A LOG MODULUS AND PHASE ANGLE FREQUENCY RESPONSE CALCULATOR PROGRAM

By

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ABSTRACT

This paper describes an interactive program implemented in the basic language. The program was developed on a TRS-80 Model I system but may be executed on any other machine supporting basic with a few minor modifications. The program accepts the transfer function G(S) polynomial in unfactored form by prompting questions on screen then proceeds to calculate the magnitude and phase angle against frequency as parameter. Complex arithmetic is used in the calculations downstream. The points obtained are useful for Bode, Nyquist or Nichols plots, thus characterizing a linear system response to a sinousoidal excitation.

I. *Introduction*

Transfer function relate responses of linear or non-linear system to inputs that cause them. The forced response or steady state response would be known as the particular solution in classical as differential equations, while the force-free response or transient response refers to the complementary solution. After the transients however have died down (i.e., stable system) only the forced response remains. Thus, if y(t) is the output, a general equation maybe written as (in laplace)

$$y(t) = \mathcal{L}^{-1}\left[\left(\sum_{i=0}^{N} a_i s^i \Big/ \sum_{i=0}^{M} b_i s^i\right) x(s) + \left\langle \text{terms due to all initial values } x_0^k,\ y_0^k \right\rangle\right]$$

where $x(s) = \mathcal{L}[x(t)]$ = Laplace transform of the exciting input

$x_0^k \cdot y_0^k$ = initial conditions inclusive in the Laplace transformation process:

If the quantity $\langle$terms due to all initial values $x_0^k \cdot y_0^k\rangle$ is zero; the Laplace transform of output y(t) in response to an input simply given by

$Y(s) = G(s)\ X(s)$ (for a linear or linearized system)

Thus $$G(s) = \frac{Y(s)}{X(s)} = \frac{\text{output transform}}{\text{input transform}} = \frac{\sum a_i s^i}{\sum b_i s_i}$$

$$G(s) = \frac{a_N s^n + a_{n-1} s^{n-1} + \dots a_1 s^1 + a_0}{b_M s^m + b_{M-1} s^{m-1} + \dots b_1 s^1 + b_0}$$

m may or may not equal N.

In the frequency domain however a is substituted for jw j — complex number i.e., j= –1 and w in radians/sec. Thus, the linear system is subjected to a sinousoidal input and a sinousoidal output of different amplitude and phase results for the steady state response, all transient, having died out. Thus, the transfer function in frequency is

$$G(jw) = \frac{a_n (jw)^N + a_{n-1} (jw)^{N-1} + \dots a_1 jw + a_0}{b_m (jw)^{M_0} + b_{m-1} (jw)^{M-1} + \dots b_1 jw + b_0} = \frac{Z(jw)}{P(jw)}$$

where z are the zero roots of which make G(jw) = 0 and P are the poles, roots of which make G(jw) infinite. G(jw) = a complex number ratios of zeros to poles thus | Gjw | = magnitude and ($\angle$Gjw = angle = ϕ = MAG in phasor form.

In the block diagram of Figure 1,

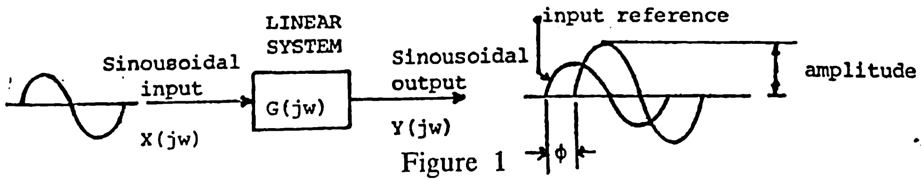


Figure 1

amplitude of the output is $|\gamma(jw)| = |G(jw)|\ |x(jw)|$

$$|y(jw)| = \frac{|z(jw)|}{|P(jw)|} |x(jw)| = \text{Amplitude}$$

$$\angle Y(jw) = \angle Z(jw) - \angle P(jw) + \angle X(jw) = \phi$$

As the systems get more and more complex and higher order, analytical solutions in G(s) transfer functions become practically impossible. These large system of equations can be solved fairly easily by going into the frequency domain. The procedure is:

a) the linear ordinary differential equations are Laplace Transformed.

b) the jaw is immediately substituted for s.

c) a specific numerical value of frequency w is chosen.

d) the resulting algebraic equations which are now in terms of complex variables, are solved numerically to obtain the desired transfer-function relationships. These G(jw) 's will be complex numbers that are points on Nyquist, Bode or Nichol's plots corresponding to the specific frequency chosen.

e) Another numerical value of w is specified and step (d) is repeated. Picking a number of frequencies over the range of interest for the process gives the complete frequency-response curves.

f) output of a system can now be determined given a sinousoidal exciting input.

II. *Program Description:*

Refer to Figure 2. The program prompts the user for any input data required. The form of the equation used in the program is:

$$G(s) = \frac{Z^N S^N + Z^{N-1} S^{N-1} + \ldots + Z^1 S + Z_O}{P^M S^M + P^{M-1} S^{M-1} + \ldots + P^1 S + P_O}$$

where the coefficient subscript corresponds to the power of s to identify where the coefficient belongs. Appropriate arrays Z (for the zeros) and P (for the poles) are then allocated. Since the program substitutes jw for S, $(jw)^N$ may be one of four cases: positive and real, negative and real, positive and imaginary or lastly negative and imaginary.

The subroutine located at line LΦΦΦ determines these cases and returns α and β as follows:

$$\alpha = \begin{cases} -1 & \text{if negative} \\ +1 & \text{if positive} \end{cases} \qquad \beta = \begin{cases} 1 - \text{if real} \\ 2 - \text{if imaginary} \end{cases}$$

Upon return, the appropriate real and imaginary numbers are accumulated (by using sums) correspondingly into Z(R), Z(I), P(R) and P(I) as the case maybe. Next the complex conjugate are used to rationalize the ratio of Z/P and are once more accumulated in G(R) and G(I). The modulus is taken as MAG $= G(R)^2 + G(I)^2$ and the angle as $\tan^1$ G(I)/G(R). Appropriate checks are then made for division by zero in case G(R) = 0 and angles. A Q flag is incorporated to signal a user defined frequency range of interest or a program generated range. Output is tabular form and may be printed or screen or out to line printer. By adding an appropriate graphics routine, a plot maybe made for angle and magnitude. This is left to left to the user.

