pm$ 2000 degrees

(b) $\pm$ 500 degrees

(c) $\pm$ 250 degrees

(d) $\pm$ 100 degrees

(e) $\pm$ 50 degrees

(f) $\pm$ 25 degrees

(g) $\pm$ 5.0 degrees

The amplitude plot has a logarithmic vertical scale labelled from -25 to +25 decibels (10 inches high). This scale (and labelling) extends vertically upwards as far as necessary and moves the phase plot to make sufficient room if the amplitude plot goes above the +25 dB mark. If the amplitude curve attempts to drop below the -25 dB point, backing-off steps of 50 dB are added in as necessary to bring the curve back onto the area of the plot. All amplitude plots are normalized to commence at the +25 dB point, and the normalizing factor is printed on the plot. The title, as defined by the user, is also printed.

4. FUNCTION LAPLACE

4.0 Function LAPLACE is a real in line function called by MANYPLOT for calculating the inverse transform of H(s) as per paragraphs 2.7 and 2.10. The time and the number of integrations required are specified in the call, and gain factor, pole, and zeros are passed in common storage. Appendixes 1 and 2 contain listings and flow charts of LAPLACE.

5. PROGRAM MERRYGEN AND MERRY

5.0 MERRYGEN (Assembly language - Compass) is the generator for the binary program MERRY. MERRY operates in 2000 words of core in CSIRO's DAD console system in the CDC 3600 computer. The program operating in the console system allows interactive creation of a drum document labelled 'MANYDRUM' and will then break-in or execute MANYPLOT as required or delete the drum document with no break-in or execution. Many execution requests may be 'stacked' in the relevant execution list for multiple-job runs. The user can specify a unique title for each executed job for later identification.

5.1 MERRY asks a question, and the user responds by typing a reply. Typically, in 1 to 2 minutes a user can type in all necessary data and break-in or execute MANYPLOT.

5.2 The structure of MERRY can be seen from the flow chart (Appendix 3) and listings (Appendix 1).

5.3 User macro IOC performs I/O transfers between user and MANYDRUM. Subroutines MANY and XFER perform the actual read and writes. Subroutine SWAP initializes index registers needed in the augmented XMIT instruction. Subroutine CRACK decodes numbers typed into the teletype keyboard, and justifies them in binary words.

5.4 MERRY uses less than 600 words of core storage and uses roughly 1 to 2 secs of Central Processor (CPU) time per session.

6. OPERATING INSTRUCTIONS

6.0 The operating instructions pertain to MERRY. Ensure that both MERRY and MANYPLOT are in the Document Region under the user's charge code before starting.

6.1 Reference to Appendix 5 will show what form the interaction with MERRY will take. Lines are terminated by CR/LF. CTRL/BELL deletes the last character. CR and retype to delete a line.

6.2 Appendix 5 shows MERRY to be virtually self-explanatory, but paragraphs 6.3 to 6.5 contain a few pertinent notes on its use.

6.3 In response to 'How many poles' or 'How many zeros', a number from 0 to 9 should be typed in, in column one. (MERRY will accept any number from 0 to 99; MANYPLOT's format will accept only I1 at present).

6.4 At present, the reply to 'MANYPOLE or MANYPLOT' will always be 'MANYPLOT'. If a document labelled 'MANYPOLE' exists in the document region, MERRY can break-in or execute it.

6.5 In response to 'Type BK or EX else just interrupt', there are three replies:

BK - (1) Break-in MANYPLOT with 1 minute time limit (cost 2*CPU time) Computer response to this can be either of:

(a) Break-in request accepted.

(b) Break-in request rejected. Wait and interrupt i.e. LF.

EX - (2) Put MANYPLOT in execution list EL003 for execution (cost 1*CPU time)
Computer response to this can be either of:

(a) Execution request accepted.

(b) System busy. Wait and interrupt i.e. LF.

LF - (3) Go back to the start and start again from scratch.

6.6 After the computer responds to a BK or EX request, LF terminates the session and gives the cost in seconds (Break-in charges + console program charge).

7. REFERENCES AND ACKNOWLEDGEMENTS

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CONTROL DATA CORPORATION, 1968 - CDC 3600 computer system reference manual No. 60021300.

CSIRO, 1973 - DAD System reference manual.

DRABBLE, J.S. & PUMMEROY, N.R., 1970 - Graph plotting. CSIRO, Div. Computing Res., Tech. Note 35. (unpubl.).

SPIEGEL, M.R., 1965 - THEORY AND PROBLEMS OF LAPLACE TRANSFORMS. N.Y., McGraw Hill.

WALSH, J.B. & MILLER, K.S. 1960 - INTRODUCTORY ELECTRIC CIRCUITS. N.Y. McGraw Hill.

SEERS, K.J. of BMR Canberra provided many of the test cases for proving and testing MANYPLOT.

