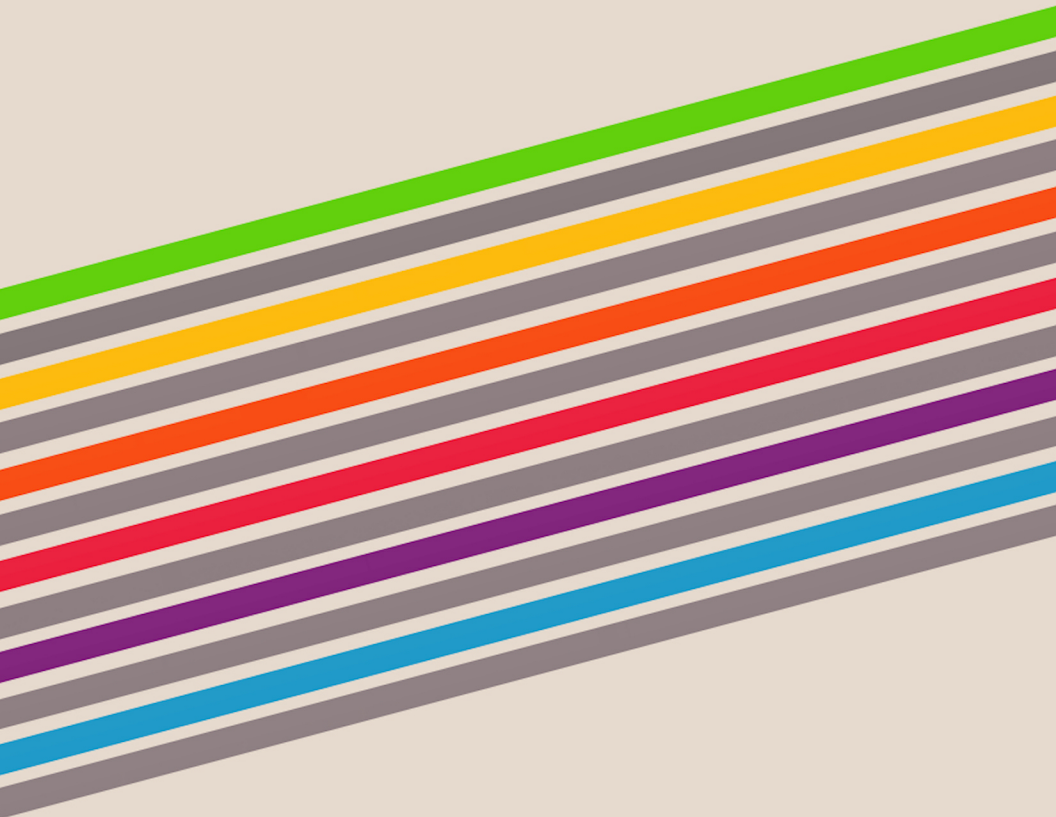# CIRCUIT ANALYSIS

C2S0003 MASTER

1981 Petrie

652-2054-00

CIRCUIT ANALYSIS

Written by A. F. Petrie

In conjunction with Apple Computer Inc.

NOTICE

Apple Computer Inc. reserves tne right to make improvements in the product described in this manual at any time and without notice.

DISCLAIMER OF ALL WARRANTIES AND LIABILITY

CONTENTS

CIRCUIT ANALYSIS INSTRUCTIONS

PROGRAM DESCRIPTION

Input to the program is made on a text file using a network description similar to that shown at the beginning of the sample printout. Output is designed for both CRT screen and most printers (alphanumerics are used in the plotting routine).

The program writes the network equations and solves them for you, but you must come up with the proper equivalent circuit. Some examples at the end will help you in this regard.

USES

CIRCUIT ANALYSIS is a general purpose circuit analysis program that can be used to analyze circuits for:

    FREQUENCY RESPONSE
    PART TOLERANCE EFFECTS
    WORST CASE PERFORMANCE
    PRODUCTION VARIATIONS
    TEST LIMITS
    PART VALUE OPTIMIZATION
    NODE VOLTAGES
    PART POWER DISSIPATION

The types of circuits that can be analyzed are only limited by the designer's ability to enter accurate equivalent circuits for the components used. Several examples are given of typical circuits. Below are some circuits that the program will handle:

    ACTIVE FILTERS
    R-F AMPLIFIERS
    AUDIO AMPLIFIERS
    VIDEO AMPLIFIERS
    L-C NETWORKS
    AUDIO OR R-F TRANSFORMERS
    A-C POWER NETWORKS
    TRANSISTOR BIAS CIRCUITS
    OP-AMP VOLTAGE FOLLOWERS

HOW TO USE THE PROGRAM

1. Draw a diagram of the network, including a signal at the input and its source impedance.

2. Substitute equivalent circuits for complex devices where required.

3. Assign node "0" to all ground connections (and power supply connections

in the A-C analysis). Number all junctions of two or more parts with node numbers except junctions between voltage sources and the next part (add a 1-ohm resistor if nessary at this point). Start with 1 near the input with the highest number node being the output. Inputs of active devices must have a lower number than outputs.

4. Insert the disk and 'boot' by turning on the computer or typing 'PR#6'. Choose AC or DC CIRCUIT ANALYSIS from the MASTER MENU. Choose 'MAKE A NEW FILE' and Give the file a short name (L-P FILTER, A-F AMP, etc.) when asked. Careful, don't use the same name twice unless you want the new file to replace the old. Type in the parts in order starting with the input voltage (VIN) first. The source impedance must be entered right after a voltage source (the program will remind you and automatically add the right node numbers). Press 'RETURN' after each entry to move to the next column. Use Q for part name to end the input. Don't forget to 'SAVE FILE ONTO DISK'.

