Title: Ladder Analysis Program

Author(s): Roger D. Norrod

Date: May 28, 1981

Distribution: M. Balister
S. Weinreb
J. Payne
P. Napier
R. Lacasse
H. Hvatum
C. Burgess
MEMORANDUM

To: Green Bank Electronics Division
From: Roger Norrod
Subj: LADDER Analysis Program

Introduction:

An APPLE computer system is now available at Green Bank for use by the Electronics Division. The purpose of this memo is to acquaint potential users with a program available on disk. The LADDER program was written by Sandy Weinreb and calculates the input impedance of a network. Results can be displayed in table form or plotted on a Smith chart. The program consists of a group of subroutines which perform various functions. The user writes a series of BASIC language statements describing his network and calling the proper subroutines.

To use the program, first insure that a disk marked NRAO LIBRARY 1.0 is in the disk drive. Then type RUN LADDER and return. After a few seconds a "menu" will be displayed (Figure 1). Just follow instructions on the menu to execute the program. Table 1 describes the functioning of the menu subprograms.

To describe his network, the user writes a BASIC language program in lines 100 to 998. Table 2 lists subroutines the user can call from within his program, and Table 3 gives a partial list of variables with special meaning to LADDER. To insert his own program into LADDER, the user should type LOAD LADDER, and then DEL 100,998 to eliminate any old programs. He then types in his own program and SAVE LADDER to store his version on disk.

Example 1:

Figure 2 is a listing of a program used to analyze a three-pole bandpass filter. For those not familiar with Applesoft BASIC, anything following REM (for remark) is ignored by the computer and colons are used to string statements together. Lines 140 through 210 are executed for each frequency defined in line 130. Line 150 initializes RN and XN to the terminating impedance, in this case 75 ohms. Line 160 defines the first filter element, a 2258 pF capacitor in parallel, and calls subroutine 1300. This subroutine converts RN and XN to admittance, combines it with the admittance of the capacitor, converts this total admittance to an impedance, and stores it in RN and XN. Lines 170 through 200 add elements until RN and XN have the input impedance of the total network. Line 210 calculates the resulting reflection coefficient, prints it on the screen and plots it on a Smith chart overlay. Line 220 loops the program back for the next frequency. When all frequency points have been completed, line 999 sends the computer back to wait for the
user to select another menu item. Figure 3 shows the printout caused by selecting menu items (T) and (P) after running the above program. The program takes about three seconds per frequency.

Example 2:

A program written to analyze a coaxial bandpass filter with design cutoff frequency of 10 GHz is listed in Figure 4. Subroutine 1400 is used to rotate impedances through transmission lines. Figure 5 shows the printout for this program. About five seconds were required for each frequency.

Program Listing:

A complete listing of LADDER is included with this memo. Table 4 lists some subroutines used by LADDER internally. These would normally not be called by the user program but are available if needed.

Housekeeping:

Manuals describing the use of the APPLE system are normally kept on the rack housing the computer. A three-ring binder labeled ADIOS #4 has much useful information. I will be glad to assist anyone interested in getting started.

Anyone using LADDER much would probably be wise to have their own disk so that other users don't erase their program. We have several blank disks and copying the NRAO LIBRARY 1.0 disk takes only a few minutes.

Future Expansions:

I hope to add a subroutine in the near future that will calculate the fringing capacitance of a stepped coaxial line. Anyone else who has a suggestion for a useful subroutine, let me know so that it can be made available to all users.

RDN/cjd

Enclosures:
1. Table 1 - LADDER Subprograms Accessed thru Menu
2. Table 2 - LADDER User Subroutines
3. Table 3 - LADDER Variables
4. Table 4 - LADDER Subroutines used by LADDER
5. Figure 1 - Menu Displayed by LADDER
6. Figure 2 - Analysis of Lumped Element Bandpass Filter
7. Figure 3 - Printout for Lumped Element Bandpass Filter
8. Figure 4 - Analysis of Coaxial Lowpass Filter
9. Figure 5 - Printout for Coaxial Lowpass Filter
10. Program Listing
### TABLE 1
LADDER SUBPROGRAMS ACCESSED THRU MENU

<table>
<thead>
<tr>
<th>Menu Item</th>
<th>Line No.</th>
<th>Function</th>
<th>Returns to</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>74</td>
<td>Clears screen.</td>
<td>End</td>
</tr>
<tr>
<td>L</td>
<td>4200</td>
<td>Prints list of lines 100-999.</td>
<td>Menu</td>
</tr>
<tr>
<td>R</td>
<td>84</td>
<td>Executes user program.</td>
<td>Menu</td>
</tr>
<tr>
<td>S</td>
<td>5014</td>
<td>Loads fresh Smith chart.</td>
<td>Menu</td>
</tr>
<tr>
<td>T</td>
<td>9300</td>
<td>Displays table of calculated data with hard copy option.</td>
<td>Menu</td>
</tr>
<tr>
<td>U</td>
<td>5000</td>
<td>Loads utilities (Smith chart and HGR shapes).</td>
<td>Menu</td>
</tr>
<tr>
<td>P</td>
<td>6500</td>
<td>Prints copy of graphics table.</td>
<td>Menu</td>
</tr>
</tbody>
</table>

### TABLE 2
LADDER USER SUBROUTINES

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Function</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1010</td>
<td>Impedance to Admittance</td>
<td>RE, X</td>
<td>G, B</td>
</tr>
<tr>
<td>1110</td>
<td>Admittance to Impedance</td>
<td>G, B</td>
<td>RE, X</td>
</tr>
<tr>
<td>1200</td>
<td>Series Branch, Series R, L, C</td>
<td>R, L, C, W, RN, XN</td>
<td>RN, XN (new)</td>
</tr>
<tr>
<td>1300</td>
<td>Shunt Branch, Series R, L, C</td>
<td>R, L, C, W, RN, XN</td>
<td>Rn, XN (new)</td>
</tr>
<tr>
<td>1400</td>
<td>Series Xmission Line</td>
<td>W, LN, ZØ, RN, XN</td>
<td>RN, XN (new)</td>
</tr>
<tr>
<td>1500</td>
<td>ZN to $\Gamma = SR + j SI$</td>
<td>RN, XN, RØ</td>
<td>SR, SI</td>
</tr>
<tr>
<td>1600</td>
<td>$\Gamma$ to ZN = RN + j XN</td>
<td>SR, SI, RØ</td>
<td>RN, XN</td>
</tr>
<tr>
<td>2000</td>
<td>Complex Multiply: $C = A \times B$</td>
<td>AR, AI, BR, BI</td>
<td>CR, CI</td>
</tr>
<tr>
<td>2100</td>
<td>Complex Reciprocal: $C = 1/B$</td>
<td>BR, BI</td>
<td>CR, CI</td>
</tr>
<tr>
<td>2200</td>
<td>Complex Divide: $C = A/B$</td>
<td>AR, AI, BR, BI</td>
<td>CR, CI</td>
</tr>
<tr>
<td>8000</td>
<td>Smith Chart Plot</td>
<td>SR, SI</td>
<td>---</td>
</tr>
<tr>
<td>9000</td>
<td>Maxes Table on CRT and Stores F, RN, XN, SR, SI, SWR</td>
<td>F, RN, XN</td>
<td>SR, SI</td>
</tr>
</tbody>
</table>
### TABLE 3

