Errata

Document Title: Example of Automatic Measurement of Conducted EMI with the 8568A Spectrum Analyzer (AN 270-1)

Part Number: 5952-9273

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HP References in this Application Note

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AN EXAMPLE OF AUTOMATIC MEASUREMENT OF CONDUCTED EMI WITH THE HP 8568A SPECTRUM ANALYZER

This note describes the application of the HP 8568A programmable Spectrum Analyzer to automatic EMI measurement.

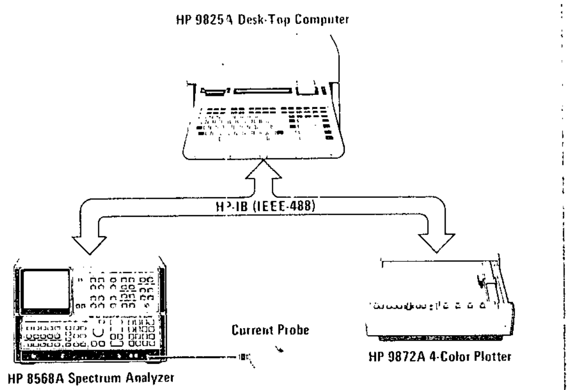
Since EMI (electromagnetic interference) measurement involves a repetitive process of collecting, analyzing and reformatting of large amounts of data, the process lends itself to automation where the time required to take data can be reduced significantly and where analysis and reformation of data can be implemented through the computer.

The HP 8568A is a general-purpose programmable spectrum analyzer. With appropriate transducers (antennas, or current probes), the HP 8568A can be used to measure broadband as well as narrowband (CW) interference signals. In the configuration used for this application (see figure 1) the HP 9825A desk-top computer serves as the instrument controller and a Genistron current probe is used as the transducer for the spectrum analyzer. Additional peripherals include the HP 9872A 4-color plotter and the HP 9866B thermal printer.

The program documented here measures conducted EMI from 200 KHz to 50 MHz in accordance with MIL STD 461 (method CE03). Four measurement sweeps are taken to characterize the broadband and narrowband emissions from the device under test. The raw data is analyzed in the computer and later reformatted in both a semi-log graph and a measurement summary which includes PASS/FAIL messages to indicate compliance.

In addition to automating the measurement and providing output graphs and summaries, the program was written to guide the operator through the measurement. Once the program is loaded and running in the computer, the graphics and service request capabilities of the spectrum analyzer enable it to become a measurement terminal in which information is received from the CRT and responses are initiated via the keyboard.

A flow-chart given in figure 2 illustrates the order of program execution. Total time to run the program is less than 5 minutes.



EQUIPMENT REQUIRED:

- HP 8568A Spectrum Analyzer
- HP 9825A Desk-Top Computer
- HP 98210A String Advanced Programming ROM
- HP 98216A Plotter General I/O-Extended I/O ROM
- HP 9866B Printer (Option 025)
- HP 98034A HP-IB Interface Card
- HP 98226A Computer Cradle
- HP 9872A Four-Color Plotter (Option 025)
- Current Probe (Genistron Model GCP-5130A or equivalent)

Figure 1. Configuration of an automatic EMI measurement system with the HP 8568A.

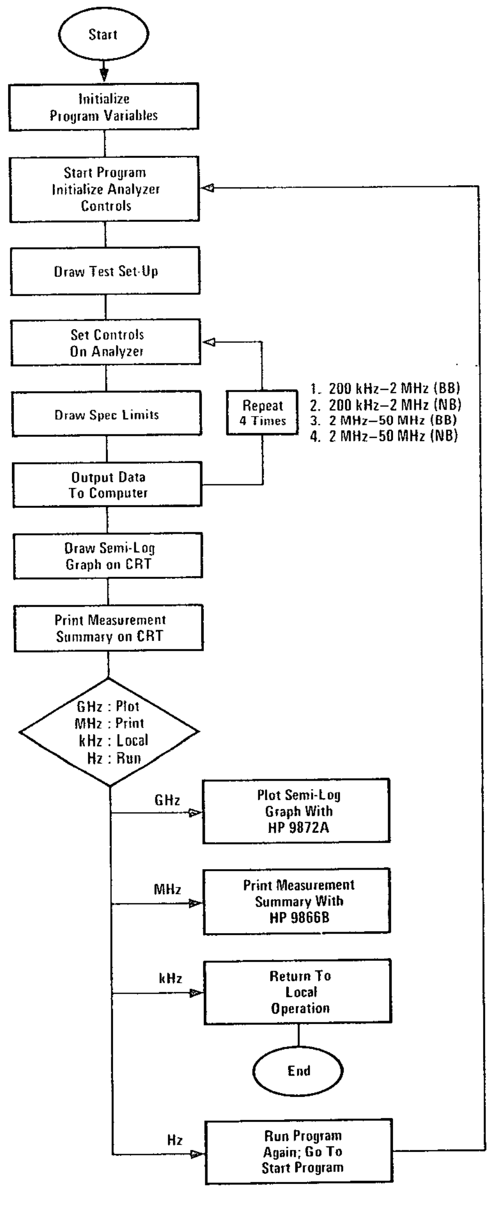


Figure 2. Program flowchart.

PROGRAM OPERATION

The program begins by drawing a test set-up on the CRT (see figure 3). This prompts the operator to check if the equipment is properly connected prior to making the measurement. A blinking message on the CRT indicates to the operator that program execution continues when the "HZ" key on the analyzer keyboard is pressed.