5. Choose from the menu and type in the frequencies when asked. Use 0 for step in 'FREQUENCY RESPONSE' if you want the frequency to double with each step. Try some of the examples included on the disk for practice. Follow the sample run as a guide if in doubt. In general, use the order on the MENU.

DEFINITIONS

FILE = A file stored on the disk containing your network data.

FILE NAME = A name you choose to identify the network (less than 30 characters).

PART = Name of the part. Use any 4-character name starting with the proper first letter shown below: (VIN,R234,CB2,L-M,B-T1).

V... =VOLTAGE GENERATOR. It must have a R, C, or L in series in the same branch or the program will calculate infinite branch current and overflow error. the first part in your network must be the input voltage (VIN), usually 1 volt, with part 2, its source impedance (RIN) in series (with the same node numbers).

I... = CURRENT GENERATOR.

NOTE: all V... and I... sources should be listed before other parts. The program will sort them to the beginning.

R... = RESISTOR. Any 4-character name starting with "R" may be used (R1,RGEN,R234,RB1)

C... = CAPACITOR.

L... = INDUCTOR.

B... = CURRENT CONTROLLED CURRENT GENERATOR (BETA of a transistor).
Current flows to (or from) the emitter in both the base and collector
of a transistor. Add a 1-ohm resistor in series with the base to
sense the current if necessary.

G... = VOLTAGE CONTROLLED CURRENT GENERATOR (GM). Control part
polarity: current flows to (or from) the source in both the gate and
drain of a J-FET or MOS-FET. For an OP-AMP: INPUT (C-PART) - FN=+,
TN=- OUTPUT (G) - FN=O, TN=OUTPUT, OUTPUT Z - FN=OUTPUT, TN=O. *NOTE*
THE CONTROL PART MUST ALWAYS BE LISTED FIRST.

VALUE = PART VALUE. .1E-6 would be .1 uF. 10E6 = 10 Megohms, 6.5E-3
= 6.5 mH. (E stands for the exponent of 10.) 'O' is a legal value
only for voltage sources (the source impedance limits the current).

TOL = TOLERANCE in %. 5 = 5%, 0 = 0% An absolute value can be spec-
ified by using a '-' TOL. (To specify a +/- 7 mv offset for an
OP-AMP, use'O' for VALUE and '-.007' for TOL.)

FROM = FROM-NODE. Current is assumed to flow from this node, through
the part, to the TO-NODE. Ground is node zero.

TO = TO-NODE. Note that current flow is arbitrary (if you guess wrong
the calculated current is nega- tive, but the answer is right), except
as specified above.   In general, current flows from the highest
voltage node toward ground.

C-PART= CONTROL PART. Use the name of the part that carries the
control current (R-B' for a transistor or R-IN for an OP-AMP).

MIN/MAX TO %TOL

This program can be used to convert data from the MIN/MAX form to the
NOMINAL +/- TOLERANCE form used in this program.

REMOVE OLD FILES

This is used to remove unwanted files from the disk.

AC CIRCUITS

Enter your name and date when requested for later printout. It is not
necessary to activate the printer until after loading your circuit. Be
sure to REVIEW you file with the printer on as a record of the circuit
being analyzed.   The printer is automatically disabled during INPUT and
MENU operations.

LOAD A FILE

If you have more than one drive, always put the APPLE/CIRCUIT disk in drive
1. The number in the upper right corner during the catalog display shows
the number of free sectors left on the disk. When this number is less than
20 it is time to start saving files on another disk. DC. or AC. are

preprinted for you to make sure you call for the right type of file. If you get an error message, make sure you typed in the name exactly as shown on the listing. When you have many files on a disk, the first part of the list will be shown first, and any key can be pressed to view the rest of the list. Do not enter the file name until requested. If you discover that you have the wrong disk in the drive, use 'RETURN' to go to the menu while you change disks, then repeat 'LOAD'.

NOMINAL OUTPUT

This can be used for a quick look at the performance at one frequency.

FREQUENCY RESPONSE

Input required is the lowest frequency desired, the highest frequency desired, and frequency change for each step. (An example is 1000,3000,100 which would start at 1000 Hz, and step in 100 Hz increments until 3000 Hz.) The program will handle a maximum of 30 steps at one time. For a quick sweep, use '0' for step size, and the program will double the frequency with each step. (Example: 20,20000,0) The plotting is completely automatic once you answer 'Y'. The plot uses letters to be compatible with all printers. 'D' is used for decibels, 'A' is used for phase angle, and 'X' is used where the curves cross. Repeat the response with new limits for additional detail at any frequency. If the frequency exceeds 1 MHz, 'M' will be added to the printout to show this.

WORST CASE & PART EFFECTS

This routine will check each part for its effect on the output and the effect of its tolerance. This will aid you in choosing the tight tolerances where they will do some good! A negative value indicates that the output goes up as the part value goes down. The WORST CASE shows the results if all parts go to the worst tolerance direction.

TRIAL RUN & TEST LIMITS

This is sometimes referred to as a MONTE CARLO analysis. Part values are picked at random as they would be on an assembly line, and the results summarized statistically. 10 trials are reasonable, 30 should be used for final test limit specifications. Statistics are adjusted for sample size.

