Program Library
Users Guide

Information Systems

Time-Sharing Service

DC Linear Network Analysis

GENERAL ELECTRIC
INFORMATION SERVICE DEPARTMENT

Program Library

DC LINEAR NETWORK ANALYSIS

USERS GUIDE

Program Name: DCNET$

January 1968

GENERAL ELECTRIC

INFORMATION SERVICE DEPARTMENT

801201

PREFACE

This users guide explains how direct current linear networks can be analyzed by using the Time-Sharing Service of General Electric's Information Service Department.

Users need not be programmers. However, familiarity with the system is required. Time-Sharing System Manual (229116) provides such information, and the manual should be used in conjunction with this one. For ease of comprehension, this guide includes a sample problem and its solution.

DC Linear Network Analysis is one in an ever-expanding library of time-sharing programs for use by subscribers to the Time-Sharing Service. Each program is designated by its six-character name (DCNET$, in this case) to store and retrieve it on the system. Library programs are classified as follows:

On-Line

On-line library programs can be accessed from any terminal that is connected to the system. The criteria for placing a library program on-line are its general utility and frequency of use. Unless classified as run-only (see below), on-line programs can be listed, modified, copied, or run at the discretion of the user.

To retrieve a program from the on-line library, its six-character name is used, followed by three asterisks. The three-asterisk suffix is not an integral part of the program name; it is only a requirement for retrieving the program.

An index to listings of programs in the on-line library is available by listing the library program CATLOG.

Off-Line

The off-line library consists of programs not in general demand. An index to the listings of off-line programs can be obtained by listing the library program CATOFF. Off-line library programs are available for direct placement in a specific user catalog on request from your General Electric representative.

Run-Only

Run-only is a term applied to programs that cannot be listed or permanently modified by the user. It is possible to have run-only programs in either the on-line or the off-line library. Run-only programs are designated by a dollar sign ($) in the sixth character position of the program name.

The terms under which library programs are made available to subscribers may vary between programs, or they may vary with a given program from time to time. General Electric reserves the right to change these terms at its discretion. Any questions regarding use of library programs should be directed to your General Electric representative.

CONTENTS

1. GENERAL INFORMATION ABOUT DC LINEAR NETWORK ANALYSIS

This FORTRAN program analyzes the direct current response of a linear network given data concerning branch elements, which may consist of:

Resistors

Current controlled dependent current sources

Independent voltage sources

Independent current sources

Four types of circuit analyses can be selected and on-line circuit modifications can be performed. In addition, the circuit node to be analyzed can be specified for each analysis except the general analysis.

The types of analyses available are:

- A general analysis where node voltages, branch voltages, branch currents, and branch power are computed.
- A tolerance analysis in which part partials are determined for each circuit element to indicate the change in voltage at a desired node due to a change in value of the circuit element. The part partials indicate the percentage change in voltage at the selected node for a 1% change in the value of the element under consideration, where a 100% part partial signifies a 1 to 1 correspondence. Also determined for a desired node are the uniform and worst case distributions of the voltage. The uniform distribution is computed for a 1% change in the values of the elements. In determining the worst case distribution, the element values are varied within the specified tolerances so that the greatest variation in output is obtained.
- A Monte Carlo analysis which indicates the distribution of voltages at a given node for a specified number of trials using randomly selected tolerances. The printout for the Monte Carlo analysis includes the following at the node under consideration:

  The nominal value of the voltage, which is the value when no tolerance increment is added to the element values.

  Sigma, the standard deviation of the voltage over n trials.

  5 percent, which indicates the value of the node voltage above and below which 5 percent of the voltage values lie when using random tolerances over n number of trials. For this calculation, a normal distribution is assumed.

  1-percent, which indicates the value of the node voltage above and below which 1 percent of the voltage values lie when using random tolerances over n number of trials. For this calculation, a normal distribution is assumed.

  3-sigma, which indicates three standard deviations above and below the mean value

  Mean value of the voltage

- A part increment, where the capability exists to increment the value of a circuit element over a desired range in order to obtain the node voltage at each incremental step.

The following operations can also be performed on-line:

Modify a circuit element
Analyze a new circuit node

The size of the circuit which can be processed depends on the extent to which the circuit is to be analyzed. When the Monte Carlo analysis or part modification option is not desired, one or both of these routines may be deleted from the program thereby providing more space in the program. This particular feature is described in detail under Operating Instructions.

METHOD

After the branch circuit data has been entered into the program, the program forms the node incident matrix, A, the circuit admittance matrix, Y, and the current and voltage source vectors, E and I respectively.

Node voltage equations are then formed using the matrix formula:

$$(A'YA)\ V = A'(I-YE)$$

where A' = transposed A and
V = desired node voltage vector.