APPENDIX 1

LISTINGS FROM MANYPLOT, LAPLACE, AND MERRYGEN

```
*DOC    ,CCDMR*DA        ,MANYPLOT,,, CP00,,1051,,25/01/73
*MESSAGE,EXECUTED FROM DR. NO CARD INPUT OR OUTPUT. PLOT FROM PL.
*EQUIP,61=SV
*EQUIP,61=LP
*EQUIP,60=SV
*DRLOCATE,20,,MANYDRUM
*DFCOPDR,20,,MANYDRUM
*EQUIP,1=PL
*KTN,X,L
      PROGRAM MANYPLOT
C     PROGRAM MAY CONTAIN ANY COMBINATION OF UP TO 24 ZEROES AND/OR
C     24 POLES. NUMBER OF ZEROES TO BE GREATER THAN NUMBER OF POLES
C     FOR TRANSIENT ANALYSIS.
C     POLES OR ZEROES NEED NOT BE COMPLEX CONJUGATES.
      COMPLEX POLE(24),ZERO (24),SUM1,SUM2,S
      REAL LAPLACE, Z00(3)
      DIMENSION HEAD(3),PHASE(250),FREQ2(250),TITLE(5),WRT2(2),WRT4(2)
     1,WRT6(2),CHAR(2)
      COMMON POLE,ZERO,NZ,NP,FUDGE
      DATA(TYPE=8HTRANSIEN),(HEAD=19HMANYPLOT ANALYSIS. )
     1,(HERTZ=8HFREQ-HZ.),(DB1=3HDB.),(PHASE4=6HPHASE.)
     1,(PHASE5=8HDEGREES.),(TOP=8HTITLE - ),(WRT3=8H DB. OR )
     1,(WRT1=37H25 DB ON THE Y SCALE NORMALISED FROM )
     1,(WRT5=22H VOLTS. GAIN FACTOR = )
      FACTOR=1.0
      WRITE(61,10)
   10 FORMAT(24X*MANYPLOT ANALYSIS*/7X*ZEROES*)
      DO 20 K=1,24
   20 POLE(K)=ZERO(K)=CMPLX(0.,0.)
      READ(20,85)TITLE
   85 FORMAT(5A8)
      D=DATE(0)
C     FUDGE IS THE GAIN FACTOR.
      READ(20,30)FUDGE
   30 FORMAT(F80.5)
C     NZ IS THE NUMBER OF ZEROES.
      READ(20,60)NZ
      DO 40 J=1,NZ
C     READ IN REAL/IMAG PARTS OF ZEROES ALTERNATELY.
      READ(20,80)FIRST,FLAST
   40 ZERO(J)=CMPLX(FIRST,FLAST)
   50 FORMAT(A8,72X)
   60 FORMAT(I1)
      READ(20,60)NP
C     NP IS THE NUMBER OF POLES.
      DO 70 J=1,NP
C     READ IN REAL/IMAG PARTS OF POLES ALTERNATELY.
      READ(20,80)FIRST,FLAST
   70 POLE(J)=CMPLX(FIRST,FLAST)
   80 FORMAT(F80.8/F80.8)
      READ(20,50)ANAL
C     READ IN TRANSIENT ANALYSIS OR STEADY STATE ANALYSIS.
      IFLAG1=1
C     MAKE EQUAL POLES UNEQUAL BY A SMALL AMOUNT.
      DO 90 I=1,NP
      DO 90 J=1,NP
      IFLAG=0
      IF(I.EQ.J)GO TO 90
      IF(POLE(I).EQ.POLE(J))IFLAG=1
      IF(IFLAG.EQ.1)POLE(I)=POLE(I)+(POLE(I)/2E5)*IFLAG1
      IF(IFLAG.EQ.1)POLE(J)=POLE(J)+(POLE(J)/2E5)*(IFLAG1+1)
      IFLAG1=IFLAG1+IFLAG
   90 CONTINUE
      WRITE(61,100)(ZERO(I),I=1,NZ)
```

```
  100 FORMAT(5X,C(E11.3,E11.3))
      WRITE(61,110)
  110 FORMAT(7X*POLES*)
      WRITE(61,100)(POLE(I),I=1,NP)
C     STATEMENT 300 IS TRANSIENT ANALYSIS START.
      IF(TYPE.EQ.ANAL) GO TO 300
C     STATEMENT 120 IS STEADY STATE START.
      WRITE(61,120)TITLE
  120 FORMAT(//6X* STEADY STATE ANALYSIS*///7X5A8//)
      WRITE(61,130)
  130 FORMAT(//6X*FREQ.HZ*10X*AMPLITUDE*10X*PHASE(DEG.)*8X*DECIBELS*//)
C     X= INITIAL FREQUENCY, Z= FINAL FREQUENCY (HZ).
      READ(20,140)X,Z
  140 FORMAT(F80.5)
      Q=Z/X
      X1=X
      HSCALE=0.1*ALOG10(Q)
      CALL PLOT(HSCALE,5.,2)
      INKLEX=0
      PH2=-10E25
      PH3=10E25
      CALL PLOT(0.0,50.0,4)
      CALL PLOT(0.0,25.0,4)
      AXIS=10.0*HSCALE
      CALL PLOT(AXIS,25.0,4)
      AXIS=AXIS/2.0
      CALL PLOT(AXIS,0.0,3)
      CALL TEXT(HEAD,19,3)
      CALL TEXT(D,8,3)
      CALL PLOT (0.0,0.0,3)
      CALL TEXT(TOP,8,2)
      CALL TEXT(TITLE,40,2)
      CALL PLOT(0.0,0.0,3)
      VMAX=-10E+25
      CALL PLOT(0.0,-50.0,1)
  150 W=6.28318*X
      PH=0.
      SUM1=SUM2=(1.,0.)
      X=(1.+ALOG10(Q)/100.)*X
      IF(X.GT.Z) GO TO 220
      S=CMPLX(0.,W)
      IF(NZ.EQ.0) GO TO 170
      DO 160 I=1,NZ
      RL=S-ZERO(I)
      IF(RL.EQ.0.)RL=RL+10E-20
C     MAKE ZERO DENOMINATORS NON-ZERO BY A SMALL AMOUNT.
      PH=PH+ATAN(AIMAG(S-ZERO(I))/RL)
  160 SUM1=SUM1*(S-ZERO(I))
  170 DO 180 I=1,NP
      IF(NP.EQ.0)GO TO 181
      RL=S-POLE(I)
      IF(RL.EQ.0.)RL=RL+10E-20
C     PH IS PHASE ANGLE.
      PH=PH-ATAN(AIMAG(S-POLE(I))/RL)
  180 SUM2=SUM2*(S-POLE(I))
  181 SUM1=SUM1/SUM2
      HW=CABS(SUM1)*FUDGE
C     HW IS THE AMPLITUDE
  190 CONTINUE
      PH=PH*180./3.14159
      FREQ=X/(1.+ALOG10(Q)/100.)
      DECIBELS=20*ALOG10(HW)
      IF(INKLEX.EQ.0)FRUN=DECIBELS
      IF(INKLEX.EQ.0)FROD=HW
C     AMPLITUDE NORMALISED FOR PLOTTING.
      DEWDEC=DECIBELS-FRUN
```

```
      INKLEX=INKLEX+1
      FREQ1=ALOG10(FREQ/X1)
      FREQ2(INKLEX)=FREQ1
      PHASE(INKLEX)=PH
      IF(PH.GT.PH2)PH2=PH
      IF(PH.LT.PH3)PH3=PH
C     BACKING OFF OF AMPLITUDE PLOT TO STOP PEN GOING OFF SCALE.
  200 IF(DEWDEC.LT.-50.)DEWDEC=DEWDEC+50.
      IF(DEWDEC.LT.-50.)GO TO 200
      CALL PLOT(FREQ1,DEWDEC,4)
      WRITE(61,210)FREQ,HW,PH,DECIBELS
  210 FORMAT(4X,E12.4,5X,E12.4,7X,E12.4,7X,E12.4)
      IF(DEWDEC/5..GT.VMAX)VMAX=DEWDEC/5.
      GO TO 150
  220 VOT=-45.0
      ENCODE(12,225,WRT2)FRUN
      ENCODE(12,225,WRT4)FROD
      ENCODE(12,225,WRT6)FUDGE
  225 FORMAT(E12.4)
      IF(PH2**2.GT.PH3**2)PH3=SQRT(PH2**2)
      PH3=SQRT(PH3**2)
      YSCALE=200.0
C     CHOOSE A SUITABLE VERTICAL SCALE FOR PHASE PLOT.
      IF(PH3.LE.500.)YSCALE=100.
      IF(PH3.LE.250.)YSCALE=50.0
      IF(PH3.LE.100.)YSCALE=20.
      IF(PH3.LE.50.)YSCALE=10.
      IF(PH3.LE.25.)YSCALE=5.
      IF(PH3.LE.5.)YSCALE=1.0
      CALL PLOT(0.0,0.0,3)
C     EXTEND VERTICAL AXIS OF AMPLITUDE PLOT IF NECESSARY.
      CALL PLOT(0.0,5.*VMAX,4)
      AXIS=-0.4*HSCALE
      CALL PLOT(AXIS,-50.0,3)
C     EXTEND AMPLITUDE SCALE VERTICALLY AS FAR AS NECESSARY.
      IVMAX=55+5*INTF(VMAX)
      DO 240 IMP=1,IVMAX,5
      IRK=IMP-26
      ENCODE(3,230,IHAR)IRK
  230 FORMAT(I3)
      CALL TEXT(IHAR,3,2)
      CALL PLOT(AXIS,VOT,3)
  240 VOT=VOT+5.0
      CALL PLOT(AXIS,-27.5,3)
      CALL TEXT(DB1,3,2)
      DO 260 LOO=1,10
C     CHOOSE A SUITABLE HORIZONTAL LOGARITHMIC SCALE FOR BOTH PLOTS.
      HOS=X1*EXPF(2.30259*FLOATF(LOO)*HSCALE)
      ALOO=HSCALE*(FLOATF(LOO)-0.1)
      CALL PLOT(ALOO,-26.0,3)
      ENCODE(9,250,CHAR)HOS
  250 FORMAT(F9.4)
      CALL TEXT(CHAR,9,1)
      CALL PLOT(ALOO,34.0+5.*VMAX,3)
  260 CALL TEXT(CHAR,9,1)
      CALL PLOT(HSCALE/10.,-26.0,3)
      CALL TEXT(HERTZ,8,1)
      CALL PLOT(HSCALE/10.,34.0+5.*VMAX,3)
      CALL TEXT(HERTZ,8,1)
      CALL PLOT(0.0,0.0,3)
      CALL PLOT(0.0,-5.*INTF(VMAX)-60.0,1)
      CALL PLOT(0.0,-55.0,3)
      CALL TEXT(WRT1,37,2)
      CALL TEXT(WRT2,12,2)
      CALL TEXT(WRT3,8,2)
      CALL TEXT(WRT4,12,2)
```

```
      CALL TEXT(WRT5,22,2)
      CALL TEXT(WRT6,12,2)
      CALL PLOT(0.0,0.0,3)
      CALL PLOT(0.0,-50.0,4)
      CALL PLOT(0.0,-25.0,4)
      AXIS=10.0*HSCALE
      CALL PLOT(AXIS,-25.0,4)
      CALL PLOT(0.0,-25.,3)
      CALL PLOT(0.0,0.0,1)
      CALL PLOT(HSCALE,YSCALE,2)
      CALL PLOT(FREQ2(1),PHASE(1),3)
      DO 270 N=1,INKLEX
  270 CALL PLOT(FREQ2(N),PHASE(N),4)
      AXIS=-0.4*HSCALE
      CALL PLOT(AXIS,-YSCALE/2.,3)
      CALL TEXT(PHASE4,6,1)
      CALL PLOT(AXIS,-YSCALE*0.7,3)
      CALL TEXT(PHASE5,8,1)
      DO 290 I=1,11
      QUP=FLOATF(I-6)*YSCALE
      IQUP=INTF(QUP)
      CALL PLOT(-0.5*HSCALE,QUP,3)
      ENCODE(4,280,IHAR)IQUP
  280 FORMAT(I4)
  290 CALL TEXT(IHAR,4,2)
      CALL EXIT
C     TRANSIENT ANALYSIS START.
  300 T=0.
      WRITE(61,310)TITLE
  310 FORMAT(//7X* TRANSIENT ANALYSIS*//7X5A8/5X*TIME*12X*UNIT IMPULSE*
     18X*UNIT STEP*11X*UNIT RAMP*)
      READ(20,320)TIME
C     ANALYSIS RUNS FROM TIME ZERO TO NOMINATED TIME.
  320 FORMAT(F80.5)
  330 DO 340 I=1,3
      J=I-1
  340 ZOO(I)=LAPLACE(T,J)

      WRITE(61,350)T,ZOO
  350 FORMAT(3X,E12.4,4X,3(E12.4,8X))
      T=T+TIME/100.
      IF(TIME.GT.T)GO TO 330
      CALL EXIT
      END
      REAL FUNCTION LAPLACE(T,ISTEP)
      COMPLEX POLE(24),ZERO(24),BOTTOM,FACTOR,DENOM,LAPLACE1
      COMMON POLE,ZERO,NZ,NP,FUDGE
C     FUNCTION LAPLACE CALCULATES THE REQUIRED INVERSE LAPLACE
C     TRANSFORM AND INTEGRATES THIS A SPECIFIED NUMBER OF
C     TIMES. ISTEP SPECIFIES THE NUMBER OF ITERATIONS.
      INDEX1=INDEX2=0
      IF(ISTEP.GE.1)INDEX1=1
      IF(ISTEP.EQ.2)INDEX2=1
      LAPLACE1=(0.,0.)
      NP1=MIN0(NZ,NP)
      DO 60 J=1,NP
      BOTTOM=(0.,0.)
      FACTOR=(1.,0.)
      IF(NP1.EQ.0)GO TO 20
      DO 10 L=1,NP1
   10 FACTOR=FACTOR*(POLE(J)-ZERO(L))
   20 DO 50 I=1,NP
      DENOM=(1.,0.)
      DO 40 K=1,NP
      IF(K.EQ.I)GO TO 40
   30 DENOM=DENOM*(POLE(J)-POLE(K))
```

