AC Circuit Analysis

Part No. 09825-12501

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Description:

This is a general purpose linear network analysis program, including effects due to component tolerances, written for the 9825A Calculator.

The components allowed in the network description are resistors, capacitors, inductors, and voltage-controlled current sources. The precision and wide dynamic range of the calculator make it possible to transform other active elements into the required form. For example, a voltage-controlled voltage source with zero ohms internal impedance cannot be realized, but one with 0.0001 ohms can be and the difference is negligible for almost all problems.

The network is specified by entering component values and node numbers associated with each component. As these values are entered, a table of these values and nodes is printed. This allows the user to easily change a component value and rerun the program without re-entering the data for the entire network.

The network may be stored on tape for recall in the future. Up to 15 networks can be stored.

Either log or linear frequency sweep may be specified as well as the number of frequency intervals. For each frequency, the magnitude of the output voltage (in dB), the phase, and the time delay may be printed and/or plotted.

The selection of the tolerance effect option allows the user to determine how a random selection of component values, within the tolerance ranges specified, will alter the magnitude, phase and time delay of the circuit response. Each tolerance pass randomly selects component values prior

to calculating the output parameters. These random values are not changed again until the magnitude, phase and time delay calculations have been performed for each interval of frequency. The next tolerance pass repeats this procedure with a fresh random selection of component values. The program saves only the maximum and minimum values, calculated during the tolerance passes, of magnitude, phase, and time delay for each frequency interval. The resulting maximum and minimum envolopes approximate the range of expected variations in output parameters due to the random selection of component values in the production of the circuit.

Two versions of this program exist on the tape cartridge:

1. Track Ø contains the standard version written for the standard 9825A with 6844 bytes of user read/write memory. This version will analyze networks with up to 9 nodes and 48 components. Either a log or linear frequency sweep may be specified with up to 20 intervals.

2. Track 1 contains an extended capability version written for a 9825A option 001, 002, or 003 with 15036 or more bytes of user read/write memory. This version will analyze networks with up to 18 nodes and 96 components. Either a log or linear frequency sweep may be specified with up to 40 intervals.

MODEL 9825A SYSTEM CONFIGURATION

MODEL 9825A CALCULATOR

6844 Bytes RWM, Basic Calculator *
15036 Bytes RWM **

The following equipment is optional and provides plotting capability.

ROMs

98212A: 9862A Plotter - General I/O ROM or
98214A: 9862A Plotter - General I/O - Extended I/O ROM

Peripherals	Standard Select Code
9862A Plotter or	5
9866B Thermal Line Printer or	6
9871A Character Impact Printer	6

* Standard capability program
** Extended capability program

Specification of Data:

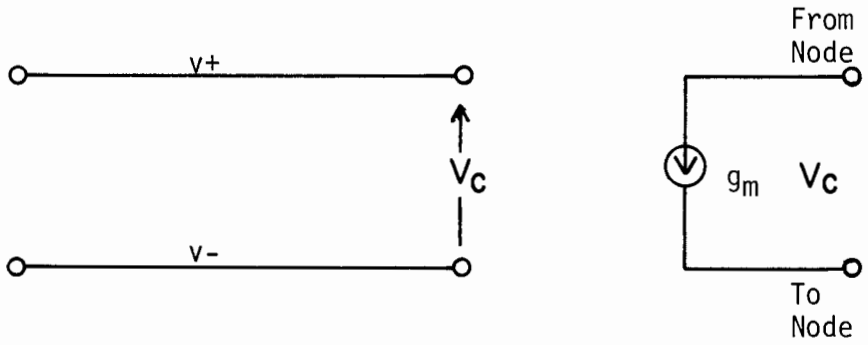
1. Draw the circuit to be analyzed. Dependent sources must be transformed to voltage-controlled current sources.

2. Number the nodes. Node 0 must be the reference or ground node; node 1 must be the input node (the program assumes a one-volt source is connected between nodes 1 and 0).

3. Number the branches sequencially beginning with 1.

4. Enter data as specified in the User Instructions. For each passive component, enter the value of the component (in ohms, farads, or henries), and the node-numbers the component is connected between. Note that the "From Node" must not be zero.

   Active components (voltage-controlled current sources) are specified as follows:

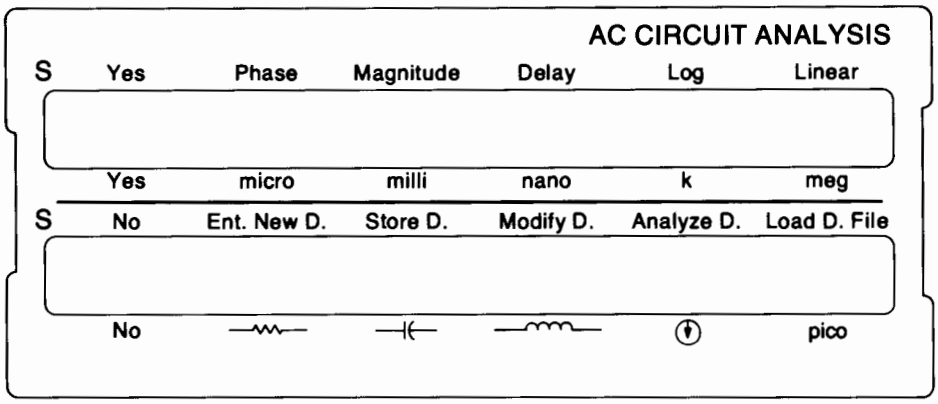


The controlling voltage, v_c, is measured between the nodes v+ and v-, either of which may be zero. The controlled current, $g_m v_c$, leaves the "From Node" and enters the "To Node".

5. For logarithmic plots, the program has been set up to use "N-cycle by 70 division" semi-log paper. If you use this kind of paper, and set-up the lower-left and upper-right limits to correspond to the limits of the grid rather than the paper, the axes and tic-marks generated by the calculator will correspond with those on the paper.

6. For logarithmic plots, the lower and upper frequency limits should by powers-of-ten; e.g., 10^5, 10^7, 10^i, etc., not 1.5×10^5, 2.3×10^6, etc.

Start Up Procedure:



To begin operation of the program, the program and definitions for the special function keys must be obtained from the program cartridge. Then the calculator must begin running the program. To do this:

1. Turn on the calculator and associated peripherals.

2. Insert the program cartridge into the calculator cartridge transport.

3. Type: erase a

4. Press: EXECUTE

5. Type: ldp

6. Press: EXECUTE

   Note: This loads the first program from the cartridge and begins running that program.

7. When "STANDARD MEMORY (YES/NO)?" is displayed:
   Press: YES (f_0) or NO (f_6).
   Note: Standard memory is 8k bytes, which is actually 6844 usable bytes. All other memory sizes require a NO answer. If the answer is standard memory, the cartridge must be unprotected.

8. When "PLOTTING DEVICE (62/66/71/Ø)?" is displayed:
   a. If there is no plotting device:
      1) Enter Ø
      2) Press CONTINUE
      3) Go to step 10

   b. If there is a plotting device:
      1) Enter the appropriate code for the plotting device
         Note: A 9862A = 62, a 9866A or B = 66 and a 9871A = 71.
      2) Press CONTINUE

9. When "PLOTTING DEVICE SELECT CODE?" is displayed:
   a. Enter the select code
      Note: Enter Ø for the factory preset select code.

   b. Press CONTINUE

10. When "SELECT KEY" is displayed:
    Note: At this point in the program, 5 functional operations are available: ENT. NEW DATA (shift f_7), STORE DATA (shift f_8), LOAD DATA FILE (shift f_{11}), MODIFY DATA (shift f_9), or ANALYZE DATA (shift f_{10}). It should be evident that

a circuit description, referred to as data, has to be brought into the calculator by either defining a circuit from the keyboard (ENT. NEW DATA) or by obtaining a circuit previously defined from the cartridge (LOAD DATA FILE).
Once the circuit description is in existence in the calculator, it can be stored on the cartridge (STORE DATA), modified (MODIFY DATA), or analyzed (ANALYZE DATA).

a. If it is desired to define a circuit from the keyboard:
   1) Press ENT. NEW DATA (shift f_7)
   2) Go to step 101

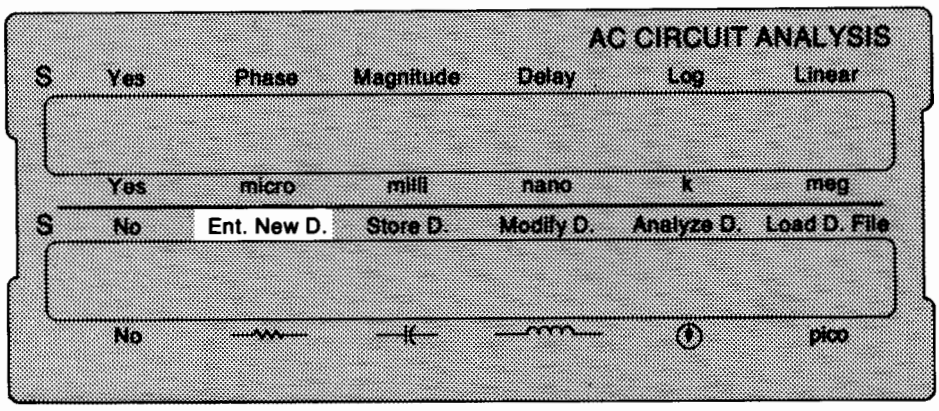
b. If it is desired to load the circuit data previously defined and stored on the cartridge:
   1) Press LOAD DATA FILE (shift f_{11}).
   2) Go to step 301

c. If it is desired to modify the circuit data presently defined in the calculator:
   1) Press MODIFY DATA (shift f_9)
   2) Go to step 201

d. If it is desired to store circuit data presently defined in the calculator on the cartridge:
   1) Unprotect the cartridge
   2) Press STORE DATA (shift f_8)
   3) Go to step 402

e. If it is desired to analyze a circuit presently defined in the calculator:
   1) Press ANALYZE DATA (shift f_{10})
   2) Go to step 501

New Circuit Definition:



The circuit to be analyzed can be defined in two ways. The first case is when the circuit is being initially described. In this situation ENT. NEW DATA (shift f_7) is pressed. This clears the calculator memory of previous circuit descriptions, and asks for each of the components required to describe the circuit.

The second case is when a circuit has already been described, but it is desired to change that circuit description. In this situation MODIFY DATA (shift f_9) is pressed. This permits individual components to be modified.

