HP 4195A
Network/Spectrum Analyzer
User’s Guide
TABLE OF CONTENTS

Chapter 1  Operating the HP 4195A
Function Keys
PRESET
Connections
Controls
Calibration
Measurement Enhancements

Chapter 2  Transmission Measurements with the HP 4195A
Insertion Loss (Gain)
3 dB Bandwidth
Out-of Band Rejection
Passband Ripple
Group delay
Gain Compression

Chapter 3  Reflection Measurements with the HP 4195A
Return Loss, Reflection Coefficient, SWR
S-parameters
Impedance (Smith Chart)

Chapter 4  Spectrum Measurement with the HP 4195A
Level Measurement
Noise Level
Harmonic Distortion
Multi-Point Spectrum Measurement

Chapter 5  Impedance Measurement with the HP 4195A
Equivalent Circuit Parameter Calculation
Frequency Characteristics Simulation

APPENDIX A  Internal Registers

APPENDIX B  User Program
Examples: Alternate Transmission/Reflection Measurement, SIN/COS waves Display, 3dB Bandwidth, THD, Go/No-Go Testing with Limit Line

APPENDIX C  User Defined Function
Examples: Filter Parameters, Signal Track, Alternate Sweep, 4-ch Spectrum Measurement

APPENDIX D  User Math Function
Examples: Max Hold, Averaging, 75Ω Measurement, Vp-p Measurement

APPENDIX E  Softkey Tree

APPENDIX F  Internal Registers/Command Listing
Chapter 1

Operating the HP 4195A

A simple and easy to use set of keys and softkeys make using the HP 4195A for measurement and analysis an easy task. When a key is pressed, the related set of softkeys are displayed, and when a softkey is pressed, an additional set of related softkeys may be displayed (the softkeys are arranged in a tree format) depending on the function selected. Consequently, operation is made easier by the reduced number of front panel keys, and by the context sensitive displayed set of softkeys. The keys are grouped by function, Measure, Sweep, Marker/Line-Cursor, etc. The softkeys are displayed by pressing the appropriate key in the related function key group. The following is a summary of the HP 4195A's primary functions and their related keys.

To Prepare for a Measurement

- Network/Spectrum/Impedance/S-parameter selection (CONFIG)
- S11/S21/S12/S22 selection (CONFIG)
- Input Port selection (CONFIG)
- Display parameters. T/R-θ, T/R-τ, |Γ| - θ, SWR, dBmV, dBm/Hz selection (FORMAT)
- Normalize, 1-port partial CAL, 1-port full CAL selection (CAL)
- User math definition, ON/OFF (DEFINE MATH)

To Modify the Display Scale

- Rectangular/Smith/Polar/Table selection (DISPLAY)
- COMMENT, Phase Expand (DISPLAY)
- Autoscale, Log Scale (SCALE REF)
- Superimpose, Storage (VIEW)
- Trace A/B ON/OFF (DISPLAY)
- Trace C/D ON/OFF (VIEW)
To Modify a Sweep

- Frequency/DC Bias/Power Sweep selection (MENU)
- SPOT frequency entry (MENU)
- Lin/Log Sweep selection (MENU)
- Partial Sweep/Program Sweep (MENU)
- Continuous/Single/Manual Sweep selection (MENU or TRIG/RESET)
- TRIG/RESET key initiates a sweep when the WAIT TRIG lamp is on while in the SINGLE sweep mode. In the CONT sweep mode pressing the TRIG/RESET key restarts the sweep.
- VIDEO FILTER performs four time averaging.

To Enter Data

Frequency, Resolution Bandwidth, and Input attenuator are set with the ✕ and ◊ keys or the numeric entry keys. When data is entered using the numeric entry keys, the ENTER, MHz/V or other unit keys must be used to terminate the entry.

To Use the Markers

- MKR→MAX, MKR→CENTER, MKR→REF, MKR→SPAN, NEXT PEAK (MKR→)
- Single Marker, Dual Marker, Cursor, Cursor with Marker selection (MODE)
- Noise Marker (MODE)

To Extend Functions

- User Defined Function (USER DEFINE)
- CATALOG, SAVE, GET, PURGE (SAVE/GET)
- PLOT, PRINT, DUMP (COPY)
- TALK ONLY, HP-IB Address (COPY or MORE)
- Impedance Equivalent Circuit Analysis (MORE)
- Partial Analysis (MORE)
- User Program edit/execution (PROGRAM)
- +, *, /, (, ) selection (MATH OPERATOR)
- SIN, COS, LOG, LN, SQR, MAX, MIN, complex, selectio

Blue key and Green key

- Blue key enables shiftkey operations while the blue key is set to on.
- Green key enables only single shiftkey operation after the green key is pressed.
**General Measurement Sequence**

With simple, easy, operation procedures, the HP 4195A can perform many types of measurement and analysis. The following basic operation sequence is common to all functions.

