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OPERATORS MANUAL FOR A COMPUTER-
CONTROLLED IMPEDANCE MEASUREMENT SYSTEM

by

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SUMMARY

Operating instructions of a computer controlled impedance measurement system based on Hewlett Packard instrumentation are given. Hardware details, program listings, flowcharts and a practical application are included.
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1. INTRODUCTION

In many areas of electronic design and in the evaluation of the performance of electronic equipment, the impedance of a component or network, at a single frequency, or over a range of frequencies is required to be known.

When this entails a large number of measurements, or the testing of many components, the data acquisition becomes tedious, time consuming and prone to error. An automated impedance measuring and recording system becomes an asset.

The need for the development of such a system at ARL arose when impedance measurements and analysis of six commercial ultrasonic transducers over a frequency range of 0.1MHz to 13MHz were required.

This paper describes the hardware, software and operating procedures of an impedance measurement system that was subsequently developed.

2. INSTRUMENTATION

A block diagram of the impedance measurement system is shown in Figure 1. It consists of the following:

i. A Hewlett Packard HP86 computer, fitted with a Hewlett Packard interface bus (HPIB) adaptor,
ii. A Hewlett Packard HP82013A monitor,
iii. Two Hewlett Packard HP9130A flexible disc drives,
iv. A Hewlett Packard 82905B printer,
v. A Hewlett Packard 7470A plotter, and
vi. A Hewlett Packard 4192A low frequency (LF) impedance analyser.

2.1 Computer

The HP86 communicates with the impedance analyser via the HPIB. This enables remote control of all setup parameters, and acquisition of measured data. After processing, the data can be displayed graphically on the monitor or the plotter. The measured data can be stored and retrieved from flexible disc.

2.2 Analyser

The HP4192A LF impedance analyser is a fully automatic, high performance instrument which can be used manually, or, as in this application, coupled to a computer via a HPIB interface. The HPIB interface provides complete remote control of all front panel functions of the analyser, and all measurements
are taken under software control. Once all the parameters are set up via the
computer keyboard, no further interaction is required.

The impedance analyser measures parameters in pairs, and in the work re-
ported here, the parameters are software selected. A detailed description of the
parameters is given in Section 4.1. A summary of the capabilities of the analyser
and brief specifications are listed in Table 1.

2.3 Test fixtures

Three types of test fixtures are provided with the analyser. The
different test fixtures described below, facilitate the connection of a range of com-
ponents.

The HP16047A is a direct coupled fixture for measurement of axial or radial
lead components. Three interchangeable contact inserts can be plugged into the
fixture. The contacts are for axial lead components, general radial lead components
and radial short lead components. Components connected to this fixture can have
up to plus or minus 35 Volts D.C. bias applied.

The HP16048A fixture has four test leads giving four terminal pairs with
BNC connectors for use with user fabricated test fixtures. The cable is one metre
long and the analyser automatically compensates for transmission line phase shift
effects between the measuring circuitry and the component being measured. Direct
current bias up to plus or minus 200 Volts can be applied to the component under
test.

The HP16095A probe fixture enables measurement of a two port component
or network in a circuit, with both ports floating or one port grounded.

2.4 Hewlett Packard Interface Bus

The hardware components of the impedance measuring system
are connected together by a Hewlett Packard Interface Bus (HPIB) which is com-
patible with the IEEE488 general purpose interface bus standard. The HPIB
enables keyboard control of the printer, plotter, and impedance analyser.

3. SOFTWARE

The software is written in HP Basic as described in reference 1. The main
program has calls to fourteen subroutines to measure, process, store, retrieve,
display or plot data, and to modify plot size and scales. A block flowchart, shown
in Figure 2, details the processes performed by the software. A complete flowchart of the main program and listing is contained in Appendix I.

The data are stored in the same format as the analyser output data. This ensures that no information is lost, and that if the direction or emphasis of an experiment changes, or some unexpected or unusual effect is observed, then relevant information has not been discarded by data reduction. The small price paid for this added flexibility is a slight increase in processing time required when converting the data into a suitable format for plotting.

The software has been written to be flexible and to allow easy modification. The subroutines are virtually self contained and thus can be utilized alone or in other programs for plotting, storing, or retrieving data, especially with the hardware used here. The graphics routines have been written in user units, which enables plots to be scaled by simply changing the size of the numbers in the limit statement and the values of eight setup parameters. When these numbers are changed the size of the plot, and the spacing of the labels is automatically scaled so that plots can be produced to fill a standard A4 size page, or of correct size for ARL publications, or any other size. Table 2 lists the constants to be changed for various common applications, and their locations in the program.

4. OPERATING INSTRUCTIONS

After loading and running the program “IMPSTORE”, the user is guided by program prompts to select the appropriate options. Specific instructions for measuring, plotting, storing and retrieving data are given below.

4.1 Measuring data

In this program mode, the operator must choose amongst the available options for each of the following:

a. Electrical parameters.

The parameters being complex quantities are measured by the analyser in pairs, allowing some option for the secondary parameter. The required parameters can be selected from the list below.
<table>
<thead>
<tr>
<th>PRIMARY PARAMETER</th>
<th>SECONDARY PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impedance (Z)</td>
<td>Phase Degrees (D)</td>
</tr>
<tr>
<td></td>
<td>Phase Radians (R)</td>
</tr>
<tr>
<td>Admittance (Y)</td>
<td>Phase Degrees (D)</td>
</tr>
<tr>
<td></td>
<td>Phase Radians (R)</td>
</tr>
<tr>
<td>Resistance (R)</td>
<td>Reactance (X)</td>
</tr>
<tr>
<td>Conductance (G)</td>
<td>Susceptance (B)</td>
</tr>
<tr>
<td>Capacitance (C)</td>
<td>Quality (Q)</td>
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<td>Dissipation (D)</td>
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<tr>
<td></td>
<td>Resistance (R)</td>
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<td>Conductance (G)</td>
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<tr>
<td>Inductance (L)</td>
<td>Quality (Q)</td>
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<tr>
<td></td>
<td>Dissipation (D)</td>
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<td>Resistance (R)</td>
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<td></td>
<td>Conductance (G)</td>
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<tr>
<td>Gain (B-A)</td>
<td>Delay (G)</td>
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<td></td>
<td>Degrees (D)</td>
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<tr>
<td></td>
<td>Radians (R)</td>
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<tr>
<td>Ref Amp (A)</td>
<td>dBV (V)</td>
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<td></td>
<td>dBm (M)</td>
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<tr>
<td>Ref Amp (B)</td>
<td>dBV (V)</td>
</tr>
<tr>
<td></td>
<td>dBm (M)</td>
</tr>
</tbody>
</table>

b. Resolution of data measurement.
Options are high speed (S), normal (N), and accuracy (A). Further details of the measurement accuracy and speed are given in reference 2.

c. Frequency scale.
Options are linear or logarithmic.
d. Upper and lower frequency.
e. Number of measurement steps for frequency sweep.
For logarithmic scale the upper and lower limits are rounded to the correct decade, and twenty-one measurements are made per decade.