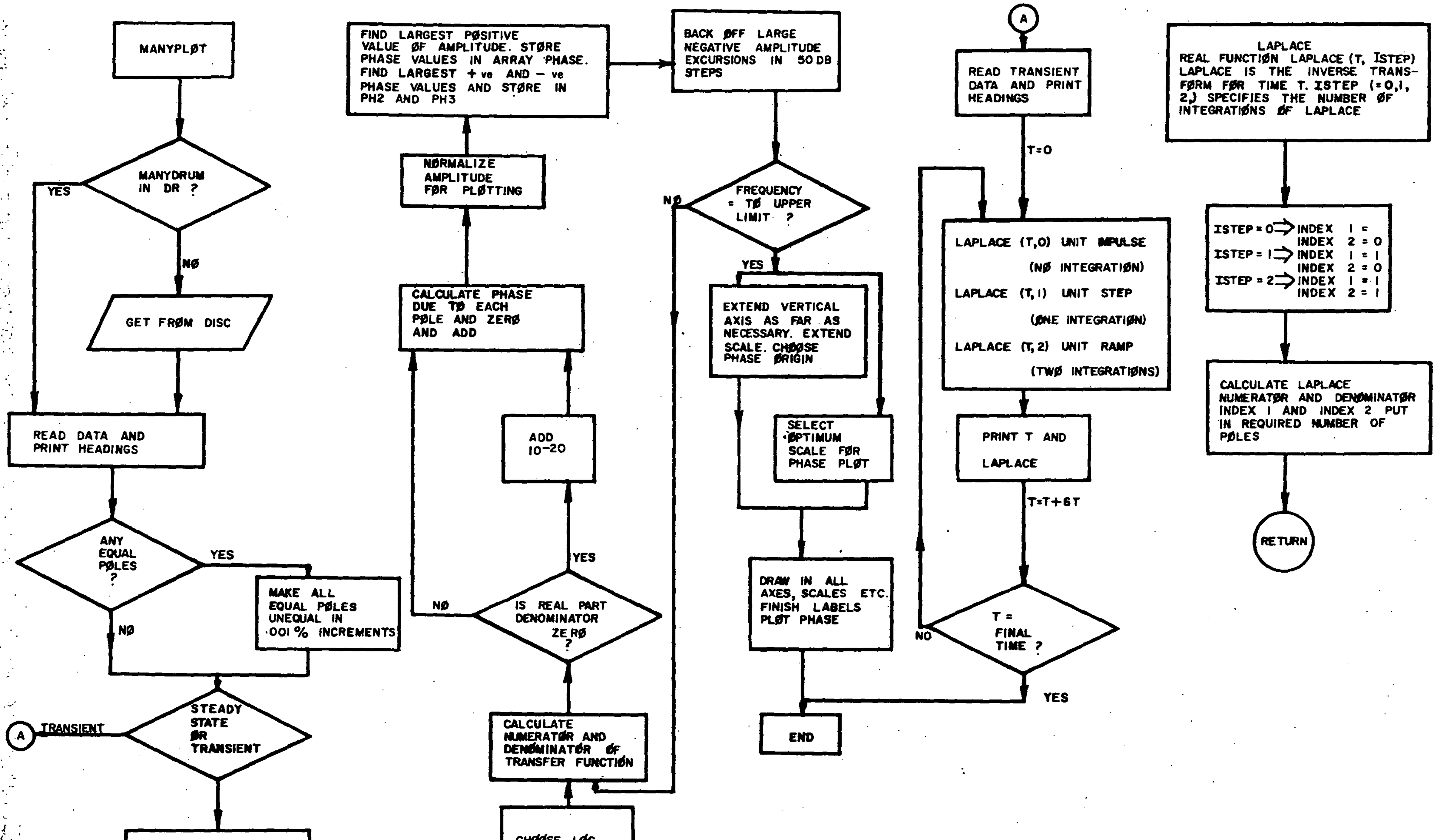
```
    40 CONTINUE
    50 BOTTOM = BOTTOM+DENOM
    60 LAPLACE1=LAPLACE1+(FACTOR/(BOTTOM*POLE(J)**ISTEP))*(CEXP(POLE(J)*T
      1)-INDEX1-INDEX2*T*POLE(J))
       LAPLACE=LAPLACE1*FUDGE
C      MULTIPLY THE NORMALISED RESULT BY THE GAIN FACTOR.
       RETURN
       END
          SCOPE
*LOAD
*RUN,1,300
[EOF
*EOD
```

```
*DOC    ,CCDMR*DA          ,MERRYGEN,,, CP00,,1227,,25/01/73
*EQUIP,40=(,MERRY),SV
*EQUIP,60=SV,61=SV
*EQUIP,61=LP
*DISPLAY
*MAIN,40,30
*COMPASS,L,X=30,R
          IDENT MERRY
IOC       MACRO A
          XMIT,AUG A,WORD
          CALL MANY
          CALL XFER
          ENDM
          ENTRY MAIN
COM1      BLOCK 0
          COMMON WORD (11B)
TYPE      BCD 1,TRANSIEN
HEAD      BCD 9, MANYPOLE ANALYSIS CONTROL LOGGED IN. CALLED ON
          BCD 9, TYPE YOUR GAIN TERM IN F FORMAT.
          BCD 9, HOW MANY ZEROES. (<9) (I FORMAT.)
          BCD 9, HOW MANY POLES. (<9) (I FORMAT.)
          BCD 9, STEADY STATE OR TRANSIENT.
          BCD 9, INITIAL FREQUENCY-HZ. (F FORMAT.)
          BCD 9, FINAL FREQUENCY-HZ. (F FORMAT.)
          BCD 9, TRANSIENT TIME-SECONDS. (F FORMAT.)
          BCD 9, TYPE A NAME FOR THE RUN. (LESS THAN 40 CHARACTERS).
CC        BSS 2
CC1       BCD 2,CCDMR*DAMANYPLOT
CC2       BCD 2,CCDMR*DAMANYPOLE
CC3       BCD 2,CCDMR*DAMANYDRUM
EXBK      BCD 9, TYPE BK OR EX, ELSE JUST INTERRUPT.
EX        BCD 1,EX
BK        BCD 1,BK
NUMB      BSS 1
COND      OCT 0
REAL      BCD 9, TYPE REAL PART. (F FORMAT.)
IMAG      BCD 9, TYPE IMAGINARY PART. (F FORMAT.)
EXACC     BCD 9, EXECUTION REQUEST ACCEPTED.
ACC       BCD 9, BREAKIN REQUEST ACCEPTED
NACC      BCD 9, BREAKIN REQUEST REJECTED. WAIT AND INTERRUPT.
BUSY      BCD 9, SYSTEM BUSY, WAIT AND INTERRUPT
MPLT      BCD 9, MANYPOLE OR MANYPLOT.
DEL       BCD 9, DRUM DOC DELETED -INTERRUPT AND TRY AGAIN.
MAIN      NOP
          UBJP START1,6
START1    SLJ START2
          CALL REENTER
START2    CALL SWAP1
          ISK 0,6
          SLJ PODD
          LABEL 25,CC3,,,DR
          SAVE 25,
          DATE
          STA HEAD+6
START3    XMIT,AUG HEAD,WORD
          CALL MANY
          ENI 1,6
          IOC HEAD+110B
          IOC HEAD+11B
          IOC HEAD+22B
OK        CALL CRACK1
          LDA WORD
          STA NUMB
BEGIN     LDA NUMB
```

```
          AJP,ZR OUT
          RSO NUMB
          IOC REAL
          IOC IMAG
          SLJ BEGIN
OUT       LDA COND
          AJP,NZ QOD
          IOC HEAD+33B
          STA COND
          SLJ OK
QOD       IOC HEAD+44B
          LDA WORD
          SUB TYPE
          AJP,ZR TRANSIEN
          IOC HEAD+55B
          IOC HEAD+66B
          SLJ EXITW
TRANSIEN  IOC HEAD+77B
EXITW     MARKEF 25,EXITMAIN
          ERASE 25,EXITMAIN
          IOC MPLT
          LDA WORD
          SUB CC1+1
          AJP,ZR *+4
          XMIT CC2,CC
          XMIT CC2+1,CC+1
          SLJ *+3
          XMIT CC1,CC
          XMIT CC1+1,CC+1
          IOC EXBK
          LDA WORD
          SUB EX
          AJP,ZR EXMANY
          LDA WORD
          SUB BK
          AJP,ZR BKMANY
          REWIND 25,EXITMAIN
          XMIT,AUG DEL,WORD
          CALL MANY
          ENI 1,6
          ENI 0,6
          ENA 0
          STA COND
          SLJ START2
EXMANY    RELEASE 25,*
          EXECUTE CC,3,MESSAGE3
          IOC EXACC
          SLJ EXITMAIN
BKMANY    RELEASE 25,*
          DBREAK CC
          AJP,ZR MESSAGE1
EXITMAIN  RELEASE 25,*
          DFINISH
PODD      ENI 1,6
          SLJ START3
MESSAGE1  IOC ACC
          SLJ EXITMAIN
MESSAGE2  IOC NACC
          SLJ BKMANY
MESSAGE3  IOC BUSY
          SLJ EXMANY
          END MAIN
          IDENT WRITLINE
          LIBM WRITE,READ
          ENTRY MANY,XFER,REENTER
COM1      BLOCK 0
```

```
          COMMON ENTK(11B)
BLANK     BCD 9,
ENTK1     BSS 11B
CWD       IOTR ENTK1,11B
REENTER   NOP
MANY      NOP
LINE      CALL SWAP1
          XMIT,AUG ENTK,ENTK1
          WRITE 61,CWD,RET
          CALL SWAP1
          ISK 0,6
          SLJ MEXIT
          SLJ MANY
MEXIT     INI -1,6
          EXIT
RET       SLJ MANY
XFER      NOP
          CALL SWAP1
          XMIT,AUG BLANK,ENTK1
          READ 60,CWD,REJ
          WRITE 25,CWD,REJ
          CALL SWAP1
          XMIT,AUG ENTK1,ENTK
          CALL SWAP1
REJ       SLJ XFER
          END
          IDENT SWAP
          ENTRY SWAP1
SWAP1     NOP
SET       ENI 9,1
          ENI 0,2
          ENI 1,3
          ENI 0,4
          ENI 1,5
          SLJ SWAP1
          END
          IDENT CRACK
          ENTRY CRACK1
COM1      BLOCK 0
          COMMON X(11B)
LEFT      BSS 1
WHOLE     BSS 1
          OCT 12
CRACK1    NOP
START     LDA X
          ARS,EO 36
          STA WHOLE
          ARS,EO 6
          ALS,EO 6
          STA LEFT
          LDA WHOLE
          SUB LEFT
          STA X
          SUB WHOLE+1
          AJP,MI CRACK2
          LDA LEFT
          ARS,EO 6
          STA X
          SLJ CRACK1
CRACK2    LDA LEFT
          ARS,EO 6
          MUI WHOLE+1
          RAD X
          SLJ CRACK1
          END
          SCOPE
```