When "SELECT KEY" is displayed, new circuit data is entered by the following operations:

100. Press ENT. NEW DATA (shift f_7)

101. When "IDENTIFIER NO.=?" is displayed:
   a. Enter ----, a positive four digit number used for identification.

   b. Press CONTINUE

102. When "TOLERANCE ENTRIES (YES/NO)?" is displayed:

a. If it is desired to enter a tolerance for some of the components:

1) Press YES (f_0)

2) Go to step 103

b. If it is not desired to enter tolerances for any of the components:

1) Press NO (f_6)

2) Go to step 103

103. When "COMPONENT TYPE (Ø TO END)?" is displayed:

a. If no components remain to be described:

1) Enter Ø

2) Press CONTINUE

3) Go to step 10

b. If the component associated with this branch is a resistor:

1) Press (f_7)

2) Go to step 104

c. If the component associated with this branch is a capacitor:

1) Press (f_8)

2) Go to step 104

d. If the component associated with this branch is an inductor:

1) Press (f_9)

2) Go to step 104

e. If the component associated with this branch is a current source:

1) Press (f_{10})

2) Go to step 104

104. When "VALUE?" is displayed:

a. Enter ----, the numerical circuit value.

b. Press:

1) MEG (f_5) to multiply the value by 10^6.

2) K (f_4) to multiply the value by 10^3.

3) CONTINUE to use the value entered.

4) milli (f_2) to multiply the value by 10^{-3}.

5) micro (f_1) to multiply the value by 10^{-6}.

6) nano (f_3) to multiply the value by 10^{-9}.

7) pico (f_{11}) to multiply the value by 10^{-12}.

105. If "TOLERANCE IN %" is displayed:

a. If a tolerance is not to be applied to this component,

1) Enter Ø

2) Press CONTINUE

3) Go to step 106

b. If a tolerance is to be applied to this component,

1) Enter --, the % tolerance.

Note: Allowable entries are Ø and numbers in the range .0001 to 99.

2) Press CONTINUE

106. When "FROM NODE?" is displayed:

a. Enter --, the number of the initial node. (Ø is not a valid initial node.)

b. Press CONTINUE

107. When "TO NODE" is displayed:

a. Enter --, the number of the terminating node. (The initial and terminating nodes cannot be the same.)

b. Press CONTINUE

108. If the component is not a source, go to step 103; otherwise go to step 109.

109. When "+ CONTROL NODE" is displayed:

a. Enter -- the number of the + control node.

b. Press CONTINUE

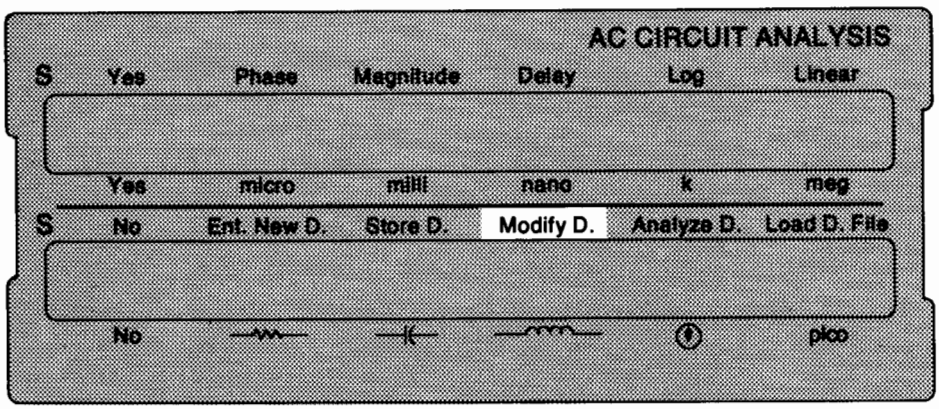
110. When "-CONTROL NODE" is displayed:

a. Enter -- the number of the - control node (The - control node cannot be the same as the + control node.)

b. Press CONTINUE

c. Go to step 103

Modification of Circuit Definition:



When "SELECT KEY" is displayed, the existing circuit data is modified by the following operations:

200. Press MODIFY DATA (shift f_9).

201. When "BRANCH NO. (Ø TO END)?" is displayed:
   a. If no components remain to be modified:
      1) Enter Ø
      2) Press CONTINUE
      3) Go to step 211

   b. If a branch is to be modified:
      1) Enter --, the number of the branch
         Note: If new branches are being added, the numbering must be continuous.
      2) Press CONTINUE

202. When "DELETE BRANCH (YES/NO)?" is displayed:
   a. If the branch is to be deleted:
      1) Press YES (f_0)
      2) Go to step 201

b. If the branch is not to be deleted:
   1) Press NO (f_6)
   2) Go to step 203

203. When "COMPONENT TYPE (Ø TO END)?" is displayed:
   a. If no components remain to be described:
      1) Enter Ø
      2) Press CONTINUE
      3) Go to step 10

   b. If the component associated with this branch is a resistor:
      1) Press (f_7)
      2) Go to step 204

   c. If the component associated with this branch is a capacitor:
      1) Press (f_8)
      2) Go to step 204

   d. If the component associated with this branch is an inductor:
      1) Press (f_9)
      2) Go to step 204

   e. If the component associated with this branch is a current source:
      1) Press (f_{10})
      2) Go to step 204

204. When "VALUE?" is displayed:*
   a. Enter ----, the numerical circuit value

b. Press:

1) MEG (f_5) to multiply the value by 10^6.
2) K (f_4) to multiply the value by 10^3.
3) CONTINUE to use the value entered.
4) milli (f_2) to multiply the value by 10^{-3}.
5) micro (f_1) to multiply the value by 10^{-6}.
6) nano (f_3) to multiply the value by 10^{-9}.
7) pico (f_{11}) to multiply the value by 10^{-12}.

205. When "TOLERANCE IN %" is displayed:*

a. If a tolerance is not to be applied to this component:

1) Enter Ø
2) Press CONTINUE
3) Go to step 206

b. If a tolerance is to be applied to this component,

1) Enter --, the % tolerance.

Note: The allowable entries are Ø and numbers in the range .0001 to 99.

2) Press CONTINUE

206. When "FROM NODE?" is displayed: *

a. Enter --, the number of the initial node. (Ø is not a valid initial node.)

b. Press CONTINUE

207. When "TO NODE" is displayed: *

a. Enter --, the number of the terminating node. (The initial and terminating nodes cannot be the same.)

b. Press CONTINUE

208. If the component is not a source, go to step 201; otherwise go to step 209.

209. When "+ CONTROL NODE" is displayed:*

a. Enter --, the number of the + control node.

b. Press CONTINUE

210. When " - CONTROL NODE" is displayed:*

a. Enter --, the number of the - control node. (The - control node cannot be the same as the + control node.)

b. Press CONTINUE

c. Go to step 201

211. When "LIST DATA?" is displayed:

a. If a listing of the modified data is desired:

1) Press YES (f_0)

2) Go to step 10

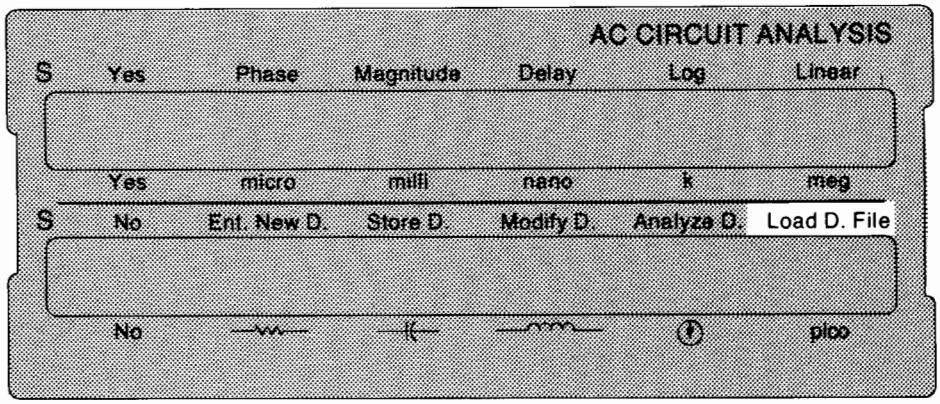
b. If no listing is desired:

1) Press NO (f_6)

2) Go to step 10

* If this circuit parameter has been previously defined, pressing CONTINUE without having made an entry will retain the previous value.

Loading Circuit Data from the Cartridge



When "SELECT KEY" is displayed, circuit data previously stored on one of the files of the AC Circuit Analysis Cartridge is loaded by the following operations:

300. Press LOAD DATA (shift f_{11}).

301. When "LIST DATA FILES?" is displayed:
   a. If a listing of the data files (file 8 through 22) with associated identification number is desired:
      1) Press YES (f_0)
      2) Go to step 304

   b. If no listing is desired:
      1) Press NO (f_6)
      2) Go to step 302

302. When "LOAD DATA FILE NO.?" is displayed:
   a. Enter --, the number of the file to be loaded

   b. Press CONTINUE

303. When "LIST DATA" is displayed:

a. If a listing of the data just loaded from the cartridge is desired:

1) Press YES (f_0)

2) Go to step 10

b. If no listing is desired:

1) Press NO (f_6)

2) Go to step 10

304. When "DELETE A FILE (YES/NO)?" is displayed:

a. If no files are to be deleted:

1) Press NO (f_6)

2) Go to step 302

b. If a data file is to be deleted:

1) Press YES (f_0)

2) Go to step 305

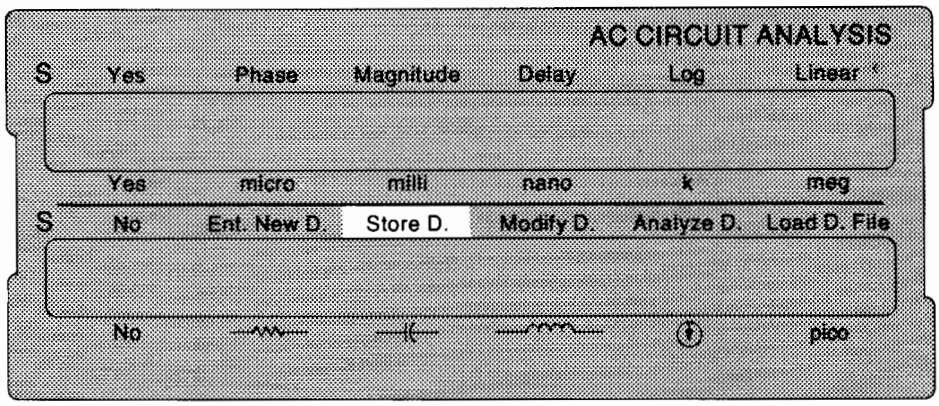
305. When "DELETE FILE NUMBER?" is displayed:

a. Enter --, the number of the file to be deleted.

b. Press CONTINUE

c. Go to step 304

Storing Circuit Data on the Cartridge



When "SELECT KEY" is displayed, circuit data is stored on one of the files of the AC Circuit Analysis Cartridge by the following operations:

400. Unprotect the cartridge.

401. Press STORE DATA (shift f_8).

402. When "LIST DATA FILES?" is displayed:
   a. If a listing of the data files (file 8 through file 22) with associated identification number is desired:
      1) Press YES (f_0)
      2) Go to step 406

   b. If no listing is desired:
      1) Press NO (f_6)
      2) Go to step 403

403. When "STORE IN FILE NO?" is displayed:
   a. Enter --, the number of the file to be used for storage.

   b. Press CONTINUE

404. When "CARTRIDGE UNPROTECTED?" is displayed,

a. If the tape is protected, unprotect it by pushing the RECORD tab on the cartridge in the direction of the arrow.

b. Press YES (f_0)

405. When "NEW IDENTIFIER NO?" is displayed:

a. If the present identifier number is to be retained:

1) Press NO (f_6)

2) Go to step 10

b. If a new identifier number is to be associated with the data:

1) Enter ----, a positive four digit number used for identification

2) Press CONTINUE

3) Go to step 10

406. When "DELETE A FILE (YES/NO)?" is displayed:

a. If no files are to be deleted:

1) Press NO (f_6)

2) Go to step 403

b. If a data file is to be deleted:

1) Press YES (f_0)

2) Go to step 407

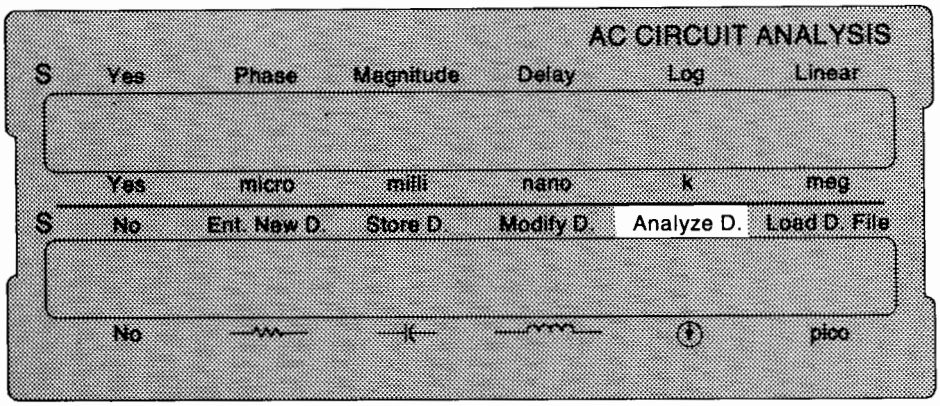
407. When "DELETE FILE NUMBER?" is displayed:

a. Enter --, the number of the file to be deleted

b. Press CONTINUE

c. Go to step 406

Analysis of Circuit Data:



When "SELECT KEY" is displayed, the AC response of the circuit described by the existing circuit data is analyzed by the following operations:

500. Press ANALYZE DATA (shifted f_{10})

501. When "NO. OF TOLERANCE PASSES?" is displayed:

a. If the output for the nominal value of the components is desired:

1) Enter Ø
2) Press CONTINUE
3) Go to step 502

b. If the upper and lower limits or the output due to the random selection of component values within the tolerance range of the components is desired:

1) Enter ___, the number of tolerance passes desired (the number must be two or greater).
2) Press CONTINUE
3) Go to step 502

502. When "OUTPUT NODE NO?" is displayed:

a. Enter ___, the number of the output node.

b. Press CONTINUE

503. When "ENVELOPE PRINTOUT?" is displayed:

a. If it is desired to have the data printed after the calculation is complete:

1) Press YES (f_0)

2) Go to step 504

b. If it is desired to suppress the data printout:

1) Press NO (f_6)

2) Go to step 504

504. When "SELECT SWEEP MODE?" is displayed:

a. If a logarithmic sweep is desired:

1) Press LOG (shift f_4)

2) Go to step 505

b. If a linear sweep is desired:

1) Press LINEAR (shift f_5)

2) Go to step 505

505. When "STARTING FREQ.?" is displayed:

a. Enter ___, the starting frequency, i.e., the lowest frequency of the analysis.

b. Press CONTINUE

506. When "ENDING FREQ.?" is displayed:

a. Enter ___, the ending frequency, i.e., the highest frequency of the analysis

b. Press CONTINUE

507. When "NO. OF INTERVALS (MAX IS 40)?" is displayed:

a. Enter ___, the number of discrete frequency intervals desired in the output.

Note: When using the 9866 printer to plot the response, the tic marks will all be of equal length,

for a log sweep if

$$\frac{2(\text{no. of intervals})}{\log(\text{ending freq.}) - \log(\text{starting freq.})} = \text{an integer},$$

or for a linear sweep if

$$\frac{\text{no. of intervals}}{10} = \text{an integer}$$

b. Press CONTINUE

508. The data is analyzed and the output is printed.

509. If there is no plotting device, go to step 10.

510. When "PHASE/MAG/DELAY/NO TO END?" is displayed:

a. If a plot of the phase is desired:
   1) Press PHASE (shift f_1)
   2) Go to step 511

b. If a plot of the magnitude is desired:
   1) Press MAGNITUDE (shift f_2)
   2) Go to step 511

c. If a plot of the delay is desired:
   1) Press DELAY (shift f_3)
   2) Go to step 511

d. If no plot is desired:
   1) Press NO (f_6)
   2) Go to step 10

511. When "ENVELOPE PRINTOUT?" is displayed:

a. If a printout of the response is desired:

1) Press YES (f_0)

2) Go to step 512

b. If no printout is desired:

1) Press NO (f_6)

2) Go to step 512

512. When "PLOTTER READY?" is displayed:

a. Check that plotting device is ready.

b. Press YES (f_0)

513. When "YMIN = ?" is displayed:

a. Enter ___, the minimum value of Y (Y is the output to be plotted).

b. Press CONTINUE

514. When "YMAX=?" is displayed:

a. Enter ___, the maximum value of Y.

b. Press CONTINUE

515. If "PLOT AXES?" is displayed:

a. If it is desired to draw the axes and label:

1) Press YES (f_0)

2) Go to step 516

b. If the axes and labels are not desired

1) Press NO (f_6)

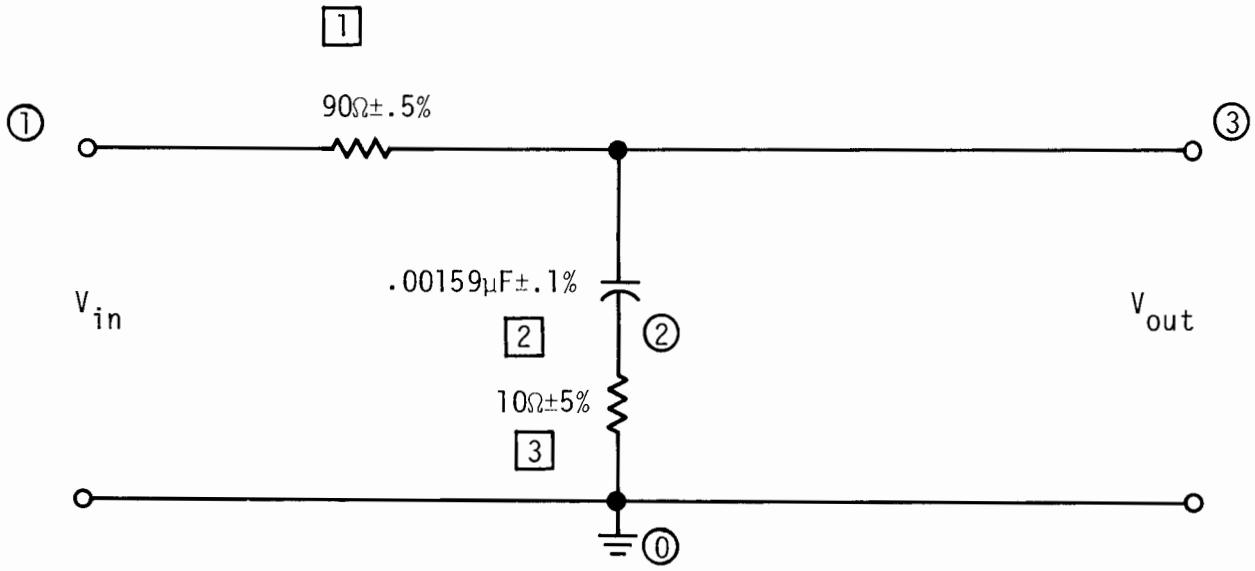
2) Go to step 516

516. Go to step 510.

EXAMPLES

EXAMPLE 1

Analysis of an RC Filter With the Output on the 9866 Printer



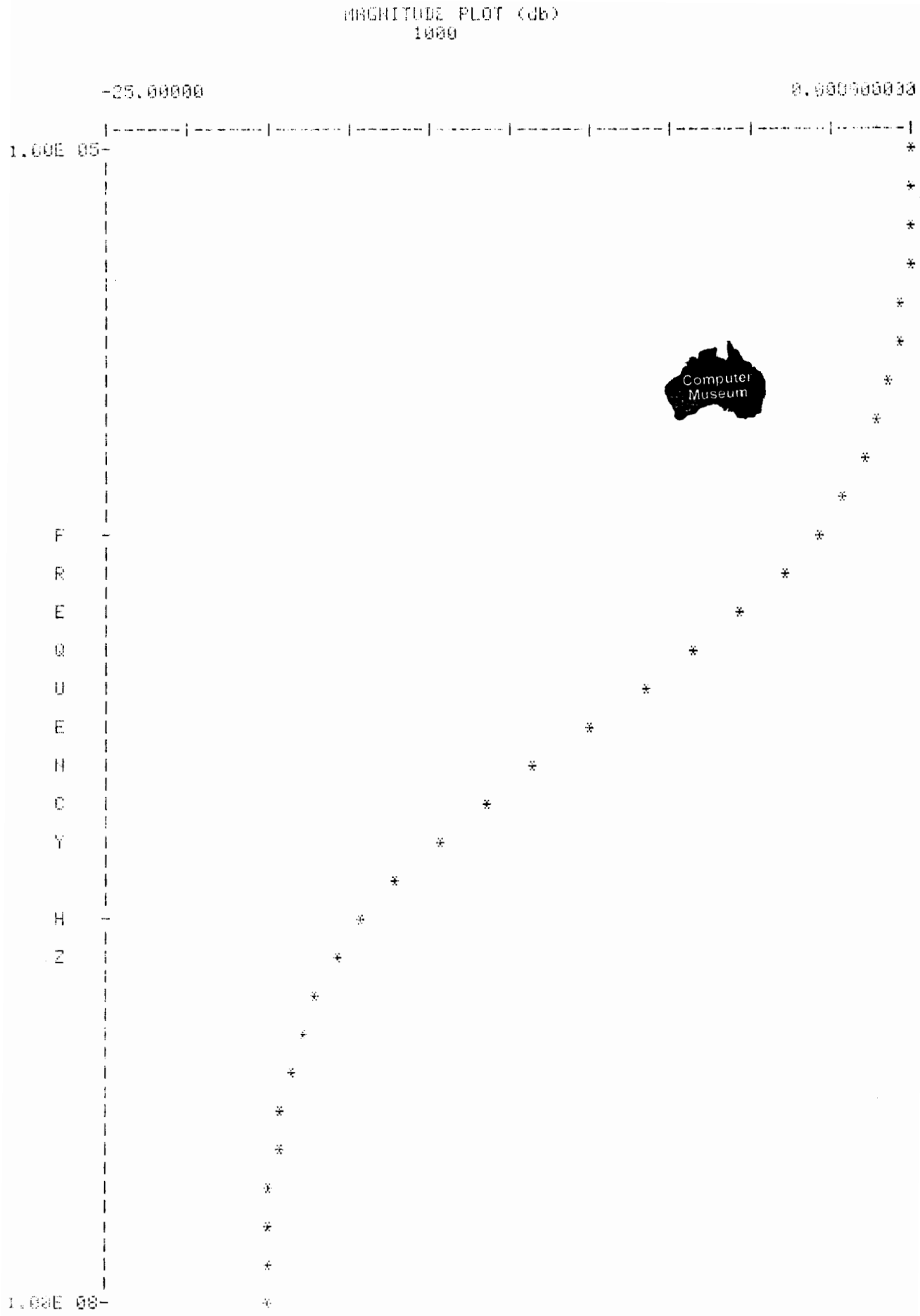

```
IDENTIFIER NO.
             1000

NO.NODES=        3

NO.BRANCHES      3

BRANCH           1
  RESISTOR
  ohms=   90.0000
  %_TOL.=    0.50
  FROM NODE     1
  TO NODE       3

BRANCH           2
  CAPACITOR
  mfd= 1590.0000
  % TOL.=    0.10
  FROM NODE     3
  TO NODE       2

BRANCH           3
  RESISTOR
  ohms=   10.0000
  % TOL.=     5.0
  FROM NODE     2
  TO NODE       0

NO. OF TOLERANCE
 PASSES          0

OUTPUT NODE      3
```