**LADDER VARIABLES**

*(Partial List)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>Resistance of Circuit Branch, Ohms</td>
</tr>
<tr>
<td>L</td>
<td>Inductance of Circuit Branch, nH</td>
</tr>
<tr>
<td>C</td>
<td>Capacitance of Circuit Branch, pF</td>
</tr>
<tr>
<td>W</td>
<td>Radian Frequency, $2\pi \times$ GHz</td>
</tr>
<tr>
<td>RE</td>
<td>Real Part of Impedance</td>
</tr>
<tr>
<td>X</td>
<td>Imaginary Part of Impedance</td>
</tr>
<tr>
<td>G</td>
<td>Real Part of Admittance</td>
</tr>
<tr>
<td>B</td>
<td>Imaginary Part of Admittance</td>
</tr>
<tr>
<td>RN</td>
<td>Real Part of Circuit Input Impedance</td>
</tr>
<tr>
<td>XN</td>
<td>Imaginary Part of Circuit Input Impedance</td>
</tr>
<tr>
<td>SR</td>
<td>Real Part of Reflection Coefficient</td>
</tr>
<tr>
<td>SI</td>
<td>Imaginary Part of Reflection Coefficient</td>
</tr>
<tr>
<td>ZØ</td>
<td>Characteristic Impedance of Transmission Line</td>
</tr>
<tr>
<td>LN</td>
<td>Length of Transmission Line, mils</td>
</tr>
<tr>
<td>AR, BR, CR</td>
<td>Real Part of Complex Number A, B, or C</td>
</tr>
<tr>
<td>AI, BI, CI</td>
<td>Imaginary Part of Complex Number A, B, or C</td>
</tr>
<tr>
<td>TP</td>
<td>$2\pi$, defined by LADDER for user</td>
</tr>
</tbody>
</table>

### TABLE 4

**LADDER SUBROUTINES USED BY LADDER**

<table>
<thead>
<tr>
<th>Line No.</th>
<th>Function</th>
<th>Called By</th>
</tr>
</thead>
<tbody>
<tr>
<td>5300</td>
<td>Turns on Printer</td>
<td>9200, 4200</td>
</tr>
<tr>
<td>9100</td>
<td>Stores Data in Arrays</td>
<td>9000</td>
</tr>
<tr>
<td>9200</td>
<td>Prints Table of Calculated Data</td>
<td>9300</td>
</tr>
</tbody>
</table>
LADDER
NETWORK ANALYSIS PROGRAM
NRAO--APRIL 1, 1981
NORMAL UNITS ARE GHZ, MILS, NH, AND PF
UTILITIES SHOULD BE LOADED AT START OF EACH SESSION.
TYPE (H) TO HALT
   (L) TO LIST MAIN PROGRAM
   (R) TO RUN ANALYSIS
   (S) TO LOAD FRESH SMITH CHART
   (T) TO MAKE HARD COPY OF DATA
   (U) TO LOAD UTILITIES FROM DISK
   (P) TO PRINT GRAPHIC TABLE

(H), (L), (R), (S), (T), (U), OR (P)?

FIGURE 1

MENU DISPLAYED BY LADDER
FIGURE 2

ANALYSIS OF LUMPED ELEMENT BANDPASS FILTER
<table>
<thead>
<tr>
<th>F</th>
<th>REAL Z</th>
<th>IMAG Z</th>
<th>GAMA/</th>
<th>ANGLE</th>
<th>VSHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.5</td>
<td>0.6</td>
<td>33.2</td>
<td>0.987</td>
<td>132.3</td>
<td>153.3</td>
</tr>
<tr>
<td>5.6</td>
<td>1.3</td>
<td>39.1</td>
<td>0.974</td>
<td>124.9</td>
<td>76.3</td>
</tr>
<tr>
<td>5.7</td>
<td>3</td>
<td>48.1</td>
<td>0.944</td>
<td>114.6</td>
<td>34.8</td>
</tr>
<tr>
<td>5.8</td>
<td>9</td>
<td>63.2</td>
<td>0.869</td>
<td>99.3</td>
<td>14.28</td>
</tr>
<tr>
<td>5.9</td>
<td>35.1</td>
<td>57.2</td>
<td>0.863</td>
<td>78.2</td>
<td>5.31</td>
</tr>
<tr>
<td>6</td>
<td>103.4</td>
<td>55.4</td>
<td>0.333</td>
<td>45.6</td>
<td>2</td>
</tr>
<tr>
<td>6.1</td>
<td>70.3</td>
<td>-1.2</td>
<td>0.93</td>
<td>-164</td>
<td>1.05</td>
</tr>
<tr>
<td>6.2</td>
<td>45.7</td>
<td>2.8</td>
<td>0.244</td>
<td>173.1</td>
<td>1.65</td>
</tr>
<tr>
<td>6.3</td>
<td>39.4</td>
<td>12.1</td>
<td>0.327</td>
<td>155.2</td>
<td>1.97</td>
</tr>
<tr>
<td>6.4</td>
<td>41.9</td>
<td>19.8</td>
<td>0.325</td>
<td>139.5</td>
<td>1.96</td>
</tr>
<tr>
<td>6.5</td>
<td>51.2</td>
<td>24</td>
<td>0.263</td>
<td>124</td>
<td>1.71</td>
</tr>
<tr>
<td>6.6</td>
<td>65.3</td>
<td>19.7</td>
<td>0.155</td>
<td>108.1</td>
<td>1.37</td>
</tr>
<tr>
<td>6.7</td>
<td>74.8</td>
<td>3.1</td>
<td>0.021</td>
<td>91.3</td>
<td>1.04</td>
</tr>
<tr>
<td>6.8</td>
<td>69.1</td>
<td>-15.6</td>
<td>0.115</td>
<td>-104.4</td>
<td>1.26</td>
</tr>
<tr>
<td>6.9</td>
<td>55.6</td>
<td>-23.1</td>
<td>0.228</td>
<td>-119.9</td>
<td>1.59</td>
</tr>
<tr>
<td>7</td>
<td>45.2</td>
<td>-21.3</td>
<td>0.3</td>
<td>-134.5</td>
<td>1.86</td>
</tr>
<tr>
<td>7.1</td>
<td>49.4</td>
<td>-15.3</td>
<td>0.325</td>
<td>-148.6</td>
<td>1.96</td>
</tr>
<tr>
<td>7.2</td>
<td>41.8</td>
<td>-7.7</td>
<td>0.281</td>
<td>-163.2</td>
<td>1.82</td>
</tr>
<tr>
<td>7.3</td>
<td>51.9</td>
<td>0</td>
<td>0.182</td>
<td>-179.9</td>
<td>1.44</td>
</tr>
<tr>
<td>7.4</td>
<td>79.1</td>
<td>-1.6</td>
<td>0.028</td>
<td>-20.4</td>
<td>1.06</td>
</tr>
<tr>
<td>7.5</td>
<td>104.3</td>
<td>-53.9</td>
<td>0.328</td>
<td>-44.8</td>
<td>1.97</td>
</tr>
<tr>
<td>7.6</td>
<td>49.3</td>
<td>-91.5</td>
<td>0.616</td>
<td>-69.3</td>
<td>4.2</td>
</tr>
<tr>
<td>7.7</td>
<td>18.5</td>
<td>-73.9</td>
<td>0.802</td>
<td>-89.4</td>
<td>9.09</td>
</tr>
<tr>
<td>7.8</td>
<td>6.5</td>
<td>-58.3</td>
<td>0.898</td>
<td>-104</td>
<td>18.55</td>
</tr>
<tr>
<td>7.9</td>
<td>3</td>
<td>-43.2</td>
<td>0.945</td>
<td>-114.5</td>
<td>35.09</td>
</tr>
<tr>
<td>8</td>
<td>1.6</td>
<td>-41.4</td>
<td>0.968</td>
<td>-122.2</td>
<td>61.87</td>
</tr>
</tbody>
</table>