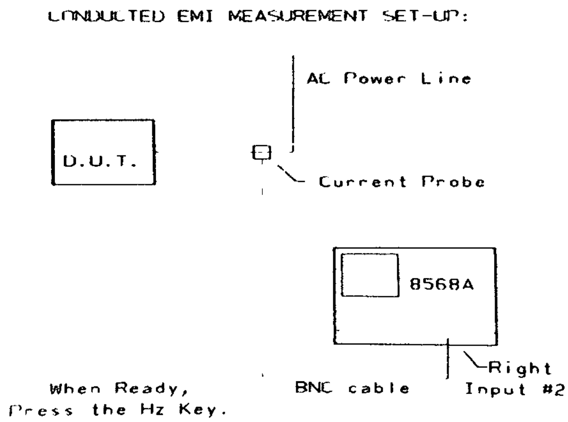


Figure 3. Test set-up drawn on CRT.

Once the "HZ" key is pressed, the program branches to a subroutine which draws a composite broadband (BB) and narrowband (NB) limit line from 200 KHz to 2 MHz on the CRT (see figure 4). The composite BB limit line represents the CE03 specifications which have been adjusted for the transfer impedance of the current probe and normalized to a 1 MHz impulse bandwidth.[1] The NB limit line only requires an adjustment for the probe impedance.

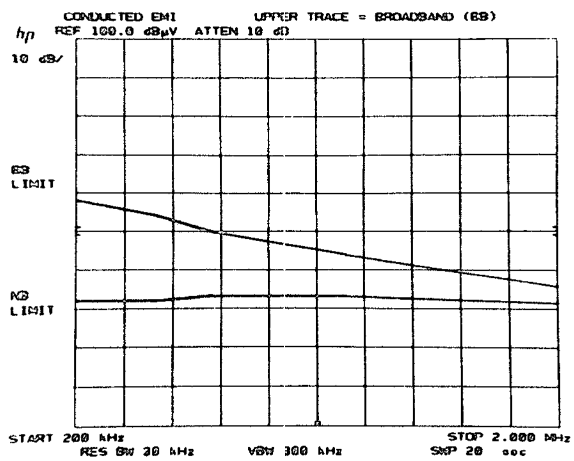


Figure 4. Composite BB and NB limit line.

The frequency span, resolution bandwidth, video bandwidth and sweep time of the analyzer are then automatically set and the first measurement sweep begins.[2] Since the BB and NB limit lines are drawn on the CRT, the operator can view the measurement in real-time and determine immediately whether or not his device will meet the CE03 specifications.

[1]Appendix A contains a detailed explanation of probe impedance and impulse bandwidth factor used.

[2]Appendix B tabulates the control settings used on the HP 8568A.

As soon as the first measurement is completed, the analyzer sends an end-of-sweep interrupt which, in effect, "tells" the controller that the analyzer is ready to output its trace data. A fast read/write operation then transfers the 1001 data points from the analyzer to a buffer in the controller and the analyzer is set for the second measurement sweep. While the analyzer is taking data, the controller will be analyzing the data from the first measurement, adjusting for probe impedance and bandwidth factor, and storing the reformatted data (now in dBμA) in an array. The CRT photo in figure 5 displays the results of the first two measurements.

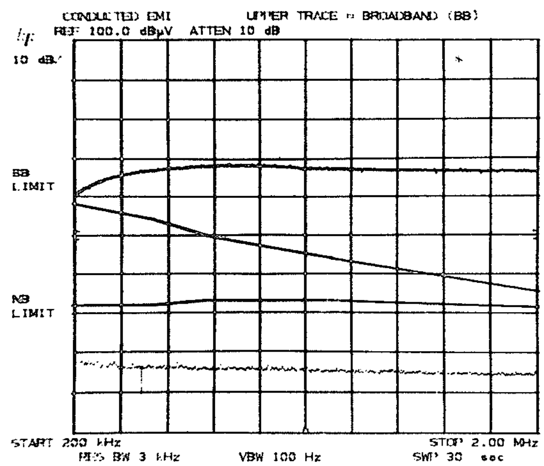


Figure 5. Measured BB and NB signals with limit lines.

This sequence of measuring and outputting data continues with the upper 2 MHz to 50 MHz frequency range. After all four measurements have been made and data stored, the program branches to another subroutine which draws a semi-log graph along with the CE03 spec limits on the CRT. The reformatted trace data are then recalled from the data array and plotted on the semi-log graph to yield the broadband and narrowband results from 200 KHz to 50 MHz. Figure 6 illustrates the completed measurement results.

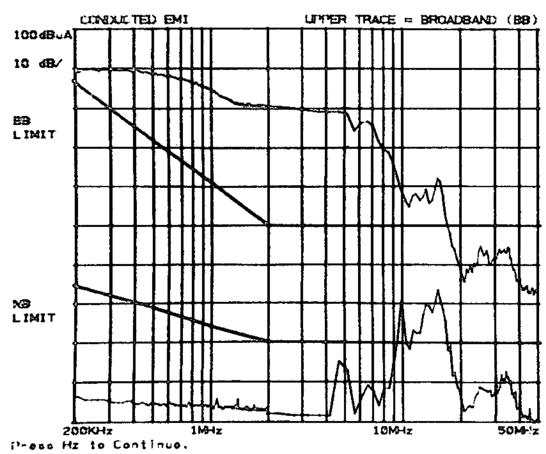


Figure 6. Semi-log graph of measured results from 200 KHz to 50 MHz.