Figure 2. PROGRAM FLOW CHART

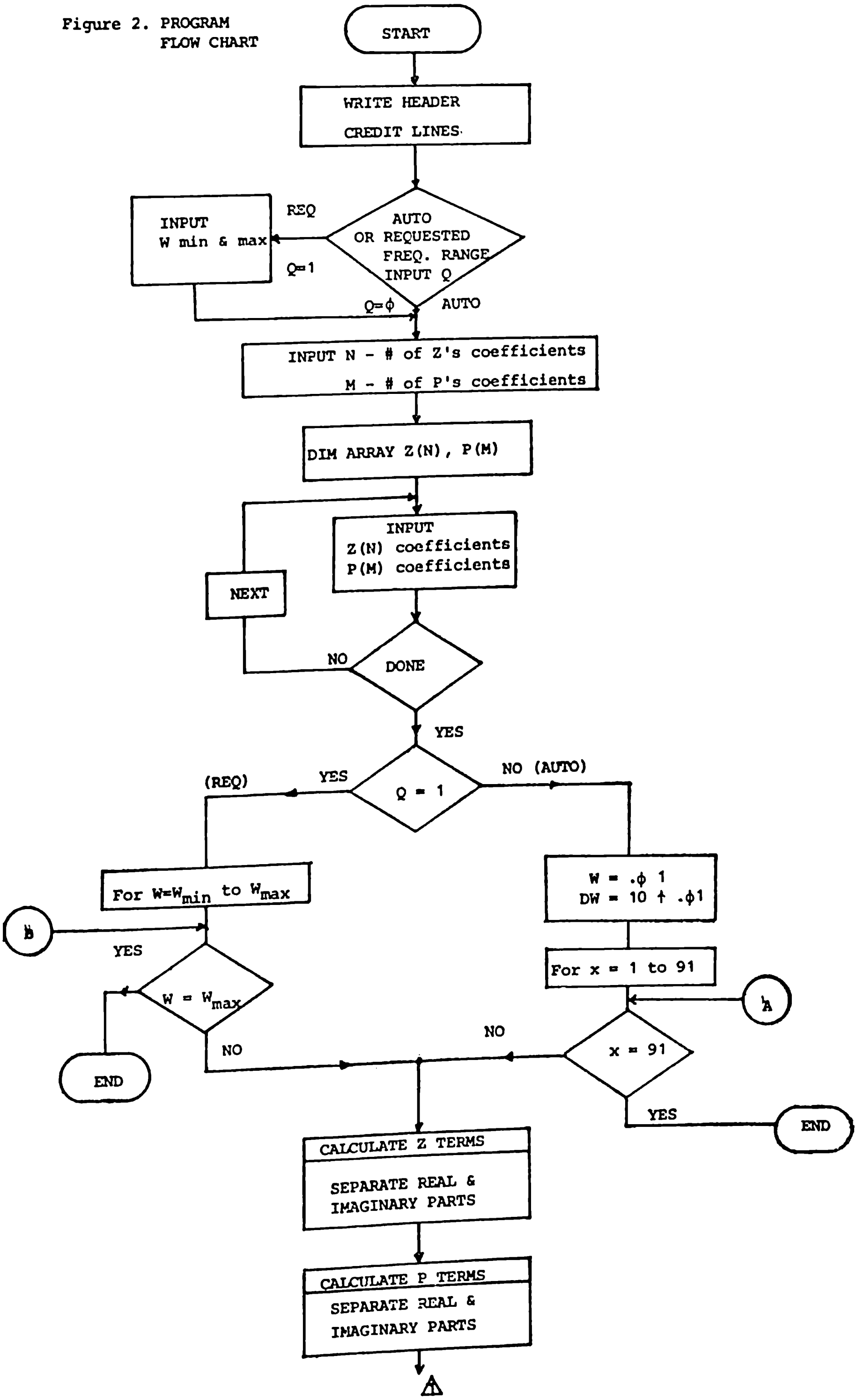
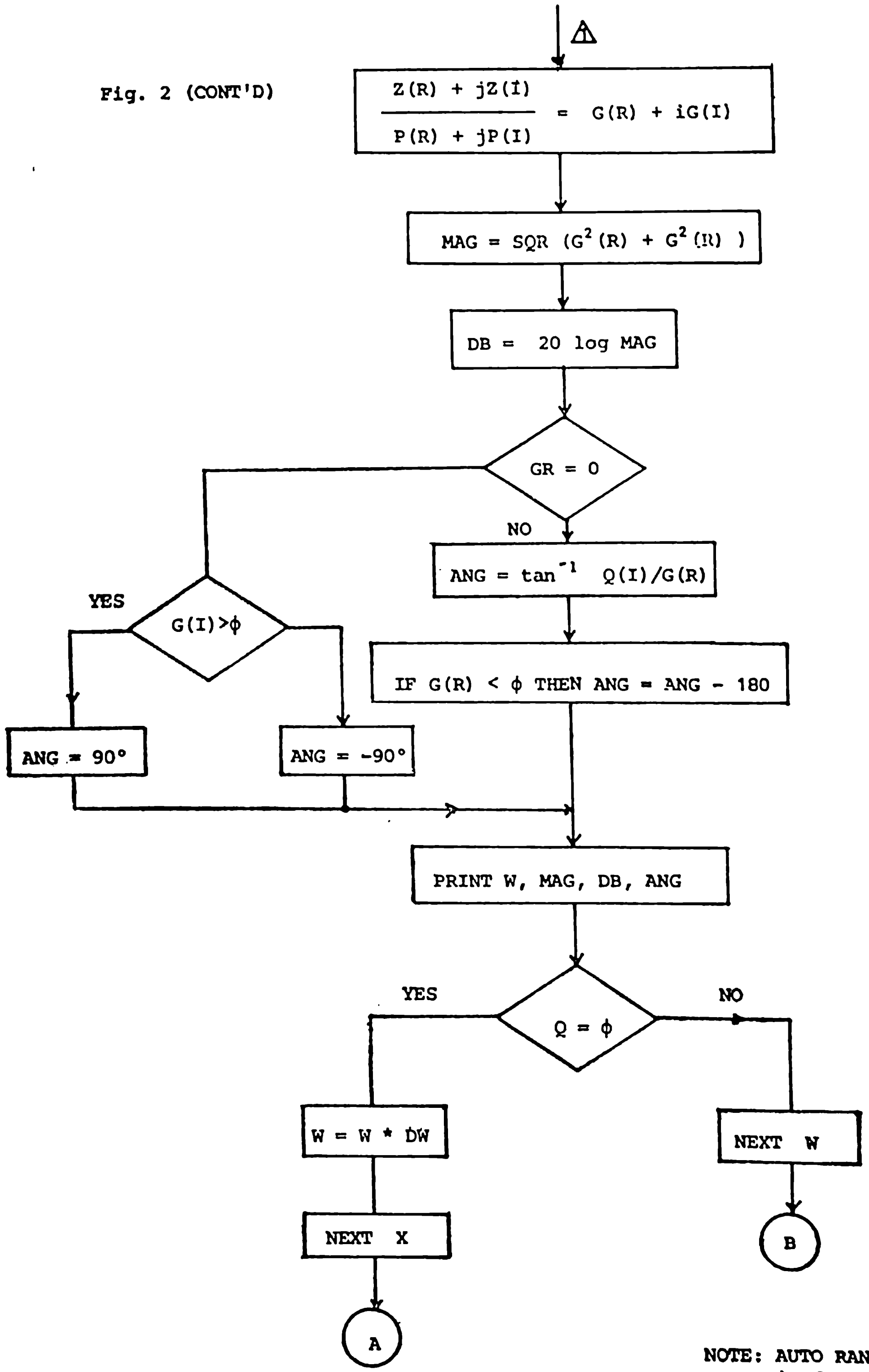


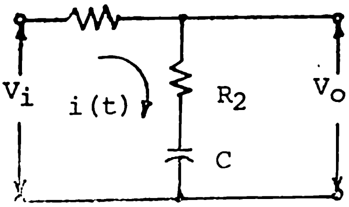
Fig. 2 (CONT'D)



NOTE: AUTO RANGE is from $W_{min}=0.01$ to $W_{max} = 1x10^7$ rad/sec

III. *Example Runs*

A. Finder the frequency response of the filter:



$R_1 = 1k\Omega$
$R_2 = 1k\Omega$
$C = 0.1ufd$
$Vc(0) = 0$

setting up the differential equations we have:

$$V_o = R\frac{1}{C}\int idt + iR_2$$

$$V_i = i(R_1 + R_2) + \frac{1}{C}\int idt$$

taking the transfer ratio we have:

$$V_o(s) = \frac{I(s)}{SC} + \frac{Q(o^+)}{C} + I(s)R_2 = I(s)\left(\frac{1}{CS} + R_2\right)$$

$$\sin V_c(0) = \frac{Q(o^+)}{C} = 0$$

$$V_i(s) = I(s)(R_1 + R_2) + \frac{I(s)}{SC} + \frac{Q(o^+)}{C} = I(s)(R_1 + R_2 + \frac{1}{SC})$$

Taking the transfer ratio we have

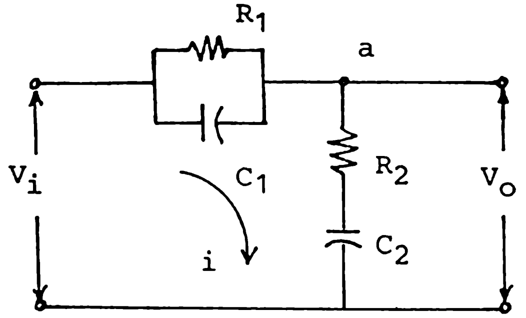
$$G(s) = \frac{V_o(s)}{V_i(s)} = \frac{I(s)\ R_2 + \frac{1}{SC}}{I(s)\left(R_1 + R_2 + \frac{1}{SC}\right)} = \frac{R_2 + 1/SC}{R_1 + R_2 + 1/SC}$$

$$G(s) = \frac{SCR_2 + 1}{SC(R_1 + R_2) + 1} = \frac{(0.1x10^{-6})(1x10^3)S + 1}{(2\ x\ 10^3)(0.1x10^{-6})S + 1} = \frac{(1E-4)S + 1}{(2E-4)S + 1}$$

$\therefore$ N = 1
Z(0) = 1
Z(1) = 1E-4
M = 1
P(0) = 1
P(1) = 2E-4

The results are shown in listing 1. It can be seen that the circuit is a low pass filter.