4.2 Displaying data

Measured or stored data can be displayed on the monitor or plotted by entering the following data:-

a. Minimum and maximum values of the primary parameter Y axis. Default values are the minimum and maximum measured values.
b. Ten or six divisions for the secondary parameter Y axis when the secondary parameter is phase and the units are degrees. A six division axis is more convenient for displaying 360 degrees or commonly used parts of 360 degrees.
c. Minimum and maximum values of the secondary parameter Y axis for either ten or six divisions. Default values are the minimum and maximum measured values for ten divisions, and minus 90 degrees to 90 degrees for six divisions.
d. Monitor or hardcopy display.

4.3 Storing

For storing raw measured data on flexible disc enter a title which becomes the name of the datafile created. An optional identifier can also be stored on the data file.

4.4 Retrieving

To read stored data it is only necessary to enter the name of the datafile in which the data are stored. The optional identifier stored with the data is displayed on the monitor.

5. EXAMPLE

The system has been used to measure the impedance of a commercial ultrasonic transducer (Krautkramer K5K). An example of the graphical output of the program is shown in Figure 3. A detailed listing of the setup procedure, the operator responses and scale modification procedure used to obtain this output is given in Appendix II.
REFERENCES

   Hewlett Packard Ltd. USA. 1982

   analyzer. 
   Yokagawa-Hewlett Packard Ltd. Tokyo. 1982
APPENDIX 1-Software flowchart and listing

START

MEASURE?

y

"MEASURE" SUB

n

DISPLAY &/or PLOT?

y

"PROCESS" SUB

n

DG=10

"YSCALEMOD" SUB

YR AXIS PHASE IN DEGREES?

n

"DEGMOD" SUB

y

"YRSCALEMOD" SUB

DISPLAY? ON VDU

n

"VDU" SUB

LINEAR?