**CONFIG**

Press the CONFIG key to select between network, spectrum, impedance and S-parameter.

**PRESET**

Initialize the HP 4195A

**CONNECTIONS**

Connect the required accessories to the HP 4195A.

**CONTROLS**

Set up the HP 4195A as follows.

1. Press the FORMAT key to select dBm, dBmV, V and other measurement parameters.

2. Press DISPLAY key to select displayed format. (RECT, TABLE, SMITH, POLAR)

3. Press the SWEEP keys to set frequency range. (START, STOP, CENTER, SPAN).

**CALIBRATE**

Remove errors that can affect the quantity of the measurement.

**DEVICE UNDER TEST**

Connect the device under test (DUT).

**AUTOSCALE**

Optimize display setting.
Step 1: CONFIG

Select network, spectrum, impedance or S-parameter measurement function. Press CONFIG key for this selection.

Step 2: PRESET

When the PRESET key is pressed, the HP 4195A is initialized for network, spectrum, impedance or S-parameter measurements.

Initialization using the PRESET key

MEASURE group

FORMAT
T/R(dB)-θ (network/S21/S12)
dBm (spectrum)
|Z|-θ (impedance)
RL-θ (S11/S22)

PORT
R1 (spectrum)
T1/R1 (network/impedance/S11)
T2/R1 (S21), T1/R2 (S12), T2/R2 (S22)

TRACE group

DISPLAY
rectan X-A&B

SCALE REF
REF=0 dB, 10 dB/div (network)
REF=0 dBm, 10 dB/div (spectrum)

SWEEP group

Sweep mode
CONT (SINGLE in program)

Sweep type
LIN Sweep

Parameter
FREQ Sweep

Range
0.001 Hz – 500 MHz, sweep of 401 points

RBW
AUTO, 300 kHz

Measurement unit (lower box)

Source amplitude
0 dBm

Atten
20 dB

DC Bias
OFF

Settings not affected by the PRESET key

- CONFIG (Network/Spectrum/Impedance/S-parameter)
- User math function and user defined function settings
- User Program
- Data stored in the registers (except A and B)
Step 3: CONNECTIONS

The HP 4195A has two output and four input terminals which can be configured to perform different measurements. The following accessories are used with the hp 4195A.

Transmission Measurements
  - Power splitter or Transmission/Reflection Test set

Reflection Measurements
  - Transmission/Reflection Test Set

Spectrum Measurements
  - No special equipment required

Direct Impedance Measurements
  - HP 41951A Impedance Measurement Kit

S-parameter Measurements
  - Two Transmission/Reflection Test Sets

The following examples use one HP 41952A Transmission/Reflection Test Set, two HP 41952A Transmission/Reflection Test Sets, and the HP 41951A Impedance Measurement Kit.

HP 41952A Transmission/Reflection Test Set

Power splitters are normally used for transmission measurements. However, if reflection measurements are also performed, the HP 41952A Transmission/Reflection Test Set should be used.
When two HP 41952A Transmission/Reflection Test Sets are used, the DUT's forward and reverse transmission and reflection factors can be measured. These measurements are made without disconnecting and changing the direction of the DUT, making S-parameter measurement is an easy process.

Connect the HP 41951A Impedance Measurement Kit to the HP 4195A as shown in the figure. The 4195A can be used to measure impedance directly when used with the HP 41951A.
Step 4: CONTROLS

1. FORMAT

Select the display measurement parameters. When the FORMAT key is pressed, softkeys like those shown in the example to the left will be displayed. The softkeys displayed upon the screen depends on the existing setting. Select the required measurement parameters.

2. DISPLAY

Select displayed format from RECT, TABLE, SMITH and POLAR. When rectan A-B is selected, horizontal axis represents measured data A and vertical axis represents measured data B.

3. SWEEP

Select the measurement frequency range using the CENTER and SPAN keys, or by using START and STOP key. The keys are used to aid entry data. Note that the marker/cursor control knob cannot be used for this purpose.