B. Find the frequency characteristic of:



$R_1 = 10k$
$C_1 = 0.01\ \mu fd$
$R_2 = 1K$
$C_2 = 0.1\mu fd$

Equating current at the output node a yields

$$\frac{1}{R_1}(V_i - V_o) + C_1 \frac{d(V_i - V_o)}{dt} = i$$

The voltage V_o and current are related by

$$\frac{1}{C_2}\int idt + iR_2 = V_o$$

Taking the Laplace of these two equations with zero initial condition

$$\left(\frac{1}{R_1} + C_1 s\right)\left[V_i(s) - V_o(s)\right] = \frac{V_o(s)}{\frac{1}{SC_2} + R_2}$$

$$G(s) = \frac{V_o(s)}{V_i(s)} = \frac{SC_1 + \frac{1}{R_1}}{\frac{1}{R_1} + SC_1 + \frac{1}{\frac{1}{SC_2} + R_2}} = \frac{R_1SC_1 + 1}{1 + SC\ R + \frac{R_1}{\frac{1}{SC_2} + R_2}}$$

$$\frac{V_o(s)}{V_i(s)} = \frac{SC_1R_1 + 1}{1 + SC_1R_1 + \frac{R_1SC_2}{1 + SC_2R_2}} = \frac{(SC_1R_1 + 1)(SC_2R_2 + 1)}{(1+SC_2R_2)(1+SC_1R_1) + R_1SC_2}$$

$$G(s) = \frac{V\ (s)}{V\ (s)} = \frac{S^2C_1C_2R_1R_2 + S(C_1R_1 + C_2R_2) + 1}{S^2R_1R_2C_1C_2 + S(C_1R_1 + C_2R_2 + C_2R_1) + 1}$$

Thus $G(s) = \dfrac{(1E{-}4)S^2 + (2E{-}4)S + 1}{(1E{-}4)S^2 + (1,2E{-}3)S+1}$ using the given values

$\therefore\quad N = 2 \qquad\qquad M = 2$

$Z(2) = 1E\text{-}4 \qquad P(2) = 1E\text{-}4$

$Z(1) = 2E\text{-}4 \qquad P(1) = 1.2\text{-}E\text{-}3$

$Z(0) = 1 \qquad P(0) = 1$

The results are shown in listing 2. It can be seen that Program appear in listing 3.

BIBLIOGRAPHY

* Feedback and Control Systems (Schaum's Series)
Di Steffans III Stubberud, Williams
McGraw Hill Copyright c 1967

* Process Modeling, Simulation and Control for Chemical Engineers
W.L. Luyben
McGraw Hill Copyright c 1967

* Process Systems Analysis and Control
Coughanowr and Koppel
McGraw Hill Copywright c 1967

DATE 70.204

LEVEL 15JUL68 IBM OS/360 BASIC FORTRAN IV (E) COMPILATION

```
S.0001      SUBROUTINE HRD
S.0002      REAL L,LQ(2,3),LV(2,3),LY(2,3),LVQ(2,3),LQV(2,23,LVJ1V(2,3)
S.0003      REAL LQQ2(2,3),LVV2(2,3),LVVI(2,3),LVQI(2,3),LQJ1V(2,3)
S.0004      REAL LYY(6),LXX(6),LX(6),LUU(6),LU(6),LUX(6),MSTLXU(6,6)
S.0005      COMMON Q(2,3),V(2(3),QO(1,3),VO(2,1),XX(2,3),KK,NPC,NTI,CT
S.0006      COMMON QMIN(2,3),QMAX(2,3),HQ(2,3),H(2,3),P(2,3),PK(2,3)
S.0007      COMMON PQ(2,3),Y(2,3),DELT,T,A(2),B(2),C(2),AP(2),BP(2),CP(2)
S.0008      COMMON AH(2),BH(2),CH(2),DH(2),AAA(2),BBB(2),CCC(2),DDD(2)
S.0009      COMMON HV(2,3),HJ1V(2,3)
S.0010      COMMON PV(2,3),PKQ(2,3),PKV(2,3),PJ1V(2,3),PKJ1V(2,3)
S.0011      COMMON PH(2,3),PQH(2,3),PVH(2,3),PJ1VH(2,3)
S.0012      COMMON ENERGY,POWERT
S.0013      COMMON LQ,LV,LY
S.0014      COMMON WQMN(2,3),WQMAX(2,3),L
S.0015      COMMON WPMX(2,3),WPMN(2,3),EFF,PMIN(2,3)
S.0016      COMMON PKQV(2,3),PKVQ(2,3)POWER3(2,3),PKQJ1V(2,3)
S.0017      COMMON PJ1VQ1(2,3),PKQQ2(2,3),PQQ2(2,3),PQV(2,3),PVQ(2,3)
S.0018      COMMON PKVV2(2,3),PVV2(2,3),POWER2(2,3),PJ1VV2(2,3)
S.0019      COMMON POWER1(2,3),PJ1VV1(2,3),PKVJ1V(2,3),PVJ1V(2,3)
S.0020      COMMON PQJ1V(2,3)
S.0021      COMMON PVQH(2,3),PQVH(2,3),POWER5(2,3),POWER6(2,3)
S.0022      COMMON POWER4(2,3),PQJ1VH(2,3),PQQ2H(2,3),PVV2H(2,3)
S.0023      COMMON PVJ1VH(2,3)
S.0024      COMMON LVQ,LQV,LVJ1V,LQQ2,LVV2,LVV1,LVQ1,LQJ1V
S.0025      COMMON LYY,LXX,LX,LUU,LU,LUX,MSTLXU
S.0026      COMMON HREDP(6,6),SMAT(6,6),HRED(6,6)
S.0027      COMMON HD(6,6),HDI(6,6),GE(6)
S.0028      COMMON VV(6),GD(6),HI(6,6)
S.0029      COMMON NTVIOL,NVIOL,NVIOL2(6),NVIOL3(6),VMIN(2,3),
              VMAX(2,3)
S.0030      COMMON DELU(6)
S.0031      WRITE(3,109)KK
S.0032  109 FORMAT('O',I5)
S.0033      K=O
S.0034      DO 5 J=1,NTI
S.0035      DO 5 I=1,NPC
S.0036      K=K+1
S.0037      VV(K)=V(I,J)
S.0038    5 CONTINUE
          C OBTAIN HD FROM HRED
S.0039      K=O
S.0040      N=1
S.0041      K4=KK-NVIOL
S.0042      DO 40 I=1,KK
S.0042      J=1
S.0044    9 IF(J-NVIOL2(N))10,11,10
S.0045   11 J=J+1
S.0046      N=N+1
S.0047      IF(J-NVIOL2(N))10,11,10
S.0048   10 K=K+1
```

```
      HD(I,K)=HRED(I,J)
      IF(K-K4)12,13,12
   13 K=O
      N=1
      GO TO 40
   12 J=J+1
      GO TO 9
   40 CONTINUE
C RE-INITIALIZE  SUBSCRIPT INDEX
      N=1
      K=O
   15 DO 41 J=1,K4
      I=1
   16 IF(I-NVIOL2(N))18,17,18
   17 I=I+1
      N=N+1
      IF(I-NVIOL2(N))18,17,18
   18 K=K+1
      HD(K,J)=HD(I,J)
      IF(K-K4)21,20,21
   20 K=O
      N=1
      GO TO 41
   21 I=I+1
      GO TO 16
   41 CONTINUE
      WRITE(3,1)K4,NVIOL,NTVIOL
    1 FORMAT('O','K4=',15,'NVIOL IS',15,'NTVIOL IS',15)
      WRITE(3,100)((HD(I,J),J=1,K4),I=1,K4)
  100 FORMAT('O',12E10.3)
      WRITE(3,94)
   94 FORMAT('O','PASSED HRD')
      RETURN
      END
```