At this point, a photo of the semi-log graph can be obtained or the "Hz" key can be pressed to display a summary of the broadband and narrowband measurement results (see figure 7). The broadband results list a sampling of the measured broadband signals from 200 KHz to 50 MHz along with the corresponding spec limit and test margin. The narrowband results list the frequency and amplitude of the largest signal in two bands: 200 KHz to 2 MHz and 2 MHz to 50 MHz. PASS/FAIL messages accompany each signal listed to summarize compliance with the CE03 specifications.

```
EMI MEASUREMENT SUMMARY

BROADBAND RESULTS:
 Frequency      Measured       Spec Limit     Margin
  (MHz)        (dBuA/MHz)     (dBuA/MHz)      (dB)
   0.20          89.2           87.0          -2.2    FAILED
   0.50          88.6           72.0         -16.6    FAILED
   1.00          84.8           61.0         -23.8    FAILED
   2.00          80.4           50.0         -30.4    FAILED
  10.00          58.8           50.0          -8.8    FAILED
  50.00          33.2           50.0          16.8    PASSED

NARROWBAND RESULTS:
  200 KHz to 2 MHz
      The Largest Signal is:   0.20  MHz      21.4 dBuA
      Spec at This Frequency is:              35.0 dBuA
                                                 PASSED
  2 MHz to 50 MHz
      The Largest Signal is:  15.44  MHz      33.6 dBuA
      Spec at This Frequency is:              20.0 dBuA
                                                 FAILED


Press: GHz for a plotter plot.
       MHz for a printout.
       KHz for LOCAL control.
       Hz to RUN again.
```

Figure 7. Measurement summary of broadband and narrowband results.

Additional messages on the CRT inform the operator that a hardcopy output of the semi-log graph or the measurement summary can be obtained. Pushing the "GHz" key will produce a 4-color plot of the semi-log graph on the HP 9872A (figure 8); pushing "MHz" outputs a printed measurement summary via the HP 9866B (figure 9); pushing "KHz" enables local control of the analyzer and pushing "HZ" allows the operator to run the measurement again.

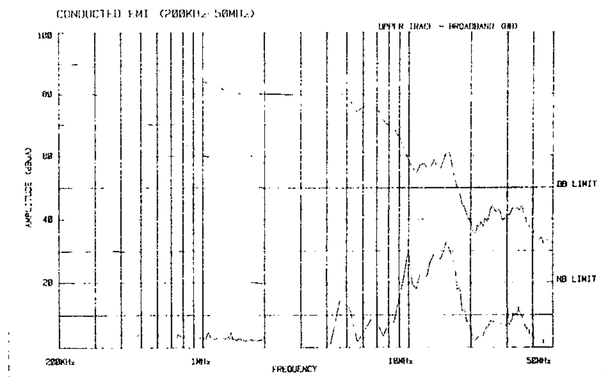


Figure 8. Semi-log graph with HP 9872A.

Figure 9. Measurement summary with HP 9866B.

Appendix A

[illegible] IMPEDANCE

A current probe is a transducer that enables conventional voltage measuring instruments to measure current. The transfer impedance of a current probe is defined as the ratio of secondary voltage (across 50 Ω) to the primary current flowing in the circuit under test ($Z_t = \frac{Es}{Ip}$).

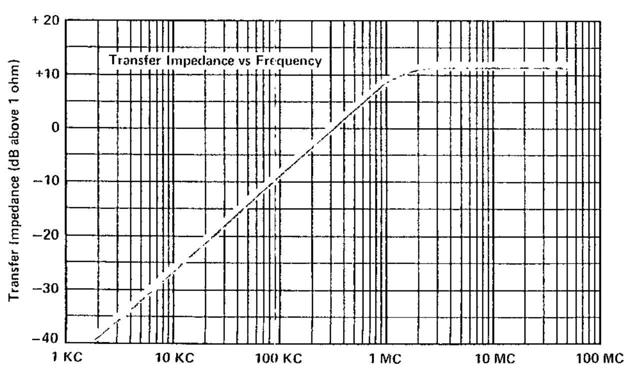


Figure 10. Current probe transfer impedance.

Transfer impedance can also be expressed in terms of dB Ω where dB Ω = 20 log Z_t.

The transfer impedance of the Genistron Model GCP-5130 current probe (see figure 10) was modeled with the following linear equation:

$$y = mx + b$$

where: y = probe impedance (dB Ω)
m = slope
x = log frequency
b = offset

Taking the 10 KHz to 100 KHz points, calculating m yields:

$$m = \frac{-8.5 \text{ dB} + 26.5 \text{ dB}}{\log(100 \text{ KHz}) - \log(10 \text{ KHz})} = 18$$

for y = 26.5 dB at 10 KHz, b = −98.5 dB

Hence:

y = 18 log x − 98.5 dB for f = 200 KHz to 1.4 MHz
y = 12 dB for f ≥ 1.4 MHz,

(Program calculation of probe impedance are in lines 282-289)

IMPULSE BANDWIDTH FACTOR

The impulse bandwidth is defined as the ideal rectangular filter bandwidth with the same voltage response as the actual instrument IF filter (see figure 11).