n

"LOGPLOT" SUB

y

"LINPLOT" SUB

PAUSE
10 REM **************************** IMPSTORE ****************************
20 PAGESIZE 16
30 PRINTER IS 300
40 CLEAR
50 DIM A$(151)[50]
60 DIM B$(50)
70 DIM AA(151), BB(151), FR(151)
80 OPTION BASE 0
90 REM ******************** IMPEDANCE MEASURE STORE AND PLOT PROGRAM ********************
100 REM disp * do you wish to measure (m) or display stored data? (d)
110 INPUT MD$
120 IF MD$#'m' AND MD$#'d' THEN BEEP 0 GOTO 100
130 REM disp * do you wish to display plot? (y/n)
140 REM ****** MEASURE sets up parameters to be measured and measures ******
150 REM disp * do you wish to display on VDU (v) or get a hard copy (h)? (v/h)
160 INPUT REP5$
170 IF REP5#’Y’ AND REP5#’H’ THEN BEEP 0 GOTO 150
180 IF REP5#’Y’ THEN GOSUB PROCESS ELSE GOTO 500
190 REM ****** PROCESS converts raw analyser data to numbers ******
200 REM ****** Sets right hand Y axis to ten divisions ******
210 REM ****** YSCALEMOD modifies left hand Y scale range ******
220 REM ****** YSCALEMOD modifies right hand Y scale range ******
230 REM disp * do you wish to store data? (y/n)
240 REM ****** PROCESS converts raw analyser data to numbers ******
250 REM disp * do you wish to measure (m) or display stored data? (d)
260 REM disp * do you wish to display plot? (y/n)
270 REM disp * do you wish to display on VDU (v) or get a hard copy (h)? (v/h)
280 REM disp * do you wish to display on VDU (v) or get a hard copy (h)? (v/h)
290 INPUT RES$
300 IF RES$#'Y’ AND RES$#'N’ THEN BEEP 0 GOTO 400
310 IF RES$#'Y’ THEN 440
320 GOSUB VDU
330 REM ****** VDU sets up graphics limits for display on screen ******
340 IF FL$#’L’ THEN GOSUB LIMPLOT
350 REM ****** LIMPLOT plots data when frequency scale is linear ******
360 IF FL$#’L’ THEN GOSUB LOGPLOT
370 REM ****** LOGPLOT plots data when frequency scale is logarithmic ******
380 PAUSE
390 ALPHA
400 REM disp * do you want a hardcopy? (y/n)
410 INPUT RES$
420 IF RES$#'Y’ AND RES$#'N’ THEN BEEP 0 GOTO 400
430 IF RES$#'Y’ THEN 500
440 GOSUB HARDCOPY
450 REM ****** HARDCOPY sets up graphics limits for plotting data ******
460 IF FL$#’L’ THEN GOSUB LIMPLOT
470 REM ****** LIMPLOT plots data when frequency scale is linear ******
480 IF FL$#’L’ THEN GOSUB LOGPLOT
490 REM ****** LOGPLOT plots data when frequency scale is logarithmic ******
500 REM disp * do you wish to store data? (y/n)
510 INPUT REP2$
520 IF REP2#’Y’ AND REP2#’N’ THEN BEEP 0 GOTO 500
530 IF REP2#’Y’ THEN 570
540 IF REP2#’Y’ THEN 500
550 GOSUB PROCESS
560 REM ****** PROCESS converts raw analyser data to numbers ******
570 GOSUB NEWFILE
580 REM ****** NEWFILE creates datafile on disc ******
590 GOSUB WRITEG
600 REM ****** WRITEG writes data to file created by NEWFILE ******
610 GOSUB CLOSE
620 REM ****** CLOSE closes the data file written by WRITEG ******
630 REM disp * do you wish to test another device? (y/n)
640 INPUT REP4$
650 IF REP4#’Y’ AND REP4#’N’ THEN BEEP 0 GOTO 630
660 IF REP4#’Y’ THEN GOSUB AGAIN ELSE 690
670 REM ****** AGAIN is a dummy routine ******
680 GOTO 90
690 REM disp * do you wish to plot any of the stored data? (y/n)
700 INPUT PLO$  
710 IF PLO$='Y' AND PLO$='N' THEN BEEP 0 GOTO 690  
720 IF PLO$='Y' THEN GOSUB READDATA ELSE 1080  
730 REM "" READDATA reads data previously on disk stored ""  
740 GOSUB PROCESS  
750 REM "" PROCESS converts raw analyser data to numbers ""  
760 DG=10  
770 REM "" DG=10 sets right hand Y axis to ten divisions ""  
780 GOSUB YSCALEMOD ! "" LEFT AXIS SCALE MOD ""  
790 REM "" YSCALEMOD modifies left hand Y scale range ""  
800 IF LAB$='PHASE DEG' THEN GOSUB DEGMOD ! ""  
810 REM "" DEGMOD is 6 divisions option for T scale if it is phase in degrees  
820 GOSUB YRSCALEMOD ! ""  
830 REM "" YRSCALEMOD modifies right hand Y scale range ""  
840 DISP "Do you wish to display on VDU (V) or get a hard copy (H)? (V/H)'  
850 INPUT REP6$  
860 IF REP6$='V' AND REP6$='H' THEN BEEP 0 GOTO 840  
870 IF REP6$='H' THEN 1010  
880 GOSUB VDU  
890 REM "" VDU sets up graphics limits for display on screen ""  
900 IF FL$='LIN' THEN GOSUB LINPLOT  
910 REM "" LINPLOT plots data when frequency scale is linear ""  
920 IF FL$='LOG' THEN GOSUB LOGPLOT  
930 REM "" LOGPLOT plots data when frequency scale is logarithmic ""  
940 PAUSE  
950 REM " " Pause to enable operator to view the plot on screen ""  
960 ALPHA  
970 DISP "Do you want a hardcopy? (Y/N)'  
980 INPUT RESI$  
990 IF RESI$='Y' AND RESI$='N' THEN BEEP 0 GOTO 970  
1000 IF RESI$='N' THEN 690  
1010 GOSUB HARDCOPY  
1020 REM " " HARDCOPY sets up graphics limits for plotting data " "  
1030 IF FL$='LIN' THEN GOSUB LINPLOT  
1040 REM " " LINPLOT plots data when frequency scale is linear " "  
1050 IF FL$='LOG' THEN GOSUB LOGPLOT  
1060 REM " " LOGPLOT plots data when frequency scale is logarithmic " "  
1070 GOTO 690  
1080 DISP " END OF PROGRAM to measure or plot press RUN key'  
1090 END  
1100 !  
1110 !  
1120 MEASURE: ! "" MEASURE SUBROUTINE\\n""  
1130 REM DISP analyzer addr=317 , plotter addr=305. What do you wish to plot?  
1140 I=317  
1150 CLEAR I  
1160 REMOVE I  
1170 REM OUTPUT I ;"S1" " " Remove for analyser self test " "  
1180 REM  
1190 DISP "To measure Type"  
1200 DISP "IMPEDANCE Z"  
1210 DISP "ADMITTANCE Y"  
1220 DISP "RESISTANCE R"  
1230 DISP "CONDUCTANCE G"  
1240 DISP "INDUCTANCE L"  
1250 DISP "CAPACITANCE C"  
1260 DISP "GAIN B-A"  
1270 DISP "REF AMP A"  
1280 DISP "INPUT AMP B"  
1290 INPUT ANSI$  
1300 Z: IF ANSI$='Z' THEN OUTPUT I ;"A1C2" @ LAB$="IMPEDEANCE Z" @ GOTO DEGI  
1310 REM " " Sets analyser to measure Z/Y series equivalent circuit " "  
1320 Y: IF ANSI$='Y' THEN OUTPUT I ;"A1C3" @ LAB$="ADMITTANCE Y" @ GOTO DEGI  
1330 REM " " Sets the analyser to measure Z/Y parallel equivalent circuit " "  
1340 GOTO R  
1350 DEGI: DISP "For angles in Type"  
1360 REM " " Sets phase in degrees or radians " "  
1370 DISP DEGREES D"  
1380 DISP RADIANS R"
4O,
RESO
2020 IF ANS1$[1.1]="D" THEN OUTPUT I ;"BI" @ LAB2$="PHASE DEG" @ GOTO RESO
1430 REM ****** Sets the analyser to measure phase in DEGREES ******
1440 IF ANS1$[1.1]="R" THEN OUTPUT I ;"B2" @ LAB2$="PHASE RAD" @ GOTO RESO