OPTIMIZE A PART

A very useful routine, with this you can adjust any part in your circuit to get the exact output you want. Be sure to pick a part that has a large effect on the output as shown in the PART EFFECTS above. If your part can't be adjusted low enough, the program will call for a negative value!

DIFFERENT OUTPUT NODE

This allows you to run all of the tests on a different node in your circuit. Be sure to check the results for reasonableness, and the REVIEW FILE for errors, as this can place outputs before inputs. Use this for looking at the low-pass, band-pass, and high-pass outputs of state variable filters.

CHANGES TO CURRENT FILE

You will use this a lot. Any file errors will automatically abort to this routine. To change a part in your circuit, type in a new line starting with the same part name. That line will automatically be substituted for the original line. Refer to the EXAMPLES and use 'RETURN' after each entry to move to the next column. Use the back arrow for corrections before 'RETURN', and type a new line for later corrections. To delete a part or change the name of a part, type the old name, and use 'D' for VALUE. The program will sort all voltage and current sources to the beginning and all dependent voltage and current sources (B,G) to the end. Use 'Q' for PART to signal the end of your circuit.

MAKE A NEW FILE

The procedure is the same as above. Name your file with a short name you will recognize later. You can use 'Q' to exit the routine with an incomplete file and save it for later completion. (If there is an error when the program tries to assemble your incomplete file just abort to the menu and 'SAVE FILE ONTO DISK'.) CAUTION: Do not abort these routines during normal loading as this will interrupt circuit assembly, causing errors in computation.

SAVE FILE TO DISK

If you want to save a new version of an old file, use FILE1 or FILE2 for a name to avoid overwriting FILE. The program will warn you before overwriting a file.

DC CIRCUIT

This is similar to AC CIRCUIT, except that power supply and bias voltages are used instead of signal voltages. This is a linear program that will come up with impossible voltages if they are required to satisfy the circuit values you enter. A separate equivalent circuit should be used for saturation conditions. This program is very useful for checking amplifier bias and power supply variations.

VOLTAGES AND POWERS

With one calculation, this routine will calculate all node voltages and all part dissipations. No additional input is required.

ERROR CODES

Should you get an 'ERROR #16' or similar message, the code can be found on page 81 of the APPLESOFT reference manual and page 115 of the DOS manual. Error trapping is used to prevent you from dropping out of the program and losing valuable data before you have a chance to save it. "PART NOT FOUND" error when the part is there is likely caused by entering an extra space with the name of the part.

ABORT

'RETURN' can be used in response to most requests for input to jump to the MENU. Do not use 'RETURN' alone during data entry into a file as you may lose your data due to not completing the input routine. It can be used for a quick exit when you find yourself in the wrong routine. The program will not abort during a long calculation until the next print-out, and then only with 'ESC' to prevent accidental aborting of a long calculation with loss of valuable data. NOTE: When you 'LOAD A file, the program automatically reviews the file as it checks for errors, and then assembles the connections. Do not abort this routine or the program will error out during calculation.

MAXIMUM CIRCUIT SIZE

A-C ANALYSIS	D-C ANALYSIS
60 PARTS	80 PARTS
30 NODES	40 NODES

ACCURACY

During the network solution, rows and columns of the matrix are multiplied and subtracted. Thus, for maximum accuracy extremely large and extremely small values should not be used in the same circuit analysis. If a component can be neglected, then leave it out. If in doubt, try a run with and without the part. One calculation cycle may take more than six minutes on a 60 part A-C network. Both accuracy and speed are better on small circuits, so analyze smaller blocks where possible to avoid errors (both computer and operator).

PRINTER

The printer routines in this program will work automatically with the APPLE SILENTYPE or PARALLEL INTERFACE cards. It will also work with any cards that can be called with "PR#(slot)". If your printer requires another input, set it up beforehand and don't use the printer command in CIRCUIT

ANALYSIS. Since this disk must be booted to run, some printer interfaces still may not work. NOTE: This program is set up to use 40 columns on the printer so you can use the TV monitor at the same time. DO NOT CALL FOR 80 COLUMNS.

```
                   2<——R2————4
                   !
                   !   2<————CCB—4
                   !   !
                   !   !    +<—B—4
                   !   !    !    !
        +—C1—>1—R1—>2—RB—>3<—RC—4
        ^                 !    !
        !                 RE   R3
        !                 !    !
        VIN               !    !
        !                 v    v
        0————————————————0————0
```
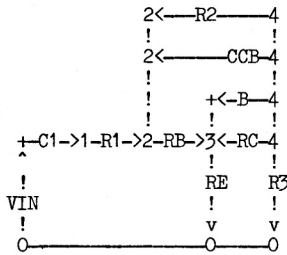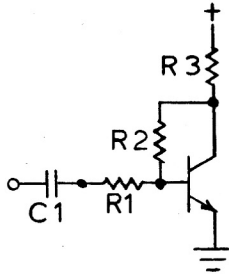
PART	VALUE	TOL%	FROM	TO	C-PART
VIN	1	0	0	1	
C1	.1E-6	10	0	1	
R1	1000	5	1	2	
RB	100	20	2	3	
RE	26	10	3	0	
R2	100E3	5	4	2	
CCB	10E-12	10	4	2	
RC	1E6	30	4	3	
R3	1000	5	4	0	
B	120	30	4	3	RB

NOTES

The "T" equivalent circuit used above is recommended since the input and output impedance change properly as BETA (HFE) varies (during tolerance analysis). Node #'s are shown at nodes. Arrows "^ v -> <-" show current flow.

2 = the base node.

3 = the internal collector-base junction.

4 = the collector node.