6.0-7.5 MHz BPF

**FIGURE 3**

PRINTOUT FOR LUMPED ELEMENT BANDPASS FILTER
100 REM SEVEN SECTION, CHEBYSCHEV, COAXIAL LPF. 0.1 DB RIPPLE.
110 R0 = 50: REM DEFINE CENTER OF SMITH CHART
120 FOR F = 1.0 TO 15.0 STEP 1
130 W = TP * F: RN = 50.0: XN = 0.0: REM TERMINATION = 50 OHMS
140 R = 0: L = 0: C = .02: GOSUB 1300: REM FRINGE CAP
150 Z0 = 15: LN = 27: GOSUB 1400: REM 1ST SECTION
160 R = 0: L = 0: C = .04: GOSUB 1300: REM FRINGE CAP
170 Z0 = 85: LN = 170: GOSUB 1400: REM 2ND SECTION
180 R = 0: L = 0: C = .04: GOSUB 1300: REM FRINGE CAP
190 Z0 = 15: LN = 49: GOSUB 1400: REM 3RD SECTION
200 R = 0: L = 0: C = .04: GOSUB 1300: REM FRINGE CAP
210 Z0 = 85: LN = 194: GOSUB 1400: REM 4TH SECTION
220 R = 0: L = 0: C = .04: GOSUB 1300: REM FRINGE CAP
230 Z0 = 15: LN = 49: GOSUB 1400: REM 5TH SECTION
240 R = 0: L = 0: C = .04: GOSUB 1300: REM FRINGE CAP
250 Z0 = 85: LN = 170: GOSUB 1400: REM 6TH SECTION
260 R = 0: L = 0: C = .04: GOSUB 1300: REM FRINGE CAP
270 Z0 = 15: LN = 27: GOSUB 1400: REM 7TH SECTION
280 R = 0: L = 0: C = .02: GOSUB 1300: REM FRINGE CAP
290 GOSUB 9000: GOSUB 8000: REM PLOT POINT ON SMITH CHART
300 NEXT F
399 GOTO 72: REM END ANALYSIS, GO TO PROMPT

FIGURE 4

ANALYSIS OF COAXIAL LOWPASS FILTER
<table>
<thead>
<tr>
<th>F</th>
<th>REAL Z</th>
<th>IMAG Z</th>
<th>GAMMA</th>
<th>ANGLE</th>
<th>USHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>49.7</td>
<td>-5 E-03</td>
<td>-113.6</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>50.2</td>
<td>2 E-03</td>
<td>30.8</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>53.2</td>
<td>1</td>
<td>.031</td>
<td>.9</td>
<td>1.06</td>
</tr>
<tr>
<td>4</td>
<td>56.7</td>
<td>-4.1</td>
<td>.074</td>
<td>-28.2</td>
<td>1.16</td>
</tr>
<tr>
<td>5</td>
<td>54.9</td>
<td>-10.6</td>
<td>.111</td>
<td>-59.6</td>
<td>1.25</td>
</tr>
<tr>
<td>6</td>
<td>48.6</td>
<td>-11.5</td>
<td>.117</td>
<td>-90.3</td>
<td>1.26</td>
</tr>
<tr>
<td>7</td>
<td>46.1</td>
<td>-5.6</td>
<td>.071</td>
<td>-121.8</td>
<td>1.15</td>
</tr>
<tr>
<td>8</td>
<td>52.6</td>
<td>1.3</td>
<td>.028</td>
<td>25.2</td>
<td>1.06</td>
</tr>
<tr>
<td>9</td>
<td>66.4</td>
<td>-3.1</td>
<td>.143</td>
<td>-9.2</td>
<td>1.33</td>
</tr>
<tr>
<td>10</td>
<td>63.1</td>
<td>-17.9</td>
<td>.194</td>
<td>-44.9</td>
<td>1.48</td>
</tr>
<tr>
<td>11</td>
<td>50.1</td>
<td>-5.8</td>
<td>.056</td>
<td>-85.3</td>
<td>1.12</td>
</tr>
<tr>
<td>12</td>
<td>75</td>
<td>43.2</td>
<td>.411</td>
<td>41.6</td>
<td>2.4</td>
</tr>
<tr>
<td>13</td>
<td>269.7</td>
<td>-275.6</td>
<td>.835</td>
<td>-10.7</td>
<td>11.12</td>
</tr>
<tr>
<td>14</td>
<td>8</td>
<td>-126.4</td>
<td>.958</td>
<td>-43</td>
<td>46.35</td>
</tr>
<tr>
<td>15</td>
<td>1.2</td>
<td>-81.7</td>
<td>.387</td>
<td>-62.9</td>
<td>147.59</td>
</tr>
</tbody>
</table>

50 OHM LPF

FIGURE 5

PRINTOUT FOR COAXIAL LOWPASS FILTER
REM RLAMER VERSION 21MAY81

12 REM MOVE PROGRAM TO HIGH MEMORY
14 PRINT CHR$ (4);"BRUN LOMEM:"; & LOMEM: 16384
16 H1MEM: 36864
18 POKE 1013,76: POKE 1014,12: POKE 1015,151
20 POKE 1016,76: POKE 1017,0: POKE 1018,151
25 PRINT CHR$ (4);"BRUN LOMEM:"; & LOMEM: 16384
30 TEXT : HOME :U = 2
32 VTAB U: HTAB 16: PRINT "LADDER"
33 VTAB U + 3: HTAB 8: PRINT "NETWORK ANALYSIS PROGRAM "
34 VTAB U + 5: HTAB 10: PRINT "NRAO—APRIL 1, 1981"
35 VTAB U + 10: PRINT "NORMAL UNITS ARE GHZ,MILS,NH, AND PF": PRINT
"UTILITIES SHOULD BE LOADED AT START OF EACH SESSION.": VTAB U +
15: REM