1450 REM ****** Sets the analyser to measure phase in RADIANS ******
1460 GOTO DEG1
1470 R: IF ANS1$="R" THEN DISP *(PLUS REACTANCE X)* @ OUTPUT I ;"A2B1C2" $ LA B1$="RESISTANCE R" @ LAB2$="REACTANCE X" @ GOTO RESO
1460 REM ****** Sets the analyser to measure R/G, phase in DEGREES, series equivalent circuit ******
1480 G: IF ANS1$="G" THEN DISP *(+ SUSCEPTANCE B)* @ OUTPUT I ;"A2B3C3" @ LAB1$ ="CONDUCTANCE G" @ LAB2$="SUSCEPTANCE B" @ GOTO RESO
1500 REM ****** Sets the analyser to measure R/G, R/G, parallel equivalent circuit ******
1510 L: IF ANS1$="L" THEN OUTPUT I ;"A3" @ LAB1$="INDUCTANCE L" @ GOTO DEG2
1520 REM ****** Sets the analyser to measure L ******
1530 C: IF ANS1$="C" THEN OUTPUT I ;"A4" @ LAB1$="CAPACITANCE C" @ GOTO DEG2
1540 REM ****** Sets the analyser to measure C ******
1550 GOTO BA
1560 DEG2: DISP * For Type*
1570 REM
1580 DISP *QUALITY Q*
1590 DISP *DISSIPATION D*
1600 DISP *RESISTANCE R*
1610 DISP *CONDUCTANCE G*
1620 DISP 0 INPUT ANS$
1630 ON ERROR GOTO DEG2
1640 REM ****** Trap errors so program does not abort ******
1650 IF ANS1$="Q" THEN OUTPUT I ;"B1C2" @ LAB2$="QUALITY Q" @ GOTO RESO
1660 REM ****** Sets analyser to measure Q, series equivalent circuit ******
1670 IF ANS1$="D" THEN OUTPUT I ;"B2C2" @ LAB2$="DISSIPATION D" @ GOTO RESO
1680 REM ****** Sets analyser to measure D, series equivalent circuit ******
1690 IF ANS1$="R" THEN OUTPUT I ;"B3C2" @ LAB2$="RESISTANCE R" @ GOTO RESO
1700 REM ****** Sets analyser to measure R/G, series equivalent circuit ******
1710 IF ANS1$="G" THEN OUTPUT I ;"B3C3" @ LAB2$="CONDUCTANCE G" @ GOTO RESO
1720 REM ****** Sets analyser to measure R/G, parallel equivalent circuit ******
1730 BEEP 100, 100 @ GOTO DEG2
1740 BA: IF ANS1$="B-A" THEN OUTPUT I ;"A5" @ LAB1$="GAIN dB" ELSE A
1750 REM ****** Sets analyser to measure B-A (dB) ******
1760 REM ****** Select right hand Y axis parameter ******
1770 REM
1780 DISP 0 INPUT ANS$
1790 ON ERROR GOTO BA
1800 REM ****** Trap errors so program does not abort ******
1810 REM
1820 IF ANS1$[1.1]="C" THEN OUTPUT I ;"B1" @ LAB2$="GROUP DELAY S" @ GOTO RESO
1830 REM ****** Sets analyser to measure GROUP DELAY******
1840 IF ANS1$[1.1]="D" THEN OUTPUT I ;"B2" @ LAB2$="PHASE DEG" @ GOTO RESO
1850 REM ****** Sets analyser to measure phase DEGREES ******
1860 IF ANS1$[1.1]="R" THEN OUTPUT I ;"B3" @ LAB2$="PHASE RAD" @ GOTO RESO
1870 REM ****** Sets analyser to measure phase RADIANS ******
1880 GOTO DEG3
1890 REM
1900 GOTO DEG3
1910 A: IF ANS1$="A" THEN OUTPUT I ;"A6" @ LAB1$="REF I/P" @ GOTO DEG4
1920 REM ****** Sets analyser to measure INPUT A dbm/dbV ******
1930 B: IF ANS1$="B" THEN OUTPUT I ;"A7" @ LAB1$="TEST I/P" @ GOTO DEG4
1940 REM ****** Sets analyser to measure INPUT B dbm/dbV ******
1950 BEEP 100, 100 @ GOTO 1190
1960 DEG4: DISP * For Type* ! ****** Gain in dBV or dbM ******
1970 DISP "dBV" @ Y*
1980 DISP "dBm" @ W*
1990 DISP 0 INPUT ANS$
2000 ON ERROR GOTO DEG4
2010 REM ****** Trap errors so program does not abort ******
2020 IF ANS1$[1.1]="M" THEN OUTPUT I ;"N1" @ LAB1$="LAB1# & dBm" @ LAB2$="" @ GOTO RESO
***** Sets analyser to measure GAIN in dBa ******
2040 IF ANS$[1,1] = "V" THEN OUTPUT I ;"%2" ; LAB1$="LAB1" ;* dbv ; LAB2$="" ; GOTO RESO
2050 REM ******* Sets analyser to measure GAIN in dBv ******
GOTO DEG4
2070 RESO : DISP "For resolution Type" 
2080 REM ******* Sets up resolution ******
2090 DISP "HIGH SPEED S" 
2100 DISP "ACCURACY A" 
2110 DISP "NORMAL N" 
2120 INPUT ANSi 
01 ERROR GOTO RESO 
2140 REM ******* Trap errors so program does not abort *******
2150 IF ANS$[1,1] = "S" THEN 2190 
2160 IF ANS$[1,1] = "A" THEN 2210 
2170 IF ANS$[1,1] = "N" THEN 2230 
2180 IF ANS$[1,1] = "" THEN 2230 
2190 OUTPUT I ;"HI" GOTO HORIZ 
2200 REM ****** Sets analyser to HIGH SPEED ON ******
2210 OUTPUT I ;"V1" GOTO HORIZ 
2220 REM ****** Sets analyser to AVERAGE ON ******
HORIZ: DISP "For freq scale type" 
2240 REM ****** Specifies log or lin freq scale ******
2250 DISP "LINEAR L" 
2260 DISP "LOG  LOG" 
2270 INPUT ANS$ 
01 ERROR GOTO HORIZ 
2290 REM ****** Trap errors so program does not abort ******
2300 IF ANS$[3,3] = "N" THEN OUTPUT I ;"GOEN" ; FL$="LIN" ; GOTO LINFREQ 
2310 REM ******* Sets analyser to LOG SWEEP OFF ******
2320 IF ANS$[3,3] = "G" THEN FL$="LOG" ; GOTO LOGFREQ 
2330 GOTO HORIZ 
2340 LINFREQ: DISP "What is the lower frequency in KHz"; 
2350 REM ******Sets up upper and lower freq ******
2360 INPUT TF 
2370 IF TF < .005 THEN DISP "Not less than .005" ; BEEP 100,100 ; GOTO LINFREQ 
2380 OUTPUT I ;"TF" ; TF ;"EN" 
2390 REM ****** Sets analyser START FREQUENCY ******
2400 OUTPUT I ;"FR" ; TF ;"EN" 
2410 REM ****** Sets analyser STOP FREQUENCY ******
2420 DISP "What is the higher frequency in KHz"; 
2430 INPUT PF 
2440 IF PF > 13000 THEN DISP "Not more than 13000" ; BEEP 100,100 ; GOTO LINFREQ 
2450 IF PF < TF THEN DISP "That's NOT higher !!!" ; BEEP 100,100 ; GOTO LINFREQ 
2460 IF PF = TF THEN DISP "SAME frequency !!!" ; BEEP 100,100 ; GOTO LINFREQ 
2470 OUTPUT I ;"PF" ; PF ;"EN" 
2480 REM ****** Sets analyser STOP FREQUENCY ******
2490 POINTS: DISP "How many steps"; 
2500 INPUT ST 
2510 IF ST > 150 THEN DISP "Too many" ; BEEP 100,100 ; GOTO POINTS 
2520 SF = ABS (PF-TF)/ST 
2530 OUTPUT I USING 2550 ; SF 
2540 REM ****** Sets analyser STEP FREQUENCY ******
2550 IMAGE *SF* ; ZZZZ-DDDD ;"EN" ; K 
2560 OUTPUT I ;"T3F1W1W2" ; GOTO SWEEP 
2570 REM ****** Sets analyser TRIGGER HOLD/MANUAL DISPLAY DATA A/B/C , AUTO SWEEP , STEP FREQUENCY UP ******
2580 LOGFREQ: DISP "What is the lower frequency in KHz" 
2590 INPUT START 
2600 IF START < 01 THEN START = .01 ; GOTO LOGFREQ 
2610 DISP "What is the higher frequency in KHz" 
2620 INPUT FINISH 
2630 IF FINISH > 13000 THEN FINISH = 13000 ; GOTO LOGFREQ 
2640 IF PF = TF THEN DISP "SAME frequency !!!" ; BEEP 100,100 ; GOTO LOGFREQ 
2650 IF START = FINISH THEN BEEP 100,100 ; GOTO LOGFREQ 
2660 STAR = INT (LGT (START)) ; *** Rounds to largest decade <or= lower freq *** 
2670 FINI = CEIL (LGT (FINISH)) ; *** Rounds to smallest decade >or= upper freq *** 
2680 DECS = FINI - STAR ; *** Calculates the number of decades in freq range ***
**Calculates the rounded lower freq**