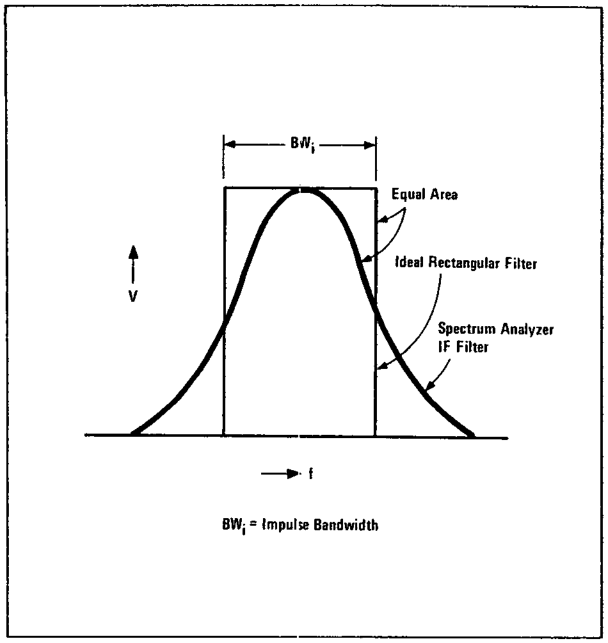


Figure 11. The impulse bandwidth is defined by an ideal filter with identical voltage response.

The 30 KHz and 100 KHz IF bandwidths on the HP 8568A are equivalent to impulse bandwidths of 48 KHz and 160 KHz respectively. Normalizing both bandwidths to 1 MHz yields the following correction factors to be included in the measured broadband signals.

$$20 \log \frac{48 \text{ KHz}}{1 \text{ MHz}} = -26 \text{ dB}$$

$$20 \log \frac{160 \text{ KHz}}{1 \text{ MHz}} = -16 \text{ dB}$$

MEASUREMENT OF IMPULSE BANDWIDTH ON HP 8568A

Manual Procedure:

1. Connect CAL OUTPUT signal to spectrum analyzer input.
2. Set following controls:
   CENTER FREQUENCY = 20 MHz
   FREQUENCY SPAN = 1 MHz
   Linear Amplitude Scale
   dBμV amplitude units (shift C)
3. Select desired Resolution Bandwidth and set Frequency Span ten times greater than the Resolution Bandwidth.
4. Adjust signal peak to top graticule line with Reference Level Control.
5. Use Δ markers to measure 6 dB Bandwidth (half voltage points) which yields the approximate impulse bandwidth of the analyzer.

Automatic Procedure:

The HP 9825A can be used to integrate the area under the IF filter and thus provide a more accurate measure of the impulse bandwidth. The program shown below is an example of automatically measuring the impulse bandwidth of the HP 8568A Spectrum Analyzer.

```
0: "CALCULATION OF HP8568A IMPULSE BANDWIDTHS":
1: wrt 6,"HP8568A IMPULSE BANDWIDTHS";wrt 6
2: wrt 6,"IF BW(Hz)      IMPULSE BW(Hz)"
3: fmt 1,f8.0,f15.0
4: 1.5e7→A
5: buf "trace",1001,3
6: wrt 718,"IP CF20MZ RB3MZ SP15MZ LN S2TS"
7: for I=1 to 12;0→T
8: wrt 718,"E1E4TSE1E4TS O4TA"
9: tfr 718,"trace"
10: rds("trace")→S;if S#1001;jmp 0
11: for J=1 to 1001
12: rdb("trace")+T→T
13: next J
14: T/250*A/1000→C
15: wrt 718,"RB OA";red 718,B
16: wrt 6.1,B,C
17: wrt 718,"RBDN OA";red 718,B
18: 10*B→A
19: wrt 718,"SP",A,"HZ"
20: next I
21: wrt 6
22: end
*697
```

Figure 12. Calculation of impulse bandwidth.

Appendix B

The following table lists the resolution bandwidth, video bandwidth, sweep time and reference level setting used on the HP 8568A spectrum analyzer. These settings are automatically set each time the "Set Analyzer Controls" subroutine is encountered in the program (lines 62-70). The measurement number listed in the table (also equal to "p-numbers" in the program) indicates the order in which the measurements are taken.

	SPECTRUM ANALYZER CONTROL SETTINGS	
	LOW LIMITS (200 kHz-2 MHz)	**HIGH LIMITS (2 MHz-50 MHz)**
BROADBAND (BB)	**Measurement (1)** Resolution Bandwidth = 30 kHz Video Bandwidth = 300 kHz Sweep Time = 20 sec Reference Level = 100 dBμV	**Measurement (3)** Resolution Bandwidth = 100 kHz Video Bandwidth = 1 MHz Sweep Time = 20 sec Reference Level = 100 dBμV
NARROWBAND (NB)	**Measurement (2)** Resolution Bandwidth = 3 kHz Video Bandwidth = 100 Hz Sweep Time = 30 sec Reference Level = 100 dBμV	**Measurement (4)** Resolution Bandwidth = 30 kHz Video Bandwidth = 100 Hz Sweep Time = 50 sec Reference Level = 100 dBμV

Program Listing with Annotation

SIMPLE VARIABLES

A, B	draw semi-log graph on plotter
C, D	draw semi-log graph on analyzer CRT
E	8568A keyboard Entry
F	Frequency
G	Sweep Counter - determines sweep being measured
H	Sweep Counter - determines sweep being plotted
I, J	For/Next loop counter
L	Narrowband spec Limit in dBμV
M, N	Used to draw semi-log graph on plotter
P	9872A Plotter address
R	Current Probe impedance
S	8568A Status byte
T	Contains Trace data points
U	Current Probe Impedance
V	Bandwidth Factor
W	9866A/B Printer address
Z	8568A Spectrum Analyzer address