0 = the emitter node (ground).

RB = the base (spreading) resistance of the transistor. 100 ohms is used as a typical value. This is the control branch (current sense) for B (HFE).

RE = the equivalent resistance of the foreward biased base-emitter junction. At room temperature this equals .026/IE (1 ma. assum- ed above).

RC = common-base output impedance, equal to 1/HOB (or HFE/HOE).

CCB = collector-base capacitance.

B = HFE, the current gain of the transistor.

OP-AMP ACTIVE FILTER (AC.FILTER)
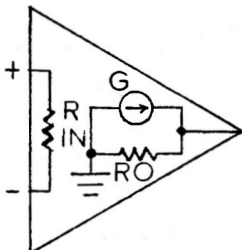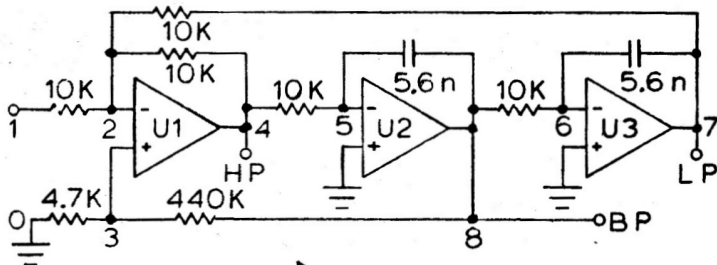
PART	VALUE	TOL%	FROM	TO	C-PART
VG	1	0	0	1	
RG	1	0	0	1	
RS1	10E3	5	1	2	
RFB1	10E3	5	4	2	
RIN1	1E6	5	3	2	
R+G1	4700	5	3	0	
RO1	100	0	4	0	
G1	1E3	30	0	4	RIN1
RS2	10E3	5	4	5	
CFB2	5.6E-9	5	8	5	
RIN2	1E6	5	0	5	
RO2	100	0	8	0	
G2	1E3	30	0	8	RIN2
RS3	10E3	5	8	6	
CFB3	5.6E-9	5	7	6	
RIN3	1E6	5	0	6	
RO3	100	0	7	0	
G3	1E3	30	0	7	RIN3
R2-1	440E3	5	8	3	
R3-1	10E3	5	7	2	

NOTES

This is a three-amplifier, statevariable 3-kHz bandpass filter. The normal

output is node 8. Look at node 7 to see the low-pass response, or node 4
to see the high- pass response.

TRANSISTOR AMPLIFIER (DC.TR AMP)

```
              +
              |
           R2 $
              |
      +-------+
      |       |
  R1 $|       |
     o+       |
      |       |
      +------< T
              |
              |
              v (ground)
```

```
2<-R1--4<-R2-1
 ^      ^   ^
 !      !   !
 RB     B   !
 !      !   RCC
 +<-VBE-3   !
 !      !   !
 RE     VCC
 !      !
 v      !
 o------o
```
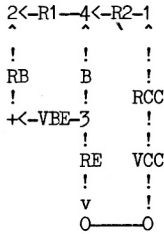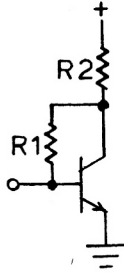
PART	VALUE	TOL%	FROM	TO	C-PART
VCC	5	0	0	1	
RCC	1	0	0	1	
VBE	.6	10	3	2	
RB	100	10	3	2	
RE	26	10	3	0	
R1	100E3	5	4	2	
R2	1E3	5	1	4	
B	150	30	3	4	RB

NOTES

The current flows out of the emitter node (3) to the base (2) and collector
(4) to obtain the correct polarity for VBE.

    1 = the supply node.
    2 = the base node.
    3 = the internal emitter node.
    4 = the collector node.
    VBE = the foreward voltage of the base-emitter junction.
    (Other parts are similar to AC.TR AMP.)

VOLTAGE FOLLOWER (DC.OP AMP)

```
            1                 3
    V S o───┤ +  ╲           ┌─o
            │     ╲         ╱
            │      ╲───────╱
            │     ╱         ╲
            └────┤ -         ╲
                 └────────────┘
```

```
1-VOS-ROS->2────+
^           !    !
!          RIN  !
!           !  IB+
RS          v   !
!           3───────3───3
!           ^   !   !   !
VS         IB-  !   !   RO
!           !   !   G   !
!           v   v   !   v
o───────────o───o───o───o
```
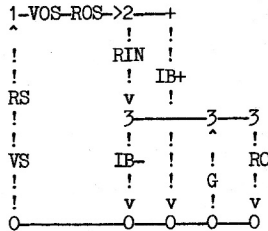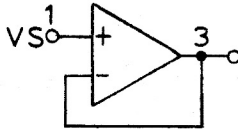
PART	VALUE	TOL%	FROM	TO	C-PART
VS	5	0	0	1	
RS	1	0	0	1	
VOS	0	-.012	1	2	
ROS	1	0	1	2	
IB+	.25E-6	20	2	0	
IB-	.25E-6	20	3	0	
RIN	1E6	30	2	3	
RO	100	0	3	0	
G	1E3	30	0	3	RIN

NOTES

This example shows how to introduce op-amp input off-set voltage and bias
currents into the equivalent circuit.

```
    2   = the non-inverting input.
    3   = the inverting input (which isconnected to the output 3).
    VS  = the input signal voltage.
    VOS = the input offset (+/-.012 V.).
    IB  = the input bias current (.25 uA.).
    RO  = the output impedance.
    G   = gm = (voltage gain/RO)(Voltage gain = 100,000)
```

c
```
*************************************
**                                 **
**      APPLE/CIRCUIT 1.0          **
**                                 **
**          DC.TR AMP              **
**                                 **
**        JOHN DOE 2/16/81         **
*************************************
```
=====================================
<< FILE — DC.TR AMP >>

