Errata

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HP References in this Application Note

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Advanced Filter Evaluation and Limit Testing with HP 4195A Network/Spectrum Analyzer

1. INTRODUCTION

Filters play a significant role in electronic equipment because of the decisive effect they have on the performance of the equipment in which they are used. Filters find extensive use in communication, telecommunication, and consumer electronics. These products are becoming more complicated and require higher quality signal processing. For example, the amount of information sent by telecommunication networks has increased (requiring more stringent performance from the filters used in these systems), and VCR's/TV's require higher quality signal for better picture resolution and quality (sharper vision). As the demand for higher quality and more sophisticated electronic equipment increases, so has the need for accurate high speed testing and characterization of the wide variety of filters used.

Both end users and filter manufactures need to be able to quickly and easily test a wide variety of filters to ever increasingly tighter tolerances. This application note describes how the HP 4195A Network/Spectrum Analyzer is used to test filters, by either measuring the filter’s parameters or by using limit lines to perform GO/NO-GO testing. Both of these test techniques can be performed without a computer by using the HP 4195A’s USER PROGRAM programming function, a BASIC-like language used to control the HP 4195A’s operation. An external computer can also be used to develop and download USER PROGRAMs to the HP 4195A over the HP-IB bus and to control the operation of the HP 4195A.
2. FILTER PARAMETER MEASUREMENT

When testing filters, several of the filter's parameters are derived from the filter's measured transmission characteristics. Older network analyzers required using markers or other functions which required several key stroke operations and special operator skill to obtain valid results. The HP 4195A's USER DEFINE function gives the user the power of assigning complicated, hard to remember, error prone multiple key and softkey key strokes operations to a single key (keyboard macros), so filter parameters can now be measured and displayed using a single key stroke operation. The USER DEFINE function gives the user the power to define a single key stroke function to replace multiple key and softkey operations. As an example, this section shows how to use the USER DEFINE keys to find the following parameters:

1) -3 dB Band Width
2) Insertion Loss
3) Center Frequency
4) Band Pass Filter Rejection Characteristics

Figure 1 shows the filter test configuration used. A power splitter is required for this measurement. The USER DEFINE keys are defined using a USER PROGRAM. The program listing for Program 1 is given in the Appendix of this application note. After executing this program, press the 'USER DEFINE' key. Softkeys defined by a USER PROGRAM will be displayed as shown in Figure 2. When the 'USER DEFINED' key is pressed, each parameter is displayed at the bottom of the screen as shown in Figure 3. When using this technique, a filter's parameters are easily obtained with just a single key stroke, no time consuming, error prone key stroke sequences or function/measurement sequences need be performed.

The HP 4195A can output measurement parameters directly to an HP-IB printer. Figure 3 shows a sample print out of measurement parameters obtained using this technique, the program listing is given in Program 2 in the Appendix of this application note.

![Diagram of filter testing configuration]

Figure 1. Filter Testing Configuration
Figure 2. Filter Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insertion Loss [dB]</td>
<td>-2.55817832947E+01</td>
</tr>
<tr>
<td>-3dB Band Width [Hz]</td>
<td>2.63951934003E+07</td>
</tr>
<tr>
<td>Center Frequency [Hz]</td>
<td>1.39858385351E+08</td>
</tr>
<tr>
<td>Outband Rejection [dB]</td>
<td>-4.68137321472E+01</td>
</tr>
</tbody>
</table>

Figure 3. Example of Parameter Printout
3. GO/NO-GO TESTING

The HP 4195A can be used to perform GO/NO-GO testing using limit lines. Before running the GO/NO-GO program listed in Program 4, the limit lines setup program, Program 3, must be executed.

3-1. Limit Line Setting

Limit lines are composed of a series of straight line segments as shown in Figure 4. Each segment is specified by its start and stop coordinates. These coordinates are given as frequency and power level \((f, p)\) or \((f', p')\) for the minimum and maximum limit points. Various shapes of limit lines can be created by modifying the setup program. The frequencies and power levels can be modified by changing lines 300-560 of Program 3, and the number of segment points can be modified in line 270. The following procedure generates and stores the limit lines.

1) Before executing Program 3, modify the frequencies and power levels for each segment and set the instrument settings as required.

2) Connect the DUT as shown in Figure 1.

3) Execute Program 3, the HP 4195A will display the limit lines and the measurement data of the DUT as shown in Figure 5.

4) If you want to modify the limit lines, press the USER DEFINE key, then move a marker to a point you want to modify and press the softkeys to modify the limit lines displayed on the screen, as shown in Figure 6.