ARRAYS

A	Trace Amplitudes storage array
B	Frequency and amplitude of largest signal for narrowband sweep
C$	contains "UPPER TRACE = BROADBAND (BB)"
F$	contains "FAILED"
P$	contains "PASSED"
W$	temporary storage for "PASSED/FAILED" message

Buffer: "trace" - contains 1001 point trace information

ADDRESS

718→Z = sa	8568A spectrum analyzer
6→W	9866A/B printer
705→P	9872A plotter

```
0: "EMI MEASUREMENT WITH THE HP8568A SPECTRUM ANALYZER":
1: "MIL STD 461, method CE03 (200KHz to 50MHz)":
2: "revision 1, 8-15-78":
3: "INITIALIZE THE PROGRAM":
4:    dim A[4,100],B[4],C$[30],F$[6],P$[6],W$[6]
5:    buf "trace",1001,3
6:    dev "sa",718→Z;6→W;705→P
7:    oni 7,"interrupt"
8:    fxd 2;deg
9:    fmt
10:   fmt 1,f.0,c,z
11:   fmt 2,c10,2c15,c10
12:   fmt 3,3x,f5.2,7x,f5.1,10x,f5.1,9x,f5.1,c10
13:   fmt 4,6x,c22,2x,f5.2,c5,5x,f5.1,c5
14:   fmt 5,6x,c26,13x,f5.1,c5
15:   fmt 6,35x,c20
16:   "UPPER TRACE = BROADBAND (BB)"→C$
17:   "FAILED"→F$
18:   "PASSED"→P$
19:
20: "START THE PROGRAM":
21: "start":
22:   wrt "sa","IP A4 KSm EM KSo DT@"
23:   gsb "set-up"
24:   wrt "sa","IP S2 TS A4"
25:   wrt "sa","KSC RL100DB HD I2 R1R2 DT@"
26:   wrt "sa","KSE CONDUCTED EMI           ",C$
27:   1→G
28:   cll 'set-controls'(G)
29:   rds("sa")→S;eir 7
30:   if G<5;jmp 0
31:   gsb "CRT-graph"
32:   gto "end"

33:
34: "***** SUBROUTINES *****":
35:
36: "DRAW TEST SET-UP":
37: "set-up":
38:   wrt "sa","D3 EM KSj DA3073 PA"
39:      for I=1 to 3
40:      wrt "sa","PU 50,400 PD 50,500,175,500,175,400,50,400"
41:      wrt "sa","PU 400,150 PD 400,300,600,300,600,150,400,150"
42:      next I
43:   wrt "sa","PU 300,440 PD 300,460,320,460,320,440,300,440,320,440"
44:   wrt "sa","PU 410,225 PD 410,290,480,290,480,225,410,225,480,225"
45:   wrt "sa","PU 175,450 PD 350,450,350,600"
46:   wrt "sa","PU 400,170 PD 600,170"
47:   wrt "sa","PU 310,440 PD 310,100,540,100,540,160"
48:   wrt "sa","PU 330,430 PD 352,405 PU 560,140 PD 576,117"
49:   wrt "sa","PAPU 48,640 LBCONDUCTED EMI MEASUREMENT SET-UP:@"
50:   wrt "sa","PAPU 368,544 LBAC Power Line@"
51:   wrt "sa","PAPU 64,416 LBD.U.T.@"
52:   wrt "sa","PAPU 352,384 LB- Current Probe@"
53:   wrt "sa","PAPU 496,240 LB8568A@"
54:   wrt "sa","PAPU 354,64 LBBNC cable@"
```