*LOAD,30
[EOF
*EOD

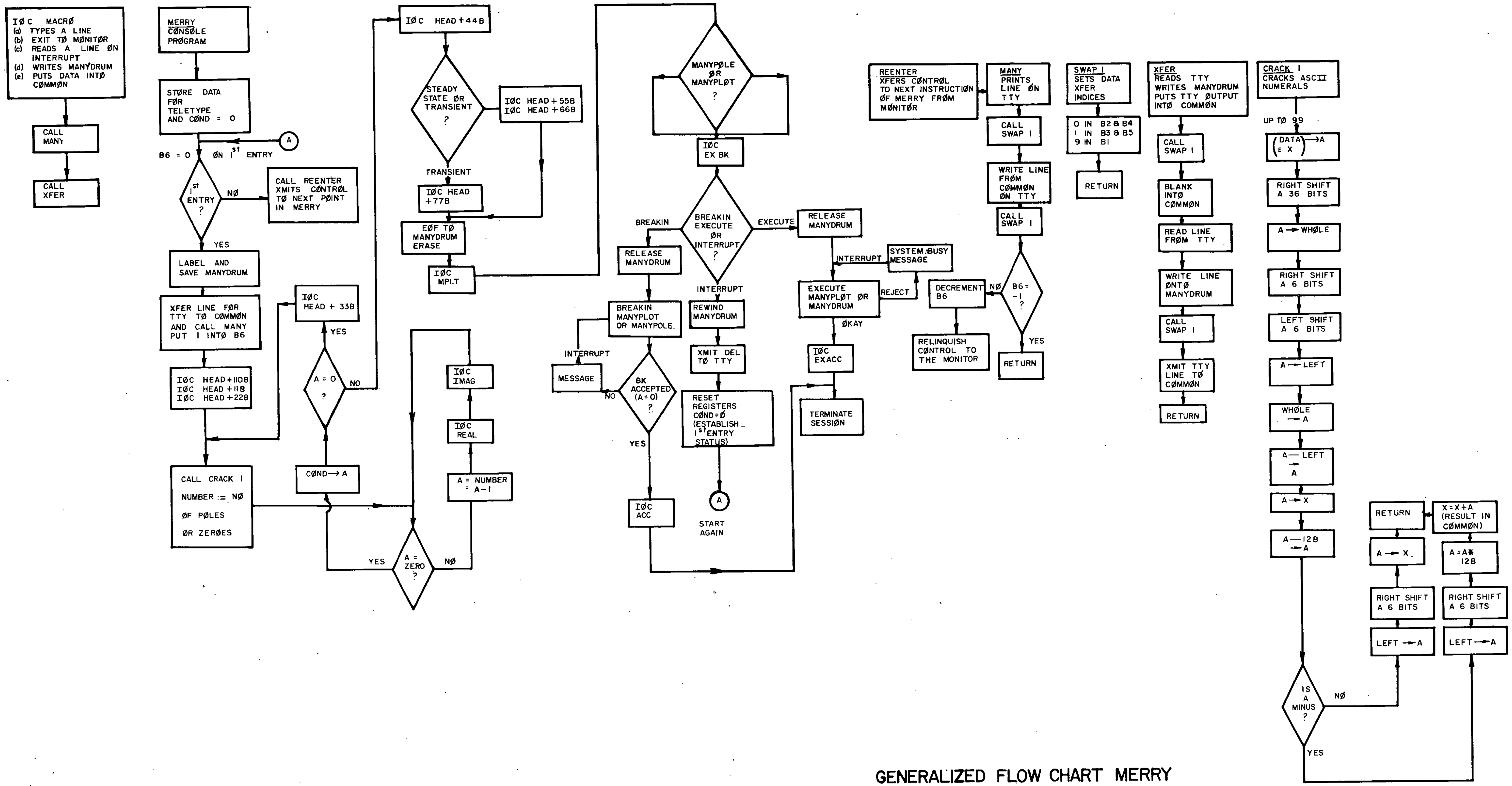


GENERALIZED FLOW CHART

MANYPLOT AND LAPLACE

APPENDIX 2

To Accompany Record No. 1973/31



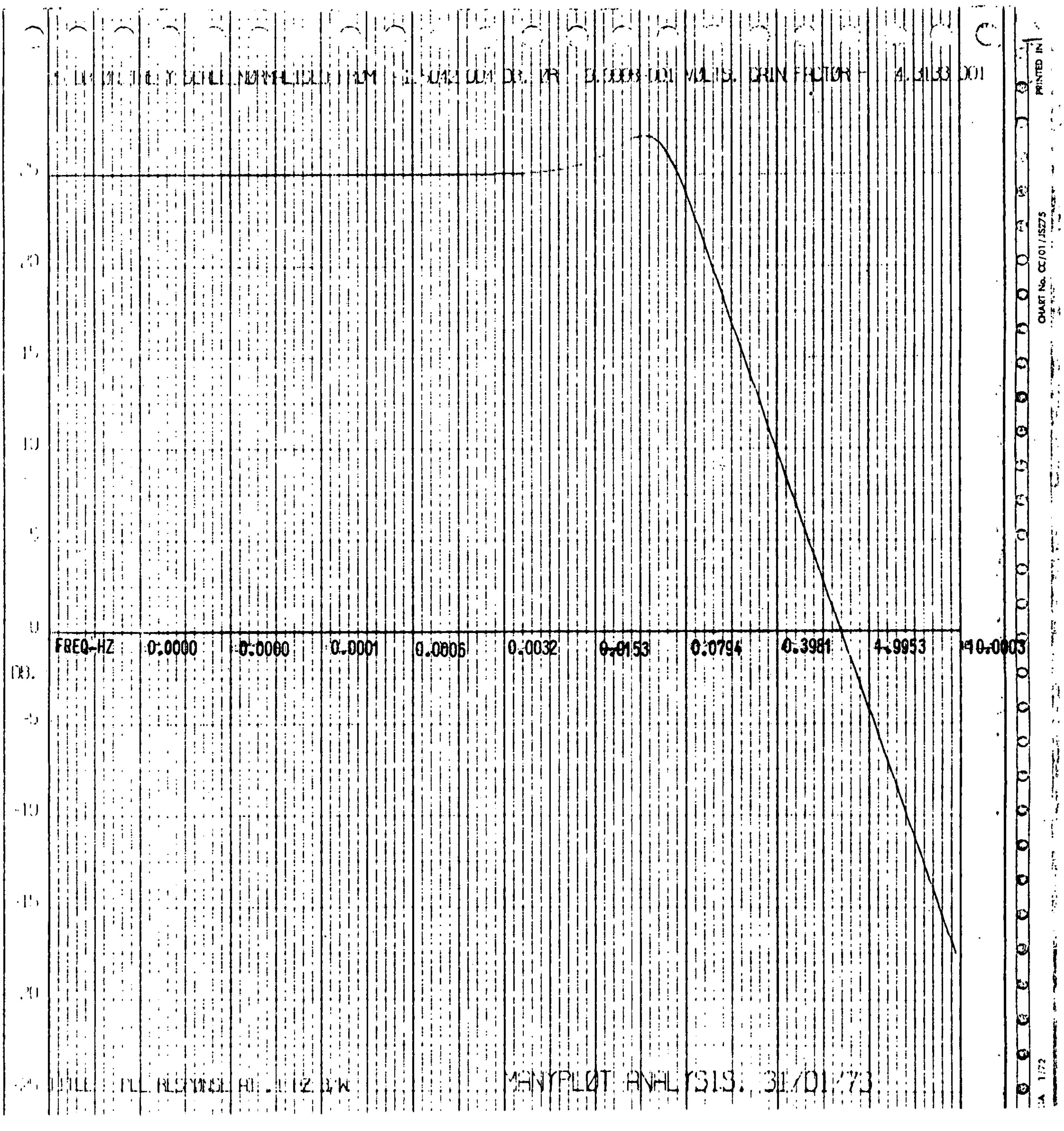
GENERALIZED FLOW CHART MERRY

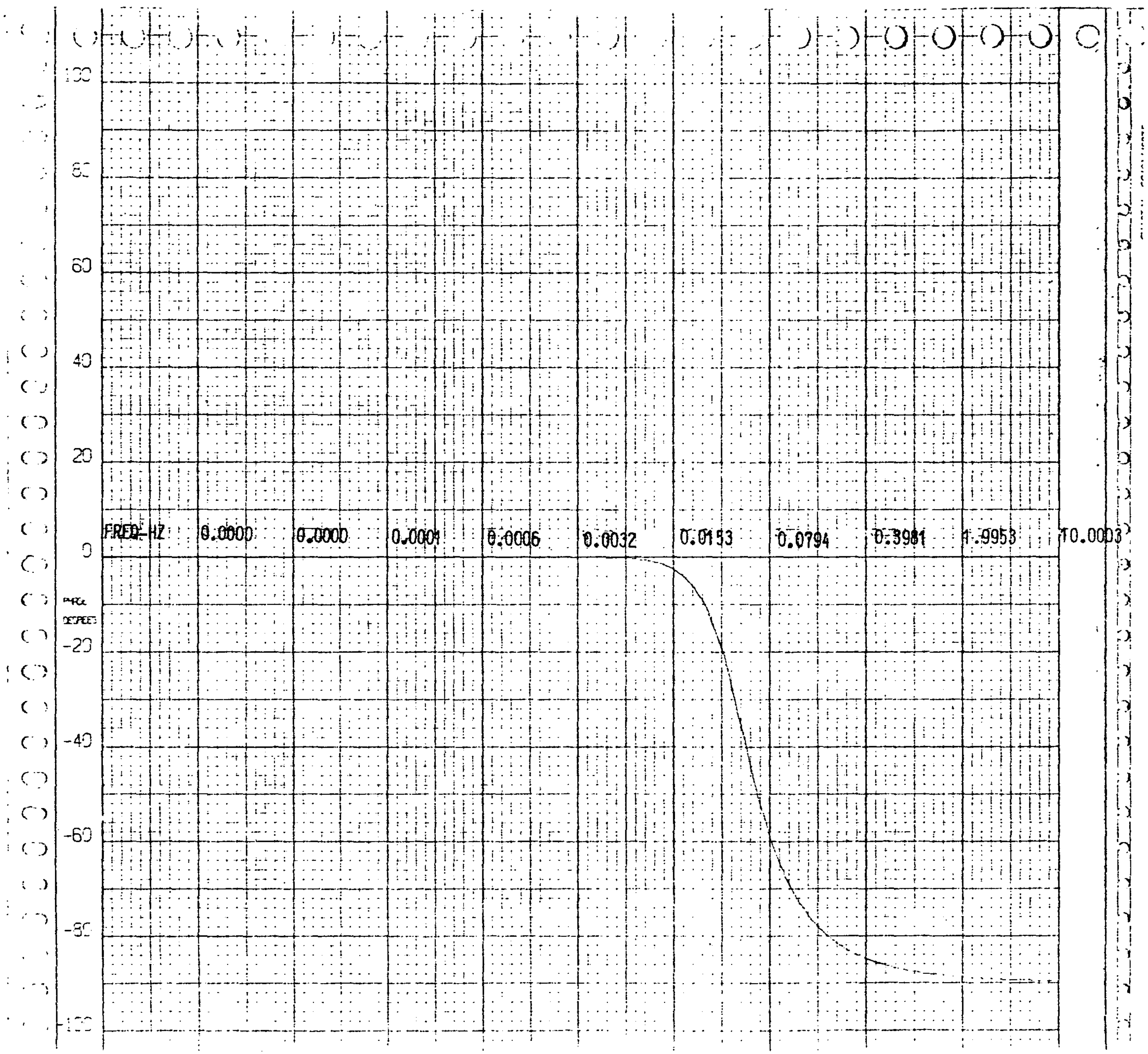
G462-2

APPENDIX 3

APPENDIX 4

SAMPLE PLOTS AND OUTPUT FROM MANYPLOT


GAIN FACTOR
FREQ-HZ
0.0000
0.0000
0.0001
0.0006
0.0032
0.0794
0.3981
10.0003
DB.
MANYPLØT ANALYSIS. 31/01/73
CHART No. CC/01/JSZ75
PRINTED IN



100
80
60
40
20
0
-20
-40
-60
-80
-100
PHASE
DEGREES
FREQ-HZ
0.0000
0.0000
0.0001
0.0006
0.0032
0.0153
0.0794
0.3981
1.9953
10.0003

MANYPLOT ANALYSIS

ZEROES

-2,157-001 0,000+000

POLES

-2,157-001 2,157-001

-2,157-001 -2,157-001

STEADY STATE ANALYSIS

PLL RESPONSE AT .1 HZ B/W

FREQ.HZ	AMPLITUDE	PHASE(DEG.)	DECIBELS
1.0000-006	9.9998-001	1.3340-008	-1.5042-004
1.0700-006	9.9998-001	1.5842-008	-1.5042-004
1.1449-006	9.9998-001	1.5008-008	-1.5042-004
1.2250-006	9.9998-001	1.6675-008	-1.5042-004
1.3108-006	9.9998-001	1.7509-008	-1.5042-004
1.4026-006	9.9998-001	2.0010-008	-1.5042-004
1.5007-006	9.9998-001	2.1678-008	-1.5042-004
1.6058-006	9.9998-001	2.0844-008	-1.5041-004
1.7182-006	9.9998-001	2.3345-008	-1.5041-004
1.8385-006	9.9998-001	2.5013-008	-1.5041-004
1.9672-006	9.9998-001	2.5013-008	-1.5041-004
2.1049-006	9.9998-001	2.8348-008	-1.5041-004
2.2522-006	9.9998-001	2.9182-008	-1.5040-004