The node voltage equations are solved by Gauss Elimination with row interchange.

This matrix method of solution is used by the following analysis routines:

- General analysis
- Tolerance analysis

  The part partials for each element are computed by first changing the value of the element under consideration by 1% and then computing the resultant change in the value of the node voltage. For resistors, the admittance is equal to 0.99 times the original admittance. The part partial for each element is expressed as:

  $$\text{part partial} = (\Delta\text{voltage/voltage}) \times 10^4$$

  Thus, if the voltage at the node was to change by 1% for a 1% change in the value of the element, the part partial would be equal to 100%, indicating a one to one correspondence.

  The total change in voltage which can be expected, if the element were to have a value as dictated by its maximum tolerance, is expressed as:

  $$\text{total expected change in voltage} = (\Delta \text{ voltage}) \times \text{tolerance}$$

  The change in voltage (Δvoltage) is the same as determined for computing the part partial.

  This total change in voltage represents the halfwidth, h, of the normal distribution of voltage change for the element. The halfwidth for the normal distribution of the voltage change for every element in the circuit can be computed in the manner.

  If the number of distributions computed is in excess of five and the values of the halfwidths, h, are within the ratio of 2:1, the standard deviation of the sum of a number of uniform distributions can be approximated by:

  $$\left[({h_a}^2 + {h_b}^2 + {h_c}^2 + \ldots \text{etc.})/3 \right]^{\frac{1}{2}}$$

  where h_a, h_b, h_c, etc., are the normal distribution halfwidths for circuit elements a, b, c, etc., respectively.

  The program prints the nominal value of the voltage and ± 3 standard deviations from the nominal using the above method of computing the standard deviations for the uniform distribution.

  The worst case distribution is computed by varying the element values within their tolerance limits as specified by the user in order to obtain the maximum shift in output. It is assumed that the sign of each element's part partial does not change. Each element is then given a value as determined by its maximum tolerance in the direction indicated by the sign of the part partial. Thus, in computing the minimum worst case, a 10 ohm resistor with a tolerance of 10% and a negative part partial would be given a value of 11 ohms since the negative part partial indicates that, by increasing the value of the resistor, the voltage at the specified node decreases.

- Monte Carlo analysis

  The tolerances for each circuit component are selected randomly within the limits specified by the user and the distribution of voltages, obtained at a given node for the indicated number of trials, is computed. A normal distribution for the voltages is assumed.

- Part increment

LIMITATIONS

The dependent current source must be current controlled.

The size of the circuit which can be analyzed with all files included in the program is 18 nodes, 25 branches, and 40 components. Larger circuits may be analyzed by deleting files from the program as described in the Operating Instructions.

2. OPERATING INSTRUCTIONS

PREPARATION OF DATA

Before circuit data can be entered into the program, the following steps must be performed:

1. Redraw the circuit schematic into the equivalent circuit form where all transistors, etc., are replaced with a proper model.

2. Number the circuit nodes from one to n where n is the number of nodes in the circuit. Node zero (0) is the reference node.

3. Number the branches from one to b, where b is the number of branches in the circuit. Each branch may include all or part of the generalized branch shown in Figure 1. A branch may also include more than one like parallel element such as several parallel resistors. An independent voltage source must include some kind of passive element in series with it within that total branch.

4. Indicate an arbitrary current flow through the entire branch:

   Currents from independent current sources must flow opposite to the general branch flow.

   Currents from dependent current sources must flow with the general branch flow.

   The "out" and "in" node convention is used to indicate that the current flows "out" of some node, through the general branch, and "in" to some other branch.

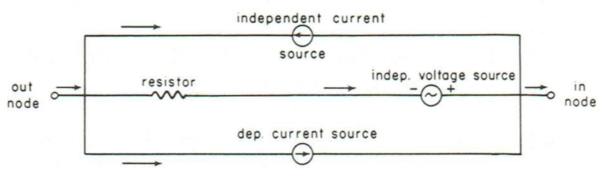

Figure 1

5. In certain subroutines the program will refer to the circuit component number. This is a number which is assigned by the program to each component to indicate the order in which it has been encountered in the data statements, though this does not include independent sources. Thus the first component in the data statement is labeled component #1, the second as component #2, and so on, disregarding independent sources.

PROCEDURE

To enter data into the program, create and save a file named TAPEDC. This is done by creating the file in the following manner. Supply all underlined information.

SYSTEM--FØRTRAN

NEW ØR ØLD--NEW

NEW PRØBLEM NAME--TAPEDC

READY

Now, enter line data into TAPEDC as indicated below. In entering data, the controlling branch of a dependent current source must be described before the dependent current source.