STORAGE MAP VARIABLE (TAGS C=COMMON, E=EQUIVALENCE)

NAME	TAG	REL ADR	NAME	TAG	REL ADR	NAME	TAG	REL ADR	NAME	TAG	REL ADR
Q	C	000000	V	C	000018	QO	C	000030	VO	C	00003C
XX	C	000044	KK	C	00005C	NPC	C	000060	NTI	C	000064
CT	C	000068	QMIN	C	00006C	QMAX	C	000084	HQ	C	00009C
H	C	000084	P	C	0000CC	PK	C	0000E4	PQ	C	0000FC
Y	C	000114	DELT	C	00012C	T	C	000130	A	C	000134
B	C	00013C	C	C	000144	AP	C	00014C	BP	C	000154
CP	C	00015C	AH	C	000164	BH	C	00016C	CH	C	000174
DH	C	00017C	AAA	C	000184	BBB	C	00018C	CCC	C	000194
DDD	C	00019C	HV	C	0001A4	HJ1V	C	0001BC	PV	C	0001D4
PKQ	C	0001EC	PKV	C	000204	PJ1V	C	00021C	PKJ1V	C	000234
PH	C	00024C	PQH	C	000264	PVH	C	00027C	PJ1VH	C	000294
ENERGY	C	0002AC	POWERT	C	0002B0	LQ	C	0002B4	LV	C	0002CC
LY	C	0002E4	WQMN	C	0002FC	WQMAX	C	000314	L	C	00032C
WPMX	C	000330	WPMN	C	000348	EFF	C	000360	PMIN	C	000364
PKQV	C	00037C	PKVQ	C	000394	POWER3	C	0003AC	PKQJ1V	C	0003C4
PJ1VQ1	C	0003DC	PKQQ2	C	0003F4	PQQ2	C	00040C	PQV	C	000424
PVQ	C	00043C	PKVV2	C	000454	PVV2	C	00046C	POWER2	C	000484
PJIVV2	C	00049C	POWER1	C	0004B4	PJ1VV1	C	0004CC	PKVJ1V	C	0004E4
PVJIV	C	0004FC	PQJ1V	C	000514	PVQH	C	00052C	PQVH	C	000544
POWER5	C	00055C	POWER6	C	000574	POWER4	C	00058C	PQJ1VH	C	0005A4
PQQ2H	C	0005BC	PVV2H	C	0005D4	PVJ1VH	C	0005EC	LVQ	C	000604
LQV	C	00061C	LVJ1V	C	000634	LQQ2	C	00064C	LVV2	C	000664
LVV1	C	00067C	LVQ1	C	000694	LQJ1V	C	0006AC	LYY	C	0006C4
LXX	C	0006DC	LX	C	0006F4	LUU	C	00070C	LU	C	000724
LUX	C	00073C	MSTLXU	C	000754	HREDP	C	0007E4	SMAT	C	000874
HRED	C	000904	HD	C	000994	HDI	C	000A24	GE	C	000AB4
VV	C	000ACC	GD	C	000AE4	HI	C	000AFC	NTVIOL	C	000084
NVIOL	C	000890	NVIOL2	C	000B94	NVIOL3	C	000BAC	VMIN	C	000B8C
VMAX	C	000BDC	DELU	C	000BF4	K		000080	J		00084
I		000088	N		00008C	K4		000090			000BC4

EXTERNAL REFERENCES

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CONSTANTS

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00000008	000144	00000018	000148				

IMPLIED EXTERNAL REFERENCES

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IBCOM=	000140						

STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR
00109	0000D8	00005	0001C6	00009	00021A	00011	000230
00010	00025E	00013	0002A4	00012	0002BA	00040	0002CC
00015	0002F0	00016	000300	00017	000316	00018	000344
00020	00038A	00021	0003A0	00041	0003B2	00001	0000E0
00100	000108	00094	000114				