PART	VALUE		TOL%	FROM	TO	C-PART
VCC	5	V	0	0	1	
VBE	.6	V	10	3	2	
RCC	1	OHM	0	0	1	
RB	100	OHM	10	3	2	
RE	26	OHM	10	3	0	
R1	100000	OHM	5	4	2	
R2	1000	OHM	5	1	4	
B	150		30	3	4	RB

=====================================
<< VOLTAGES AND POWERS >>

NODE:	VOLTAGE:
1	4.99739632
2	.669420045
3	.0676957516
4	2.39371338

(NEGATIVE POWER = SUPPLYING POWER)

PART:	POWER(MW.):
VCC	-13.02
VBE	.01
RCC	<.01
RB	<.01
RE	.18
R1	.03
R2	6.78
B	6.02

=====================================
<< PART EFFECTS & WORST CASE >>

PART NAME	EFFECT ON OUTPUT %	TOLERANCE EFFECT %
VCC	85.15	0
VBE	14.85	1.48
RCC	-.044213939	0
RB	.042894991	4.2894991E-03
RE	1.67	.167491225
R1	42.5	2.13
R2	-44.08	-2.2
B	-42.17	-12.65

WORST CASE: OUTPUT VOLTS

MINIMUM	=	1.99435713
NOMINAL	=	2.39371338
MAXIMUM	=	2.90618289
TOTAL RANGE	=	.911825764 (38.09 %)