4: Initialize arrays
5: Set-up trace buffer
6: Assign instrument address
7: Assign interrupt entry point
9-15: Format statements
16-18: Assign string variables
22: Blank the analyzer CRT
23: Draw test set-up
24: Instrument preset and blank trace A
25: Set reference level, enable service requests and assign label terminations
26: Label CRT
27: Initialize sweep counter
28: Set controls for first sweep
29: Read analyzer status; enable controller interrupt.
30: Wait until four sweeps are taken
31: Draw CRT graph
38: Draw set-up in page 4 of memory
39-42: Draw D.U.T. and analyzer outline (3 times)
43: Draw current probe
44: Draw analyzer CRT
45: Draw AC power line
46: Draw detail
47: Draw probe cable
48: Draw miscellaneous pointers
49-56: Label items

```
 55:     wrt "sa","PAPU 576,96 LB-Right@"
 56:     wrt "sa","PAPU 544,64 LB Input #2@"
 57:     wtb "sa","PAPU 48,64 LB",17,"When Ready,",13,10
 58:     wtb "sa","Press the Hz Key.",18,3
 59:     cll 'read-entry'(E)
 60:     ret

 61:
 62:  "SET ANALYZER CONTROLS":
 63:  "set-controls":
 64:     if p1=1;gsb "low-limits"
 65:     if p1=1;wrt "sa","B4 FA200KZ FB2MZ RB30KZ VB300KZ ST20SC HD A1 A2 S2"
 66:     if p1=2;wrt "sa","A3 RB3KZ VB100HZ CT HD B1 B2 S2"
 67:     if p1=3;gsb "high-limits"
 68:     if p1=3;wrt "sa","B4,FA2MZ FB50MZ RB100KZ VB1MZ ST20SC HD A1 A2 S2"
 69:     if p1=4;wrt "sa","A3 RB30KZ VB100HZ CT HD B1 B2 S2"
 70:     ret

 71:
 72:  "SERVICE THE INTERRUPT":
 73:  "interrupt":
 74:     rds("sa")→S
 75:     if bit(2,S)=1;gsb "data-out"
 76:     eir 7
 77:     iret

 78:
 79:  "DRAW 200 KHz to 2 MHz LIMITS":
 80:  "low-limits":
 81:     wrt "sa","EM D1 PA"
 82:        for I=1 to 4
 83:        wrt "sa","PU 0,580 PD 167,540,278,500,556,440,1000,355"
 84:        wrt "sa","PU 0,320 PD 167,320,278,330,556,330,1000,315"
 85:        next I
 86:     wrt "sa","D2 PAPU 0,656 LBBB@"
 87:     wrt "sa","D2 PAPU 0,624 LBLIMIT@"
 88:     wrt "sa","PAPU 0,352 LBNB@"
 89:     wrt "sa","PAPU 0,320 LBLIMIT@"
 90:     ret

 91:
 92:  "DRAW 2 to 50 MHz LIMITS":
 93:  "high-limits":
 94:     wrt "sa","EM D1 PA"
 95:        for I=1 to 4
 96:        wrt "sa","PU 0,460 PD 1000,460 PU 0,320 PD 1000,320"
 97:        next I
 98:     wrt "sa","D2 PAPU 0,525 LBBB@"
 99:     wrt "sa","D2 PAPU 0,493 LBLIMIT@"
100:     wrt "sa","PAPU 0,336 _BNB@"
101:     wrt "sa","PAPU 0,304 _BLIMIT@"
102:     ret

103:
104:  "READ DATA FROM ANALYZER":
105:  "data-out":
106:     if G=1 or G=3;wrt "sa","O4 TA";gto +2
107:     wrt "sa","O4 TB"
108:     tfr "sa","trace",1001
109:     rds("trace")→S;if S#1001;jmp 0
110:     if G#2;gto +5
111:     wrt "sa","E1 O3 MF";red "sa",B[1]
112:     wrt "sa","MA";red "sa',B[2]
113:     cll 'probe'(B[1],R)
114:     B[2]-R→B[2]
115:     if G#4;gto +5
116:     wrt "sa","E1 O3 MF";red "sa",B[3]
117:     wrt "sa","MA";red "sa",B[4]
118:     cll 'probe'(B[3],R)
119:     B[4]-R→B[4]
120:     wrt "sa","M1"
121:     cll 'set-controls'(G+1)
122:     rdb("trace")→T
123:        for I=1 to 100
124:        0→A[G,I]
125:           for J=1 to 10
126:           4*rdb("trace")→T
127:           max(T,A[G,I])→A[G,I]
128:           next J
129:        if G=1;26→V;I*1.8e4+2e5→F
130:        if G=3;16→V;I*4.8e5+2e6→F
131:        if G=2 or G=4;0→V
132:        cll 'probe'(F,U)
133:        A[G,I]/10-U+V→A[G,I]
134:        min(102,max(0,A[G,I]))→A[G,I]
135:        next I
136:     G+1→G
137:     ret

138:
139:  "DRAW CRT SEMI-LOG GRAPH":
140:  "CRT-graph":
141:     wrt "sa","A1A3 B4 EM KSm KŜo DA1 D1 PA"
142:        for I=2e5 to 5e7
143:        log(I)→C;417(C-5.3)→D
144:        wrt "sa","PU",D,",0 PD",D,",1000"
145:        I+tn↑int(C)-1→I
```

57-58: Print instructions and blink on/off
59: Read keyboard response
60: Return to subroutine entry point

64: Draw 200 KHz to 2 MHz limit lines
65: Set analyzer for sweep #1
66: Set analyzer for sweep #2
67: Draw 2 MHz to 50 MHz limit lines
68: Set analyzer for sweep #3
69: Set analyzer for sweep #4

74: Read analyzer status
75: Transfer data if end-of-sweep interrupt encountered
76: Enable controller interrupt
77: Returns to interrupt entry point

81: Erase memory in page 4
83: Draw composite BB limit
84: Draw composite NB limit
86-89: Label limit lines

94: Erase memory in page 4
96: Draw BB and NB composite limits
98-101: Label limit lines

106: Output trace A if sweep #1 or 3
107: Output trace B
108: Transfer trace to buffer
109: Check if all 1001 points are outputted
110: Is this sweep #2
111: Read frequency of largest signal
112: Read amplitude of largest signal
113: Given frequency B [1], calculate probe impedance R
114: Correct amplitude for probe impedance
115: Is this sweep#4
116-119: See 111-114

120: Turn marker off
121: Set analyzer controls for next sweep
122: Throw away first trace point

126: Convert buffer to display units
127: Store maximum amplitude in trace array
129: If sweep #1; V = 26; convert horizontal points to frequency units
130: If sweep #3; V = 16; convert horizontal points to frequency units
131: If sweep #2 or 4; V = 0
132: Calculate probe impedance
133: Correct amplitude for probe and bandwidth factor
134: Set minimum and maximum boundary points