5) After setting the limit lines, the limit line data and instrument state (measurement conditions) information must be stored to a file on a floppy disc. Press the 'SAVE/GET' key and the 'SAVE' softkey. Choose and enter a file name, and press the 'EXEC/ENTER' key. The data is saved on the disc and is used for the following GO/NO-GO test procedure.

\[
\begin{align*}
\text{fm} & : m \text{th frequency of a maximum limit line} \\
\text{pm} & : m \text{th power level of a maximum limit line} \\
\text{f'm} & : m \text{th frequency of a minimum limit line} \\
\text{p'm} & : m \text{th power level of a minimum limit line} \\
n & : \text{number of segment points}
\end{align*}
\]

Each value should be modified in line 270-560 of Program 3.

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Figure 4. Segments for Limit Line
Figure 5. Limit Lines

Figure 6. Limit Line Modification
3-2. GO/NO-GO Testing

After executing Program 3 to set the limit lines, the HP 4195A is ready to perform GO/NO-GO filter testing. Connect a DUT as shown in Figure 1 and execute Program 4. The GO/NO-GO test procedure is as follows:

1) When the program is executed, the program displays the catalog of files on the disc and then pauses.

2) Recall the stored limit line and instrument state data. Press the ‘GET’ softkey and select the data file that you stored the data in and press the ‘EXEC/ENTER’ key.

3) Press the ‘PROGRAM’ key and the ‘CONT’ softkey, the HP 4195A will start the GO/NO-GO test. Figure 7 shows some sample results of a GO/NO-GO test of a bandpass filter.

4) Change the DUT and press the ‘CONT’ key to continue the GO/NO-GO testing.

The HP 4195A’s USER FUNCTION can be used to easily set the limit lines for filter testing. Using the HP 4195A’s built-in floppy disc drive, the limit line data and instrument states are stored for recall as required anytime. GO/NO-GO testing of a variety of devices can be accomplished easily and quickly using the HP 4195A!

![Graphs showing (a) Pass and (b) Fail results of GO/NO-GO testing](image-url)

Figure 7. Results of GO/NO-GO testing
4. Advanced Filter Tests

The HP 4195A, with its many outstanding features, can be used to perform advanced test procedures on filters.

4-1. Multi-Device Measurement and Multi-Output Filter Measurement

The HP 4195A can be used to increase your measurement speed by being used with a handler to compare a test device with a standard device. Because the HP 4195A has two output channel ports and four input ports, three devices can be connected simultaneously to the HP 4195A for testing. Figure 8 shows the configuration for testing multiple devices.

The HP 4195A with its multi-inputs can measure multi-output filters such as state variable filters. Figure 9 shows a configuration for testing multi-output filters.

(a) Comparison with Standard Device

(b) Using Handler

Figure 8. Example of Configuration for Multi-device Measurement

Figure 9. Example of Configuration for a State Variable Filter Testing
4-2. Phase Measurement

For filter test, in addition to measuring transmission characteristics, phase characteristics must also be measured. For example, Group Delay (derivative of phase with respect to frequency) represents phase nonlinearity, and phase nonlinearity degrades the quality of the signal.

The HP 4195A with its high accuracy and resolution can perform precise Group Delay measurements. Figure 10 shows some sample results of Group Delay measurements. The HP 4195A can simultaneously measure Group Delay and Transmission characteristics.

![Group Delay and Transmission Characteristic](image)

Figure 10. Group Delay and Transmission Characteristic

5. Conclusion

The HP 4195A, with its ability to provide precision transmission and phase measurement, is a very powerful tool for testing filters. The HP 4195A's USER FUNCTION provides for flexible, easy operation, so it can quickly and easily perform parameter measurement and GO/NO-GO testing. The flexible operation of the HP 4195A allow it to be quickly reconfigured to meet the test requirements of various test devices.
Program 1. USER DEFINE key Definition

100 ****************************
110  FILTER TEST
120  FINDING PARAMETER
130  FOR HP 4105A FEB.10.1980
140  YOKOGAWA-HEWLETT-PACKARD, LTD.
150 ****************************
160 **************************** SETTING MESS. CONDITION ****************************
170  SW
180  DPB0
190  CENTER=140 MHz CENTER FREQ. 140 MHz
200  SPAN=140 MHz SPAN 140 MHz
210  OSC1=100 DBM 110 OSC. LEVEL -10 DBM
220  ATT=0     ATT. 0 DB
230  ATT=0     ATT. 0 DB
240  RBW=10 KHZ RES. BW 10 KHZ
250 **************************** DEFINING USER DEFINE KEY ****************************
260  DF1="MC4;MK4;R0;MKRA;DISP";'INSERTION LOSS";R0"
270  DF2="MC4;MK4;MKRA;WIDTH1;LCURS=3;R0;WID;DISP";'JOB BAND WIDTH";R0"
280  DF3="MC4;MK4;MKRA;WIDTH1;LCURS=3;R1=LCURS+1;CURSL=1;DISP";'CENTER";R0"
290  DF4="MC4;MK4;MKRA;DCA=1;SPAN=1;R0;MKRA;DISP";'REJECTION";R0;DELTA"
300  DF5="SVER"
310 **************************** DEFINING LABEL OF USER DEF. KEY ****************************
320  SBL1="INS. LOSS"
330  SBL2="JOB BAND WIDTH"
340  SBL3="CENTER FREQ."
350  SBL4="REJECTION"
360  SBL5="TRIG"
370 END