SIZE OF COMMON 003084 PROGRAM 001180

END OF COMPILATION HRD

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                                                            DATE 79.204
LEVEL  15JUL68    IBM OS/360 BASIC FORTRAN IV (E) COMPILATION
S.0001      SUBROUTINE HDINV
S.0002      REAL L,LQ(2,3),LV(2,3),LY(2,3),LVQ(2,3),LQV(2,3),LVJ1V(2,3)
S.0003      REAL LQQ2(2,3),LVV2(2,3),LVV1(2,3),LVQ1(2,3),LQJ1V(2,3)
S.0004      REAL LYY(6),LXX(6),LX(6),LUU(6),LU(6),LUX(6),MSTLXU(6,6)
S.0005      COMMON Q(2,3),V(2,3),QO(1,3),VO(2,1),XX(2,3),KK,NPC,NTT,CT
S.0006      COMMON QMIN(2,3),QMAX(2,3),HQ(2,3),H(2,3),P(2,3),PK(2,3)
S.0007      COMMON PQ(2,3),Y(2,3),DELT,T,A(2),B(2),C(2),AP(2),BP(2),CP(2)
S.0008      COMMON AH(2),BH(2),CH(2),DH(2),AAA(2),BBB(2),CCC(2),DDD(2)
S.0009      COMMON HV(2,3),HJ1V((,3)
S.0010      COMMON PV(2,3),PKQ(2,3),PKV(2,3),PJ1V(2,3),PKJ1V(2,3)
S.0011      COMMON PH(2,3),PQH(2,3),PVH(2,3),PJ1VH(2,3)
S.0012      COMMON ENERGY,POWERT
S.0013      COMMON LQ,LV,LY
S.0014      COMMON WQMN(2,3),WQMAX(2,3),L
S.0015      COMMON WPMX(2,3),WPMN(2,3),EFF,PMIN(2,3)
S.0016      COMMON PKQV(2,3),PKVQ(2,3),POWER3(2,3),PKQJ1V(2,3)
S.0017      COMMON PJIVQ1(2,3),PKQQ2(2,3),PQQ2(2,3),PQV(2,3),PVQ(2,3)
S.0018      COMMON PKVV2(2,3),PVV2A2,3),POWER2(2,3),PJ1VV2(2,3)
S.0019      COMMON POWER1(2,3),PJ1VV1(2,3),PKVL1V(2,3),PVJ1V(2,3)
S.0020      COMMON PQJ1V(2,3)
S.0021      COMMON PVQH(2,3),PQVH(2,3),POWER5(2,3),POWER6(2,3)
S.0022      COMMON POWER4(2,3),PQJ1VH(2,3),PQQ2H(2,3),PVV2H(2,3)
S.0023      COMMON PVJ1VH(2,3)
S.0024      COMMON LVQ,LQV,LVJ1V,LQQ2,LVV2,LVV1,LVQ1,LQ1V
S.0025      COMMON LYY,LXX,LX,LUU,LU,LUX,MSTLXU
S.0026      COMMON HREDP(6,6),SMAT(6,6),HRED(6,6)
S.0027      COMMON HD(6,6),HDI(6,6),GE(6)
S.0028      COMMON VV(6),GD(6),HI(6,6)
S.0029      COMMON NTVIOL,NVIOL,NVIOL2(6),NVIOL3(6),VMIN(2,3),
               VMAX(2,3)
S.0030      COMMON DELU(6)
S.0031      DIMENSION L2(6),M2(6),DD(36)
S.0032      WRITE(3,109)KK
S.0033  109 FORMAT('0',15)
S.0034      K4=KK-NVIOL
S.0035      DO 40 J=1,K4
S.0036      DO 40 I=1,K4
S.0037      HDI(I,J)=HD(I,J)
S.0038   40 CONTINUE
S.0039      CALL ARRAY(2,K4,K4,KK,KK,DD,HDI)
S.0040      CALL MINV(DD,K4,W,L2,M2)
S.0041      CALL ARRAY(1,K4,K4,KK,KK,DD,HDI)
S.0042      WRITE(3,95)
S.0043   95 FORMAT('0','PASSEDHDINV')
S.0044      WRITE(3,100)((HDI(I,J),J=1,K4),I=1,K4)
S.0045  100 FORMAT('0',12E10.3)
S.0046      RETURN
S.0047      END
```

STORAGE MAP VARIABLES (TAGS C=COMMON, E=EQUIVALENCE)

NAME	TAG	REL ADR	NAME	TAG	REL ADR	NAME	TAG	REL ADR	NAME	TAG	REL ADR
Q	C	000000	V	C	000018	QO	C	000030	VO	C	00003C
XX	C	000044	KK	C	00005C	NPC	C	000060	NTI	C	000064
CT	C	000068	QMIN	C	00006C	QMAX	C	000084	HQ	C	00009C
H	C	0000B4	QMIN	C	0000CC	PK	C	0000E4	PQ	C	0000FC
Y	C	000114	P	C	00012C	T	C	000130	A	C	000134
B	C	00013C	DELT	C	000144	AP	C	00014C	BP	C	000154
CP	C	00015C	C	C	000164	BH	C	00016C	CH	C	000174
DH	C	00017C	AH	C	000184	BBB	C	00018C	CCC	C	000194
DDD	C	00019C	AAA	C	0001A4	HJ1V	C	0001BC	PV	C	0001D4
PKQ	C	0001EC	HV	C	000204	PJ1V	C	00021C	PKJ1V	C	000234
PH	C	00024C	PKV	C	000264	PVH	C	00027C	PJ1VH	C	000294
ENERGY	C	0002AC	PQH	C	0002B0	LQ	C	0002B4	LV	C	0002CC
LY	C	0002E4	POWERT	C	0002FC	WQMAX	C	000314	L	C	00032C
WPMX	C	000330	WQMN	C	000348	EFF	C	000360	PMIN	C	000364
PKQV	C	00037C	WPMN	C	000394	POWER3	C	0003AC	PKQJ1V	C	0003C4
PJ1VQ1	C	0003DC	PKVQ	C	0003F4	PQQ2	C	00040C	PQV	C	000424
PVQ	C	00043C	PKQQ2	C	000454	PVV2	C	00046C	POWER2	C	000484
PJ1VV2	C	00049C	PKVV2	C	0004B4	PJ1VV1	C	0004CC	PKVJ1V	C	0004E4
PVJ1V	C	0004FC	POWER1	C	000514	PVQH	C	00052C	PQVH	C	000544
POWER5	C	00055C	PQJ1V	C	000574	POWER4	C	00058C	PQJ1VH	C	0005A4
PQQ2H	C	0005BC	POWER6	C	0005D4	PVJ1VH	C	0005EC	LVQ	C	000604
LQV	C	00061C	PVV2H	C	000634	LQQ2	C	00064C	LVV2	C	000664
LVV1	C	00067C	LVJ1V	C	000694	LQJ1V	C	0006AC	LYY	C	0006C4
LXX	C	0006DC	LVQ1	C	0006F4	LUU	C	00070C	LU	C	000724
LUX	C	00073C	LX	C	000754	HREDP	C	0007E4	SMAT	C	000874
HRED	C	000904	MSTLXU	C	000994	HDI	C	000A24	GE	C	000AB4
VV	C	000ACC	HD	C	000AE4	HI	C	000AFC	NTVIOL	C	000B8C
NVIOL	C	000B90	GD	C	000B94	NVIOL3	C	000BAC	VMIN	C	000BC4
VMAX	C	000BDC	NVIOL2	C	000BF4	J		000080	I		000084
W		000088	DELU	C	00008C	M2		0000A4	DD		0000BC
K4		00014C									