141: Blank display, plot absolute
142-146: Draw vertical semi-log lines

```
146:        next I
147:        for I=0 to 1000 by 100
148:        wrt "sa","PU 0",I,"PD 1000",I
149:        next I
150:        for I=1 to 5
151:        wrt "sa","PU0,870 PD166,720,292,610,417,500,1000,500"
152:        wrt "sa","PU0,350 PD166,290,292,240,417,200,1000,200"
153:        next I
154:    wrt "sa","D2 PAPU 128,960 LBCONDUCTED EMI@"
155:    wrt "sa","PAPU 560,960 LB",C$,"@"
156:    wrt "sa","PAPU 0,928 LB100dBuA@"
157:    wrt "sa","PAPU 0,864 LB10 dB/@"
158:    wrt "sa","PAPU 10,736 LBBB@"
159:    wrt "sa","PAPU 0,704 LBLIMIT@"
160:    wrt "sa","PAPU 10,320 LBNB@"
161:    wrt "sa","PAPU 0,288 LBLIMIT@"
162:    wrt "sa","PAPU 96,32 LB200KHz@"
163:    wrt "sa","PAPU 336,32  LB1MHz@"
164:    wrt "sa","PAPU 688,32 LB10MHz@"
165:    wrt "sa","PAPU 928,32 LB50MHz@ PS"
166:    wrt "sa","A3 D1 EM DA3073 KSj PA"
167:        for I=1 to 2
168:        wrt "sa","PU 0,",10*A[I,1],"PD"
169:            for J=1 to 100
170:            wrt "sa",417(log(1.8e4*J+1.907e5)-5.3),10*A[I,J]
171:            next J
172:        next I
173:        for I=3 to 4
174:        wrt "sa","PU 417,",10*A[I,1],"PD"
175:            for J=1 to 100
176:            wrt "sa",417(log(4.8e5*J+1.76e6)-5.3),10*A[I,J]
177:            next J
178:        next I
179:    beep
180:    wtb "sa","D2 PAPU 0,0 LB",17,"Press Hz to Continue.",18,3
181:    cll 'read-entry'(E)
182:    ret

183:
184: "PLOT SEMI-LOG GRAPH ON PLOTTER":
185: "plot-graph":
186:    psc P;pclr
187:    scl -100,1100,-100,1100
188:    pen# 1
189:    plt -100,-100;plt -100,1100;plt 1100,1100,-1
190:    plt 1100,1100;plt 1100,-100;plt -100,-100,-1
191:        for N=2e5 to 5e7
192:        log(N)→A;417(A-5.3)→B
193:        plt B,0;plt B,1000,-1
194:        N+tn↑int(A)→N
195:        log(N)→A;417(A-5.3)→B
196:        plt B,1000;plt B,0,-1
197:        N+tn↑int(A)→N
198:        next N
199:        for M=0 to 1000 by 200
200:        plt 1000,M;plt 0,M,-1
201:        if M>=1000;gto +3
202:        plt 0,M+100;plt 1000,M+100,-1
203:        next M
204:    pen# 2
205:    csiz 2,1.7,.7,0
206:    plt 0,1050,-1;lbl "CONDUCTED EMI (200KHz-50MHz)"
207:    csiz 1.5,1.8,.7,90
208:    plt -55,380,-1;lbl "AMPLITUDE (dBuA)"
209:    csiz 1.5,1.8,.7,0
210:    plt -40,985,-1;lbl "100"
211:    plt -30,795,-1;lbl "80"
212:    plt -30,595,-1;lbl "60"
213:    plt -30,395,-1;lbl "40"
214:    plt -30,195,-1;lbl "20"
215:    plt -25,-50,-1;lbl "200KHz"
216:    plt 270,-50,-1;lbl "1MHz"
217:    plt 670,-50,-1;lbl "10MHz"
218:    plt 950,-50,-1;lbl "50MHz"
219:    plt 435,-75,-1;lbl "FREQUENCY"
220:    pen# 3
221:    plt 650,1010,-1;lbl C$
222:    plt 0,870;plt 417,500;plt 1000,500,-1
223:    plt 1000,500;plt 417,500;plt 1000,500,-1
224:    plt 1010,500,-1;lbl "BB LIMIT"
225:    pen# 4
226:    plt 0,350;plt 417,200;plt 1000,200,-1
227:    plt 1000,200;plt 417,200;plt 1000,200,-1
228:    plt 1010,200,-1;lbl "NB LIMIT"
229:
230:        for H=1 to 4
231:        pen# 3+(H=2 or H=4)
232:        1→N
233:        if H=3 or H=4;gto +5
234:        plt 0,10*A[H,1]
235:        plt 417(log(1.8e4*N+1.907e5)-5.3),10*A[H,N]
236:        N+1→N;if N<=100;gto -1
237:        gto +4

238:        plt 417,10*A[H,1]
239:        plt 417(log(4.8e5*N+1.76e6)-5.3),10*A[H,N]
240:        N+1→N;if N<=100;gto -1
```