2.4098-006	9.9998-001	3.1683-008	-1.5040-004
2.5785-006	9.9998-001	3.5852-008	-1.5040-004
2.7590-006	9.9998-001	3.5852-008	-1.5040-004
2.9522-006	9.9998-001	3.8353-008	-1.5039-004
3.1588-006	9.9998-001	3.9187-008	-1.5039-004
3.3799-006	9.9998-001	4.4189-008	-1.5038-004
3.6165-006	9.9998-001	4.8358-008	-1.5037-004
3.8697-006	9.9998-001	4.9192-008	-1.5037-004
4.1406-006	9.9998-001	5.1693-008	-1.5036-004
4.4304-006	9.9998-001	5.6696-008	-1.5035-004
4.7405-006	9.9998-001	6.1699-008	-1.5034-004
5.0724-006	9.9998-001	6.5034-008	-1.5033-004
5.4274-006	9.9998-001	6.9202-008	-1.5031-004
5.8074-006	9.9998-001	7.3371-008	-1.5030-004
6.2139-006	9.9998-001	7.9208-008	-1.5028-004
6.6488-006	9.9998-001	8.5878-008	-1.5026-004
7.1143-006	9.9998-001	9.0047-008	-1.5023-004
7.6123-006	9.9998-001	9.6717-008	-1.5021-004
8.1451-006	9.9998-001	1.0422-007	-1.5018-004
8.7153-006	9.9998-001	1.1006-007	-1.5014-004
9.3253-006	9.9998-001	1.1756-007	-1.5010-004
9.9781-006	9.9998-001	1.2757-007	-1.5005-004
1.0677-005	9.9998-001	1.3340-007	-1.5000-004
1.1424-005	9.9998-001	1.4424-007	-1.4994-004
1.2224-005	9.9998-001	1.5091-007	-1.4987-004
1.3079-005	9.9998-001	1.6258-007	-1.4979-004
1.3995-005	9.9998-001	1.7509-007	-1.4969-004
1.4974-005	9.9998-001	1.8593-007	-1.4959-004
1.6023-005	9.9998-001	1.9927-007	-1.4947-004
1.7144-005	9.9998-001	2.1261-007	-1.4933-004
1.8344-005	9.9998-001	2.2595-007	-1.4917-004