38 REM INITIALIZE CONSTANTS
40 DS = CHRS (4): REM OS=CTRL 0415 = 1E06: DIM FS<50),RS(50),XS(50),MS(50),AS(50),VS(50)
48 HCOLOR= 3: srALE
50 TP = 6.22318:K1 = 11811:K2 = 57.2958: REM
58 REM DEFINE ROUNDING FHNCTInNS
130 IDEF FN....R1(X) = INT (X * 1A + .5) / 10
61 DEF Al P2' >' = INT (X .* 100 + .5) 1011.1.
62 OEF FN. P.3(X) = INT (X * 1000 + .5) 1017101 REM

68 REM DISPLAY MENU FOR USER
69 PRINT "TYPE (H) TO HALT": HTAB 6: PRINT "(L) TO LIST MAIN PROGRAM":
HTAB 6: PRINT "(R) TO RUN ANALYSIS": HTAB 6: PRINT "(S) TO LOAD FRESH
SMITH CHART"
70 HTAB 6: PRINT "(T) TO MAKE HARD COPY OF DATA ",
71 HTAB 6: PRINT "(U) TO LOAD UTILITIES FROM DISK": HTAB 6: PRINT
"(P) TO PRINT GRAPHIC TABLE"
72 PRINT "(H),(L),(R),(S),(T),(U),OR (P)?": GET P$: PRINT CHR$ (0):
HOME
74 IF P$ = "H" THEN TEXT : HOME : END
75 IF P$ = "L" THEN GOTO 4200
76 IF P$ = "R" THEN GOTO 84
78 IF P$ = "S" THEN GOTO 5014
79 IF P$ = "T" THEN GOTO 9300
80 IF P$ = "U" THEN GOTO 5000
81 IF P$ = "P" THEN GOTO 6500
82 GOTO 68: REM DISPLAY MENU
34 REM BEGIN ANALYSIS
90 12 = 0
95 I = PEEK (8125) + 1
96 POKE 8125,I: REM CHANGE PLOT SHAPE
11
REM BEGIN DEFINITION OF PROBLEM
100 REM SEVEN SECTION, CHEBYSCHEV, COAXIAL LPF, 0.1 DB RIPPLE.
110 R0 = 50: REM DEFINE CENTER OF SMITH CHART
120 FOR F = 1.0 TO 15.0 STEP 1
130 H = TP * F:RN = 50.0:RN = 0.0: REM TERMINATION = 50 OHMS
150 20 = 15:LN = 27: GOSUB 1400: REM 1ST SECTION
170 20 = 85:LN = 170: GOSUB 1400: REM 2ND SECTION
190 20 = 49: LN = 49: GOSUB 1400: REM 3RD SECTION
210 20 = 85:LN = 194: GOSUB 1400: REM 4TH SECTION
230 20 = 49: LN = 49: GOSUB 1400: REM 5TH SECTION
250 20 = 85:LN = 170: GOSUB 1400: REM 6TH SECTION
270 20 = 27: LN = 27: GOSUB 3000: REM PLOT POINT ON SMITH CHART
300 NEXT F
999 GOTO 72: REM END ANALYSIS, GO TO PROMPT
1000 REM CONVERT IMPEDANCE TO ADMITTANCE
1001 X = L * H: RE = R
1005 IF C < 0 THEN X = X - 1000 / (C * H)
1010 D = RE + 2 + X / 2: G = RE / D: D = - X / D: REM INVERT Z=RE+JX
1020 RETURN: REM
1100 REM CONVERT ADMITTANCE TO IMPEDANCE
1101 G = 1 / R: B = C * H / 1000
1105 IF L < 0 THEN B = B - 1 / (L * H)
1120 RETURN: REM
1200 REM SERIES ELEMENT: SERIES R, L, C
1201 X = L * H
1205 IF C < 0 THEN X = X - 1000 / (C * H)
1210 RN = R + RN: XN = X + XN
1220 RETURN: REM
1300 REM SHUNT ELEMENT, SERIES R, L, C
1304 RE = R: X = L * H
1305 IF C < 0 THEN X = X - 1000 / (C * H)
1310 RN = SHUNT ELEMENT, RE+JX
1315 GOSUB 1100: G = G: B1 = B
1320 RE = RN: X = XN: GOSUB 1010
1330 G = G1 + G: B = B1 + B
1340 GOSUB 1110: RN = RE: XN = X
1350 RETURN: REM
1400 REM SERIES TRANSMISSION LINE WITH CHARACTERISTIC IMPEDANCE Z0
1410 TN = TAN (H * LN / K1)
1420 AR = RN: AI = XN + 20 * TN
1430 BR = 1 - XN + TN / 20: BI = RN * TN / Z0
1440 GOSUB 2200: RN = CR: XN = CI: REM CALCULATE RN+JX XN=CR+JCI
1450 RETURN: REM
1500 REM ZN TO GAMMA (REFLECTION COEFFICIENT SR+J SI); ASSUMES REAL
12

R0; DEFAULT R0=50 Ω
1505 IF R0 = 0 THEN R0 = 50.0
1510 AR = RN - R0: AI = XN
1520 BR = RN + R0: BI = XN
1530 GOSUB 2200: SR = CR: SI = CI: REM CALCULATE SR+J SI=(ZN-R0)/(ZN+R0)
1540 RETURN: REM

1600 REM GAMMA TO ZN; ASSUMES REAL R0; DEFAULT R0=50 OHMS
1605 IF R0 = 0 THEN R0 = 50.0
1610 AR = R0(1 + SR): AI = R0 * SI
1620 BR = 1 - SR: BI = - SI
1630 GOSUB 2200: RN = CR: XN = CI: REM CALCULATE RN+J XN=R0(1+SR+J SI)/(1-SR-J SI)
1640 RETURN: REM

2000 REM COMPLEX MULTIPLY C=A*B
2010 CR = AR * BR - AI * BI
2020 CI = AR * BI + AI * BR
2030 RETURN: REM

2100 REM COMPLEX RECIPROCAL C=1/B
2110 AR = 1: AI = 0: REM

2200 REM COMPLEX DIVIDE, C=A/B
2210 D = BR * 2 + BI * 2
2220 CR = (AR * BR + AI * BI) / D
2230 CI = (AI * BR - AR * BI) / D
2240 RETURN: REM

4200 REM LIST MAIN PROGRAM
4210 TEXT: HOME: POKE 33,30: GOSUB 5300: REM TURN PRINTER ON
4220 POKE 1913,6: REM LEFT MARGIN
4240 LIST 100,999
4250 PRINT 0$; "PR#0": REM TURN PRINTER OFF
4260 POKE 33,40: HOME
4270 GOTO 68: REM DISPLAY MENU