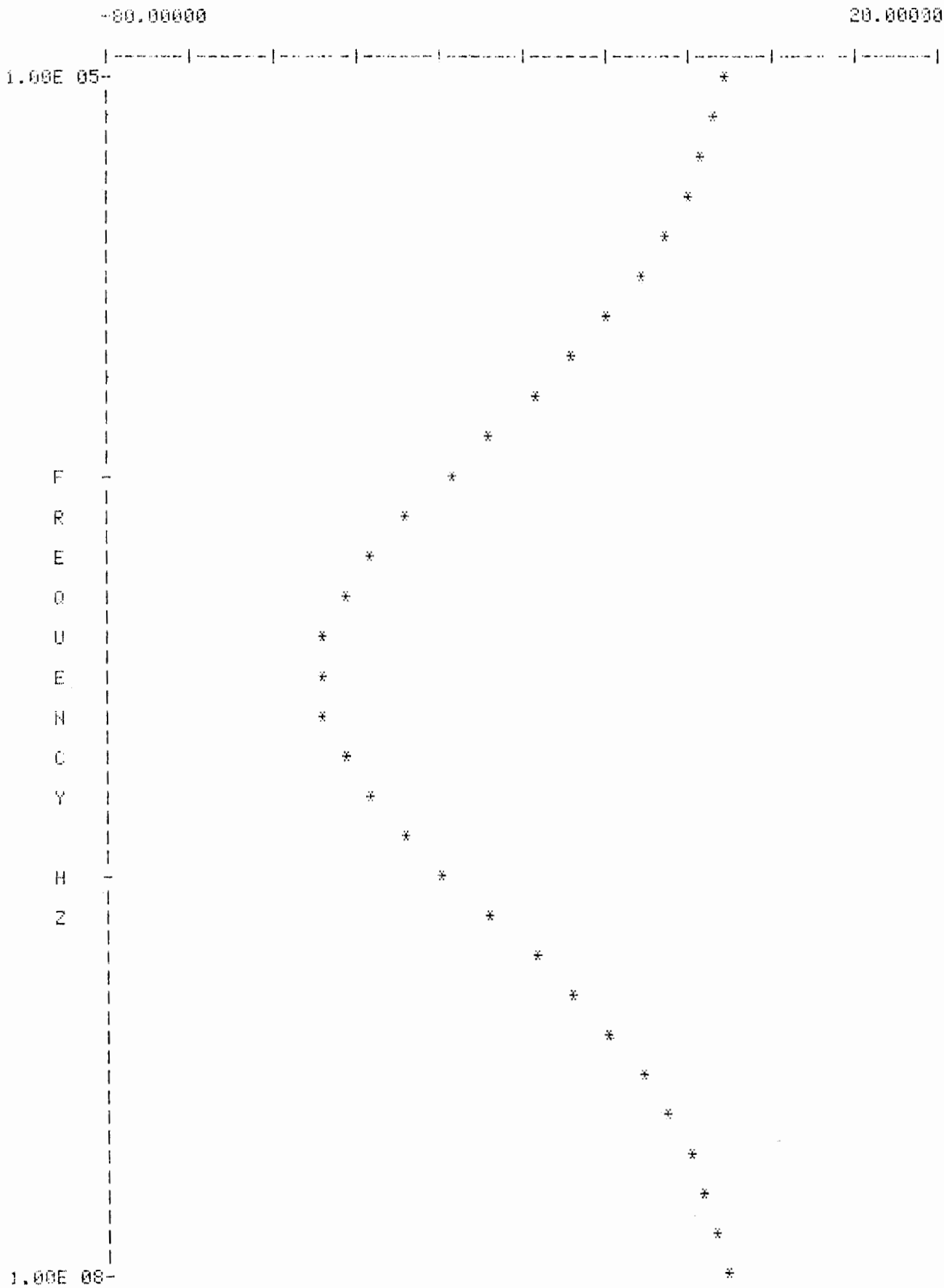
```
  LOG SWEEP

X AXIS DATA:

  STARTING FREQ=
          100000
  ENDING FREQ.=
       100000000

  # OF INTERVALS
              30


*****************
MAGNITUDE PLOT
IN db


Y AXIS DATA:

  Y MIN=
       -25.00000
  Y MAX=
     0.000000000

*****************
PHASE PLOT
IN DEGREES
```

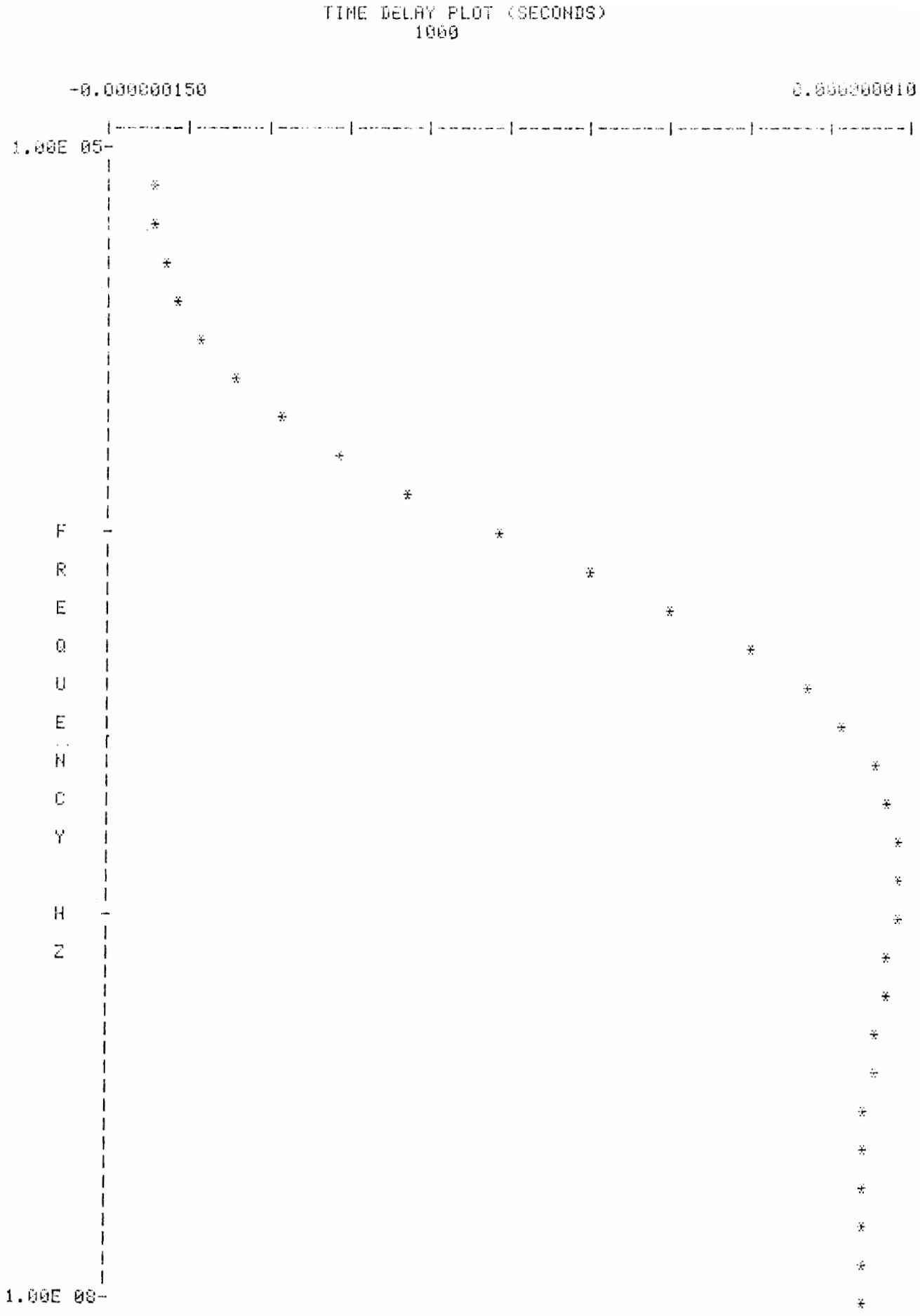
```
Y AXIS DATA:

  Y MIN=
       -80.00000
  Y MAX=
        20.00000

*****************
TIME DELAY PLOT
IN SECONDS


Y AXIS DATA:

  Y MIN=
    -0.000000150
  Y MAX=
     0.000000010

*****************
```