Program 2. Parameter Printing

100 ****************************
110  FILTER TEST
120  PRINT PARAMETER
130  FOR HP 4105A FEB.10.1980
140  YOKOGAWA-HEWLETT-PACKARD, LTD.
150 ****************************
160 **************************** INITIALIZING ****************************
170  SW
180  CENTER=140 MHz CENTER FREQ. 140 MHz
190  SPAN=140 MHz SPAN 140 MHz
200  OSC1=100 DBM 110 OSC. LEVEL -10 DBM
210  ATT=0     ATT. 0 DB
220  ATT=0     ATT. 0 DB
230  RBW=10 KHZ RES. BW 10 KHZ
240  SVER     TALK ONLY
250  DPB0
260  SEND ""
270 **************************** FINDING PARAMETER ****************************
280  SBL1="MEAS. LOOP TOP"<---
290  MF4;MK4;MKRA;WIDTH1;LCURS=3;R1=WID
300  MF4;MK4;MKRA;WIDTH1;LCURS=3;R2=(LCURS+1)/2
310  MF2;MK4;MKRA;DCA=1;SPAN=1;R3=MKRA
320  SENDER=**** PRINTING DATA ****************************
330  SEND "INSERTION LOSS" (DBI)
340  SEND R0
350  WAIT 500
360  SEND ""
370  SEND "-3DB BAND WIDTH (HZI)"
380  SEND R1
390  WAIT 500
400  SEND ""
410  SEND "CENTER FREQUENCY (HZI)"
420  SEND R2
430  WAIT 500
440  SEND ""
450  SEND "REJECTION" (DBI)
460  SEND R0
470  WAIT 500
480  SEND ""
490  PAUSE
500  SGO TO 700 I MEAS. LOOP END ---+--+ 700
510  END
520 END
Program 3. Limit Line Setting

These instrument settings should be modified according to measurement requirements.

The number of segment points can be modified.

The frequencies and power levels of each segment of limit lines should be modified for the measurement requirements.

800 END
Program 4. GO/NO-GO Testing

100 ***************
110 I FILTER TEST (GO NOGO) PROGRAM *
120 I FOR HP 4155A *
130 I FEB.8,1988 *
140 I YOKOGAWA-HEWLETT-PACKARD, LTD. *
150 *****************************
160 ****************INITIALIZING AND PAUSING ************
170 CAT "GO/NO-GO TESTING"
180 DISPA,DISPB,DISPC,DISPD OFF
190 CAT DISC CATALOG
200 DISP "PLEASE GET MEAS. CONDITION DATA"
210 PAUSE
220 **********SETTING INSTRUMENT STATES **********
230 CENTER=0, CENTER FREQ, I
240 SPAN=1, SPAN, I
250 OSCR=0, OSC LEVEL, I
260 ATT=0, ATT, I
270 ATTI=0, TEST ATT, I
280 RBW=1, RES BW
290 NOF=8, NUMBER OF POINTS
300 *************SETTING LIMIT LINES *************
310 SPONG
320 SCL1:REF=D,DIV=10 I DISPScale REF, FOR A
330 SCL2:REF=D,DIV=10 I DISPScale REF, FOR B
340 DPAI:OPAB,SPCI:SPDI I DSP A-ON, B-OFF, C-ON, D-OFF
350 DMB=(C-MB)+(MA-MB) I USER MATH B DEFINE
360 PRMB”,”UNITB” I USER MATH LABEL ENTRY
370 MTHA,MTHB I MATH A-OFF, B-ON
380 ******************GO/NO-GO TESTING ****************
390 SWING I **MEAS. LOOP TOP {}-------
400 MCF1:MCF2;MCFN I
410 IF MRRB<0 THEN 430 I
420 DISP "PASS " I ;GOTO 440 I
430 DISP "FAIL " I ;GEP I
440 PAUSE I
450 GOTO 390 I **MEAS. LOOP END --> --> -->
460 END