1000 B,N

B = Total number of branches

N = Total number of nodes (not including reference node)

1010 Branch, out-node, in-node, type, value, tolerance, control branch

.
.
.

through

.
.
.

9999

branch = the branch number of the element being described.

out-node = the node number out of which the branch current flows into the general branch.

in-node = the node number into which the branch current flows from the general branch.

type = a number which indicates the kind of component being described according to the following code:

Element	Code
resistor	0
dependent current source	3
independent voltage source	4
independent current source	5

value = the size or magnitude of the element (ohms, volts, amperes).

tolerance is entered in percent for all non-independent source elements. No tolerance is entered for independent sources.

control branch is used only with the current controlled dependent current source and consists of the branch number that controls that dependent source. The control branch must be described before the dependent source in the data statements.

After the data has been entered into TAPEDC as described above, type SAVE followed by a carriage return. This file may be unsaved when the circuit analysis has been completed so as to minimize storage charges.

Once TAPEDC has been saved, call the main program in the following manner. Supply all underlined information.

ØLD

ØLD PRØBLEM NAME--DCNET$***

READY

Type RUN and after a certain elapsed time, the word CØMMAND ? will appear at the teletypewriter. Here, type a code number followed by a carriage return to indicate the type of operation to be performed. The subroutine available for each code number is described below:

Command	Code	Description
General analysis	1	Node voltage, branch voltage, branch current, and branch power are computed for each node and branch.
Part modification	2	This routine permanently changes the value of a component for the run. The program will ask for the component number, code, and value. Supply these followed by a carriage return. When changing the value of a dependent source and its control branch, the value of the control branch must be changed first.
Tolerance analysis	3	The program will ask for the node to be analyzed. Supply this number followed by a carriage return.

Monte Carlo	4	The program will first ask for the number of the node to be analyzed and then for the number of trials over which the analysis is to be carried out. Enter each number followed by a carriage return. The voltage distribution obtained at the node is then indicated assuming a normal distribution.
Part increment	5	The program will ask for the component number, initial value, step size, and the node to be analyzed. Enter the desired data followed by a carriage return. The node voltage will then be printed out at each step for ten incremental steps of the element's value.
Stop	6	This command terminates the run.

PROGRAM SIZE

DCNET$ has been dimensioned to analyze circuits consisting of up to 18 nodes, 25 branches, and 40 components. However, these dimensions may be increased, as discussed below, to handle larger circuits.

When working with larger circuits, more space can be provided for data if exact dimensions for all program lists and matrices are used. Type the following lines into the program to specify exact circuit size:

```
5 DIMENSION G(N,N+1), Y(C), P ", DP ",
     VE(B), IE ", ES ", IS ", VB ", IB ", VN (N) Ⓡ

6 INTEGER IA(B,N), IY(C, 4), IN(4)
```

where N = number of nodes (not including the reference node)
B = number of branches
C = number of components

When the circuit to be analyzed is larger in one or two of the basic dimensions (18 nodes, 25 branches, and 40 components) and if the following relation is satisfied, enter the exact dimensions in Lines 5 and 6 of the program DCNET$ as given above.

$$2N(N+2) + 10C + 12B + (B)(N) + 4 \leq 1874$$

Circuits greater in all three dimensions can be analyzed by eliminating either the part modification or the Monte Carlo analysis, or both, from the program before the run. The relation which applies in each case is shown below. When the relation is satisfied, eliminate the appropriate routine and enter the exact dimensions in Lines 5 and 6 of the program.

With part modification deleted:

$$2N(N+2) + 10C + 12B + (B)(N) + 4 \leq 2160$$

With Monte Carlo analysis deleted:

$$2N(N+2) + 10C + 12B + (B)(N) + 4 \leq 2413$$

With both analyses deleted:

$$2N(N+2) + 10C + 12B + (B)(N) + 4 \leq 2698$$

To eliminate these routines, type the following lines before running the program.

To eliminate the part modification, type

```
169
526 20 GØ TØ 1
```

To eliminate the Monte Carlo analysis, type

```
229
530 40 GØ TØ 1
```

If it is desired to place a file and subroutine back into the program after a run, type ØLD and recall the old program DCNET$***, which contains all the files.

3. SAMPLE PROBLEM

It is desired to analyze the circuit shown in Figure 2 using the DCNET$ program.

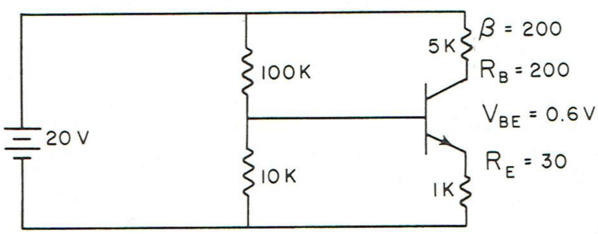

Figure 2

The equivalent circuit of Figure 2 must be drawn and the transistor replaced by its appropriate model. Figure 3 shows the equivalent circuit with nodes and branches numbered and the assumed current directions indicated.