1000

FREQUENCY(HZ)	MAGNITUDE(db)	PHASE(DEG)	TIME DELAY(SEC)
1.000E 05	-0.04	-5.133	
1.259E 05	-0.07	-6.448	-1.411E-07
1.585E 05	-0.11	-8.090	-1.399E-07
1.995E 05	-0.17	-10.131	-1.382E-07
2.512E 05	-0.26	-12.650	-1.354E-07
3.162E 05	-0.41	-15.723	-1.313E-07
3.981E 05	-0.63	-19.411	-1.251E-07
5.012E 05	-0.96	-23.731	-1.164E-07
6.310E 05	-1.44	-28.618	-1.046E-07
7.943E 05	-2.09	-33.897	-8.975E-08
1.000E 06	-2.96	-39.267	-7.253E-08
1.259E 06	-4.05	-44.343	-5.446E-08
1.585E 06	-5.34	-48.727	-3.736E-08
1.995E 06	-6.80	-52.085	-2.273E-08
2.512E 06	-8.37	-54.186	-1.130E-08
3.162E 06	-9.99	-54.903	-3.064E-09
3.981E 06	-11.62	-54.198	2.393E-09
5.012E 06	-13.19	-52.108	5.631E-09
6.310E 06	-14.65	-48.761	7.166E-09
7.943E 06	-15.94	-44.384	7.442E-09
1.000E 07	-17.03	-39.312	6.850E-09
1.259E 07	-17.90	-33.942	5.760E-09
1.585E 07	-18.56	-28.662	4.500E-09
1.995E 07	-19.04	-23.770	3.311E-09
2.512E 07	-19.37	-19.445	2.325E-09
3.162E 07	-19.59	-15.751	1.578E-09
3.981E 07	-19.74	-12.673	1.044E-09
5.012E 07	-19.83	-10.150	6.798E-10
6.310E 07	-19.89	-8.106	4.377E-10
7.943E 07	-19.93	-6.460	2.797E-10
1.000E 08	-19.96	-5.143	1.786E-10

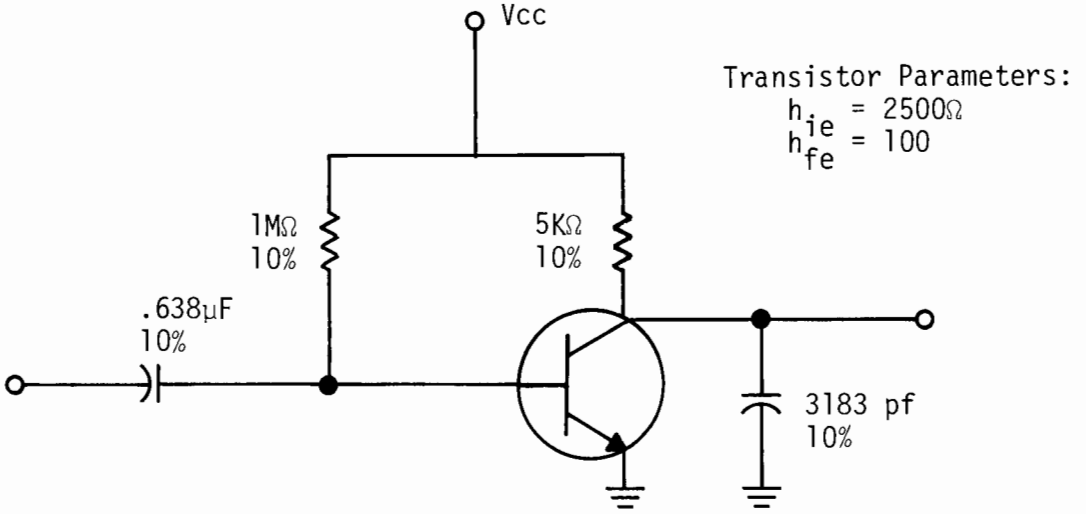

MAGNITUDE PLOT (dB)
1000
-25.00000
0.000000000
1.00E 05
1.00E 08
FREQUENCY (Hz)
Computer Museum


PHASE PLOT (DEGREES)
1000
-80.00000
20.00000
1.00E 05
FREQUENCY HZ
1.00E 08


TIME DELAY PLOT (SECONDS)
1000
-0.000000150
0.000000010
1.00E 05
FREQUENCY HZ
1.00E 00

EXAMPLE 2

ANALYSIS OF A COMMON-EMITTER AMPLIFIER
with the Output on the 9871 Printer



The transistor can be modelled using a voltage controlled current source. The g_m of this source is established in the following manner:

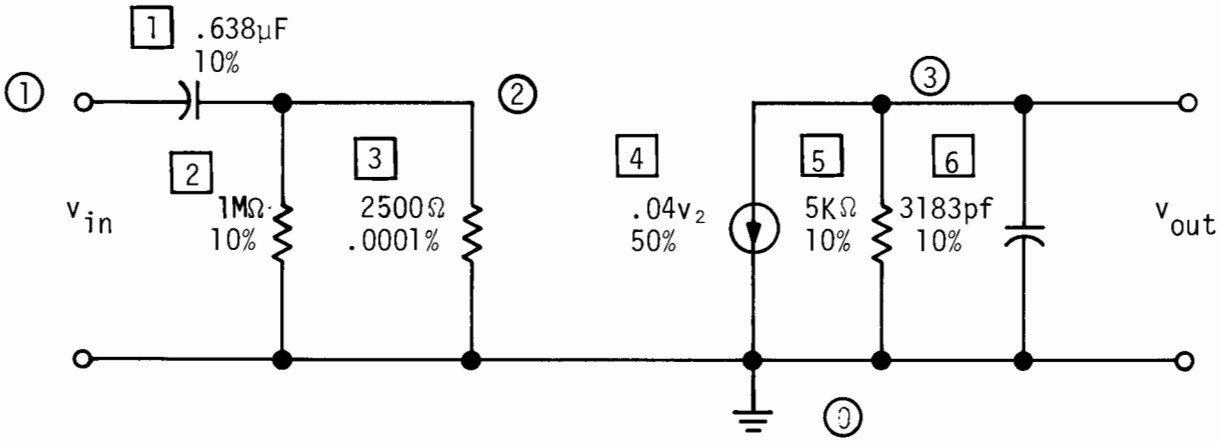
since

$g_m v_b = h_{fe} i_b$ and

$v_b = i_b h_{ie}$,

solving for g_m in terms of h_{fe} and h_{ie} yields

$$g_m = \frac{h_{fe}}{h_{ie}} = \frac{100}{2500} = .04 \text{ mhos}$$



FREQUENCY(HZ)	MAGNITUDE(db)	PHASE(DEG)	TIME DELAY(SEC)
UPPER ENVELOPE			
1.000E 01	30.13	-95.408	
1.359E 01	32.76	-97.334	-1.489E-03
1.848E 01	35.35	-99.925	-1.474E-03
2.512E 01	37.89	-103.384	-1.447E-03
3.415E 01	40.33	-107.933	-1.400E-03
4.642E 01	42.60	-113.767	-1.321E-03
6.310E 01	44.62	-120.953	-1.197E-03
8.577E 01	46.33	-129.287	-1.021E-03
1.166E 02	47.68	-138.223	-8.012E-04
1.585E 02	48.64	-147.004	-5.528E-04
2.154E 02	49.26	-154.972	-3.548E-04
2.929E 02	49.63	-161.796	-2.174E-04
3.981E 02	49.85	-167.479	-1.308E-04
5.412E 02	49.96	-172.086	-7.970E-05
7.356E 02	50.02	-175.815	-5.061E-05
1.000E 03	50.03	180.000	-3.440E-05
1.359E 03	50.00	177.523	-2.519E-05
1.848E 03	49.91	174.011	-1.997E-05
2.512E 03	49.76	169.989	-1.682E-05
3.415E 03	49.47	165.163	-1.485E-05
4.642E 03	48.98	159.271	-1.334E-05
6.310E 03	48.20	152.168	-1.183E-05
8.577E 03	47.05	143.960	-1.006E-05
1.166E 04	45.63	135.104	-7.947E-06
1.585E 04	44.07	126.331	-5.302E-06
2.154E 04	42.16	118.362	-3.288E-06
2.929E 04	39.96	111.637	-1.933E-06
3.981E 04	37.56	106.258	-1.098E-06
5.412E 04	35.05	102.104	-6.106E-07
7.356E 04	32.47	98.964	-3.354E-07
1.000E 05	29.85	96.618	-1.830E-07
LOWER ENVELOPE			
1.000E 01	21.23	-96.334	
1.359E 01	23.87	-98.582	-1.737E-03
1.848E 01	26.47	-101.595	-1.713E-03
2.512E 01	29.02	-105.589	-1.671E-03
3.415E 01	31.48	-110.783	-1.598E-03
4.642E 01	33.79	-117.318	-1.479E-03
6.310E 01	35.87	-125.135	-1.302E-03
8.577E 01	37.62	-133.849	-1.068E-03
1.166E 02	38.98	-142.769	-8.083E-04
1.585E 02	39.94	-151.147	-5.822E-04
2.154E 02	40.57	-158.477	-3.886E-04
2.929E 02	40.94	-164.610	-2.448E-04
3.981E 02	41.16	-169.668	-1.500E-04
5.412E 02	41.28	-173.912	-9.232E-05
7.356E 02	41.34	-177.644	-5.892E-05
1.000E 03	41.35	-179.994	-4.029E-05
1.359E 03	41.33	175.064	-3.027E-05
1.848E 03	41.27	170.796	-2.459E-05
2.512E 03	41.14	165.743	-2.114E-05
3.415E 03	40.91	159.680	-1.866E-05
4.642E 03	40.51	152.450	-1.637E-05
6.310E 03	39.85	144.148	-1.393E-05
8.577E 03	38.85	135.224	-1.093E-05
1.166E 04	37.44	126.407	-8.056E-06
1.585E 04	35.65	118.410	-5.817E-06
2.154E 04	33.54	111.668	-3.887E-06
2.929E 04	31.21	106.279	-2.413E-06
3.981E 04	28.74	102.119	-1.420E-06
5.412E 04	26.18	98.974	-8.065E-07
7.356E 04	23.57	96.626	-4.486E-07
1.000E 05	20.94	94.884	-2.465E-07