=====================================
<< TRIAL RUN & TEST LIMITS >>

NUMBER OF TRIALS (10) = 10
NOMINAL = 2.39371338   VOLTS
AVERAGE = 2.34458921   VOLTS
STD DEV = .204396026   VOLTS

99 PERCENT FALL WITHIN:
MINIMUM = 1.81724746   VOLTS
MAXIMUM = 2.87193096   VOLTS

```
========================================
          << OPTIMIZE A PART >>

PART TO BE OPTIMIZED = R1
DESIRED VOLTAGE      = 2.5

PART R1        = 100000
OUTPUT VOLTAGE = 2.39371338

PART R1        = 110447.134
OUTPUT VOLTAGE = 2.49622016

PART R1        = 110849.813
OUTPUT VOLTAGE = 2.50000998

ANOTHER TRY ( Y/N )? N

RETURN PART TO ORIGINAL VALUE ( Y/N )? Y
========================================
         << CHANGE OUTPUT NODE >>

CAUTION NODE EXCHANGE CAN CAUSE ERRORS

NEW OUTPUT NODE # = 3

NODE 3 IS NOW NODE 4

NODE 4 IS NOW NODE 3
========================================
          << FILE - DC.TR AMP >>

PART VALUE          TOL%  FROM TO C-PART
----------------------------------------
VCC  5          V    0     0   1
VBE  .6         V    10    4   2
RCC  1          OHM  0     0   1
RB   100        OHM  10    4   2
RE   26         OHM  10    4   0
R1   100000     OHM  5     3   2
R2   1000       OHM  5     1   3
B    150             30    4   3  RB
========================================
       << TRIAL RUN & TEST LIMITS >>

NUMBER OF TRIALS (10) = 10
NOMINAL = .0676957516     VOLTS
AVERAGE = .0676494753     VOLTS
STD DEV = 9.61904149E-03 VOLTS

99 PERCENT FALL WITHIN:
MINIMUM = .0428323483     VOLTS
MAXIMUM = .0924666023     VOLTS
========================================

        << END OF DC.TR AMP >>
```

```
**************************************
**          APPLE/CIRCUIT 1.0       **
**                                  **
**              AC.TR AMP           **
**                                  **
**          JOHN DOE 2/16/81        **
**************************************
======================================
         << FILE - AC.TR AMP >>

PART VALUE           TOL%  FROM TO C-PART
--------------------------------------
VIN  1          V     0      0  1
C1   .1         UF    10     0  1
R1   1000       OHM   5      1  2
RB   100        OHM   20     2  3
RE   26         OHM   10     3  0
R2   100000     OHM   5      4  2
CCB  10         PF    10     4  2
RC   1          MEG   30     4  3
R3   1000       OHM   5      4  0
B    120              30     4  3  RB
======================================
         << NOMINAL OUTPUT >>

FREQUENCY IN HERTZ = 1000
VOLTAGE GAIN       = 18.2265718
DECIBELS           = 25.21
PHASE SHIFT DEG    = -147.23
======================================
        << FREQUENCY RESPONSE >>

LOW, HIGH, STEP FREQ.= 20,20000,0

FREQ-HZ OUTPUT-VOLTS DECIBELS PHASE-DEG
--------------------------------------
20      .671648071     -3.46    -91.78
40      1.34136937      2.55    -93.55
80      2.6674888       8.52    -97.07
160     5.21798057     14.35   -103.93
320     9.63357803     19.68   -116.39
640     15.2729085     23.68   -134.8
1280    19.370986      25.74   -153.34
2560    21.0374482     26.46   -166.06
5120    21.5254543     26.66   -173.24
10240   21.6511876     26.71   -177.24
20480   21.6762676     26.72   -179.9

PLOT DATA (Y/N)? Y
                   DECIBELS
        -30        -10      10          30
FREQ-HZ+----+----+----+----+----+----+
20      +    + A  +  D +    +    +    +
40      +    + A  +   +D    +    +    +
80      +    + A  +    +   D+    +    +
160     +    +A   +    +    + D  +    +
320     +    A    +    +    +   D+    +
640     +   A+    +    +    +    D +  +
1280    + A  +    +    +    +    + D +
2560    +A   +    +    +    +    + D +
5120    +A   +    +    +    +    + D +
10240   A    +    +    +    +    + D +
20480   A    +    +    +    +    + D +
        +----+----+----+----+----+----+
       -180 -120  -60   0   60  120  180
            PHASE ANGLE (DEG)
```

```
=======================================
   << PART EFFECTS & WORST CASE >>

FREQUENCY IN HERTZ = 1000

PART      EFFECT ON        TOLERANCE
NAME      OUTPUT %         EFFECT %
---------------------------------------
VIN       100              0
C1        29.21            2.92
R1        -28.53           -1.43
RB        -1.32            -.263662812
RE        -41.3            -4.13
R2        32.35            1.62
CCB       -.0928452364     -9.28452364E-03
RC        .0279439104      8.38317311E-03
R3        67.95            3.4
B         27.6             8.28

WORST CASE: OUTPUT   DECIBELS PHASE-DEG
---------------------------------------
MINIMUM=14.1518717      23.02   -143.98
NOMINAL=18.2265718      25.21   -147.23
MAXIMUM=22.3661475      26.99   -149.08
TOTAL RANGE = 45.07 %    3.97      5.11
=======================================
     << TRIAL RUN & TEST LIMITS >>

FREQUENCY IN HERTZ   = 1000
NUMBER OF TRIALS (10)= 10
NOMINAL = 18.2265718     25.21   DB
AVERAGE = 17.7997719     25.01   DB
STD DEV = 1.22260462

99 PERCENT FALL WITHIN:
MINIMUM = 14.6454519     23.31   DB
MAXIMUM = 20.9540918     26.43   DB
=======================================
        << OPTIMIZE A PART >>

FREQUENCY IN HERTZ        = 1000
PART TO BE OPTIMIZED      = R3
PARAMETER TO BE OPTIMIZED:
(1=VOLTS, 2=DB, 3=DEGREES)= 2
DESIRED PARAMETER VALUE   = 20

PART R3       = 1000
PARAM. VALUE = 25.2140998

PART R3       = 975.483234
PARAM. VALUE = 25.0664834

PART R3       = 142.405544
PARAM. VALUE = 10.9331799

PART R3       = 300.724402
PARAM. VALUE = 16.8938559

PART R3       = 422.814195
PARAM. VALUE = 19.4565468

PART R3       = 454.336918
PARAM. VALUE = 19.9805549

PART R3       = 455.563974
PARAM. VALUE = 20.0000833

ANOTHER TRY (Y/N)? N

RETURN PART TO ORIGINAL VALUE (Y/N)? Y
=======================================
      << END OF AC.TR AMP >>
```

```
*************************************
**        APPLE/CIRCUIT 1.0       **
**                                **
**          AC.TR AMP             **
**                                **
**        JOHN DOE 2/16/81        **
*************************************
=====================================
        << FILE - AC.TR AMP >>

PART VALUE           TOL%  FROM TO C-PART
-----------------------------------------
VIN   1        V      0      0   1
C1    .1       UF     10     0   1
R1    1000     OHM    5      1   2
RB    100      OHM    20     2   3
RE    26       OHM    10     3   0
R2    100000   OHM    5      4   2
CCB   10       PF     10     4   2
RC    1        MEG    30     4   3
R3    1000     OHM    5      4   0
B     120             30     4   3   RB
=========================================
          << NOMINAL OUTPUT >>

FREQUENCY IN HERTZ = 1000
VOLTAGE GAIN       = 18.2265718
DECIBELS           = 25.21
PHASE SHIFT DEG    = -147.23
=========================================
         << FREQUENCY RESPONSE >>

LOW, HIGH, STEP FREQ.= 20,20000,0

FREQ-HZ OUTPUT-VOLTS DECIBELS PHASE-DEG
---------------------------------------
20      .671648071     -3.46    -91.78
40      1.34136937      2.55    -93.55
80      2.6674888       8.52    -97.07
160     5.21798057     14.35   -103.93
320     9.63357803     19.68   -116.39
640     15.2729085     23.68   -134.8
1280    19.370986      25.74   -153.34
2560    21.0374482     26.46   -166.06
5120    21.5254543     26.66   -173.24
10240   21.6511876     26.71   -177.24
20480   21.6762676     26.72   -179.9
```