**Calculates the rounded upper freq**

****** Sets analyser START FREQUENCY ******

****** Sets analyser SPOT FREQUENCY ******

****** Sets analyser STOP FREQUENCY ******

****** Sets analyser LOG SWEEP ON ******

****** Sets analyser TRIGGER HOLD/MANUAL , DISPLAY DATA A/B/C , AUTO SWEEP , STEP FREQUENCY UP ******

****** Sweep , trigger analyser , measure data ******

****** Sets analyser EXECUTE ******

****** Conducts a serial poll of the analyser for handshaking ******

****** Error trap off ******

****** Extract data from analyser output ******

****** Display max/min measured values which become plot default values ******

****** Label plot axes ******

****** Label plot axes ******
3380  LABEL  "FREQUENCY  KHz"
3370  REM
3380  FOR  M=0  TO  ARM
3390  PLOT  FR(M),AA(M)
3400  NEXT  M
3410  IF  ANSI$="A"  THEN  GOTO  FINISH
3420  IF  ANSI$="B"  THEN  GOTO  FINISH
3430  SCALE  MINFR,MAXFR,MINBB,MAXBB
3440  REM
3450  PEN  2
3460  TAXIS  MAXFR,(MAXBB-MINBB)/DG,MINBB,MAXBB
3470  LORG  2
3480  FOR  Y-MINBB  TO  MAXBB  STEP  (MAXBB-MINBB)/DG
3490  MOVE  MAXFR-(MAXFR-MINFR)/100,Y
3500  REM
3510  LABEL  Y
3520  NEXT  Y
3530  MOVE  MAXFR,MAXBB+(MAXBB-MINBB)/20
3540  LORG  5
3550  PEN  2
3560  LABEL  LAB2$
3570  SETUU
3580  REM
3590  FOR  M=0  TO  ARM
3600  PLOT  FR(M),BB(M)
3610  NEXT  M
3620  IF  DG=6  THEN  3650
3630  GOTO  3680
3640  REM
3650  MOVE  MINFR,(MAXBB-MINBB)/2
3660  LINE  TYPE  4
3670  DRAW  MAXFR,(MAXBB-MINBB)/2
3680  GOTO  FINISH
3690  FINISH:
3700  RETURN
3710  LOGPLOT:  !  **************LOGPLOT  SUBROUTINE**************
3720  REM  ******** LOGPLOT  plots  data  when  frequency  scale  is  logarithmic ********
3730  LOCATE  PXMINPXMAXPYMINPYMAX
3740  REM  ******** Sets  up  plot  limits ********
3750  SCALE  LGT  (MINFR),LGT (MAXFR),MINAA,MAXAA
3760  REM  ******** Sets  up  plot  axes ********
3770  FXD  1,1
3780  XAXIS  MINAA,(LGT (MAXFR)-LGT (MINFR))/DECS,LGT (MINFR),LGT (MAXFR)
3790  L=MINFR
3800  FOR  X=LGT (MINFR)  TO  LGT (MAXFR)  STEP  (LGT (MAXFR)-LGT (MINFR))/DECS
3810  MOVE  X,MINAA-(MAXAA-MINAA)/35
3820  LORG  6
3830  LABEL  L
3840  FOR  I=2  TO  9
3850  IF  Y>=LGT (MAXFR)  THEN  3920
3860  MOVE  X*,(LGT (MAXFR)-LGT (MINFR))/DECS*LGT (I),MINAA
3870  SETGU
3880  IPLOT  0,1,-1
3890  IMOVE  0,-1
3900  SETUU
3910  NEXT  I
3920  L=L+10
3930  NEXT  X
3940  MOVE  (LGT (MAXFR)+LGT (MINFR))/2,MINAA-(MAXAA-MINAA)/10
3950  LORG  8
3960  REM  ******** Label  plot  axes ********
3970  LABEL  "FREQUENCY  KHz"
3980  XAXIS  LGT (MINFR), (MAXAA-MINAA)/10,MINAA,MAXAA
3990  LORG  8
4000  FOR  Y=MINAA  TO  MAXAA  STEP  (MAXAA-MINAA)/10
4010  MOVE  LGT (MINFR),Y
4020  LABEL  Y
4030  NEXT  Y
4040  MOVE  LGT (MINFR),MAXAA*(MAXAA-MINAA)/20
4050 LORG 4
4060 LABEL LAB1$
4070 PEN 1
4080 REM ****** Plot data ******
4090 FOR M=0 TO ARM
4100 PLOT LGT (FR(M)),AA(M)
4110 NEXT M
4120 IF ANSI$='A' THEN GOTO FINISH
4130 IF ANSI$='B' THEN GOTO FINISH
4140 PEN 2
4150 SCALE LGT (MINFR).LG T (MAXFR).MINBB.MAXBB
4160 REM ****** Sets up plot scale ******
4170 YAXIS LGT (MAXFR),(MAXBB-MINBB)/DG,MINBB[MAXBB
4180 REM ****** Sets up plot axes ******
4190 LORG 2
4200 FOR Y=MINBB TO MAXBB STEP (MAXBB-MINBB)/DG
4210 MOVE LGT (MAXFR)-(LGT (KAXFR)-LGT (MINFR))/100T.
4220 REM ****** Label plot axes ******
4230 LABEL Y
4240 NEXT Y
4250 MOVE LGT (MAXFR).MAXBB*(MAXBB-MINBB)/20
4260 REM ****** Plot data ******
4270 FOR M=0 TO ARM
4280 PLOT LGT (FR(M)),BB(M)
4290 NEXT M
4300 IF DG=6 THEN GOTO 4380
4310 RETURN
4320 YYSCALEMOD: ! ********** YL AXIS SCALE MODIFICATION SUBROUTINE **********
4330 REM ****** YYSCALEMOD enables the left hand Y axis scale to be
4340 REM modified from the default values (measured min and max) ******
4350 DIS P @ DISP "Do you wish to modify the Y axis (";LAB1$;") scale?" (Y/N)*
4360 INPUT ALT1$
4370 IF ALT1$='Y' THEN 4470
4380 IF ALT1$='N' THEN RETURN
4390 GOTO 4410
4400 REM ****** Display the default min/max values of Y (measured max/min) ******
4410 DISP 'THE CURRENT Y SCALE VALUES OF ';LAB1$=' ARE ';MINAA=' MAXAA
4420 REM ****** Modification of Y value of Y scale ******
4430 DISP 'What minimum Y scale value do you want?'
4440 INPUT YMIN
4450 IF YMIN< MINAA THEN 4650
4460 DISP 'THIS IS GREATER THAN THE MEASURED MIN VALUE ARE YOU SURE?' (Y/N)*
4470 INPUT ALT2$
4480 IF ALT2$='Y' THEN 4570
4490 MINAA=YMIN
4500 IF YMAX> MAXAA THEN 4660
4510 DISP 'THE CURRENT Y SCALE VALUES OF ';LAB1$=' ARE ';MINAA=' MAXAA
4520 REM ****** Modification of MAX value of Y scale ******
4530 DISP 'What maximum Y scale value do you want?'
4540 INPUT YMAX
4550 IF YMAX< MAXAA THEN 4680
4560 DIS P 'THIS IS LESS THAN THE MEASURED MAX VALUE ARE YOU SURE? (Y/N)*
4570 INPUT ALT3$
4580 IF ALT3$='Y' THEN 4690
4590 MAXAA=YMAX
4600 GOTO 4470
4610 IF YMAX= MAXAA THEN 4670
4620 REM ****** YYSCALEMOD enables the right hand Y axis scale to be
4630 REM modified from the default values (measured min and max) ******
4640 DIS P
4650 FINISH
4660 TRSCALEMOD: ! ********** YR AXIS SCALE MODIFICATION SUBROUTINE **********
4670 REM ****** TRSCALEMOD enables the right hand Y axis scale to be
4680 REM modified from the default values (measured min and max) ******
4690 DIS P
4720 DISP "Do you wish to modify the Y axis (';LAB2$;') scale? (Y/N)"