5000 REM LOADS SHAPES,HGR CHARACTERS, AND SMITH CHART
5001 D$ = CHR$(4)
5003 PRINT D$; "LOAD SHAPES"
5004 POKE 232,191: POKE 233,31
5010 PRINT D$: "LOAD HGR CHR GEN"
5014 REM LOAD SMITH CHART INTO GRAPHICS
5015 HGR
5020 PRINT D$: "LOAD NUMB SMITH.A8192"
5025 POKE 8125,0: REM PLOT SHAPE PARAMETER IS IN 8125
5030 TEXT: HOME
5040 SCALE = 1: ROT = 0: HCOLOR = 3
5050 GOTO 68: REM DISPLAY MENU

5300 REM TURNS ON TRENOCOM PRINTER
5305 D$ = CHR$(4): REM D$=CTRL D
5307 PRINT CHR$(0)
5310 PRINT D$; "PR# 1": PRINT CHR$(0)
13

5320 POKE 1913,0: Pw=E 1785,70: REM MARGINS
5330 POKE 1657,80: REM LINE LENGTH
5340 RETURN : REM

6500 REM DUMPS GRAPHICS TABLE TO THE PRINTER, NO ROTATION, NORMAL SIZE.
6510 POKE - 16301,0: POKE - 16300,0: POKE - 16237,0: POKE - 16304,0:
REM DISPLAY GRAPHICS TABLE
6520 UTAB 23: INPUT "LABEL?";LA$
6540 PRINT D$;"PR#1": PRINT TAB (8); LA$: PRINT D$;"PR#0": REM
PRINT LABEL
6550 POKE 1784,15: POKE 1912,170: POKE 1272,0: POKE 1144,32: POKE 1528,0: REM SET PRINTER GRAPHICS TEMPORARIES
6560 CALL - 16000: REM CALL PRINTER SERVICE ROUTINE
6580 HCOLOR=
8000 REM SMITH PLOT
8002 ON I 60SUB 8006,8007,8008,8009
8003 GOTO 8010
8006 SH = 2: ROT= 0: SCALE= 1: RETURN
8007 SH = 2: ROT= 8: SCALE= 2: RETURN
8008 SH = 2: ROT= 0: SCALE= 2: RETURN
8009 SH = 2: ROT= 0: SCALE= 3: RETURN
8010 POKE - 16304,0: POKE - 16301,0
8011 HCOLOR=
8020 HCOLOR= 3
8030 XP = XC + SR * RM
8040 YP = YC - SI * RM
8050 DRAW SH AT XP,VP
8060 RETURN : REM

8500 REM
8501 RETURN : REM
8510 CALL 25674: REM INIT HGR CHR 6EN
8520 PRINT CHR$ (1); CHR$ (17)
8530 HCOLOR= 3
8535 DRAW SH AT 1,7 * I
8540 INPUT "COMMENT? ";CM$
8550 CALL 1013: RETURN : REM
8560 CALL 1013: RETURN : REM

9000 REM PRINT ON CRT
9005 FZ = FN R2(F)
9010 RZ = FN R1(RN)
9020 XZ = FN R1(XN)
9022 60SUB 1500
9024 SM = SOR (SR ^ 2 + SI ^ 2)
9026 SA = K2 * ATN (SI / SR)
9027 IF SR < 0 THEN SA = SA + 180
9028 IF SA > 180 THEN SA = SA - 360
9035 IF SM = 1 THEN SHR = IN
9040 IF SM < 1 THEN SHR = (1 + SM) / (1 - SM)
9045 SM = FN R3(XM);SA = FN R1(SA);SHR = FN R2(SHR): REM ROUND
DATA FOR DISPLAY
9070 PRINT FZ; TAB(8); RZ; TAB(16); XZ; TAB(24); SM; TAB(32); SA
9080 GOSUB 9100; REM STORE DATA IN ARRAYS
9090 RETURN; REM
9100 REM STORES F, ZN, AND GAMMA IN ARRAYS
9110 IZ = IZ + 1
9120 FS(IZ) = FZ; RS(IZ) = RZ; XS(IZ) = XZ
9130 HS(IZ) = SM; AS(IZ) = SA; US(IZ) = SR
9140 RETURN; REM
9200 REM PRINTS TABLE OF CALCULATED DATA
9201 HOME; GOSUB 5300; REM TURN ON PRINTER
9202 I$ = CHR$(9); REM I$=CTRL I
9205 PRINT I$; "N"; REM DISABLE VIDEO
9207 POKE 33,30; REM SET APPLESOFT LINE LENGTH
9220 REM PRINT DATA
9230 PRINT TAB(8); "F"; TAB(16); "REAL Z"; TAB(24); "IMAG Z";
9240 PRINT TAB(32); "/GAMMA/"; TAB(40); "ANGLE"; TAB(48); "USR"
9245 FOR J = 1 TO 56: PRINT "-"; NEXT J
9250 PRINT "";
9255 REM PRINT DATA
9260 FOR J = 1 TO IZ
9270 PRINT TAB(8); FS(J); TAB(16); RS(J); TAB(24); XS(J);
9280 PRINT TAB(32); HS(J); TAB(40); AS(J); TAB(48); US(J)
9285 NEXT J
9280 PRINT "";
9285 REM PRINT DATA
9290 IF J2% = 0 THEN PRINT " ** NO TABLE **": PRINT ""; GOTO 68
9295 J2% = 0; REM INITIALIZE ARRAY COUNTER
9310 TEXT; HOME
9320 REM PRINT HEADING
9330 PRINT "$"; TAB(8); "REAL Z"; TAB(16); "IMAG Z": PRINT "$"
9340 J1% = 0; REM INITIALIZE SCREEN COUNTER
9350 J1% = J1% + 1: J2% = J2% + 1: PRINT FS(J2%); TAB(8); HS(J2%); TAB(16); X6(J2%); REM PRINT LINE
9360 IF J2% = IZ THEN GOTO 9400; REM CHECK FOR END OF ARRAY
9370 IF J1% < 20 THEN GOTO 9350; REM CHECK FOR FULL SCREEN
9380 UTAH 23: PRINT "PRESS ANY KEY FOR REST OF TABLE": GET P$: PRINT CHR$(0)
9390 GOTO 9310; REM PRINT REST OF ARRAY
9400 J2% = 0; REM INITIALIZE ARRAY COUNTER
9405 UTAH 23: PRINT "PRESS ANY KEY FOR REST OF TABLE": GET P$: PRINT CHR$(0)
9410 TEXT; HOME
9420 REM PRINT HEADING
9430 PRINT "$"; TAB(8); "\GAMMA/"; TAB(16); "ANGLE"; TAB(24); "USR": PRINT "$"
9440 J1% = 0; REM INITIALIZE SCREEN COUNTER
9450 J1% = J1% + 1: J2% = J2% + 1
9455 PRINT FS(J2%); TAB(8); HS(J2%); TAB(16); RS(J2%); TAB(24); US(J2%);
9460 REM PRINT LINE
9470 IF J2% = IZ THEN GOTO 9500; REM CHECK FOR END OF ARRAY
9480 IF J1% < 20 THEN GOTO 9450; REM CHECK FOR FULL SCREEN
9490 UTAH 23: PRINT "PRESS ANY KEY FOR REST OF TABLE": GET P$: PRINT CHR$(0)
9490 GOTO 9410; REM PRINT REST OF TABLE
9500 UTAH 23: PRINT "HARD COPY? (Y/N)";
9510 GET P$: PRINT CHR$(0)
9520 IF P$ = "Y" THEN GOSUB 9200; TEXT; HOME; GOTO 68
9530 IF P$ = "N" THEN TEXT; HOME; GOTO 68
Some revisions and additions have recently been made to the LADDER program at Green Bank. The revised program is stored on the NRAO Library 1.1 diskette under the name LADDER1. The changes are:

1. Three items have been added to the menu. These are:

   (M) TO DISPLAY MENU
   (G) TO DISPLAY GRAPHICS TABLE
   (Z) TO SAVE LINES 100-999 ON DISK

   Item (Z) allows the user to save his analysis program and later EXEC it back into LADDER.

2. A soft reentry point has been provided. The user may restart LADDER after halting (with menu item H) by typing ESC 9.

3. Subroutine 1700 has been added. This routine combines the impedance $R_N + jX_N$ with the admittance of a shunt stub having impedance $Z_0$ and length $L_N$.

4. Subroutine 7000 has been added. This routine calculates and stores the reflection coefficient, VSWR, and reflection loss of the impedance $R_N + jX_N$ at frequency $F$. This could be used when studying filter networks and would be called instead of subroutine 9000.

A listing of the revised program follows.

Distribution:

M. Balister  J. Payne  R. Lacasse  TU Mountain File
S. Weinreb  P. Napier  H. Hvatum  TU Downtown File
GB Library  CV Library  VLA Library  C. Burgess
PROGRAM LENGTH = 9589 BYTES   VARIABLES = 35 BYTES
FREE MEMORY = 16835 BYTES
START = 16385 LOMEM = 25934 FREE = 26029 STRING = 36864 HIMEM = 36864

10 REM  ALADDER VERSION 4.JAN82

12 REM  MOVE PROGRAM TO HIGH MEMORY
14 PRINT CHR$(4); "RUN LOMEM:");: LOMEM = 16384
16 HIMEM = 36864
18 POKE 1013,76: POKE 1014,12: POKE 1015,15
20 POKE 1016,76: POKE 1017,9: POKE 1018,15
25 DIM U(50), U(50), U(50), U(50), U(50), U(50): REM

30 TEXT = HOME; U = 2
32 UTAB U: HTAB 16: PRINT "LADDER1"
33 UTAB U + 2: HTAB 8: PRINT "NETWORK ANALYSIS PROGRAM"
34 UTAB U + 4: HTAB 10: PRINT "HRAO--4.JAN82"
35 UTAB U + 6: PRINT "NORMAL UNITS ARE GHZ, HILS, NH, AND PF"; PRINT
   "UTILITIES SHOULD BE LOADED AT START OF EACH SESSION."; UTAB U +
10: REM
38 REM  INITIALIZE CONSTANTS
40 D$ = CHR$(4): REM  D$ = CTRL D
45 IN = 1E68
48 HCOLOR = 3: SCALE = 1: ROT = 0
50 TP = 6.28318 + K1 = 11811: K2 = 57.2958: REM

52 REM  DEFINE ROUNDING FUNCTIONS
54 DEF FN R1(X) = INT (X * 10 + .5) / 10
56 DEF FN R2(X) = INT (X * 100 + .5) / 100
58 DEF FN R3(X) = INT (X * 1000 + .5) / 1000: REM

60 REM  DISPLAY MENU FOR USER
62 PRINT "TYPE (G) TO DISPLAY GRAPHICS"; HTAB 6: PRINT "(H) TO HALT"
   "(USE ESC8 TO RESTART)"; HTAB 6: PRINT "(L) FOR HARDCOPY LINES 100,999"
63 HTAB 6: PRINT "(M) TO DISPLAY MENU"; HTAB 6: PRINT "(R) TO RUN
   PROGRAM 100"; HTAB 6: PRINT "(S) TO LOAD FRESH SMITH CHART"
64 HTAB 6: PRINT "(T) TO DISPLAY TABLE OF DATA"
66 HTAB 6: PRINT "(U) TO LOAD UTILITIES FROM DISK"; HTAB 6: PRINT
   "(P) TO PRINT GRAPHIC TABLE"; HTAB 6: PRINT "(Z) TO SAVE MAIN PROGRAM"
68 PRINT : PRINT "ENTER SELECTION "; GET P$: PRINT CHR$(0): HOME

70 IF P$ = "H" THEN TEXT = HOME: END
71 IF P$ = "H" THEN TEXT = HOME: GOTO 60
72 IF P$ = "L" THEN GOTO 4200
73 IF P$ = "G" THEN GOTO 8500
74 IF P$ = "R" THEN GOTO 90
76 IF P$ = "S" THEN GOTO 5014
78 IF P$ = "T" THEN GOTO 9300
80 IF P$ = "U" THEN GOTO 5000
81 IF P$ = "P" THEN GOTO 6500
82 IF P$ = "Z" THEN GOTO 2500
83 GOTO 60: REM  DISPLAY MENU

90 REM  BEGIN ANALYSIS


REM BEGIN DEFINITION OF PROBLEM

**INSERT USER PROGRAM HERE**

REM END ANALYSIS DISPLAY PROMPT
1000 REM CONVERT IMPEDANCE TO ADMITTANCE
1001 X = L * W; RE = R
1005 IF C > 0 THEN X = X - 1000 / (C * W)
1010 D = RE + X + Z; G = RE / D; B = -X / D; REM INVERT Z=RE+JX TO Y=R+B
1020 RETURN : REM

1100 REM CONVERT ADMITTANCE TO IMPEDANCE
1101 G = 1 / R; B = C * W / 1000
1105 IF L < 0 THEN B = B - 1 / (L * W)
1110 D = G + X + Z; RE = G / D; X = -B / D; REM INVERT Y=G+JB TO Z=RE+JX
1120 RETURN : REM

1200 REM SERIES ELEMENT; SERIES R,L,C
1201 X = L * W
1205 IF C > 0 THEN X = X - 1000 / (C * W)
1210 RN = R + RN; XN = X + XN
1220 RETURN : REM

1300 REM SHUNT ELEMENT,SERIES R,L,C
1304 RE = R; X = L * W
1305 IF C > 0 THEN X = X - 1000 / (C * W)
1310 REM SHUNT ELEMENT, RE+JX
1315 GOSUB 1010; G1 = G; B1 = B
1320 RE = RN; X = XN; GOSUB 1010
1330 G = G1 + G; B = B1 + B
1340 GOSUB 1110; RN = RE; XN = X
1350 RETURN : REM