PLOT DATA (Y/N)? Y

```
                      DECIBELS
        -30         -10       10          30
FREQ-HZ+----+----+----+----+----+----+----+
20      +    +   A +    D +    +    +    +    +
40      +    +   A +    +D   +    +    +    +
80      +    +   A +    +    D+   +    +    +
160     +    +  +A +    +    +    D+   +    +
320     +    + A  +    +    +    +    D+   +
640     +    +A   +    +    +    +   D+   +
1280    + A  +    +    +    +    +    + D +
2560    +A   +    +    +    +    +    + D +
5120    +A   +    +    +    +    +    + D +
10240   A    +    +    +    +    +    + D +
20480   A    +    +    +    +    +    + D +
        +----+----+----+----+----+----+----+
       -180 -120  -60   0    60  120  180
            PHASE ANGLE (DEG)
```

```
===================================
   << PART EFFECTS & WORST CASE >>

FREQUENCY IN HERTZ = 1000

PART     EFFECT ON        TOLERANCE
NAME     OUTPUT %         EFFECT %
-----------------------------------
VIN      100              0
C1       29.21            2.92
R1       -28.53           -1.43
RB       -1.32            -.263662812
RE       -41.3            -4.13
R2       32.35            1.62
CCB      -.0928452364     -9.28452364E-03
RC       .0279439104      8.38317311E-03
R3       67.95            3.4
B        27.6             8.28

WORST CASE: OUTPUT    DECIBELS PHASE-DEG
-----------------------------------
MINIMUM=14.1518717       23.02    -143.98
NOMINAL=18.2265718       25.21    -147.23
MAXIMUM=22.3661475       26.99    -149.08
TOTAL RANGE = 45.07 %    3.97      5.11
===================================
     << TRIAL RUN & TEST LIMITS >>

FREQUENCY IN HERTZ    = 1000
NUMBER OF TRIALS (10)= 10
NOMINAL = 18.2265718      25.21   DB
AVERAGE = 17.6292922      24.92   DB
STD DEV = .732832778

99 PERCENT FALL WITHIN:
MINIMUM = 15.7385837      23.94   DB
MAXIMUM = 19.5200008      25.81   DB
===================================
         << OPTIMIZE A PART >>

FREQUENCY IN HERTZ          = 1000
PART TO BE OPTIMIZED        = R3
PARAMETER TO BE OPTIMIZED:
(1=VOLTS, 2=DB, 3=DEGREES)= 2
DESIRED PARAMETER VALUE     = 20

PART R3       = 1000
PARAM. VALUE = 25.2140998

PART R3       = 975.483234
PARAM. VALUE = 25.0664834

PART R3       = 142.405544
PARAM. VALUE = 10.9331799

PART R3       = 300.724402
PARAM. VALUE = 16.8938559

PART R3       = 422.814195
PARAM. VALUE = 19.4565468

PART R3       = 454.336918
PARAM. VALUE = 19.9805549

PART R3       = 455.563974
PARAM. VALUE = 20.0000833

ANOTHER TRY (Y/N)? N

RETURN PART TO ORIGINAL VALUE (Y/N)? Y
===================================

        << END OF AC.TR AMP >>
```

```
**************************************
**         APPLE/CIRCUIT 1.0        **
**                                  **
**            DC.TR AMP             **
**                                  **
**         JOHN DOE 2/16/81         **
**************************************
========================================
        << FILE - DC.TR AMP >>
```

PART VALUE / TOL% / FROM TO C-PART

PART	VALUE	TOL%		FROM	TO	C-PART
VCC	5	V	0	0	1	
VBE	.6	V	10	3	2	
RCC	1	OHM	0	0	1	
RB	100	OHM	10	3	2	
RE	26	OHM	10	3	0	
R1	100000	OHM	5	4	2	
R2	1000	OHM	5	1	4	
B	150		30	3	4	RB

```
========================================
       << VOLTAGES AND POWERS >>
```

NODE: VOLTAGE:

NODE	VOLTAGE
1	4.99739632
2	.669420045
3	.0676957516
4	2.39371338

(NEGATIVE POWER = SUPPLYING POWER)

PART: POWER(MW.):

PART	POWER(MW.)
VCC	-13.02
VBE	.01
RCC	<.01
RB	<.01
RE	.18
R1	.03
R2	6.78
B	6.02

```
========================================
     << PART EFFECTS & WORST CASE >>
```

PART NAME	EFFECT ON OUTPUT %	TOLERANCE EFFECT %
VCC	85.15	0
VBE	14.85	1.48
RCC	-.044213939	0
RB	.042894991	4.2894991E-03
RE	1.67	.167491225
R1	42.5	2.13
R2	-44.08	-2.2
B	-42.17	-12.65