4730 INPUT ALT4$
4740 IF ALT4$='Y' THEN 4780
4750 IF ALT4$='N' THEN RETURN
4760 GOTO 4720
4770 REM ***** Display the default min/max values of Y (measured max/min) *****
4780 DISP *THE CURRENT Y SCALE VALUES OF ';LAB2$;' ARE ';MINBB;' ';MAXBB*
4790 REM ***** Modification of MIN value of Y scale *****
4800 DISP *What minimum Y scale value do you want?*
4810 INPUT TRMIN
4820 IF TRMIN<= MINBB THEN 4870
4830 DISP *THIS IS GREATER THAN THE MEASURED MIN VALUE ARE YOU SURE? (T/)*
4840 INPUT ALT5$
4850 IF ALT5$='Y' THEN 4870
4860 GOTO 4780
4870 MINBB=TRMIN
4880 REM ***** Modification of MAX value of Y scale *****
4890 DISP *What maximum Y scale value do you want?*
4900 INPUT TRMAX
4910 IF TRMAX>= MAXBB THEN 4970
4920 DISP *THIS IS LESS THAN THE MEASURED MAX VALUE ARE YOU SURE? (Y/N)*
4930 INPUT ALT6$
4940 IF ALT6$='Y' THEN 4970
4950 GOTO 4880
4960 MAXBB=TRMAX
4970 RETURN
4980 DEGMOD: ! ************ YR AXIS MOD FROM 10 TO 6 DIVISIONS ************
5000 REM ***** DEGMOD enables the right hand axis to be modified from
10 to 6 divisions when the axis is phase angle in degrees *****
5010 DISP
5020 DISP
5030 DISP *Do you wish to modify the Y axis (';LAB2$;') scale to six divisions*
5040 DISP *This enables phase to be displayed from -90 to +90 Degrees*
5050 DISP *in 30 Degree steps (Y/N)*
5060 INPUT ALTD$
5070 IF ALTD$='Y' THEN 5100
5080 IF ALTD$='N' THEN DG=100 0 RETURN
5090 GOTO 5030
5100 DG=6
5110 REM ***** DG=6 sets the right hand axis to six divisions *****
5120 REM ***** Set default values of right hand axis to =/-90 degrees *****
5130 MINBBB=MINBB 0 MINBB=-90
5140 MAXBBI30=MAXBB 0 MAXBBI30=90
5150 REM ***** Display the measured min/max values (MINBBB/MAXBBB) *****
5160 DISP *THE MIN VALUE OF ';LAB2$;' IS ';MINBBB;' THE MAX VALUE OF ';LAB2$;' IS ';MAXBBB'*
5170 REM ***** Display the plot default min/max values (-90/+90 degrees) *****
5180 DISP *THE ';LAB2$;' SCALE RANGE IS ';MINBB;' TO ';MAXBB;' IN 30 DEGREE STEPS*
5190 RETURN
5200 HARDCOPY: PLOTTER IS 305 ! ********** HARDCOPY ************
5210 REM ***** HARDCOPY sets plotter parameters to plot data *****
5220 LIMIT 0.270,5,185
5230 REM ***** Set plot limits , change for different sized plot *****
5240 PEN 1
5250 REM FRAME
5260 REM ***** Set location of axes , change for different sized plot *****
5270 PXMIN=15
5280 PXMAX=135
5290 PYMIN=10
5300 PYMAX=90
5310 CSIZE 3
5320 RETURN
5330 VDU: PLOTTER IS 1 ! ************** VDU **************
5340 REM ***** VDU sets graphics parameters to display data *****
5350 CLEAR
5360 DISP 4 DISP 4 DISP 4 DISP 4 DISP 4 DISP 4 DISP
5370 DISP * After viewing plot press CONT to continue*
5380 REM *** 3.5 Sec pause to enable operator to read message on screen *****
5390 WAIT 3500
5400 GCLEAR
5410 GRAPHL
5420 LIMIT 0.171,0.75
5430 REM ***** Set plot limits , change for different sized plot *****
5440 PEN 1
5450 REM FRAME
5460 REM ***** Set location of axes , change for different sized plot *****
5470 PXMIN=22
5480 PXMAX=205
5490 PYMIN=12
5500 PYMAX=92
5510 CSIZE 5
5520 RETURN
5530 NEWFILE: ! ********** NEWFILE SUBROUTINE **********
5540 REM ********** NEWFILE creates datafile on disc **********
5550 REM * Enter datafile title*
5560 INPUT NAME$
5570 REM ********** Trap errors so program does not abort **********
5580 ON ERROR GOTO 5650
5590 CREATE NAME*,20.256
5610 DISP 'CREATING ';NAMES
5620 ASSIGN# 1 TO NAMES
5630 OFF ERROR
5640 RETURN
5650 OFF ERROR
5660 REM ********** Display details of any errors **********
5670 IF ERRN =63 THEN DISP NAMES;$* exists use a different name* ELSE DISP *ERROR *;ERRW ;*HAS OCCURED ON CREATING FILE at line*;ERRL ;* in program*
5680 GOTO 5560
5690 WRITEG: ! **************** WRITEG SUBROUTINE ****************
5700 REM ********** WRITEG writes data to file created by NEWFILE **********
5710 DISP * Enter datafile identification*
5720 INPUT IDENT$
5730 OFF ERROR
5740 REM ********** Trap errors so program does not abort **********
5750 ON ERROR GOTO 5860
5760 PRINT# 1 ; IDENT$
5770 PRINT# 1 ; LAB1$;LAB2$,MINFR,MAXFR,ARM,ANS1$,FL$,PF,TF
5780 IF FL$='LIN' THEN
5790 FOR I=0 TO ARM
5800 PRINT# 1 ; AS(I)
5810 NEXT I
5820 CLOSE:
5830 DISP *DATA STORED*
5840 OFF ERROR
5850 RETURN
5860 REM ********** Display details of any errors **********
5870 OFF ERROR @ PRINTER IS 1 @ PRINT *ERROR*;ERRW ;*HAS OCCURED*
5880 IF ERRN =66 THEN DISP *FILE CLOSED,OPENING NEWFILE* @ GOSUB NEWFILE
5890 IF ERRN =71 THEN DISP *DATAFILE FULL, OPENING NEWFILE* @ GOSUB NEWFILE
5900 DISP *FILE HAS NOT BEEN WRITTEN*
5910 RETURN
5920 DISP *ERROR NUMBER *;ERRN ;* HAS OCCURED WHEN ENTERING IDENT TRY AGAIN*
5930 GOTO 5790
5940 CLOSE: ! ********** CLOSE ROUTINE **********
5950 REM ********** Trap errors so program does not abort **********
5960 ON ERROR GOTO 6030
5970 ASSIGN# 1 TO *
5980 DISP NAME$;* CLOSED*
5990 RETURN
6000 OFF ERROR
6010 REM ********** Display details of any errors **********
6020 IF ERRN =66 THEN DISP *FILE IS ALREADY CLOSED* @ RETURN
6030 DISP * ;ERRW ;* Has occurred at line*;ERRL ;*file has NOT been closed*
6040 RETURN
6050 READDATA: ! ********** READDATA SUBROUTINE **********
6060 REM ********** READDATA reads data previously stored **********
6070 DISP * Which data file do you wish to access?*
6080 INPUT NAME$