Frequency, signal level, and DC bias level can be swept by selecting the proper softkey in the SWEEP MENU.

- Select either linear or log sweep.
- Select the sweep direction.
- Set the sweep points, steps, and time.
- Select the sweep parameter - frequency, signal level, or DC bias.
- Press this softkey to perform a programmed points sweep.
- Press this softkey to perform a partial sweep.
- Press this softkey to select the trigger mode - SINGLE, DUAL, or MANUAL.
Step 5: CALIBRATE

in the case of high frequency network and impedance measurement, the cables and test sets will greatly affect the measurement results. To obtain the most accurate measurements, it is necessary to reduce the errors caused by the measurement system. The HP 4195A analyzer is equipped with a variety of calibration modes to meet different measurement requirements.

Transmission Measurement
- Normalize
- Normalize + Isolation

Reflection Measurement
- Normalize (OPEN)
- 1-port Partial (OPEN, LOAD)
- 1-port Full (OPEN, SHORT, LOAD)

Impedance Measurements
- Calibration (CAL: OPEN, SHORT, LOAD)
- Compensation (COMPEN: 0S, 0Ω)

Calibration is not allowed during spectrum measurement. However, when a high loss probe is used, the User Math Function should be used to compensate for the loss.

Typical calibration procedures for different types of measurement will be described next.

Calibration Standard

Any types of calibration standard can be used for calibration but their calibrated data must be entered correctly. For example, if a 7 mm OPEN standard is used, 0.108pF of its capacitance value should be entered using the following procedure.

1. Press CAL key.
2. Press more 1/2 softkey.
3. Press CAL STD modify softkey.
5. Type OPENSTD=0, 108E-15 and press ENTER.

Use the same procedure to modify 0Ω and 50Ω standard values.
Transmission Measurement
- Normalization

Normalization is an easy and commonly used calibration method. It eliminates transmission measurement errors. Make a "thru" connection to establish the 0 dB and 0 degree references as shown in the figure, then perform the following procedure.

1. Press the CAL key.
2. Press the TRANS CAL menu softkey.
3. Press the NORMALIZE (THRU) softkey.
4. Press the THRU softkey.
5. Press the ENTER key.
6. Press the return softkey when the HP 4195A beeps and displays "THRU CAL completed."
7. Press the CORRECTION on/off softkey to enable correction (on/off).

After the preceding procedure is completed, the HP 4195A will display the measurement data normalized to the 0 dB and 0 degree reference established during the "Thru" calibration.

Normalization, however, does not eliminate errors such as leakage between a DUT's input and output. To eliminate such errors as this, perform the Isolation CAL in addition to the normalize CAL. To perform Isolation CAL, press the NORM & ISN CAL softkey instead of the NORMALIZE (THRU) softkey. To perform an "Isolation" CAL, disconnect the DUT and terminate the input/output terminal connected to the DUT with the correct characteristic impedance (50Ω or 75Ω).
Reflection Measurement
- 1 port Full CAL

To perform 1-port Full CAL, three reference terminations: "OPEN", "SHORT" and "LOAD" are required. With reference to these three terminations connected one by one to the measurement terminal, the HP 4195A can minimize the errors in reflection measurements. The calibration procedure for the 1-port Full CAL is as follows.

1. Press the CAL key.

2. Press the REFLECTN CAL menu softkey.

3. Press the ONE PORT FULL CAL softkey.

4. Press the OPEN softkey.

5. Connect the "OPEN" termination to the measurement port and press the ENTER key.

6. Press the SHORT softkey.

7. Replace the "OPEN" termination with the "SHORT" termination and press the ENTER key.

8. Press the LOAD softkey.

9. Connect the "LOAD" termination (50Ω or 75Ω termination) and press the ENTER key.

10. Press the return softkey.

11. Press the CORRECTION on/off softkey to enable correction (on/off).

Now the HP 4195A is ready to make calibrated reflection measurements.

Other than 1-port Full CAL, the HP 4195A can perform 1-port Partial CAL, and Normalize CAL for calibrating reflection measurements. These two calibrations require fewer terminations to perform, but produce less accuracy than performing the 1-port Full CAL.

Two independent 1-port Full CALs can be performed. This allows S11 and S22 measurements to be performed without recalibrating.
The HP 4195A and HP 41951A can be used to perform impedance measurements. A reflection coefficient measurement method is used when making impedance measurements. Therefore, the calibration procedure is almost the same as 1-port Full CAL and is performed as follows.