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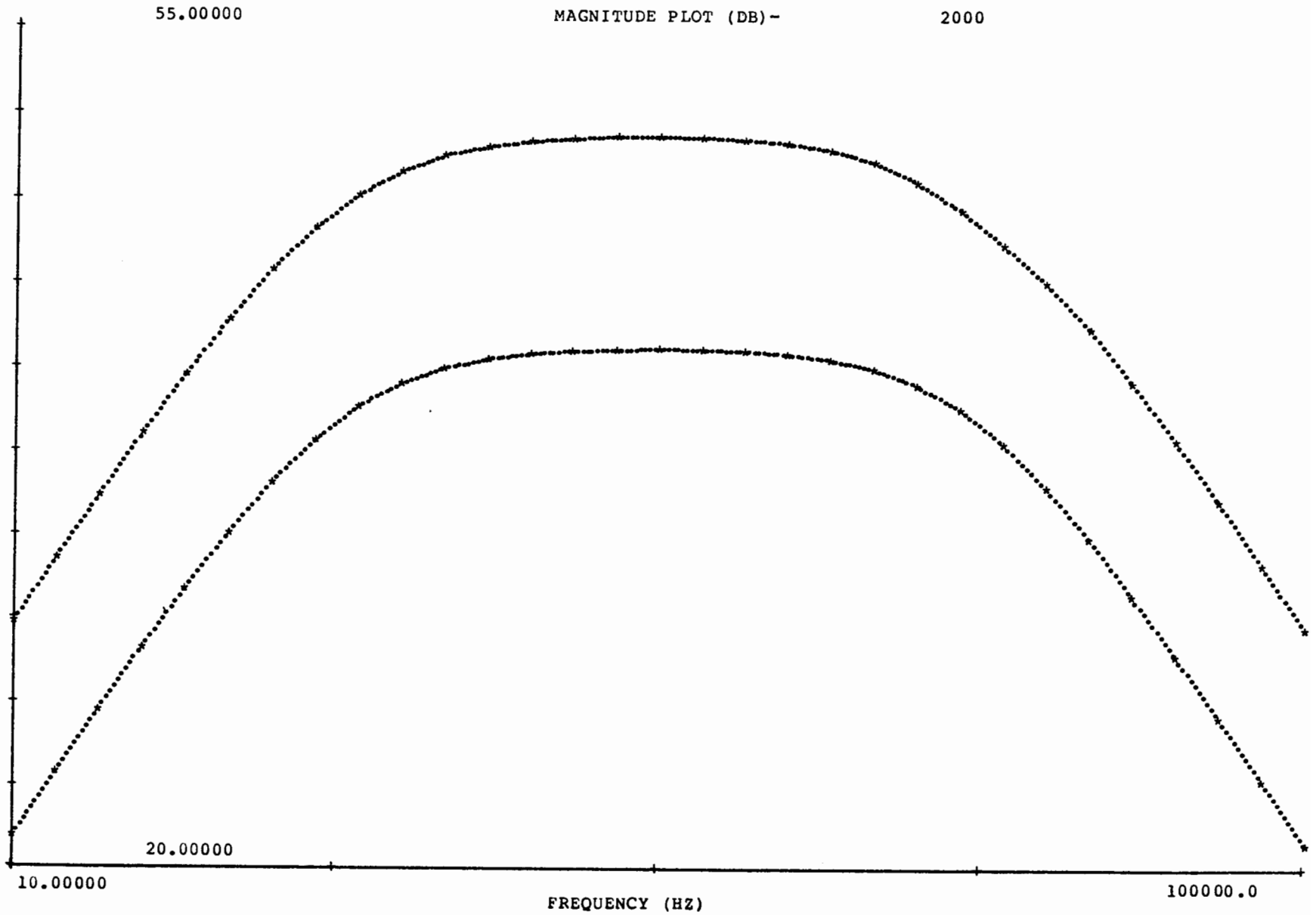
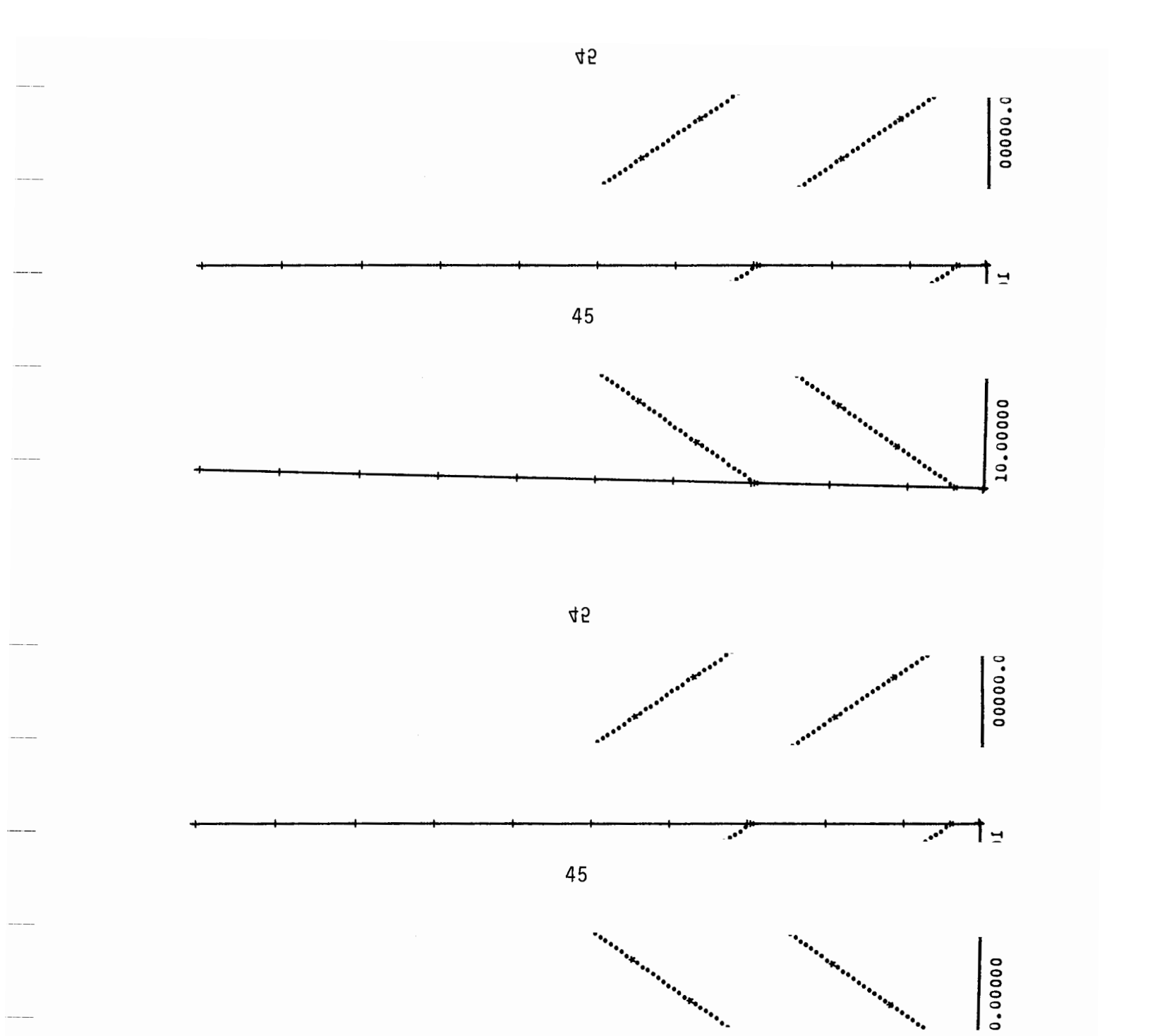
1.000E 04	37.44	126.407	-8.056E-06
1.585E 04	35.65	118.410	-5.817E-06
2.154E 04	33.54	111.668	-3.887E-06
2.929E 04	31.21	106.279	-2.413E-06
3.981E 04	28.74	102.119	-1.420E-06
5.412E 04	26.18	98.974	-8.065E-07
7.356E 04	23.57	96.626	-4.486E-07
1.000E 05	20.94	94.884	-2.465E-07

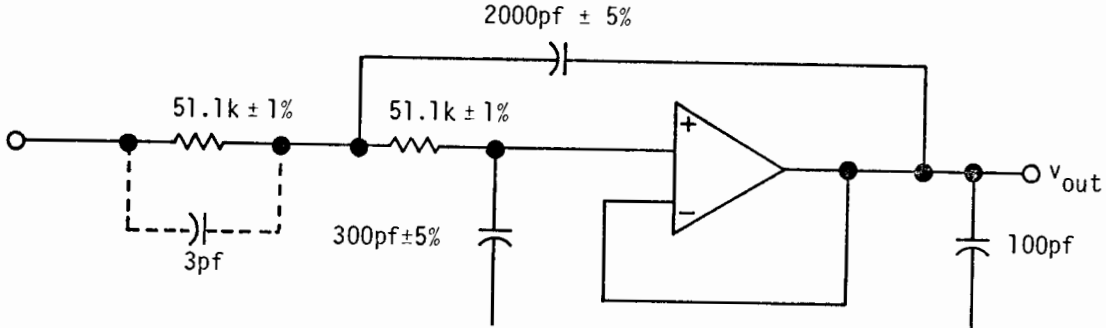
43

1.000E 04	37.44	126.407	-8.056E-06
1.585E 04	35.65	118.410	-5.817E-06
2.154E 04	33.54	111.668	-3.887E-06
2.929E 04	31.21	106.279	-2.413E-06
3.981E 04	28.74	102.119	-1.420E-06


55.00000
MAGNITUDE PLOT (DB)-
2000
20.00000
10.00000
FREQUENCY (HZ)
100000.0



Example 3
Analysis of an Active Filter
With the Output on the 9862 Plotter



OPERATIONAL AMPLIFIER CHARACTERISTICS

R_i = 3M

R_o = 1.5K ± 50%

$A_{vol} = \frac{A_o \omega A}{j\omega + \omega A}$

A_o = 100,000

```
IDENTIFIER NO.
          4276

NO.NODES=       5

NO.BRANCHES    11

BRANCH          1
  RESISTOR
  Kohms= 51.1000
  % TOL.=     1.0
  FROM NODE     1
  TO NODE       2

BRANCH          2
  CAPACITOR
  pfd=     3.0000
  % TOL.=
         0.00010
  FROM NODE     1
  TO NODE       2

BRANCH          3
  RESISTOR
  Kohms= 51.1000
  % TOL.=     1.0
  FROM NODE     2
  TO NODE       3

BRANCH          4
  CAPACITOR
  pfd=   300.0000
  % TOL.=     5.0
  FROM NODE     3
  TO NODE       0

BRANCH          5
  CAPACITOR
  pfd= 2000.0000
  % TOL.=     5.0
  FROM NODE     2
  TO NODE       5

BRANCH          6
  RESISTOR
  Mohms=   3.0000
  % TOL.=
         0.00010
  FROM NODE     3
  TO NODE       5

BRANCH          7
  RESISTOR
  Mohms=
    1000000.0000
  % TOL.=
         0.00010
  FROM NODE     3
  TO NODE       4

BRANCH          8
  CAPACITOR
  pfd=     0.0160
  % TOL.=
         0.00010
  FROM NODE     4
  TO NODE       5

BRANCH          9
  SOURCE
  amps=   66.0000
  % TOL.=
         0.00010
  FROM NODE     5
  TO NODE       0
  + CONTROL     4
  - CONTROL     5

BRANCH         10
  RESISTOR
  Kohms=   1.5000
  % TOL.=    50.0
  FROM NODE     5
  TO NODE       0

BRANCH         11
  CAPACITOR
  pfd=   100.0000
  % TOL.=
         0.00010
  FROM NODE     5
  TO NODE       0

NO. OF TOLERANCE
 PASSES        20

OUTPUT NODE     5

  LOG SWEEP

X AXIS DATA:

  STARTING FREQ=
                10
  ENDING FREQ.=
          1000000

  # OF INTERVALS
                40
```