6090 REM ******* Trap errors so program does not abort ******

6100 ON ERROR GOTO 6270

6110 ASSIGN# 1 TO NAME$

6120 READ# 1; IDENT$

6130 READ# 1; LAB1$,LAB2$,MINFR,MAXFR,ARM,ANS1$,FL$,PF,TF

6140 IF FL$=*LIN* THEN GOTO 6170

6150 READ# 1; DECS

6160 REM ******* DECS is the number of decades for a log sweep ******

6170 FOR N=0 TO ARM

6180 READ# I; A$(N)

6190 NEXT N

6200 PRINTER IS 1

6210 REM PRINT IDENT$

6220 REM FOR N=0 TO ARM @ PRINT A$(N) @ NEXT N

6230 PRINTER IS 301

6240 OFF ERROR

6250 OFF ERROR

6260 RETURN

6270 OFF ERROR

6280 REM ******* Display details of any errors ******

6290 IF ERRN=71 THEN ARM=N-1 @ GOTO 6070

6300 IF ERRN=67 THEN DISP *;NAME$;* does not exist, try again* @ GOTO 6070

6310 DISP *; Error *;ERRN:* Occurred at line *;ERRL:* Of program* @ GOTO 6070

6320 AGAIN: ! *************** AGAIN SUBROUTINE ***************

6330 REM *************** AGAIN is a dummy routine ***************

6340 RETURN
APPENDIX II - Listing of program prompts and operator responses for a typical application

*** IMPEDANCE MEASURE STORE AND PLOT PROGRAM ***

Do you wish to measure (M) or display stored data? (D)

To measure Type
IMPEDANCE Z
ADMITTANCE Y
RESISTANCE R
CONDUCTANCE G
INDUCTANCE L
CAPACITANCE C
GAIN B-A
REF AMP A
INPUT AMP B

For angles in Type
DEGREES D
RADIANS R

For resolution Type
HIGH SPEED S
ACCURACY A
NORMAL N

For freq scale Type
LINEAR LIN
LOG

What is the lower frequency in KHz?
1000
What is the higher frequency in KHz?
13000

SWEEPING ..........
SWEEPING COMPLETED TAKEN 24 READINGS

Do you wish to display plot? (Y/N)

CONVERTING DATA TO NUMBERS ..........
FINDING MAX/MINS ..........
MAX IMPEDANCE Z=1211.2 PHASE DEG=85.78 FREQ=100000
MIN IMPEDANCE Z=20.87 PHASE DEG=-86.93 FREQ=1000

Do you wish to modify the Y axis (IMPEDANCE Z) scale? (Y/N)