1.9628-005	9.9998-001	2.4096-007	-1.4899-004
2.1002-005	9.9998-001	2.5763-007	-1.4879-004
2.2473-005	9.9998-001	2.7514-007	-1.4855-004
2.4046-005	9.9998-001	2.9098-007	-1.4828-004
2.5729-005	9.9998-001	3.1099-007	-1.4797-004
2.7530-005	9.9998-001	3.3100-007	-1.4761-004
2.9457-005	9.9998-001	3.5185-007	-1.4721-004
3.1519-005	9.9998-001	3.7436-007	-1.4674-004
3.3725-005	9.9998-001	3.9604-007	-1.4621-004
3.6086-005	9.9998-001	4.1772-007	-1.4560-004
3.8612-005	9.9998-001	4.4440-007	-1.4490-004
4.1315-005	9.9998-001	4.6858-007	-1.4411-004
4.4207-005	9.9998-001	4.9275-007	-1.4319-004
4.7302-005	9.9998-001	5.1777-007	-1.4215-004
5.0613-005	9.9998-001	5.4278-007	-1.4095-004
5.4156-005	9.9998-001	5.6529-007	-1.3958-004
5.7946-005	9.9998-001	5.8697-007	-1.3801-004
6.2003-005	9.9998-001	6.0948-007	-1.3621-004
6.6343-005	9.9998-001	6.2449-007	-1.3416-004
7.0987-005	9.9998-001	6.3616-007	-1.3180-004
7.5956-005	9.9999-001	6.4200-007	-1.2911-004
8.1273-005	9.9999-001	6.3700-007	-1.2603-004
8.6962-005	9.9999-001	6.2282-007	-1.2249-004
9.3049-005	9.9999-001	5.9447-007	-1.1845-004
9.9563-005	9.9999-001	5.4695-007	-1.1382-004
1.0653-004	9.9999-001	4.7608-007	-1.0852-004
1.1399-004	9.9999-001	3.7686-007	-1.0246-004
1.2197-004	9.9999-001	2.4179-007	-9.5512-005
1.3051-004	9.9999-001	5.9197-008	-8.7561-005
1.3964-004	9.9999-001	-1.8176-007	-7.8458-005
1.4942-004	9.9999-001	-4.9359-007	-6.8037-005
1.5988-004	9.9999-001	-8.9463-007	-5.6106-005
1.7107-004	1.0000+000	-1.4074-006	-4.2447-005
1.8304-004	1.0000+000	-2.0561-006	-2.6810-005
1.9585-004	1.0000+000	-2.8723-006	-8.9066-006
2.0956-004	1.0000+000	-3.8987-006	1.1589-005
2.2423-004	1.0000+000	-5.1852-006	3.5054-005
2.3993-004	1.0000+000	-6.7860-006	6.1919-005
2.5673-004	1.0000+000	-8.7795-006	9.2674-005
2.7470-004	1.0000+000	-1.1252-005	1.2789-004
2.9393-004	1.0000+000	-1.4317-005	1.6820-004
3.1450-004	1.0000+000	-1.8108-005	2.1435-004
3.3652-004	1.0000+000	-2.2794-005	2.6719-004
3.6007-004	1.0000+000	-2.8576-005	3.2768-004
3.8528-004	1.0000+000	-3.5703-005	3.9693-004
4.1225-004	1.0001+000	-4.4486-005	4.7621-004
4.4110-004	1.0001+000	-5.5293-005	5.6698-004
4.7198-004	1.0001+000	-6.8590-005	6.7090-004
5.0502-004	1.0001+000	-8.4941-005	7.8987-004
5.4037-004	1.0001+000	-1.0503-004	9.2607-004
5.7820-004	1.0001+000	-1.2971-004	1.0820-003
6.1867-004	1.0001+000	-1.6002-004	1.2605-003
6.6198-004	1.0002+000	-1.9722-004	1.4649-003
7.0831-004	1.0002+000	-2.4288-004	1.6988-003
7.5790-004	1.0002+000	-2.9890-004	1.9666-003
8.1095-004	1.0003+000	-3.6761-004	2.2732-003
8.6772-004	1.0003+000	-4.5189-004	2.6242-003
9.2846-004	1.0003+000	-5.5524-004	3.0260-003
9.9345-004	1.0004+000	-6.8195-004	3.4859-003
1.0630-003	1.0005+000	-8.3728-004	4.0124-003
1.1374-003	1.0005+000	-1.0277-003	4.6150-003
1.2170-003	1.0006+000	-1.2611-003	5.3049-003
1.3022-003	1.0007+000	-1.5471-003	6.0944-003

1.3934-003	1.0008+000	-1.8975-003	6.9981-003
1.4909-003	1.0009+000	-2.3269-003	8.0324-003
1.5953-003	1.0011+000	-2.8531-003	9.2161-003
1.7069-003	1.0012+000	-3.4977-003	1.0571-002
1.8264-003	1.0014+000	-4.2873-003	1.2121-002
1.9543-003	1.0016+000	-5.2546-003	1.3895-002
2.0911-003	1.0018+000	-6.4393-003	1.5924-002
2.2374-003	1.0021+000	-7.8903-003	1.8246-002
2.3941-003	1.0024+000	-9.6673-003	2.0901-002
2.5616-003	1.0028+000	-1.1843-002	2.3939-002
2.7410-003	1.0032+000	-1.4508-002	2.7413-002
2.9328-003	1.0036+000	-1.7769-002	3.1385-002
3.1381-003	1.0041+000	-2.1763-002	3.5925-002
3.3578-003	1.0047+000	-2.6650-002	4.1115-002
3.5928-003	1.0054+000	-3.2631-002	4.7045-002
3.8443-003	1.0062+000	-3.9950-002	5.3819-002
4.1134-003	1.0071+000	-4.8903-002	6.1555-002
4.4014-003	1.0081+000	-5.9855-002	7.0386-002
4.7095-003	1.0093+000	-7.3246-002	8.0463-002
5.0391-003	1.0106+000	-8.9618-002	9.1956-002
5.3919-003	1.0122+000	-1.0963-001	1.0506-001
5.7693-003	1.0139+000	-1.3407-001	1.1998-001
6.1732-003	1.0159+000	-1.6392-001	1.3696-001
6.6053-003	1.0182+000	-2.0036-001	1.5628-001
7.0676-003	1.0207+000	-2.4481-001	1.7824-001
7.5624-003	1.0237+000	-2.9902-001	2.0315-001
8.0917-003	1.0270+000	-3.6507-001	2.3139-001
8.6582-003	1.0308+000	-4.4550-001	2.6335-001
9.2642-003	1.0351+000	-5.4333-001	2.9947-001
9.9127-003	1.0399+000	-6.6224-001	3.4021-001
1.0607-002	1.0454+000	-8.0660-001	3.8604-001
1.1349-002	1.0517+000	-9.8162-001	4.3748-001
1.2144-002	1.0586+000	-1.1935+000	4.9504-001
1.2994-002	1.0665+000	-1.4497+000	5.5922-001
1.3903-002	1.0753+000	-1.7587+000	6.3050-001
1.4876-002	1.0851+000	-2.1308+000	7.0929-001
1.5918-002	1.0960+000	-2.5777+000	7.9589-001
1.7032-002	1.1080+000	-3.1131+000	8.9047-001
1.8224-002	1.1211+000	-3.7524+000	9.9295-001
1.9500-002	1.1354+000	-4.5131+000	1.1030+000
2.0865-002	1.1508+000	-5.4147+000	1.2197+000
2.2325-002	1.1671+000	-6.4784+000	1.3420+000
2.3888-002	1.1841+000	-7.7265+000	1.4677+000
2.5560-002	1.2015+000	-9.1820+000	1.5942+000
2.7350-002	1.2187+000	-1.0868+001	1.7178+000
2.9264-002	1.2350+000	-1.2803+001	1.8337+000
3.1313-002	1.2497+000	-1.5005+001	1.9361+000
3.3504-002	1.2616+000	-1.7482+001	2.0182+000
3.5850-002	1.2694+000	-2.0234+001	2.0721+000
3.8359-002	1.2720+000	-2.3247+001	2.0896+000
4.1044-002	1.2680+000	-2.6496+001	2.0627+000
4.3917-002	1.2566+000	-2.9937+001	1.9840+000
4.6992-002	1.2370+000	-3.3516+001	1.8477+000
5.0281-002	1.2093+000	-3.7169+001	1.6506+000
5.3801-002	1.1738+000	-4.0827+001	1.3917+000
5.7567-002	1.1315+000	-4.4426+001	1.0732+000
6.1596-002	1.0838+000	-4.7907+001	6.9928-001
6.5908-002	1.0323+000	-5.1225+001	2.7590-001
7.0522-002	9.7836-001	-5.4346+001	-1.8999-001
7.5458-002	9.2350-001	-5.7253+001	-6.9122-001
8.0740-002	8.6887-001	-5.9938+001	-1.2209+000
8.6392-002	8.1537-001	-6.2401+001	-1.7729+000
9.2440-002	7.6368-001	-6.4652+001	-2.3418+000