```
                                                              DATE 79.204
LEVEL  15JUL68    IBM OS/360 BASIC FORTRAN IV (E) COMPILATION
S.0001      SUBROUTINE CONTRD
S.0002      REAL L,LQ(2,3),LV(2,3),LY(2,3),LVQ(2,3),LQV(2,3),LVJ1V(2,3)
S.0003      REAL LQQ2(2,3),LVV2(2,3),LVV1(2,3),LVQ1(2,3),LQJ1V(2,3)
S.0004      REAL LYY(6),LXX(6),LX(6),LUU(6),LU(6),LUX(6),MSTLXU(6,6)
S.0005      COMMON Q(2,3),V(2,3),QO(1,3),VO(2,1),XX(2,3),KK,NPC,NTI,CT
S.0006      COMMON QMIN(2,3),QMAX(2,3),HQ(2,3),H(2,3),P(2,3),PK(2,3)
S.0007      COMMON PQ(2,3),Y(2,3),DELT,T,A(2),B(2),C(2),AP(2),BP(2),CP(2)
S.0008      COMMON AH(2),BH(2),CH(2),DH(2),AAA(2),BBB(2),CCC(2),DDD(2)
S.0009      COMMON HV(2,3),HJ1V(2,3)
S.0010      COMMON PV(2,3),PKQ(2,3),PKV(2,3),PJ1V(2,3),PKJ1V(2,3)
S.0011      COMMON PH(2,3),PQH(2,3),PVH(2,3),PJ1VH(2,3)
S.0012      COMMON ENERGY,POWERT
S.0013      COMMON LQ,LV,LY
S.0014      COMMON WQMN(2,3),WQMAX(2,3),L
S.0015      COMMON WPMX(2,3),WPMN(2,3),EFF,PMIN(2,3)
S.0016      COMMON PKQV(2,3),PKVQ(2,3),POWER3(2,3),PKQJ1V(2,3)
S.0017      COMMON PJ1VQ1(2,3),PKQQ2(2,3),PQQ2(2,3),PQV(2,3),PVQ(2,3)
S.0018      COMMON PKVV2(2,3),PVV2(2,3),POWER2(2,3),PJIVV2(2,3)
S.0019      COMMON POWER1(2,3),PJ1VV1(2,3),PKVJ1V(2,3),PVJ1V(2,3)
S.0020      COMMON PQJ1V(2,3)
S.0021      COMMON PVQH(2,3),PQVH(2,3),POWER5(2,3),POWER6(2,3)
S.0022      COMMON POWER4(2,3),PQJ1VH(2,3),PQQ2H(2,3),PVV2H(2,3)
S.0023      COMMON PVJ1VH(2,3)
S.0024      COMMON LVQ,LQV,LVJ1V,LQQ2,LVV2,LVV1,LVQ1,LQJ1V
S.0025      COMMON LYY,LXX,LX,LUU,LU,LUX,MSTLXU
S.0026      COMMON HREDP(6,6),SMAT(6,6),HRED(6,6)
S.0027      COMMON HD(6,6),HDI(6,6),GE(6)
S.0028      COMMON VV(6),GD(6),HI(6,6)
S.0029      COMMON NTVIOL,NVIOL,NVIOL2,(6),NVIOL3(6),VMIN(2,3),
               VMAX(2,3)
S.0030      COMMON DELU(6)
S.0031      COMMON DELUD(6),DELX(6),DELY(6)
S.0032      KKK=KK-NVIOL
S.0033      DO 40 I=1,KKK
S.0034      DELUD(I)=0.0
S.0035      DO 40 K=1,KKK
S.0036      DELUD(I)=DELUD(I)-HDI(I,K)*GD(K)
S.0037   40 CONTINUE
      C CALCULATE FOR NEW VARIABLES (NON-VIOLATING VALUES)
S.0038      DO 41 N=1,KKK
S.0039      K=NVIOL3(N)
S.0040      VV(K)=VV(K)+DELUD(N)
S.0041   41 CONTINUE
S.0042      K=0
S.0043      DO 42 J=1,NTI
S.0044      DO 42 I=1,NPC
S.0045      K=K+1
S.0046      V(I,J)=VV(K)
S.0047   42 CONTINUE
S.0048      WRITE(3,96)
S.0049   96 FORMAT('0','PASSED CONTRD')
S.0050      WRITE(3,100)(DELUD(I),I=1,KKK)
S.0051  100 FORMAT('0',12E10.3)
S.0052      RETURN
```

EXTERNAL REFERENCES

NAME	REL ADR	NAME	REL ADR	NAME	REL ADR	NAME	REL ADR
MINV	000150	ARRAY	000154				

CONSTANTS

NAME	REL ADR	NAME	REL ADR	NAME	REL ADR	NAME	REL ADR
00000002	000164	00000001	000168	NAME		NAME	
00000018	0001F8						

IMPLIED EXTERNAL REFERENCES

NAME	REL ADR	NAME	REL ADR	NAME	REL ADR	NAME	REL ADR
IBCOM=	0001F4						

STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR
00109	000170	00040	000266	00095	000178	00100	00018C

STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR	STATEMENT NUMBER	REL ADR

SIZE OF COMMON 003084 PROGRAM 000864

END OF COMPILATION HDINV

S.0053 END

STORAGE MAP VARIABLES (TAGS C=COMMON, E=EQUIVALENCE)

NAME	TAG	REL ADR	NAME	TAG	REL ADR	NAME	TAG	REL ADR	NAME	TAG	REL ADR
Q	C	000000	V	C	000018	QO	C	000030	VO	C	00003C
XX	C	000044	KK	C	00005C	NPC	C	000060	NTI	C	000064
CT	C	000068	QMIN	C	00006C	QMAX	C	000084	HQ	C	00009C
H	C	0000B4	P	C	0000CC	PK	C	0000E4	FQ	C	0000FC
Y	C	000114	DELT	C	00012C	T	C	000130	A	C	000134
B	C	00013C	C	C	000144	AP	C	00014C	BP	C	000154
CP	C	00015C	AH	C	000164	BH	C	00016C	CH	C	000174
DH	C	00017C	AAA	C	000184	BBB	C	00018C	CCC	C	000194
DDD	C	00019C	HV	C	0001A4	HJ1V	C	0001BC	PV	C	0001D4
PKQ	C	0001EC	PKV	C	000204	PJ1V	C	00021C	PKJ1V	C	000234
PH	C	00024C	PQH	C	000264	PVH	C	00027C	PJ1VH	C	000294
ENERGY	C	0002AC	POWERT	C	0002B0	LQ	C	0002B4	LV	C	0002CC
LY	C	0002E4	WQMN	C	0002FC	WQMAX	C	000314	L	C	00032C
WPMX	C	000330	WPMN	C	000348	EFF	C	000360	PMIN	C	000364
PKQV	C	00037C	PKVQ	C	000394	POWER3	C	0003AC	PKQJ1V	C	0003C4
PJ1VQ1	C	0003DC	PKQQ2	C	0003F4	PQQ2	C	00040C	PQV	C	000424
PVQ	C	00043C	PKVV2	C	000454	PVV2	C	00046C	POWER2	C	000484
PJ1VV2	C	00049C	POWER1	C	0004B4	PJ1VV1	C	0004CC	PKVJ1V	C	0004E4
PVJ1V	C	0004FC	PQJ1V	C	000514	PVQH	C	00052C	PQVH	C	000544
POWER5	C	00055C	POWER6	C	000574	POWER4	C	00058C	PQJ1VH	C	0005A4
PQQ2H	C	0005BC	PVV2H	C	0005D4	PVJ1VH	C	0005EC	LVQ	C	000604
LQV	C	00061C	LVJ1V	C	000634	LQQ2	C	00064C	LVV2	C	000664
LVV1	C	00067C	LVQ1	C	000694	LQJ1V	C	0006AC	LYY	C	0006C4
LXX	C	0006DC	LX	C	0006F4	LUU	C	00070C	LU	C	000724
LUX	C	00073C	MSTLXU	C	000754	HREDP	C	0007E4	SMAT	C	000874
HRED	C	000904	HD	C	000994	HDI	C	000A24	GE	C	000AB4
VV	C	000ACC	GD	C	000AE4	HI	C	000AFC	NTVIOL	C	000B8C
NVIOL	C	000B90	NVIOL2	C	000B94	NVIOL3	C	000BAC	VMIN	C	000BC4
VMAX	C	000BDC	DELU	C	000BF4	DELUD	C	000C0C	DELX	C	000C24
DELY	C	000C3C	I		000080	K		000084	N		000088
J		00008C	KKK		000090						

EXTERNAL REFERENCES

NAME	REL ADR	NAME	REL ADR	NAME	REL ADR	NAME	REL ADR

CONSTANTS

NAME	REL ADR	NAME	REL ADR	NAME	REL ADR	NAME	REL ADR
00000000	0000A8	00000001	0000AC	00000000	0000B0		
00000018	0000F0	00000008	0000F4				

IMPLIED EXTERNAL REFERENCES

NAME	REL ADR	NAME	REL ADR	NAME	REL ADR	NAME	REL ADR
IBCOM=	0000F8						

LISTING #1 FOR EXAMPLE A

RADIAN FREQ	MAGNITUDE	DECIBELS	DEGREES
.01	1	0	-5.72964E-05
.0125893	1	0	-7.21319E-05
.0158489	1	0	-9.08086E-05
.0199526	1	0	-1.14321E-04
.0251189	1	0	-1.43922E-04
.0316228	1	0	-1.81187E-04
.0398107	1	0	-2.28101E-04
.0501187	1	0	-2.87162E-04
.0630958	1	0	-3.61516E-04
.0794329	1	0	-4.55121E-04
.1	1	0	-5.72964E-04
.125893	1	0	-7.21319E-04
.158489	1	0	-9.08087E-04
.199526	1	0	-1.14321E-03
.251189	1	0	-1.43922E-03
.316228	1	0	-1.81187E-03
.398107	1	0	-2.28101E-03
.501187	1	0	-2.87162E-03
.630958	1	0	-3.61516E-03
.794329	1	0	-4.55122E-03
1	1	0	-5.72964E-03
1.25893	1	-6.98687E-07	-7.21319E-03
1.58489	1	-6.98697E-07	-9.08087E-03
1.99526	1	0	-.0114321
2.51189	1	-6.98697E-07	-.0143922
3.16228	1	0	-.0181187
3.98107	1	-6.98697E-07	-.0228101
5.01188	1	-2.32899E-06	-.0287162
6.30958	1	-4.42509E-06	-.0361516
7.94329	.999999	-7.45278E-06	-.0455121
10	.999998	-1.28095E-05	-.0572963
12.5893	.999998	-1.968E-05	-.0721317
15.8489	.999996	-3.27225E-05	-.0908082
19.9526	.999994	-5.17041E-05	-.11432
25.1189	.999991	-8.17489E-05	-.14392
31.6228	.999985	-1.29728E-04	-.181183
39.8108	.999976	-2.0659E-04	-.228093
50.1188	.999962	-3.2771E-04	-.287146
63.0958	.99994	-5.18368E-04	-.361483
79.4329	.999906	-8.20282E-04	-.455055
100	.99985	-1.30165E-03	-.572831
125.893	.999763	-2.06348E-03	-.721053
158.49	.999623	-3.27159E-03	-.907556
199.526	.999404	-5.18118E-03	-1.14215
251.189	.999056	-8.20633E-03	-1.43711
316.228	.998505	-.0129966	-1.80766
398.108	.997635	-.020568	-2.27261
501.188	.996263	-.0325221	-2.85491
630.958	.994105	-.0513587	-3.58193
794.329	.990726	-.0809323	-4.48532

1000	.985472	-.127119	-5.5994
1258.93	.977388	-.198659	-6.95718
1584.9	.965155	-.308061	-8.58174
1995.27	.947087	-.472202	-10.4709
2511.89	.921335	-.711648	-12.5737
3162.28	.886405	-1.04735	-14.7633
3981.08	.842026	-1.49349	-16.8196
5011.88	.790006	-2.04739	-18.4487
6309.58	.734373	-2.68167	-19.3551
7943.29	.680321	-3.34573	-19.3502
10000	.632455	-3.97941	-18.4351
12589.3	.593452	-4.53229	-16.8001
15849	.563816	-4.97726	-14.741
19952.7	.542508	-5.31188	-12.5513
25118.9	.527811	-5.55044	-10.4502
31622.8	.51797	-5.71391	-8.56361
39810.8	.511514	-5.82285	-6.94184
50118.8	.507337	-5.89407	-5.58672
63095.8	.504659	-5.94005	-4.47499
79432.9	.502951	-5.96948	-3.57359
100000	.501867	-5.98823	-2.84821
125893	.50118	-6.00013	-2.26726
158490	.500745	-6.00767	-1.80339
199527	.50047	-6.01243	-1.43371
251189	.500297	-6.01545	-1.13945
316228	.500187	-6.01735	-.905406
398108	.500118	-6.01855	-.719344
500118	.500075	-6.0193	-.571473
630959	.500047	-6.01978	-.453976
794330	.50003	-6.02009	-.360625
1E+06	.500019	-6.02028	-.286464
1.25893E+06	.500012	-6.0204	-.227552