THE CURRENT Y SCALE VALUES OF IMPEDANCE Z ARE 20.87 1211.2
What minimum Y scale value do you want?
0

THE CURRENT Y SCALE VALUES OF IMPEDANCE Z ARE 0 1211.2
What maximum Y scale value do you want?
1500

Do you wish to modify the Y axis (PHASE DEG) scale to six divisions
This enables phase to be displayed from -90 to +90 Degrees
in 30 Degree steps (Y/N)

THE MIN VALUE OF PHASE DEG IS -86.93 THE MAX VALUE OF PHASE DEG IS 85.78
THE PHASE DEG SCALE RANGE IS -90 TO 90 IN 30 DEGREE STEPS
Do you wish to modify the Y axis (PHASE DEG) scale? (Y/N)

N

Do you wish to display on VDU (V) or get a hard copy (H)? (V/H)

V

After viewing plot press CONT to continue

Do you want a hardcopy? (Y/N)

Y

Do you wish to store data? (Y/N)

Y

Enter datafile title

EXAMPLE1

CREATING EXAMPLE1

Enter datafile identification?

KRAUT K5K S/N 52831

DATA STORED

EXAMPLE1 "CLOSED"

Do you wish to test another device? (Y/N)

N

Do you wish to plot any of the stored data? (Y/N)

N

END OF PROGRAM to measure or plot press RUN key

NEXT EXAMPLE

RETRIEVING DATA

*** IMPEDANCE MEASURE STORE AND PLOT PROGRAM ***

Do you wish to measure (M) or display stored data? (D)

D

Which data file do you wish to access?

EXAMPLE1

CONVERTING DATA TO NUMBERS .......... FINDING MAX/MINS ...........

MAX IMPEDANCE Z= 1211.2 PHASE DEG= 85.78 FREQ=100000
MIN IMPEDANCE Z= 20.87 PHASE DEG= -86.93 FREQ= 1000

Do you wish to modify the Y axis (IMPEDANCE Z) scale? (Y/N)

Y

THE CURRENT Y SCALE VALUES OF IMPEDANCE Z ARE 20.87 1211.2

What minimum Y scale value do you want?

0

THE CURRENT Y SCALE VALUES OF IMPEDANCE Z ARE 0 1211.2

What maximum Y scale value do you want?

1500

Do you wish to modify the Y axis (PHASE DEG) scale to six divisions

This enables phase to be displayed from -90 to +90 Degrees in 30 Degree steps (Y/N)

Y

THE MIN VALUE OF PHASE DEG IS -86.93 THE MAX VALUE OF PHASE DEG IS 85.78

THE PHASE DEG SCALE RANGE IS -90 TO 90 IN 30 DEGREE STEPS

Do you wish to modify the Y axis (PHASE DEG) scale? (Y/N)

N

Do you wish to display on VDU (V) or get a hard copy (H)? (V/H)

V

After viewing plot press CONT to continue

Do you want a hardcopy? (Y/N)
Do you wish to plot any of the stored data?  
(Y/N)

END OF PROGRAM to measure or plot press RUN key
<table>
<thead>
<tr>
<th>Function</th>
<th>Parameter</th>
<th>Range</th>
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<tbody>
<tr>
<td>Test signal</td>
<td>Level</td>
<td>5mV to 1.1V rms</td>
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<tr>
<td></td>
<td>Frequency</td>
<td>5Hz to 13.0MHz</td>
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<tr>
<td>Amplitude and phase measurement</td>
<td>$B - A$</td>
<td>0 to ±100dB</td>
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<tr>
<td></td>
<td>$\theta$</td>
<td>-180 to +180 Degrees</td>
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<tr>
<td></td>
<td>$A, B$</td>
<td>+0.8 to -100dBV</td>
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<tr>
<td></td>
<td>Group Delay</td>
<td>+13.8dBm to -87dBm</td>
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<tr>
<td></td>
<td></td>
<td>0.1nS to 10S</td>
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<tr>
<td>Impedance measurement</td>
<td>$Z, R, X$</td>
<td>0.1mΩ to 1MΩ</td>
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<tr>
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<td>$Y, G, B$</td>
<td>1.0nS to 10S</td>
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<tr>
<td></td>
<td>$L$</td>
<td>0.01nH to 1.0KH</td>
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<td></td>
<td>$C$</td>
<td>0.1fF to 100mF</td>
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<tr>
<td></td>
<td>$D$</td>
<td>0.0001 to 10</td>
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<td></td>
<td>$Q$</td>
<td>0.1 to 1000</td>
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<td>$\theta$</td>
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<td>Accuracy</td>
<td>Amplitude</td>
<td>0.02 to 0.09dB</td>
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<td></td>
<td>Phase</td>
<td>0.1 to 0.2 Degrees</td>
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<td></td>
<td>Impedance</td>
<td>0.1% of reading</td>
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Table I. Brief specifications of analyser.
<table>
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<th>PLOT SIZE</th>
<th>NUMBER OF PLOTS ACROSS PAGE</th>
<th>Y AXES</th>
<th>AXIS LOCATIONS</th>
<th>PLOT LIMITS</th>
<th>POSITION ON PAGE</th>
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<td>PX MIN</td>
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<td>PY MIN</td>
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<td>7</td>
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<td>80</td>
<td>145</td>
<td>10</td>
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</table>

Plot limits are specified by the variables in line 5220 (plot) and 5420 (monitor) with the following format:
5220 LIMIT XMIN,XMAX,YMIN,YMAX
5420 LIMIT XMIN,XMAX,YMIN,YMAX

AXIS LOCATION is specified by values of variables in lines 5270,5280,5290,5300 (plot) and 5470,5480,5490,5500 (monitor)

LABEL SIZE is specified by the value of CSIZE in line 5310 (plot) and 5510 (monitor)

Table 2. Constants for modifying the plot size
FIG. 2 SOFTWARE BLOCK FLOWCHART
FIG. 3 EXAMPLE OF GRAPHICAL OUTPUT
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16. ABSTRACT (CONT.)

17. IMPRINT

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<thead>
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<th>20. TYPE OF REPORT AND PERIOD COVERED</th>
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<td>Structures Technical Memorandum 458</td>
<td>27 1055</td>
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21. COMPUTER PROGRAMS USED

22. ESTABLISHMENT FILE REF. (SI)

23. ADDITIONAL INFORMATION (AS REQUIRED)
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