9.8910-002	7.1423-001	-6,6703+001	-2,9232+000
1.0583-001	6.6730-001	-6,8567+001	-3.5135+000
1.1324-001	6.2302-001	-7,0262+001	-4.1100+000
1.2117-001	5.8141-001	-7,1802+001	-4.7104+000
1.2965-001	5.4243-001	-7,3203+001	-5.3132+000
1.3873-001	5.0599-001	-7,4479+001	-5.9171+000
1.4844-001	4.7199-001	-7,5642+001	-6.5214+000
1.5883-001	4.4028-001	-7,6705+001	-7.1254+000
1.6995-001	4.1074-001	-7,7677+001	-7.7287+000
1.8184-001	3.8321-001	-7,8568+001	-8.3312+000
1.9457-001	3.5758-001	-7,9386+001	-8.9326+000
2.0819-001	3.3370-001	-8,0139+001	-9.5329+000
2.2277-001	3.1145-001	-8,0831+001	-1.0132+001
2.3836-001	2.9073-001	-8,1470+001	-1.0730+001
2.5504-001	2.7141-001	-8,2061+001	-1.1327+001
2.7290-001	2.5341-001	-8,2607+001	-1.1923+001
2.9200-001	2.3663-001	-8,3112+001	-1.2519+001
3.1244-001	2.2098-001	-8,3581+001	-1.3113+001
3.3431-001	2.0638-001	-8,4015+001	-1.3707+001
3.5771-001	1.9276-001	-8,4419+001	-1.4300+001
3.8275-001	1.8005-001	-8,4794+001	-1.4892+001
4.0954-001	1.6819-001	-8,5142+001	-1.5484+001
4.3821-001	1.5712-001	-8,5467+001	-1.6075+001
4.6889-001	1.4679-001	-8,5768+001	-1.6666+001
5.0171-001	1.3714-001	-8,6050+001	-1.7256+001
5.3683-001	1.2814-001	-8,6312+001	-1.7847+001
5.7441-001	1.1972-001	-8,6556+001	-1.8436+001
6.1462-001	1.1187-001	-8,6784+001	-1.9026+001
6.5764-001	1.0453-001	-8,6996+001	-1.9615+001
7.0367-001	9.7673-002	-8,7194+001	-2.0205+001
7.5293-001	9.1270-002	-8,7379+001	-2.0793+001
8.0564-001	8.5288-002	-8,7552+001	-2.1382+001
8.6203-001	7.9699-002	-8,7713+001	-2.1971+001
9.2237-001	7.4478-002	-8,7863+001	-2.2559+001
9.8694-001	6.9599-002	-8,8003+001	-2.3148+001
1.0560+000	6.5041-002	-8,8134+001	-2.3736+001
1.1299+000	6.0782-002	-8,8257+001	-2.4324+001
1.2090+000	5.6803-002	-8,8371+001	-2.4913+001
1.2937+000	5.3084-002	-8,8478+001	-2.5501+001
1.3842+000	4.9609-002	-8,8578+001	-2.6089+001
1.4811+000	4.6362-002	-8,8671+001	-2.6677+001
1.5848+000	4.3327-002	-8,8758+001	-2.7265+001
1.6957+000	4.0491-002	-8,8840+001	-2.7853+001
1.8144+000	3.7841-002	-8,8916+001	-2.8441+001
1.9415+000	3.5365-002	-8,8987+001	-2.9029+001
2.0774+000	3.3051-002	-8,9053+001	-2.9616+001
2.2228+000	3.0888-002	-8,9115+001	-3.0204+001
2.3784+000	2.8867-002	-8,9173+001	-3.0792+001
2.5449+000	2.6978-002	-8,9227+001	-3.1380+001
2.7230+000	2.5213-002	-8,9278+001	-3.1968+001
2.9136+000	2.3563-002	-8,9325+001	-3.2555+001
3.1176+000	2.2021-002	-8,9369+001	-3.3143+001
3.3358+000	2.0581-002	-8,9410+001	-3.3731+001
3.5693+000	1.9234-002	-8,9449+001	-3.4319+001
3.8191+000	1.7976-002	-8,9485+001	-3.4906+001
4.0865+000	1.6800-002	-8,9519+001	-3.5494+001
4.3725+000	1.5701-002	-8,9550+001	-3.6082+001
4.6786+000	1.4673-002	-8,9580+001	-3.6669+001
5.0061+000	1.3713-002	-8,9607+001	-3.7257+001
5.3565+000	1.2816-002	-8,9633+001	-3.7845+001
5.7315+000	1.1978-002	-8,9657+001	-3.8433+001
6.1327+000	1.1194-002	-8,9679+001	-3.9020+001
6.5620+000	1.0462-002	-8,9700+001	-3.9608+001

7.0213+000	9.7773-003	-8.9720+001	-4.0196+001
7.5128+000	9.1377-003	-8.9738+001	-4.0783+001
8.0387+000	8.5399-003	-8.9755+001	-4.1371+001
8.6014+000	7.9812-003	-8.9771+001	-4.1959+001
9.2035+000	7.4590-003	-8.9786+001	-4.2546+001

MANYPLOT ANALYSIS

ZEROES
-3,333+001 0,000+000
POLES
-3,762+001 3,306+001
-3,762+001 -3,306+001

TRANSIENT ANALYSIS

MNS2 PLL, TRANSIENT ANALYSIS,

TIME	UNIT IMPULSE	UNIT STEP	UNIT RAMP
0,0000+000	7,5237+001	0,0000+000	0,0000+000
1,0000-002	4,6678+001	6,0425-001	3,2596-003
2,0000-002	2,5162+001	9,5732-001	1,1247-002
3,0000-002	1,0679+001	1,1311+000	2,1809-002
4,0000-002	2,0101+000	1,1903+000	3,3488-002
5,0000-002	-2,4220+000	1,1854+000	4,5403-002
6,0000-002	-4,0925+000	1,1510+000	5,7099-002
7,0000-002	-4,1732+000	1,1088+000	6,8399-002
8,0000-002	-3,4908+000	1,0701+000	7,9287-002
9,0000-002	-2,5666+000	1,0398+000	8,9829-002
1,0000-001	-1,6880+000	1,0186+000	1,0011-001
1,1000-001	-9,8256-001	1,0054+000	1,1023-001
1,2000-001	-4,8050-001	9,9825-001	1,2024-001
1,3000-001	-1,6096-001	9,9518-001	1,3021-001
1,4000-001	1,7412-002	9,9456-001	1,4015-001
1,5000-001	9,8462-002	9,9521-001	1,5010-001
1,6000-001	1,1965-001	9,9634-001	1,6006-001
1,7000-001	1,0899-001	9,9750-001	1,7003-001
1,8000-001	8,5148-002	9,9847-001	1,8001-001
1,9000-001	5,9213-002	9,9919-001	1,9000-001
2,0000-001	3,6769-002	9,9967-001	1,9999-001
2,1000-001	1,9845-002	9,9995-001	2,0999-001
2,2000-001	8,4436-003	1,0001+000	2,1999-001
2,3000-001	1,6132-003	1,0001+000	2,2999-001
2,4000-001	-1,8841-003	1,0001+000	2,3999-001
2,5000-001	-3,2070-003	1,0001+000	2,4999-001
2,6000-001	-3,2767-003	1,0001+000	2,5999-001
2,7000-001	-2,7439-003	1,0000+000	2,6999-001
2,8000-001	-2,0191-003	1,0000+000	2,8000-001
2,9000-001	-1,3290-003	1,0000+000	2,9000-001
3,0000-001	-7,7438-004	9,9999-001	2,9999-001
3,1000-001	-3,7932-004	9,9998-001	3,0999-001
3,2000-001	-1,2767-004	9,9998-001	3,1999-001
3,3000-001	1,2960-005	9,9998-001	3,2999-001
3,4000-001	7,6995-005	9,9998-001	3,3999-001
3,5000-001	9,3879-005	9,9998-001	3,4999-001
3,6000-001	8,5629-005	9,9998-001	3,5999-001
3,7000-001	6,6959-005	9,9998-001	3,6999-001
3,8000-001	4,6601-005	9,9998-001	3,7999-001
3,9000-001	2,8963-005	9,9998-001	3,8999-001
4,0000-001	1,5651-005	9,9998-001	3,9999-001
4,1000-001	6,6760-006	9,9998-001	4,0999-001
4,2000-001	1,2941-006	9,9998-001	4,1999-001
4,3000-001	-1,4656-006	9,9998-001	4,2999-001
4,4000-001	-2,5130-006	9,9998-001	4,3999-001
4,5000-001	-2,5728-006	9,9998-001	4,4999-001
4,6000-001	-2,1568-006	9,9998-001	4,5999-001
4,7000-001	-1,5885-006	9,9998-001	4,6999-001
4,8000-001	-1,0464-006	9,9998-001	4,7999-001
4,9000-001	-6,1031-007	9,9998-001	4,8999-001
5,0000-001	-2,9945-007	9,9998-001	4,9999-001