TO NODE 2 FROM NODE 3 0.000010 ∠ TOL.=	TO NODE 0 FROM NODE 2

∠ TOL.= 0.000010 FROM NODE 3 TO NODE 5	FROM NODE 5 TO NODE 0

47

TO NODE 2 FROM NODE 3 0.000010 ∠ TOL.=	TO NODE 0 FROM NODE 2

47

∠ TOL.= 0.000010 FROM NODE 3 TO NODE 5	FROM NODE 5 TO NODE 0

UPPER ENVELOPE 4276 FRQ 10.00 MGN 0.00 PHS -0.11 FRQ 13.34 MGN 0.00 PHS -0.14 TDL -2.920e-05	FRQ 177.83 MGN 0.01 PHS -1.87 TDL -2.929e-05 FRQ 237.14 MGN 0.02 PHS -2.50 TDL -2.937e-05 FRQ 316.23 MGN 0.04 PHS -3.34 TDL -2.951e-05	FRQ 4216.97 MGN 2.15 PHS -90.40 TDL -9.716e-05 FRQ 5623.41 MGN -2.36 PHS -126.87 TDL -6.433e-05 FRQ 7498.94 MGN -8.29 PHS -146.89 TDL -2.516e-05

FRQ	100000.00
MGN	-48.81
PHS	-104.82
TDL	2.798e-06
FRQ	133352.14
MGN	-47.64
PHS	-84.79
TDL	1.693e-06
FRQ	177827.94
MGN	-45.51
PHS	-70.75
TDL	8.887e-07
FRQ	237137.37
MGN	-43.23
PHS	-59.23
TDL	5.414e-07
FRQ	316227.77
MGN	-41.02
PHS	-48.09
TDL	3.915e-07
FRQ	421696.50
MGN	-38.95
PHS	-36.61
TDL	3.020e-07
FRQ	562341.32
MGN	-37.09
PHS	-25.05
TDL	2.284e-07
FRQ	749894.21
MGN	-35.48
PHS	-14.11
TDL	1.620e-07
FRQ	1000000.00
MGN	-34.15
PHS	-4.70
TDL	1.046e-07

LOWER ENVELOPE

4276

FRQ	10.00
MGN	0.00
PHS	-0.11
FRQ	13.34
MGN	0.00
PHS	-0.15
TDL	-3.181e-05
FRQ	17.78
MGN	0.00
PHS	-0.20
TDL	-3.181e-05
FRQ	23.71
MGN	0.00
PHS	-0.27
TDL	-3.181e-05
FRQ	31.62
MGN	0.00
PHS	-0.36
TDL	-3.181e-05
FRQ	42.17
MGN	0.00
PHS	-0.48
TDL	-3.181e-05
FRQ	56.23
MGN	0.00
PHS	-0.64
TDL	-3.182e-05
FRQ	74.99
MGN	0.00
PHS	-0.86
TDL	-3.183e-05
FRQ	100.00
MGN	0.00
PHS	-1.15
TDL	-3.184e-05
FRQ	133.35
MGN	0.01
PHS	-1.53
TDL	-3.187e-05

FRQ	177.83
MGN	0.01
PHS	-2.04
TDL	-3.192e-05
FRQ	237.14
MGN	0.02
PHS	-2.72
TDL	-3.200e-05
FRQ	316.23
MGN	0.03
PHS	-3.64
TDL	-3.216e-05
FRQ	421.70
MGN	0.06
PHS	-4.87
TDL	-3.243e-05
FRQ	562.34
MGN	0.11
PHS	-6.54
TDL	-3.293e-05
FRQ	749.89
MGN	0.19
PHS	-8.82
TDL	-3.384e-05
FRQ	1000.00
MGN	0.34
PHS	-12.01
TDL	-3.557e-05
FRQ	1333.52
MGN	0.61
PHS	-16.67
TDL	-3.880e-05
FRQ	1778.28
MGN	1.07
PHS	-23.89
TDL	-4.542e-05
FRQ	2371.37
MGN	1.79
PHS	-36.44
TDL	-5.910e-05
FRQ	3162.28
MGN	2.51
PHS	-60.81
TDL	-8.562e-05

FRQ	133.32	TDL	-2.310e-02
TDL	-3.184e-05	PHS	-36.44
PHS	-1.15	MGN	1.79
TDL	-3.185e-05	TDL	-8.295e-02
PHS	-1.23	PHS	-60.81
MGN	0.01	MGN	5.21
FRQ	133.35	FRQ	3165.58

PHS	-1.15	MGN	1.79
TDL	-3.184e-05	PHS	-36.44
FRQ	133.35	TDL	-5.910e-05
MGN	0.01	FRQ	3162.28
PHS	-1.53	MGN	2.51
TDL	-3.187e-05	PHS	-60.81
		TDL	-8.562e-05

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FRQ	133.32	TDL	-2.310e-02
TDL	-3.184e-05	PHS	-36.44
PHS	-1.15	MGN	1.79
TDL	-3.185e-05	TDL	-8.295e-02
PHS	-1.23	PHS	-60.81
MGN	0.01	MGN	5.21
FRQ	133.35	FRQ	3165.58

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PHS	-1.15	MGN	1.79
TDL	-3.184e-05	PHS	-36.44
FRQ	133.35	TDL	-5.910e-05

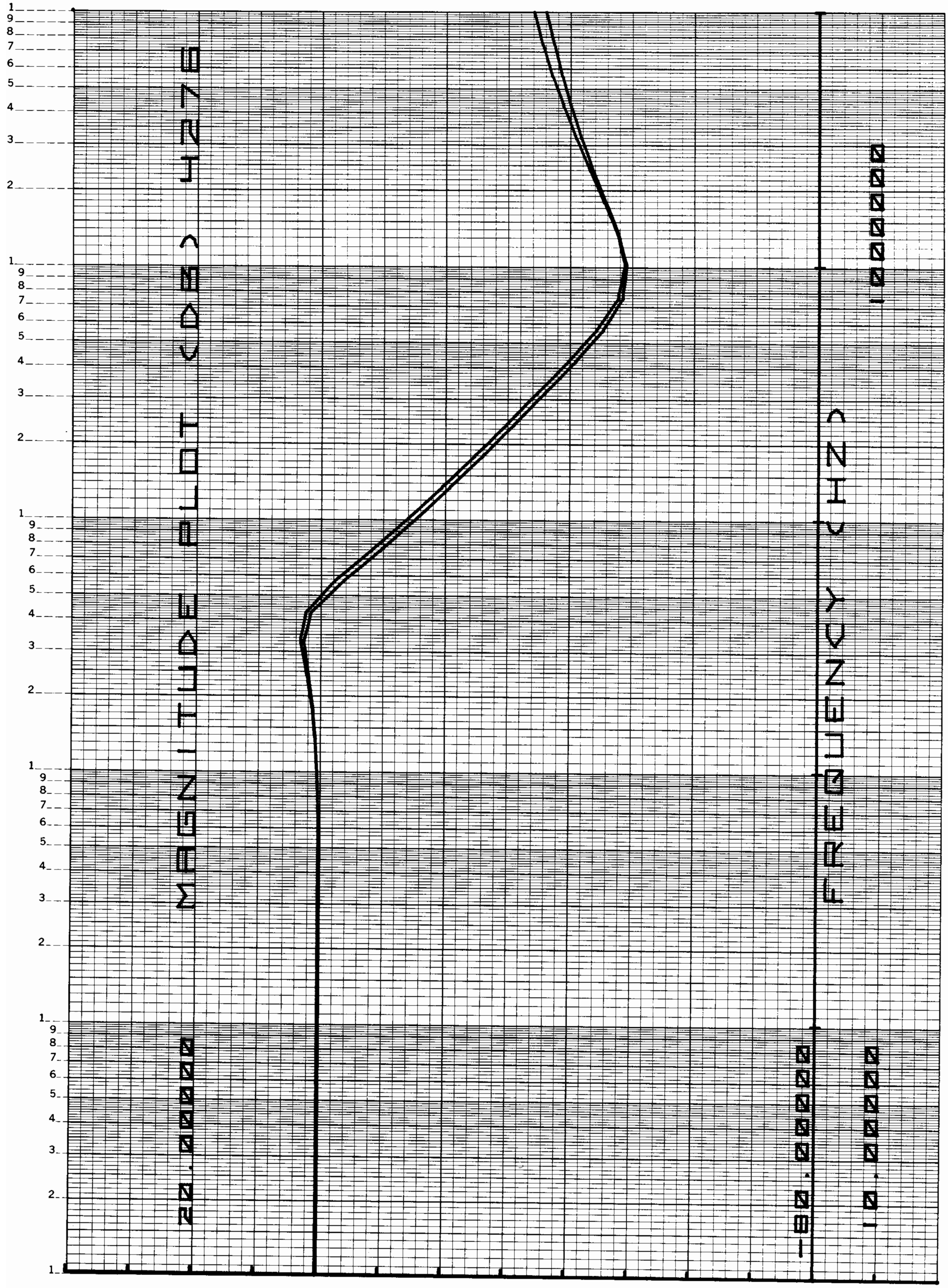
FRQ	4216.97	FRQ	100000.00
MGN	1.33	MGN	-49.14
PHS	-100.57	PHS	-112.72
TDL	-1.051e-04	TDL	2.633e-06
FRQ	5623.41	FRQ	133352.14
MGN	-3.77	MGN	-47.83
PHS	-133.14	PHS	-93.23
TDL	-7.205e-05	TDL	1.488e-06
FRQ	7498.94	FRQ	177827.94
MGN	-9.71	MGN	-45.83
PHS	-150.13	PHS	-80.88
TDL	-2.965e-05	TDL	7.247e-07