1400 REM SERIES TRANSMISSION LINE WITH CHARACTERISTIC IMPEDANCE 20
1410 TN = TAN (W * LN / K1)
1420 AR = RN; AT = XN + 20 * TN
1430 BR = 1 - XN * TN / 20; BI = RN * TN / 20
1500 REM ZN TO GAMMA (REFLECTION COEFFICIENT SR+J SI); ASSUMES REAL
   R0: DEFAULT R0=50 OHMS
1505 IF R0 = 0 THEN R0 = 50.0
1510 AR = RN - R0; AI = XN
1520 BR = RN + R0; BI = XN
1530 GOSUB 2200: SR = CR: SI = CI: REM CALCULATE SR+J SI=(ZN-R0)/(ZN+R0)
1540 SM = 30R (SR ^ 2 + SI ^ 2)
1545 SA = K2 * ATN (SI / SR)
1550 IF SR < 0 THEN SA = SA + 180
1555 IF SA > 180 THEN SA = SA - 360
1560 IF SM > = .999 THEN SHR = IN
1565 IF SH < .999 THEN SHR = (1 + SM) / (1 - SM)
1570 RETURN : REM

1600 REM GAMMA TO ZN; ASSUMES REAL R0; DEFAULT R0=50 OHMS
1605 IF R0 = 0 THEN R0 = 50.0
1610 OR = R0 * (1 + SR); AI = R0 * SI
1620 BR = 1 - SR; BI = - SI
1630 GOSUB 2200: RN = CR: XN = CI: REM CALCULATE RN+J XN=R0(1+SR+J
   SI)/(1-SR-J SI)
1640 RETURN : REM

1700 REM SHUNT SHORTED STUB, LENGTH LN, IMPEDANCE Z0
1710 RE = RN * X = XN; GOSUB 1010: REM CALC INPUT ADMITTANCE AND SAVE
1720 GI = G * BI = B
1730 RN = A; XN = 0; GOSUB 1400: REM CALC IMPEDANCE OF STUB
1740 RE = RN * X = XN; GOSUB 1010: REM CALC STUB ADMITTANCE
1750 G = G + GI; B = B + BI: GOSUB 1110: REM COMBINE ADMITTANCES AND
   CONVERT TO IMPEDANCE
1760 RN = RE; XN = X
1770 RETURN : REM
1900 RUN 25: REM REENTRY VIA ESC 9

2000 REM COMPLEX MULTIPLY C=A+B
2010 CR = AR * BR - AI * BI
2020 CI = AR * BI + AI * BR
2030 RETURN : REM

2100 REM COMPLEX RECIPROCAL C=1/B
2110 AR = 1; AI = 0; REM

2200 REM COMPLEX DIVIDE; C=A/B
2210 D = BR ^ 2 + BI ^ 2
2220 CR = (AR * BR + AI * BI) / D
2230 CI = (AI * BR - AR * BI) / D
2240 RETURN : REM

2500 REM CAPTURE LISTING
2505 TEXT : HOME
2514 PRINT ":"
2516 PRINT "THE TEXT FILE CAN BE RECALLED INTO"
2518 PRINT "THE LADDER1 PROGRAM BY:"
2520 PRINT TAB( 5);"FIRST - LOAD LADDER1"
2522 PRINT TAB( 4);"SECOND - EXEC FILENAME"
2524 PRINT TAB( 5);"THIRD - RUN"
2526 PRINT ":"
2530 INPUT "NOW, WHAT NAME WOULD YOU LIKE LINE NUMBERS 100-999SAVED UNDER? ";TF$
2535 PRINT "; PRINT "THANK YOU, PLEASE WAIT"
2540 PRINT D$:"OPEN";TF$
2545 PRINT D$:"DELETE";TF$
2550 PRINT D$:"OPEN";TF$
2555 PRINT D$:"WRITE";TF$
2560 POKE 33,30
2565 LIST 100,999
2570 PRINT D$:"CLOSE";TF$
2575 TEXT : HOME : PRINT "LINES 100-999SAVED UNDER FILENAME ";TF$
2580 UTAB 5: GOTO 60: REM DISPLAY MENU
2580 REM LIST MAIN PROGRAM
2581 UTAB 5: GOTO 60: REM DISPLAY MENU
2590 PRINT 0$;"PR#A": REM TURN PRINTER ON
2595 LIST 100,999
2600 PRINT D$:"PR#0"; REM TURN PRINTER OFF
2605 POKE 33,40: HOME
2610 GOTO 60: REM DISPLAY MENU

5000 REM LOADS SHAPES,HGR CHARACTERS,AND SMITH CHART
5001 D$ = CHR$(4)
5003 PRINT D$:"LOAD SHAPES,A8127": REM LENGTH 24 BYTES
5004 POKE 232,191: POKE 233,31
5010 PRINT D$:"LOAD HGR CH GEN,A2048": REM LENGTH 3328 BYTES
5014 REM LOAD SMITH CHART INTO GRAPHICS
5015 HGR
5020 PRINT D$:"LOAD NUMB SMITH,A8192": REM LENGTH 8192 BYTES
5025 POKE 8125,0: REM PLOT SHAPE PARAMETER IS IN 8125
5030 TEXT : HOME
5040 SCALE= 1: ROT= 0: HCOLOR= 3
5045 GOTO 60: REM DISPLAY MENU
5050 REM TURN ON TRENDCOM PRINTER
5060 D$ = CHR$(4); REM D$=CTRL D
5065 PRINT D$:CHR$(0)
5070 PRINT D$:"PR# 1"; PRINT CHR$(0)
5075 POKE 1913,0: POKE 1785,70: REM MARGINS
5080 POKE 1857,80: REM LINE LENGTH
5085 RETURN : REM