5,1000-001	-1,0126-007	9,9998-001	5,0999-001
5,2000-001	9,6147-009	9,9998-001	5,1999-001
5,3000-001	5,0205-008	9,9998-001	5,2999-001
5,4000-001	7,3652-008	9,9998-001	5,3999-001
5,5000-001	6,7274-008	9,9998-001	5,4999-001
5,6000-001	5,2655-008	9,9998-001	5,5999-001
5,7000-001	3,6576-008	9,9998-001	5,6999-001
5,8000-001	2,2814-008	9,9998-001	5,7999-001
5,9000-001	1,2343-008	9,9998-001	5,8999-001
6,0000-001	5,2783-009	9,9998-001	5,9999-001
6,1000-001	1,0377-009	9,9998-001	6,0999-001
6,2000-001	-1,1398-009	9,9998-001	6,1999-001
6,3000-001	-1,9692-009	9,9998-001	6,2999-001
6,4000-001	-2,0201-009	9,9998-001	6,3999-001
6,5000-001	-1,6953-009	9,9998-001	6,4999-001
6,6000-001	-1,2496-009	9,9998-001	6,5999-001
6,7000-001	-8,2386-010	9,9998-001	6,6999-001
6,8000-001	-4,8100-010	9,9998-001	6,7999-001
6,9000-001	-2,3639-010	9,9998-001	6,8999-001
7,0000-001	-8,0309-011	9,9998-001	6,9999-001
7,1000-001	7,1067-012	9,9998-001	7,0999-001
7,2000-001	4,7074-011	9,9998-001	7,1999-001
7,3000-001	5,7782-011	9,9998-001	7,2999-001
7,4000-001	5,2853-011	9,9998-001	7,3999-001
7,5000-001	4,1406-011	9,9998-001	7,4999-001
7,6000-001	2,8864-011	9,9998-001	7,5999-001
7,7000-001	1,7970-011	9,9998-001	7,6999-001
7,8000-001	9,7347-012	9,9998-001	7,7999-001
7,9000-001	4,1731-012	9,9998-001	7,8999-001
8,0000-001	8,3182-013	9,9998-001	7,9999-001
8,1000-001	-8,8634-013	9,9998-001	8,0999-001
8,2000-001	-1,5430-012	9,9998-001	8,1999-001
8,3000-001	-1,5861-012	9,9998-001	8,2998-001
8,4000-001	-1,3326-012	9,9998-001	8,3998-001
8,5000-001	-9,8307-013	9,9998-001	8,4998-001
8,6000-001	-6,4865-013	9,9998-001	8,5998-001
8,7000-001	-3,7908-013	9,9998-001	8,6998-001
8,8000-001	-1,8661-013	9,9998-001	8,7998-001
8,9000-001	-6,3688-014	9,9998-001	8,8998-001
9,0000-001	5,2310-015	9,9998-001	8,9998-001
9,1000-001	3,6806-014	9,9998-001	9,0998-001
9,2000-001	4,5331-014	9,9998-001	9,1998-001
9,3000-001	4,1523-014	9,9998-001	9,2998-001
9,4000-001	3,2560-014	9,9998-001	9,3998-001
9,5000-001	2,2716-014	9,9998-001	9,4998-001
9,6000-001	1,4155-014	9,9998-001	9,5998-001
9,7000-001	7,6772-015	9,9998-001	9,6998-001
9,8000-001	3,2992-015	9,9998-001	9,7998-001
9,9000-001	6,6556-016	9,9998-001	9,8998-001
1,0000+000	-6,8914-016	9,9998-001	9,9998-001

```
LUN TYPE SECTORS CHARGE  SERIAL (MT)        LABEL
 68  DR       2
 60  DR       7                          CCDMR*DAMANYPLOT
 20  DR       2
 61  LP      13       6
JOB,CCDMR*DA,MANYPLOT.          END JOB 121326 CPU TIME,  0H  0M 17S
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APPENDIX 5

SAMPLE OUTPUT FROM MERRY

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*LG,CCLMF*DA,MERRY
140740 25/01/73
MANYPLOT ANALYSIS CONTROL LOGGED IN. CALLED ON 25/01/73
 TYPE A NAME FOR THE RUN. (LESS THAN 40 CHARACTERS).
:***TEST RUN NUMBER 1***
 TYPE YOUR GAIN TERM IN F FORMAT.
:12345.875
 HOW MANY ZEROES. (<9) (I FORMAT.)
:1
 TYPE REAL PART. (F FORMAT.)
:335.768
 TYPE IMAGINARY PART. (F FORMAT.)
:-99.7
 HOW MANY POLES. (<9) (I FORMAT.)
:2
 TYPE REAL PART. (F FORMAT.)
:1.222
 TYPE IMAGINARY PART. (F FORMAT.)
:8.975
 TYPE REAL PART. (F FORMAT.)
:1.222
 TYPE IMAGINARY PART. (F FORMAT.)
:-8.975
 STEADY STATE OR TRANSIENT.
:STEADY STATE
 INITIAL FREQUENCY-HZ. (F FORMAT.)
:0.001
 FINAL FREQUENCY-HZ. (F FORMAT.)
:100.0
 MANYPOLE OR MANYPLOT.
:MANYPLOT
 TYPE BK OR EX, ELSE JUST INTERRUPT.
:BK
BKJOB 00
 BREAKIN REQUEST ACCEPTED
:
CCLMF*DA            MERRY                     NORMAL TERM          0 +    2 SEC
:
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*LG,CCDMI*EA,MERRY
141107 25/01/73
MANYPLOT ANALYSIS CONTROL LOGGED IN. CALLED ON 25/01/73
TYPE A NAME FOR THE RUN. (LESS THAN 40 CHARACTERS).
:***TEST RUN NUMBER TWO***
TYPE YOUR GAIN TERM IN F FORMAT.
:654381234.98765
HOW MANY ZEROES. (<9) (I FORMAT.)
:0
HOW MANY POLES. (<9) (I FORMAT.)
:1
TYPE REAL PART. (F FORMAT.)
:2.76
TYPE IMAGINARY PART. (F FORMAT.)
:0.00
STEADY STATE OR TRANSIENT.
:TRANSIENT
TRANSIENT TIME-SECONDS. (F FORMAT.)
:12.78
MANYPOLE OR MANYPLOT.
:MANYPLOT
TYPE RK OR RX, ELSE JUST INTERRUPT.
:RX
EXECUTION REQUEST ACCEPTED.
:
CCDMI*EA            MERRY                    NORMAL TERM          0 +    2 SEC
:
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*LG,CCLMR*DA,MERRY
141256 25/01/73
MANYPLOT ANALYSIS CONTROL LOGGED IN. CALLED ON 25/01/73
TYPE A NAME FOR THE RUN. (LESS THAN 40 CHARACTERS).
:***TEST RUN NUMBER THREE***
TYPE YOUR GAIN TERM IN F FORMAT.
:1.1
HOW MANY ZEROES. (<9) (I FORMAT.)
:1
TYPE REAL PART. (F FORMAT.)
:7.77
TYPE IMAGINARY PART. (F FORMAT.)
:3.21
HOW MANY POLES. (<9) (I FORMAT.)
:0
STEADY STATE OR TRANSIENT.
:STEADY STATE
INITIAL FREQUENCY-HZ. (F FORMAT.)
:0.23
FINAL FREQUENCY-HZ. (F FORMAT.)
:0.24
MANYPOLE OR MANYPLOT.
:MANYPLOT
TYPE EK OR EX, ELSE JUST INTERRUPT.
:
DRUM LOG DELETED -INTERRUPT AND TRY AGAIN.
:
MANYPLOT ANALYSIS CONTROL LOGGED IN. CALLED ON 25/01/73
TYPE A NAME FOR THE RUN. (LESS THAN 40 CHARACTERS).
:


CCLMR*DA            MERRY               NORMAL TERM          0 +    2 SEC
:
```

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*LO,CCLMR*LA,MERRY
090106 30/01/73
MANYPLOT ANALYSIS CONTROL LOGGED IN. CALLED ON 30/01/73
TYPE A NAME FOR THE RUN. (LESS THAN 40 CHARACTERS).
: *** MMS2 PLL RESPONSE. ***
TYPE YOUR GAIN TERM IN F FORMAT.
:75.837
HOW MANY ZEROES. (<9) (I FORMAT.)
:1
TYPE REAL PART. (F FORMAT.)
:-33.333
TYPE IMAGINARY PART. (F FORMAT.)
:0.
HOW MANY POLES. (<9) (I FORMAT.)
:2
TYPE REAL PART. (F FORMAT.)
:-37.62
TYPE IMAGINARY PART. (F FORMAT.)
:33.06
TYPE REAL PART. (F FORMAT.)
:-37.62
TYPE IMAGINARY PART. (F FORMAT.)
:-33.06
STEADY STATE OR TRANSIENT.
:STEADY STATE
INITIAL FREQUENCY-HZ. (F FORMAT.)
:.001
FINAL FREQUENCY-HZ. (F FORMAT.)
:100.
MANYPOLE OR MANYPLOT.
:MANYPLOT
TYPE EK OR EX, ELSE JUST INTERRUPT.
:EK
EKUOE 01
EKUOE 00
BREAKIN REQUEST ACCEPTED
:
CCLMR*LA          MERRY                 NORMAL TERM          86 +    2 SEC
:
```