1.5849E+06	.500007	-6.02047	-.180753
1.99527E+06	.500005	-6.02052	-.143579
2.51189E+06	.500003	-6.02055	-.114049
3.16228E+06	.500002	-6.02057	-.0905929
3.98108E+06	.500001	-6.02058	-.0719606
5.01188E+06	.500001	-6.02059	-.0571604
6.30959E+06	.500001	-6.02059	-.0454042
7.9433E+06	.5	-6.0206	-.0360658
1E+07	.5	-6.0206	-.0286481

********** END **********

LISTING #2 FOR EXAMPLE B

RADIAN FREQ	MAGNITUDE	DECIBELS	DEGREES
.01	1	0	-5.72964E-04
.0125893	1	0	-7.21319E-04
.0158489	1	0	-9.08087E-04
.0199526	1	0	-1.14321E-03
.0251189	1	0	-1.43922E-03
.0316228	1	0	-1.81187E-03
.0398107	1	0	-2.28101E-03
.0501187	1	0	-2.87162E-03
.0630958	1	0	-3.61516E-03
.0794329	1	0	-4.55122E-03
.1	1	0	-5.72965E-03
.125893	1	0	-7.2132E-03
.158489	1	0	-9.08089E-03
.199526	1	0	-.0114322
.251189	1	-6.98697E-07	-.0143923
.316228	1	0	-.0181189
.398107	1	-6.98697E-07	-.0228105
.501187	1	-1.74674E-06	-.0287169
.630958	1	-2.21254E-06	-.036153
.794329	1	-3.84284E-06	-.045515
1	.999999	-5.93893E-06	-.0573021
1.25893	.999999	-9.08308E-06	-.0721433
1.58489	.999998	-1.49056E-05	-.0908313
1.99526	.999997	-2.38723E-05	-.114367
2.51189	.999996	-3.80793E-05	-.144012
3.16228	.999993	-6.06709E-05	-.181368
3.98107	.999989	-9.70043E-05	-.228461
5.01188	.999982	-1.53369E-04	-.287881
6.30958	.999972	-2.43507E-04	-.362953
7.94329	.999955	-3.88272E-04	-.457995
10	.999929	-6.20051E-04	-.578718
12.5893	.999886	-9.94551E-04	-.732867
15.8489	.999815	-1.60715E-03	-.931344
19.9526	.999698	-2.62457E-03	-1.19032
25.1189	.999497	-4.36723E-03	-1.53551
31.6228	.999137	-7.49899E-03	-2.01177
39.8108	.998437	-.0135847	-2.70715
50.1188	.99688	-.0271475	-3.8251
63.0958	.992399	-.0662777	-5.96884
79.4329	.969121	-.272437	-12.0175
100	.166667	-15.563	3.98432E-03
125.893	.969122	-.272432	12.0174
158.49	.992399	-.0662766	5.96882
199.526	.99688	-.0271464	3.82509
251.189	.998437	-.0135858	2.70714
316.228	.999137	-7.49899E-03	2.01176

398.108	.999497	-4.36781E-03	1.53551
501.188	.999698	-2.62457E-03	1.19032
630.958	.999815	-1.60563E-03	.931342
794.329	.999886	-9.94551E-04	.732865
1000	.999929	-6.20051E-04	.578717
1258.93	.999955	-3.88272E-04	.457994
1584.9	.999972	-2.43507E-04	.362952
1995.27	.999982	-1.53369E-04	.287881
2511.89	.999989	-9.70043E-05	.228461
3162.28	.999993	-6.06709E-05	.181367
3981.08	.999996	-3.80793E-05	.144012
5011.88	.999997	-2.38723E-05	.114366
6309.58	.999998	-1.49056E-05	.0908311
7943.29	.999999	-9.08308E-06	.0721432
10000	.999999	-5.93893E-06	.057302
12589.3	1	-3.84284E-06	.0455149
15849	1	-2.32899E-06	.036153
19952.7	1	-6.98697E-07	.0287169
25118.9	1	-6.98697E-07	.0228104
31622.8	1	0	.0181189
39810.8	1	0	.0143923
50118.8	1	0	.0114322
63095.8	1	0	9.08088E-03
79432.9	1	0	7.21319E-03
100000	1	0	5.72964E-03
125893	1	0	4.55121E-03
158490	1	0	3.61515E-03
199527	1	0	2.87162E-03
251189	1	0	2.28101E-03
316228	1	0	1.81187E-03
398108	1	0	1.43922E-03
501188	1	0	1.14321E-03
630959	1	0	9.08085E-04
794330	1	0	7.21318E-04
1E+06	1	0	5.72963E-04
1.25893E+06	1	0	4.55121E-04
1.5849E+06	1	0	3.61515E-04
1.99527E+06	1	0	2.87162E-04
2.51189E+06	1	0	2.28101E-04
3.16228E+06	1	0	1.81187E-04
3.98108E+06	1	0	1.43922E-04
5.01188E+06	1	0	1.14321E-04
6.30959E+06	1	0	9.08085E-05
7.9433E+06	1	0	7.21318E-05
1E+07	1	0	5.72963E-05

********** END **********

LISTING #2 FOR ZOOM IN RANGE 70–130 RADIANS/SEC

RADIAN FREQ	MAGNITUDE	DECIBELS	DEGREES
70	.987078	–.112974	–7.78063
71	.985964	–.122781	–8.10861
72	.984726	–.133695	–8.45822
73	.983345	–.14588	–8.83168
74	.9818	–.159538	–9.23157
75	.980065	–.174901	–9.66084
76	.978109	–.192257	–10.1229
77	.975894	–.211948	–10.6216
78	.973375	–.234398	–11.1615
79	.970496	–.260126	–11.7478
80	.967189	–.289775	–12.3867
81	.963369	–.32415	–13.0855
82	.958929	–.364271	–13.8527
83	.953736	–.411434	–14.6985
84	.94762	–.467312	–15.6349
85	.940363	–.534094	–16.6763
86	.93168	–.614666	–17.8402
87	.921202	–.712898	–19.1474
88	.908442	–.834055	–20.623
89	.892751	–.985398	–22.2966
90	.87326	–1.17713	–24.2032
91	.848804	–1.42385	–26.3824
92	.817821	–1.74684	–28.876
93	.778247	–2.17766	–31.7199
94	.727431	–2.76416	–34.9257
95	.662194	–3.5803	–38.4341
96	.579252	–4.74266	–42.0021
97	.47649	–6.43893	–44.9093
98	.356078	–8.9691	–45.0572
99	.23305	–12.651	–35.6352
100	.166667	–15.563	–7.11486E–04
101	.231953	–12.692	35.4421
102	.351125	–9.09078	44.9427
103	.466581	–6.62147	45.0816
104	.564749	–4.96289	42.5216
105	.644163	–3.82009	39.294
106	.707062	–3.01085	36.09
107	.756551	–2.42323	33.1443
108	.795563	–1.98651	30.5173
109	.826506	–1.65508	28.2033
110	.85127	–1.39866	26.172
111	.87128	–1.19684	24.3877
112	.887614	–1.03552	22.8159
113	.90108	–.904729	21.4255
114	.912289	–.797357	20.1902
115	.921701	–.708198	19.0873
116	.929674	–.633389	18.0981
117	.936479	–.570043	17.207
118	.94233	–.515938	16.4007
119	.947396	–.469365	15.6681

120	.95181	−.428996	14.9999
121	.955678	−.39377	14.3882
122	.959086	−.362851	13.8264
123	.962104	−.335562	13.3087
124	.964789	−.311353	12.8302
125	.967189	−.289775	12.3867
126	.969342	−.270457	11.9746
127	.971282	−.253092	11.5906
128	.973036	−.237423	11.2321
129	.974627	−.223234	10.8965
130	.976075	−.210341	10.5818

********** END **********

.01	1.00001	1.08016E–04	−.286508
.0125893	1.00002	1.7261E–04	−.360712
.0158489	1.00003	2.72013E–04	−.454148
.0199526	1.00005	4.30627E–04	−.571815
.0251189	1.00008	6.84338E–04	−.720026
.0316228	1.00012	1.08195E–03	−.906766
.0398107	1.0002	1.71354E–03	−1.14216
.0501187	1.00031	2.71223E–03	−1.43912
.0630958	1.00049	4.28546E–03	−1.81418
.0794329	1.00078	6.75761E–03	−2.28879
.1	1.00122	.0106232	−2.89116
.125893	1.00191	.0166172	−3.65922
.158489	1.00297	.0257727	−4.64571
.199526	1.00455	.0393945	−5.92692
.251189	1.00677	.0586291	−7.61921
.316228	1.00957	.0827242	−9.91031
.398107	1.01192	.102921	−13.1196
.501187	1.00949	.0819978	−17.8034
.630958	.987201	−.111891	−24.8522
794329	.903554	−.880918	−34.9583
1	.707106	−3.01031	−45.0005
1.25893	.477465	−6.42118	−43.1689
1.58489	.38019	−8.39999	−25.7504
1.99526	.391911	−8.13625	−11.4098
2.51189	.424616	−7.44008	−4.91813
3.16228	.450884	−6.9187	−2.2085
3.98107	.468661	−6.58282	−1.02973
5.01188	.480145	−6.37255	−.492783
6.30958	.487453	−6.24135	−.239846
7.94329	.492079	−6.15931	−.118002
10	.495001	−6.10788	−.0584535
12.5893	.496845	−6.07558	−.0290807
15.8489	.49801	−6.05525	−.0145071
19.9526	.498744	−6.04244	−7.2495E–03
25.1189	.499208	−6.03438	−3.62666E–03
31.6228	.4995	−6.02929	−1.81551E–03
39.8108	.499685	−6.02608	−9.0927E–04
50.1188	.499801	−6.02406	−4.55468E–04
63.0958	.499874	−6.02278	−2.28207E–04
79.4329	.499921	−6.02198	−1.14364E–04
100	.49995	−6.02147	−5.73076E–05

125.893	.499969	-6.02115	-2.87157E-05
158.49	.49998	-6.02094	-1.43716E-05
199.526	.499987	-6.02082	-7.21258E-06
251.189	.499992	-6.02074	-3.61254E-06
316.228	.499995	-6.02069	-1.81059E-06
398.108	.499997	-6.02066	-9.12412E-07
501.188	.499998	-6.02063	-4.57677E-07
630.958	.499999	-6.02062	-2.25586E-07
794.329	.499999	-6.02061	-1.15137E-07
1000	.5	-6.02061	-5.86713E-08
1258.93	.5	-6.02061	-2.62772E-08
1584.9	.5	-6.0206	-1.39481E-08
1995.27	.5	-6.0206	-7.4038E-09
2511.89	.5	-6.0206	-4.42126E-09
3162.28	.5	-6.0206	-2.34686E-09
3981.08	.5	-6.0206	-9.34298E-10
5011.88	.5	-6.0206	-7.43901E-10
6309.58	.5	-6.0206	0
7943.29	.5	-6.0206	0
10000	.5	-6.0206	0
12589.3	.5	-6.0206	0
15849	.5	-6.0206	0
19952.7	.5	-6.0206	0
25118.9	.5	-6.0206	0
31622.8	.5	-6.0206	0
39810.8	.5	-6.0206	0
50118.8	.5	-6.0206	0
63095.8	.5	-6.0206	0
79432.9	.5	-6.0206	0
100000	.5	-6.0206	0
125893	.5	-6.0206	0
158490	.5	-6.0206	0
199527	.5	-6.0206	0
251189	.5	-6.0206	0
316228	.5	-6.0206	0
398108	.5	-6.0206	0
501188	.5	-6.0206	0
630959	.5	-6.0206	0
794330	.5	-6.0206	0
1E+06	.5	-6.0206	0
1.25893E+06	.5	-6.0206	0
1.5849E+06	.5	-6.0206	0
1.99527E+06	.5	-6.0206	0
2.51189E+06	.5	-6.0206	0
3.16228E+06	.5	-6.0206	0
3.98108E+06	.5	-6.0206	0
5.01188E+06	.5	-6.0206	0
6.30959E+06	.5	-6.0206	0
7.9433E+06	.5	-6.0206	0
1E+07	.5	-6.0206	0

PROGRAM LISTING #3