1. Press the CAL key.
2. Press the CAL menu softkey.
3. Press the ONE PORT FULL CAL softkey.
4. Press the OPEN softkey.
5. Connect the 0S (OPEN) termination to the 41951A's 7 mm connector and press the ENTER key.
6. Press the SHORT softkey.
7. Replace the 0S (OPEN) termination with the 0Ω (SHORT) termination and press the ENTER key.
8. Press the LOAD softkey.
9. Connect the 50Ω (LOAD) termination and press the ENTER key.
10. Press the return softkey.
11. Press the CORRECTN on/off to enable correction (on/off).

After the preceding procedure (Calibration) is performed, the HP 4195A will eliminate the measurement errors due to the HP 41951A Impedance Test Kit, and give the best impedance measurement accuracy at the 7 mm connector.

When a test fixture is connected to the 7 mm connector, error COMPENSATION for the test fixture is required. To compensate for fixture induced error, use the following procedure.

1. Press the CAL key.
2. Press the COMPEN menu softkey.
3. Press the 0S & 0Ω OFFSET softkeys.
4. Press the 0S softkey.
5. Connect the test fixture leaving its test terminal open, and press the ENTER key.
6. Press the 0Ω softkey.
7. Short the test terminal of the test fixture, and press the ENTER key.

8. Press the return softkey.

9. Press the CORRECTN on/off softkey to enable correction (on/off).

NOTE Compensation must be performed after Calibration is completed.

**Step 6: DUT**

Connect the DUT (device under test) and perform the measurement.

**Step 7: AUTO SCALE**

When the measurement results are too large or too small press the SCALE REF key to select the AUTO SCALE soft key (see figure). The scale of the display can be modified either by entering a new value with the REF LEVEL softkey the /DIV softkey, or by incrementing or decrementing the scale values using the \[ + \] and \[ - \] keys. This will adjust the scale of either trace A or B. Scale adjustment of the trace B display scale can be performed using the SCALE for A/B softkey.
Measurement Enhancements

The following functions enable the HP 4195A analyzer to be used more efficiently.

- Dynamic range
- Marker
- Recording of measurement data

The HP 4195A has many additional convenient functions. Refer to the APPENDIX and the HP 4195A's operation manual for the most complete description of the available functions.

Dynamic Range

The HP 4195A uses the following methods to improve its dynamic range (the difference between the maximum level of the input signal compared with the noise level).

1. Increasing Output Signal Level
   (Transmission Measurement Only)

The HP 4195A's signal level can be changed by entering a new value after pressing the AMPLITUDE key, or by using the \( \square \) and \( \square \) keys. The default value is 0.0 dBm, and can be increased to +15.0 dBm. This method is particularly effective with transmission/reflection test sets where the losses are high. Raising the signal level is equivalent to raising the input level and may cause waveform distortion. In this case, reduce the signal level so it does not exceed the allowable input value (RANGE value displayed on the CRT).

2. Changing the Input Attenuators

The input attenuators can be set by entering a new value after pressing the REF ATTN or the TEST ATTN keys, or by using the \( \square \) and \( \square \) keys. The 4195A's maximum allowable input level is the RANGE values displayed in the lower right corner of the CRT. For example, the figure shows RANGE values at the time when the R1 input attenuator is changed. These values mean that the maximum allowable input is +10 dBm for R1 and -20 dBm for T1.

If the input level exceeds the allowable input range, the displayed waveform could be distorted.
3. Changing the IF Range

The HP 4195A has 3 IF ranges - normal, low distortion, and high sensitivity - they are described below.

Normal Mode: This mode is normally used (default mode).

Low distortion Mode: This mode reduces distortion within the analyzer and is used for low distortion measurement.

High Sensitivity Mode: This mode reduces the internal noise of the analyzer, and is suitable for measurement of low level signals.

The IF range can be changed by pressing the ATTEN key and selecting the required softkey.

4. Narrowing the Resolution Bandwidth

The Resolution bandwidth (RBW) of the HP 4195A can be set in increments of 1 and 3 within the range of 3 Hz - 30 kHz. RBW can be set by entering a new value after pressing the RES BW key, or by pressing the [2] and [3] keys.

Note that the time increases as the dynamic range is increased by narrowing the IF bandwidth (i.e. lowering the value). When the RES BW is set to AUTO, the IF bandwidth is automatically set according to the frequency SPAN.