147-149: Draw horizontal lines
150-153: Draw CE03 spec. lines
154-165: Label graph
166: Erase memory and plot on page 4
167: Plot sweep #1 and 2
168: Plot first trace point
169-171: Plot 100 trace points
173: Plot sweep #3 and #4
174: Plot first trace point
175-177: Plot 100 trace points
186: Initialize plotter address and clear
187: Scale plotter
189-190: Plot border
191-198: Plot vertical semi-log lines
199-203: Plot horizontal lines
205: Establish character size and shape
206-219: Label graph
221-224: Plot and label BB limit
226-228: Plot and label NB limit
230: For sweeps #1 to #4
231: Use pen #3 for BB, #4 for NB
232: Initialize trace counter
234: Plot first data point
235: Plot x, y of trace
236: Increment counter and check if end of trace

```
241:        pen
242:        next H
243:     pen# 0;plt 1100,1100,-1;beep
244:     ret

245:
246: "PRINT MEASUREMENT SUMMARY":
247: "print-out":
248:     wrt p1,"EMI MEASUREMENT SUMMARY"
249:     wtb p1,13,10
250:     wrt p1,"BROADBAND RESULTS:"
251:     wrt p1+.2,"Frequency","Measured  ","Spec Limit  ","Margin"
252:     wrt p1+.2,"(MHz)    ","(dBuA MHz)","(dBuA MHz)","(dB) "
253:     P$→W$;if A[1,1]>87;F$→W$
254:     wrt p1+.3,.2,A[1,1],87,87-A[1,1],W$
255:     P$→W$;if A[1,17]>72;F$→W$
256:     wrt p1+.3,.5,A[1,17],72,72-A[1,17],W$
257:     P$→W$;if A[1,45]>61;F$→W$
258:     wrt p1+.3,1,A[1,45],61,61-A[1,45],W$
259:     P$→W$;if A[1,100]>50;F$→W$
260:     wrt p1+.3,2,A[1,100],50,50-A[1,100],W$
261:     P$→W$;if A[3,17]>50;F$→W$
262:     wrt p1+.3,10,A[3,17],50,50-A[3,17],W$
263:     P$→W$;if A[3,100]>50;F$→W$
264:     wrt p1+.3,50,A[3,100],50,50-A[3,100],W$
265:     wtb p1,10,10
266:     wrt p1,"NARROWBAND RESULTS:"
267:     wrt p1,"   200 KHz to 2 MHz"
268:     -15*log(B[1])+114.52→L
269:     wrt p1+.4,"The Largest Signal is:",B[1]/1e6,"MHz",B[2],"dBuA"
270:     wrt p1+.5,"Spec at This Frequency is:",L,"dBuA"
271:     P$→W$;if B[2]>L;F$→W$
272:     wrt p1+.6,W$
273:     wrt p1,"   2 MHz to 50 MHz"
274:     20→L
275:     wrt p1+.4,"The Largest Signal is:",B[3]/1e6,"MHz",B[4],"dBuA"
276:     wrt p1+.5,"Spec at This Frequency is:",L,"dBuA"
277:     P$→W$;if B[4]>L;F$→W$
278:     wrt p1+.6,W$
279:     wtb p1,10,10
280:     ret

281:
282: "CALCULATE PROBE IMPEDANCE":
283: "probe":
284:     if p1>=1.4e6;gto +4
285:     log(p1)→X
286:     18X-98.5→p2
287:     ret
288:     12→p2
289:     ret

290:
291: "READ THE KEYBOARD ENTRY":
292: "read-entry":
293:     wait 100
294:     eir 7,0
295:     wrt "sa","R1R4 EE"
296:     rds("sa")→p1;if bit(1,p1)=1;gto +0
297:     rds("sa")→p1;if bit(1,p1)=0;jmp 0
298:     wrt "sa","OA";red "sa",p1
299:     eir 7
300:     ret

301:
302: "END OF PROGRAM":
303: "end":
304:     wtb "sa","A4 B4 KSa KSo EM D2 PAPU 0,992 LB",10
305:     cll 'print-out'(Z)
306:     wrt "sa","@ PAPU 0,96 LBPress: GHz for a plotter plot."
307:     wrt "sa","         MHz for a printout."
308:     wrt "sa","         KHz for LOCAL control."
309:     wrt "sa","         Hz to RUN again.@ PS"
310:     cll 'read-entry'(E)
311:     if E=1e9;cll 'plot-graph';gto -1
312:     if E=1e6;cll 'print-out'(W);gto -2
313:     if E=1e3;wrt "sa","1P";gto +3
314:     if E=1;gto "start"
315:     beep;gto -5

316:     end

317:

     8250 bytes    15951 check sum
```

- 243: Put pen away
- 248-252: Print title and headings
- 253: 200 KHz in spec.?
- 254: Print 200 KHz results
- 255: 500 KHz in spec.?
- 256: Print 500 KHz results
- 257: 1 MHz in spec.?
- 258: Print 1 MHz results
- 259: 2 MHz in spec.?
- 260: Print 2 MHz results
- 261: 10 MHz in spec.?
- 262: Print 10 MHz results
- 263: 50 MHz in spec.?
- 264: Print 50 MHz results
- 266-267: Print Narrowband headings
- 268: Calculate narrowband spec. limit
- 269-270: Print largest signal
- 271: Largest signal in spec.?
- 272: Print Pass or Fail
- 274: Assign NB limit
- 275-276: Print largest signal
- 277-278: Largest signal in spec.?
- 284: If frequency ≥1.4 MHz go to line 288
- 285: Convert frequency to log units
- 286: Probe impedance = 18 x 98.5 dB
- 288: Probe impedance = 12 dB
- 294: Disable controller interrupt
- 295: Enable keyboard entry
- 296: Wait for units key release
- 297: Wait for units key pressed
- 298: Read keyboard entry
- 299: Enable controller interrupt
- 304: Blank display and plot in page 4
- 305: Print measurement summary on CRT
- 306-309: Print instructions
- 311: Plot graph with plotter
- 312: Print measurement summary on printer
- 313: Enable local control
- 314: Run program again

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In Europe, Hewlett-Packard S.A., 7, rue du Bois-du-lan, PO Box, CH-1217 Meyrin 2-Geneva, Switzerland **In Japan**, Yokogawa-Hewlett-Packard Ltd., 29-21, Takaido-Higashi 3-chome, Suginami-ku, Tokyo 168.