```
10 CLS
20 PRINT "THIS PROGRAM CALCULATES THE LOG MODULUS AND
   PHASE ANGLE"
30 PRINT "FOR THE TRANSFER FUNCTION G(S)." :PRINT:PRINT:
   INPUT "AUTO STEP (0) OR REQUESTED (1)"; Q: IF Q=0 THEN 50
40 PRINT:PRINT:PRINT: INPUT "MIN FREQ, MAX FREQ, STEP";
   W1, W2, W3
50 INPUT "LARGEST POWER FOR ZEROS"; N
60 INPUT "LARGEST POWER FOR POLES"; M
70 DIM Z(N), P(M): E=0. 434294482
80 FOR I=NTO0 STEP -1: PRINT "Z("; I; ")=";: INPUT Z(I): NEXT I
90 FOR L=MTO0 STEP -1: PRINT "P("; L;")=";: INPUT P(L): NEXT L
93 IF Q=1 THEN 105
95 W=.01
97 DW=10∧(.1)
100 FOR X=1 TO 91 : GOTO 110
105 FOR W=W1 TO W2 STEP W3
110 ZR=O : ZI=0 : IF N=0 THEN 170
120 FOR J=N TO 1 STEP -1: GOSUB 1000
130 ON BETA GOTO 140, 150
140 ZR=ZR+W∧J*Z(J)* ALPHA: GOTO 160
150 ZI =ZI +W∧J*Z(J)* ALPHA
160 NEXT J
170 ZR=ZR+Z(0)
180 P1R=0 : PI=0 : IF M=0 THEN 240
190 FOR J=M TO 1 STEP -1: GOSUB 1000
200 ON BETA GOTO 210, 220
210 P1R=P1R+W∧J*P(J)* ALPHA: GOTO 230
220 PI=PI+W∧J*P(J)* ALPHA
230 NEXT J
240 P1R=P1R+P(0)
250 MA=P1R*P1R+PI*PI
260 GR=(ZR*P1R+ZI *PI)/MA
270 GI =(ZI *P1R-ZR*PI)/MA
280 MAG=SQR(GR*GR+GI*GI)
285 IF GR=0 THEN 320
290 ANG=ATN(GI/GR)*180/3. 14156
295 DB=20 * LOG(MAG) * E
300 IF GR<0 THEN ANG=ANG-180
305 LPRINT W, MAG, DB, ANG
310 IF Q=0 THEN W=W*DW: NEXT X ELSE NEXT W
315 END
320 IF GI<0 THEN ANG= -90 ELSE ANG=90
330 GOTO 295
1000 K=J
1010 IF K/2=INT(K/2) THEN BETA=1: GOTO 1030 ELSE BETA=2
1020 K=K-1
1030 IF K/4=INT(K/4) THEN ALPHA=1 ELSE ALPHA= -1
1040 RETURN
```