6500 REM DUMPS GRAPHICS TABLE TO THE PRINTER, NO ROTATION, NORMAL SIZE.
6510 POKE -16301,0: POKE -16300,0: POKE -16297,0: POKE -16304,0: REM DISPLAY GRAPHICS TABLE
6520 UTAB 23: INPUT "LABEL?";LA$
6530 PRINT D$:"PR#1": PRINT TAB (8);LA$: PRINT D$:"PR#0": REM PRINT LABEL
6540 PRINT D$:"PR#1": PRINT TAB (8);LA$: PRINT D$:"PR#0": REM PRINT LABEL
6550 POKE 1784,15: POKE 1912,179: POKE 1272,0: POKE 1144,32: POKE 1528,0: POKE 1400,1: POKE 1656,0: REM SET PRINTER GRAPHICS TEMPORARIES
6560 CALL -16000: REM CALL PRINTER SERVICE ROUTINE
6570 TEXT : HOME : GOTO 60: REM DISPLAY MENU
7000 REM PRINTS REFLECTED COEFFICIENT, SWR, AND LOSS ON CRT
7010 60SUB 1500: REM CALCULATE GAMMA AND USWR
7020 LOSS = -4.342945 * LOG (1 - SM * SHM): REM CALCULATE INSERTION
7025 LOSS = FN R2(LOSS); SM = FN R2(SMR); REM ROUND DATA
7030 SH = FN R3(SH); SM = FN R1(SA)
7050 PRINT FZ; TAB(8); LOSS; TAB(16); SM; TAB(24); SH; TAB(32); SA
7060 U3$ = "FREQ"; U2$ = "LOSS"; U3$ = "USWR"; U4$ = "ANGM"; U5$ = "Rdana";
7070 RETURN: REM
7080 60SUB 7100: REM STORE DATA IN ARRAY
7090 RETURN: REM
7100 REM STORES F, LOSS, GAMMA, AND SHR IN ARRAYS
7110 12 = 12 + 1
7115 IF (1Z) = FZ: U2(IZ) = LOSS; U3(IZ) = SM: U5(IZ) = SA
7118 RETURN: REM
8000 REM SMITH PLOT
8002 ON I 60SUB 8006, 8007, 8008, 8009
8003 GOTO 8010
8006 SH = 2: ROT = 0: SCALE = 1: RETURN
8007 SH = 2: ROT = 8: SCALE = 2: RETURN
8008 SH = 2: ROT = 0: SCALE = 2: RETURN
8009 SH = 2: ROT = 0: SCALE = 3: RETURN
8010 POKE -16304, 0: POKE -16305, 0
8011 POKE -16297, 0: POKE -16301, 0
8012 HCOLOR = 3
8020 RM = 79; X = 140; Y = 80
8030 XP = XC + SR * RM
8040 YP = YC - SI * RM
8050 DRAW SH AT XP, YP
8060 RETURN: REM
8500 REM DISPLAYS GRAPHICS TABLE AND
8510 REM THEN RETURNS TO PROMPT.
8520 POKE - 16304, 0: POKE - 16305, 0
8530 POKE - 16297, 0: POKE - 16301, 0
8540 UTA S 22: GOTO 68: REM
9000 REM PRINT ON CRT
9005 FZ = FN R2(F)
9010 RZ = FN R3(RN)
9020 XZ = FN R2(XN)
9022 60SUB 1500
9045 SM = FN R3(SH); SA = FN R1(SA); SMR = FN R2(SMR); REM ROUND DATA FOR DISPLAY
9050 PRINT FZ; TAB(8); RZ; TAB(16); XZ; TAB(24); SH; TAB(32); SA
9075 U3$ = "FREQ"; U2$ = "REAL Z"; U3$ = "IMAG Z"; U4$ = "GAMMA"; U5$ = "ANGLE";
9080 RETURN: REM
9080 60SUB 9100: REM STORE DATA IN ARRAYS
9090 RETURN: REM
9100 REM STORES F, ZN, AND GAMMA IN ARRAYS
9110 I2 = IZ + 1
**REM**

9200 REM PRINTS TABLE OF CALCULATED DATA  
9201 HOME: GOSUB 5300: REM TURN ON PRINTER  
9203 I$ = CHR$(9): REM I$=CTRL I  
9205 PRINT I$;"N": REM DISABLE VIDEO  
9207 POKE 33,30: REM SET APPLESOF LIN LENGTH  
9209 PRINT PRINT HEADING  
9230 PRINT TAB(8);U1$(J); TAB(16);U2$(J); TAB(24);U3$(J);  
9240 PRINT TAB(32);U4$(J); TAB(40);U5$(J); TAB(48);U6$(J)  
9245 FOR J = 1 TO 56: PRINT "-"; : NEXT J  
9250 PRINT " ** NO TABL **": PRINT "": GOTO 68  
9255 REM PRINT DATA  
9260 FOR J = 1 TO IZ  
9275 PRINT TAB(8);U1(J); TAB(16);U2(J); TAB(24);U3(J);  
9280 PRINT TAB(32);U4(J); TAB(40);U5(J); TAB(48);U6(J)  
9285 NEXT J  
9290 PRINT 0$:"PR$0": REM TURN PRINTER OFF  
9292 POKE 33,40: PRINT I$;"I": REM RESTORE VIDEO  
9295 TEXT : HOME : RETURN : REM  

9300 REM DISPLAYS VIDEO TABLE OF CALCULATED DATA  
9302 IF IZ = 0 THEN PRINT " ** NO TABL **": PRINT "": GOTO 68  
9305 JZ% = 0: REM INITIALIZE ARRAY COUNTER  
9310 TEXT : HOME  
9320 REM PRINT HEADING  
9330 PRINT U1$: TAB(8);U2$: TAB(16);U3$: PRINT ""  
9340 J1% = 0: REM INITIALIZE SCREEN COUNTER  
9350 J1% = J1% + 1: J2% = J2% + 1: PRINT U1(J2%); TAB(8);U2(J2%); TAB(16);U3(J2%): REM PRINT LINE  
9360 IF J2% = IZ THEN GOTO 9400: REM CHECK FOR END OF ARRAY  
9370 IF J1% < 20 THEN GOTO 9350: REM CHECK FOR FULL SCREEN  
9380 UTAB 23: PRINT "PRESS ANY KEY FOR REST OF TABLE"; : GET P$: PRINT CHR$(0)  
9390 GOTO 9310: REM PRINT REST OF ARRAY  
9400 JZ% = 0: REM INITIALIZE ARRAY COUNTER  
9405 UTAB 23: PRINT "PRESS ANY KEY FOR REST OF TABLE"; : GET P$: PRINT CHR$(0)  
9410 TEXT : HOME  
9420 REM PRINT HEADING  
9430 PRINT U1$: TAB(8);U4$: TAB(16);U5$: TAB(24);U6$: PRINT ""  
9440 J1% = 0: REM INITIALIZE SCREEN COUNTER  
9450 J1% = J1% + 1: J2% = J2% + 1  
9455 PRINT U1(J2%); TAB(8);U4(J2%); TAB(16);U5(J2%); TAB(24);U6(J2%): REM PRINT LINE  
9460 IF J2% = IZ THEN GOTO 9500: REM CHECK FOR END OF ARRAY  
9470 IF J1% < 20 THEN GOTO 9450: REM CHECK FOR FULL SCREEN  
9480 UTAB 23: PRINT "PRESS ANY KEY FOR REST OF TABLE"; : GET P$: PRINT CHR$(0)  
9490 GOTO 9410: REM PRINT REST OF TABLE  
9500 UTAB 23: PRINT "HARD COPY?(Y/N)";  
9510 GET P$: PRINT CHR$(0)  
9520 IF P$ = "Y" THEN GOSUB 9200: TEXT : HOME : GOTO 68  
9530 IF P$ = "N" THEN TEXT : HOME : GOTO 68  
9540 GOTO 9500: REM