WORST CASE: OUTPUT VOLTS

```
MINIMUM     = 1.99435713
NOMINAL     = 2.39371338
MAXIMUM     = 2.90618289
TOTAL RANGE = .911825764   (38.09 %)
========================================
      << TRIAL RUN & TEST LIMITS >>
```

```
NUMBER OF TRIALS (10) = 10
NOMINAL = 2.39371338      VOLTS
AVERAGE = 2.38244119      VOLTS
STD DEV = .191639553      VOLTS

99 PERCENT FALL WITHIN:
MINIMUM = 1.88801114      VOLTS
MAXIMUM = 2.87687123      VOLTS
```

```
==========================================
          << OPTIMIZE A PART >>

PART TO BE OPTIMIZED = R1
DESIRED VOLTAGE      = 2.5

PART R1        = 100000
OUTPUT VOLTAGE = 2.39371338

PART R1        = 110447.134
OUTPUT VOLTAGE = 2.49622016

PART R1        = 110849.813
OUTPUT VOLTAGE = 2.50000998

ANOTHER TRY (Y/N)? N

RETURN PART TO ORIGINAL VALUE (Y/N)? N
==========================================
          << CHANGE OUTPUT NODE >>

CAUTION NODE EXCHANGE CAN CAUSE ERRORS

NEW OUTPUT NODE # = 3

NODE 3 IS NOW NODE 4

NODE 4 IS NOW NODE 3
==========================================
          << FILE - DC.TR AMP >>

PART VALUE           TOL%  FROM TO C-PART
------------------------------------------
VCC  5           V   0      0   1
VBE  .6          V   10     4   2
RCC  1           OHM 0      0   1
RB   100         OHM 10     4   2
RE   26          OHM 10     4   0
R1   110849.813OHM  5      3   2
R2   1000        OHM 5      1   3
B    150             30     4   3    RB
==========================================
        << TRIAL RUN & TEST LIMITS >>

NUMBER OF TRIALS (10) = 10
NOMINAL = .0649348008      VOLTS
AVERAGE = .064156361       VOLTS
STD DEV = 5.82386655E-03 VOLTS

99 PERCENT FALL WITHIN:
MINIMUM = .0491307853      VOLTS
MAXIMUM = .0791819367      VOLTS
==========================================

          << END OF DC.TR AMP >>
```

```
****************************************
**        APPLE/CIRCUIT 1.0          **
**                                   **
**          D-C CIRCUITS             **
**                                   **
**       A. F. PETRIE 2/12/81        **
****************************************
YOUR NAME: JOHN DOE
DATE: 2/16/81


****************************************
**        APPLE/CIRCUIT 1.0          **
**                                   **
**          D-C CIRCUITS             **
**                                   **
**        JOHN DOE 2/16/81           **
****************************************
                        PRINTER IS: OFF
    L - LOAD FILE FROM DISK
    P - PRINTER ON/OFF
    R - REVIEW CURRENT FILE
    V - VOLTAGES AND POWERS
    W - WORST CASE & PART EFFECTS
    T - TRIAL RUN & TEST LIMITS
    O - OPTIMIZE A PART
    D - DIFFERENT OUTPUT NODE
    C - CHANGES TO CURRENT FILE
    M - MAKE A NEW FILE
    S - SAVE FILE ONTO DISK
    Q - QUIT THIS PROGRAM

SELECT BY LETTER: L

  (TO EXIT ROUTINE, PRESS 'RETURN')
      << LOAD FILE FROM DISK >>

INSERT DISK WITH DESIRED NETWORK FILE
THEN TYPE DRIVE NUMBER (1 OR 2): 2


DISK VOLUME 254              345

A 022 H   APPLE/CIRCUIT
A 058 A COPYRIGHT 1981 BY
A 048 DAPPLE &   A F PETRIE

T 002 AC.TR AMP
T 003 AC.FILTER
T 002 DC.TR AMP
T 002 DC.OP AMP
T 006 AC.R61
T 008 DC.R81

NAME OF FILE = DC.TR AMP

========================================
      << FILE - DC.TR AMP >>
```

PART	VALUE		TOL%	FROM	TO	C-PART
VCC	5	V	0	0	1	
VBE	.6	V	10	3	2	
RCC	1	OHM	0	0	1	
RB	100	OHM	10	3	2	
RE	26	OHM	10	3	0	
R1	100000	OHM	5	4	2	
R2	1000	OHM	5	1	4	
B	150		30	3	4	RB

```
    << ASSEMBLING CONNECTIONS >>
```

```
*******************************************
**        APPLE/CIRCUIT 1.0          **
**                                   **
**          DC.TR AMP                **
**                                   **
**        JOHN DOE 2/16/81           **
*******************************************
                         PRINTER IS: OFF
    L - LOAD FILE FROM DISK
    P - PRINTER ON/OFF
    R - REVIEW CURRENT FILE
    V - VOLTAGES AND POWERS
    W - WORST CASE & PART EFFECTS
    T - TRIAL RUN & TEST LIMITS
    O - OPTIMIZE A PART
    D - DIFFERENT OUTPUT NODE
    C - CHANGES TO CURRENT FILE
    M - MAKE A NEW FILE
    S - SAVE FILE ONTO DISK
    Q - QUIT THIS PROGRAM
```

SELECT BY LETTER: P
            PRINTER PROBLEM

TURN PRINTER ON AND 'ON LINE'

IF YOU ARE NOT USING AN APPLE
PRINTER INTERFACE CARD, THE PRINTER
COMMANDS IN THIS PROGRAM MAY NOT WORK
PROPERLY.

IF YOUR PRINTER IS 'ON LINE', AND THIS
MESSAGE IS STILL HERE, THEN YOUR
PRINTER CAN'T BE USED WITH THIS
PROGRAM.

PUSH 'RESET' TO START AGAIN FROM THE
BEGINNING AND DON'T USE THE PRINT
COMMAND IN THIS PROGRAM (SORRY).

```
*******************************************
**        APPLE/CIRCUIT 1.0          **
**                                   **
**          DC.TR AMP                **
**                                   **
**        JOHN DOE 2/16/81           **
*******************************************
===========================================
```

      << END OF DC.TR AMP >>

APPENDIX B - SETTING UP THE APPLE II SYSTEM

This appendix includes a list of the equipment you will need to use the Circuit Analysis Programs on your Apple II. You do not need to read all the manuals but they should be on hand to answer questions that may arise in operating the equipment (eg. how to boot the diskette).

In order to be able to provide Special Delivery Software at a lower cost the master program diskette has been copy protected and write protected. It is suggested that you put this diskette in a safe place in the event that you should need to use it following damage to the backup diskette.

The Circuit Analysis programs are written in Applesoft BASIC. To use them you will need the following equipment.
-an Apple II Plus with 48K bytes of RAM; or

-an Apple II with 48K bytes RAM and an Applesoft firmware card; or

-an Apple II with the Language System.

Plus:

-an Apple Disk II with Controller (16 sector PROMs);

-a video monitor or television.

For reference you should have on hand a copy of the following manuals:

-This Manual;

-Apple II BASIC Programming Manual (Setting up the Apple II);

-DOS Manual (How to boot the diskettes).