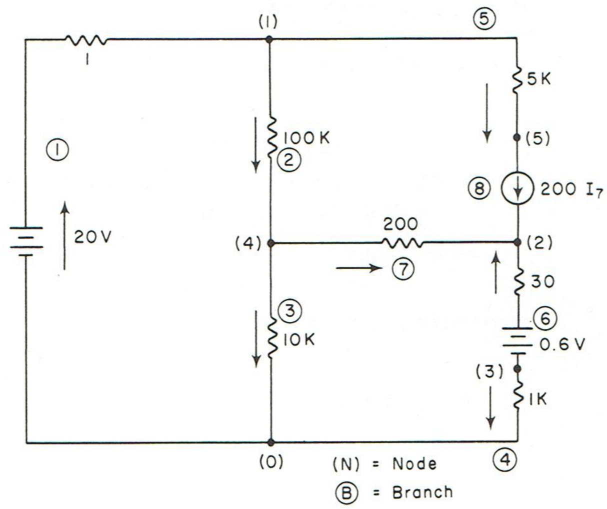

Figure 3

Note that in Figure 3, a 1 ohm resistor has been placed in series with the 20-volt source. This passive element is required by the program to be placed in the branch containing the independent voltage source. The solution is shown as it appears at the teletypewriter. The program is executed by supplying all underlined information.

INPUT FILE FOR SAMPLE PROGRAM

```
SYSTEM--FØRTRAN
NEW ØR ØLD--NEW
NEW PRØBLEM NAME--TAPEDC
READY.

1000 8,5
1010 1,0,1,0,1,10
1020 1,0,1,4,20
1030 2,1,4,0,100E3,10
1040 3,4,0,0,10E3,10
1050 4,3,0,0,1E3,10
1060 5,1,5,0,5E3,10
1070 6,3,2,0,30,10
1080 6,3,2,4,0.6
1090 7,4,2,0,200,10
1100 8,5,2,3,200,10,7

SAVE
WAIT.

READY.
```

In line 1000, the number of branches (8) and number of nodes (5) are entered.

In line 1010, data for the resistor in branch 1 is entered. Note that a 10% tolerance has been placed on this resistor.

In line 1020, data on the independent voltage source is entered. The same branch number is used as for line 1010 since this voltage source must be in series with a passive element in the same branch as required by the program. No tolerance is indicated since this is an independent source.

Each following line contains data on a circuit element. Note that the dependent current source, in line 1100, has been described after its controlling branch which is in line 1090.

OUTPUT FOR SAMPLE PROBLEM

```
ØLD
ØLD PRØBLEM NAME--DCNET$***
WAIT

READY.

RUN
WAIT.


DCNET$

IN DCNT1$
IN .FIRST
IN DCNT2$
IN .FIRST

CØMMAND? 1

GENERAL ANALYSIS

     NØDE    NUMBER   BRANCH    BRANCH      BRANCH
     VØLTS             VØLTS   MILLIAMPS   MILLIWATTS

     20.00     1      -20.00      1.308      -26.17
     1.766     2       18.23      .1823       3.324
     1.132     3       1.767      .1767       .3122
     1.767     4       1.132      1.132       1.281
     14.37     5       5.631      1.126       6.341
               6      -.6340     -1.132       .7175
               7  .1126E-02   .5631E-02   .6341E-05
               8       12.60      1.126       14.19

CØMMAND? 3

TØLERANCE ANALYSIS AT NØDE NØ. =? 2

NØMINAL VØLTAGE =        1.7657VØLTS

PART PARTIALS
-------------
NUMBER CØDE VØLTS-PCT
  1    RES     -.01
  2    RES   -89.90
  3    RES    87.82
  4    RES     2.76
  5    RES      .00
  6    RES      .08
  7    RES     2.76
  8    BTA     2.79

   TYPE          MINIMUM   NØMINAL   MAXIMUM
UNIFØRM DIST      1.381     1.766     2.150
WØRST CASE        1.464     1.766     2.123

CØMMAND? 4
```

Computer Centers and offices of the Information Service Department are located in principal cities throughout the United States.

Check your local telephone directory for the address and telephone number of the office nearest you. Or write . . .

General Electric Company
Information Service Department
7735 Old Georgetown Road
Bethesda, Maryland 20014

GENERAL ELECTRIC

INFORMATION SERVICE DEPARTMENT

801201 (7M) 2-68