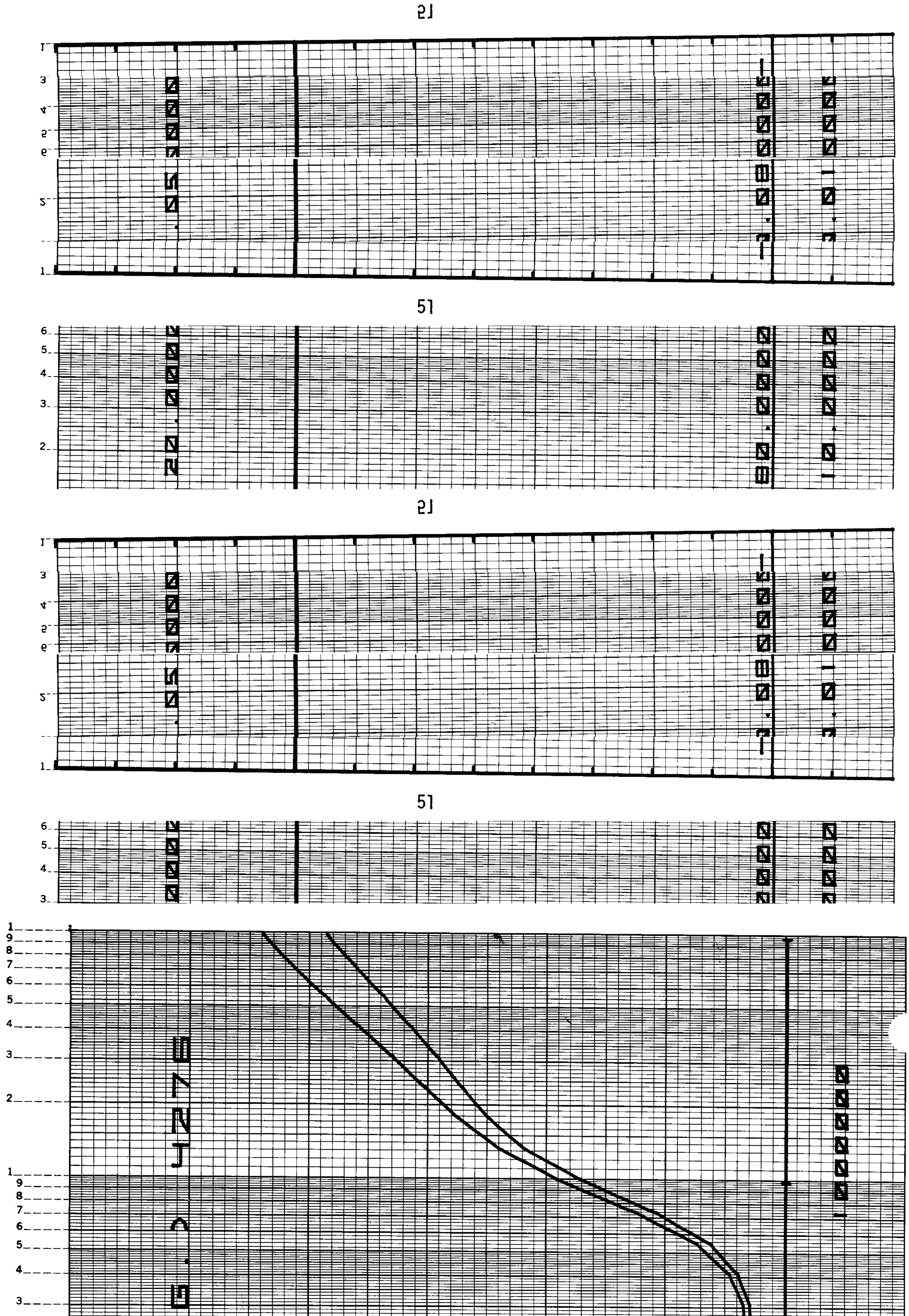
****
MAGNITUDE PLOT
IN db

Y AXIS DATA:

Y MIN=
-80.00000
Y MAX=
20.00000

UPPER ENVELOPE


MAGNITUDE PLOT <DB> H276
FREQUENCY <HZ>
20.00000
-80.00000
10.00000
1000000



EXAMPLE 4

LISTING CIRCUIT DATA

1. When "SELECT KEY" is displayed:
   Press MODIFY DATA (shift f_9)

2. When "BRANCH NO. (Ø TO END) is displayed:
   a. Enter Ø
   b. Press CONTINUE

3. When "LIST DATA?" is displayed:
   Press YES (f_0)

4. Data is listed.

23

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EXAMPLE 5

ERROR RECOVERY

The special function keys will respond properly only when the keyboard is in the proper shift mode. One of the following may happen if a special function key is pressed when the calculator is in the inappropriate shift mode:

1. When "SELECT KEY" is displayed, the calculator will beep and repeat the display.

2. The calculator will beep and an error message will be displayed.

   Recovery: Put the calculator in the proper shift mode and again press the appropriate key. Proper operation will resume.

22

55

22

55

An electrical network with n nodes* can be completely specified for steady-state analysis by its n x n node admittance matrix, which in turn depends on the value of each component, the network topology (how the components are connected), and the frequency.

The node admittance matrix, [Y], is formed by starting with a null matrix (each element = 0), and adding to it for each component as follows:

Let:

y_c = the admittance of the given component,

i and j = the numbers of the nodes the component is connected between ($i \neq 0$).

Then:

add y_c to y_{ii} and if $j \neq 0$,
add y_c to y_{jj},
add $-y_c$ to y_{ij},
add $-y_c$ to y_{ji},

where y_{ij} = the element in the ith row and jth column of the node admittance matrix being formed.

Note that while y_{ij} is in general a complex quantity depending on frequency, each component contributes to either the real part or the imaginary part of y_{ij}:

for resistors, $y_c = \frac{1}{R}$, where R = resistance in ohms;

for inductors, $y_c = \frac{-j}{\omega L}$, where L = inductance in henries, ω = frequency in radians/second;

for capacitors, $y_c = j\omega C$, where C = capacitance in farads.

* Nodes are numbered sequentially from 0, letting node 0 be the reference node (usually ground). Then n is defined as the number of nodes, excluding node 0.

for capacitors, $y_C = j\omega C$, where C = capacitance in farads.

* Nodes are numbered sequentially from 0, letting node 0 be the reference node (usually ground). Then n is defined as the number of nodes, excluding node 0.

for capacitors, $y_C = j\omega C$, where C = capacitance in farads.

* Nodes are numbered sequentially from 0, letting node 0 be the reference node (usually ground). Then n is defined as the number of nodes, excluding node 0.

The sinusoidal steady-state performance of the network at a particular frequency is given by a set of simultaneous linear equations:

$$y_{11}v_1 + y_{12}v_2 + \ldots + y_{1n}v_n = i_1$$
$$y_{21}v_1 + y_{22}v_2 + \ldots + y_{2n}v_n = i_2$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$y_{n1}v_1 + y_{n2}v_2 + \ldots + y_{nn}v_n = i_n$$

where i_n = the current entering node n from a current source (which may be either a dependent source or an independent source).

From this new [Y] matrix, the network transfer function, v_{out}/v_{in}, can be found as follows:

Let:

node 1 be the input node;
node 2 be the output node.

Then:

$v_{out}/v_{in} = v_2/v_1$, which is computed in this manner:

1) Partition $[Y]_{nxn}$

$$[Y]_{nxn} = \begin{bmatrix} [Y_a]_{n-1 \times n-1} & [Y_b]_{n-1 \times 1} \\ [Y_c]_{1 \times n-1} & [Y_d]_{1 \times 1} \end{bmatrix}$$

2) Form a new matrix, [Y'], of order n-1

$$[Y']_{n-1 \times n-1} = [Y_a] - \frac{[Y_b][Y_c]}{y_d}$$

3) Repeat the reduction until the order of the reduced matrix [Y'] is 2. Then, $v_2/v_1 = y'_{21}/y'_{22}$

The precision and dynamic range of the Model 9825A Calculator make it possible to solve the above equations fairly rapidly and with high accuracy.

The output magnitude is given in db by using the following expression:

$$20 \log (V_{out} / V_{in}).$$

The range for the phase is between -180° and +180°.

The delay at the frequency f_i is obtained from the following expression:

$$(\phi_i - \phi_{i-1})/(360(f_i - f_{i-1})),$$ where ϕ_j is the phase shift at the frequency f_j.

Reasons for modification:

1. User may have more than 15,036 bytes of read/write memory and may need more nodes, branches and frequency intervals.

2. User may want to create more nodes and/or branches by reducing the number of frequency intervals.

3. User may want to create more frequency intervals by reducing the number of nodes and/or branches.

Method:

Let N = the maximum number of nodes (N cannot be less than 6).
Let B = the maximum number of branches.
Let I = the maximum number of frequency intervals.

The total number of array elements dimensional for nodes, branches and frequency intervals can be calculated by the following formula:

$$\text{Number of array elements} = 2(N^2 + B + 3I) = T_E$$

The number of array elements required for the expanded program is (assuming 15,036 bytes of RWM):

$$2[18^2 + 96 + (3)(40)] = 1080 = T_E.$$

The number of array elements required for the basic program is:

$$2[9^2 + 48 + (3)(20)] = 378 = T_E.$$

The number of array elements required for the basic program is:

$$2[9^2 + 48 + (3)(20)] = 378 = T_E.$$

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The number of array elements required for the basic program is:

$$2[9^2 + 48 + (3)(20)] = 378 = T_E.$$

The user may pick more desireable values of N, B, and I as long as T_E does not exceed the above figures.

Users with more than 15,036 bytes of read/write memory may increase the value of T_E by using the following formula:

New T_E = 1080 + (Bytes of RWM - 15,036)/8.

Modification requires alteration of the following lines of program.

File 3

line 39 & 40: Change 20 to the new number of frequency intervals.

```
39: if flg1=0;ent "NO. OF INTERVALS(MAX IS 20)",P[3];if flg13+(P[3]<1)+(P[3]>20);sto +0
40: if P[3]>20;dsp "MAXIMUM NO. OF INTERVALS IS 20";wait 1500;sto -1
```

File 5

line 1: Change 21 to 1 more than the new number of frequency intervals.

```
 1: 21→M;dim M[M],S[M],A[M],W[M],G[M],H[M];sto 7;ssfg 11
```

line 10 & 12: Change 9 to the new number of nodes.

```
10: I+1→I;if I>9;sto +4
12: J+1→J;if J>9;sto -2
```

Extended Capability Program

File Ø

line 29: Change 18 to the new number of nodes; change 96 to the new number of branches.

```
29: prt " 18 NODES MAX"," 96 BRANCHES MAX";spc 2
```

File 2

line Ø: Change 96 to the new number of branches in E[] and L[]; change 18 to the new number of nodes in Y[] and K[]; change 41 to 1 more than the new number of frequency intervals (7 places).

```
J: lkd ;dim E[96],L[96],N[2],Y[18,18],K[18,18],C[4],F[4],P[4],Q[2],R[2];41→H
```

line 7: Change 95 to 1 less than the new number of branches.

```
 7: I+1→I:10→E[I]→L[I]:goto 46:if I>95:goto 16
```

line 22 & 47: Change 96 to the new number of branches.

```
22: ent "BRANCH NO.(0 TO END)?",I:if (int(I)≠I)+(I<0)+(I>96):goto 22
47: I+1→I:if I>96:dsp "ALL BRANCHS FULL":wait 1000:goto 21
```

File 3

line 39 & 40: Change 40 to the new number of frequency intervals

41 to 1 more than the new number of frequency intervals (7 places).

line 9: Change 96 to the new number of branches in E[] and L[];
change 18 to the new number of nodes in Y[] and K[]; change
41 to 1 more than the new number of frequency intervals (7 places).