5. Using a Video Filter

When the VIDEO FILTER is set to ON, the measurement data is displayed after the average of four measurements taken. This operation reduces random noise and improves the effective dynamic range.
The Marker

The marker functions of the HP 4195A help to reduce the time needed to make complicated measurements. The following describes the basic operation of the marker functions (refer to Chapter 2 and beyond for more information). One marker is initially displayed. The frequency and the measurement data at the marker's position are shown in the upper right corner of the display.

Press the MKR→ key and the softkeys shown to the left will be displayed.

- **MKR→ MAX**
  - Moves the marker to the maximum value (peak) displayed.

- **MKR→ MIN**
  - Moves the marker to the minimum value displayed.

- **MKR→ CENTER**
  - Modifies the REF LEVEL value so that the marker is positioned at the reference level.

- **MKR→ NEXT PEAK**
  - Modifies the center value so that the marker is positioned at the center.

- **MKR→ more**
  - Moves the marker to the next highest peak.

- **MKR→ 1/2**
  - This makes it possible to use the marker on trace B.

"More" indicates that additional softkeys are available. These additional softkeys make it possible to use a marker's position as the START or STOP value, or to display the noise level at a marker's position.

When the MODE key is pressed the softkeys shown to the left will be displayed.

Normal Marker Mode

- **MKR→ OFF**
  - This causes an additional marker (•) - the sub-marker - to appear. It is used for zooming, partial sweep, partial analysis and deviation display (delta marker).

- **MKR→ CURSOR**
  - This causes the marker to toggle the cursor off/on the screen. The value of measurement data intersected by the cursor is displayed.

- **MKR→ CURSOR OFF**
  - This makes it possible to determine the cursor's position with reference to the marker position. This is convenient when searching for the -3 dB bandwidth.

- **MKR→ CURSOR OFF**
  - This turns the marker and cursor off. This function is used to reduce the measurement time.
Flexible Disc Drive (FDD)  The HP 4195A can save/recall the following files using its internal FDD.

- Instrument's setting state (STATE file)
  User Defined Function keys, User Math Function and Calibration data are also included.

- Program Point Table (TABLE file)

- Measurement Data (DATA file)

- User Program (ASP file)

All files are recorded in LIF format. The figure below shows the screen after the CAT softkey is pressed.

<table>
<thead>
<tr>
<th>NETWORK</th>
<th>CATALOG</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOLUME LABEL</td>
<td>AVAILABLE SECTOR</td>
</tr>
<tr>
<td>FLD195</td>
<td>2296</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FILE NAME</th>
<th>TYPE</th>
<th>SECTOR-FILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONS</td>
<td>ASP</td>
<td>1</td>
</tr>
<tr>
<td>LNE</td>
<td>ASP</td>
<td>2</td>
</tr>
<tr>
<td>SDE_IN</td>
<td>ASP</td>
<td>3</td>
</tr>
<tr>
<td>CALD10</td>
<td>ASP</td>
<td>4</td>
</tr>
<tr>
<td>TRAC1</td>
<td>ASP</td>
<td>5</td>
</tr>
<tr>
<td>TRAC2</td>
<td>ASP</td>
<td>6</td>
</tr>
<tr>
<td>TRAC3</td>
<td>ASP</td>
<td>7</td>
</tr>
<tr>
<td>TRAC4</td>
<td>ASP</td>
<td>8</td>
</tr>
<tr>
<td>V1556</td>
<td>ASP</td>
<td>9</td>
</tr>
<tr>
<td>V1566</td>
<td>ASP</td>
<td>10</td>
</tr>
<tr>
<td>NOA1</td>
<td>ASP</td>
<td>11</td>
</tr>
<tr>
<td>ONS file</td>
<td>ASP</td>
<td>12</td>
</tr>
<tr>
<td>FIS</td>
<td>ASP</td>
<td>13</td>
</tr>
<tr>
<td>FRON.CVR</td>
<td>ASP</td>
<td>14</td>
</tr>
<tr>
<td>CAL</td>
<td>ASP</td>
<td>15</td>
</tr>
</tbody>
</table>

CAT  Displays disc content.
SAVE  Records instrument setup, measurement data or user program.
RE-SAVE  Rewrites an existing file and saves it.
GET  Reads a recorded file.
PURGE  Deletes files. RECOVER is used to recall files deleted by mistake.
morc  Used with RECOVER, and to format a disc.

When the SAVE and RE-SAVE softkeys are selected, softkeys which indicate the type of file to be saved are displayed: STATE (instrument setting), PROG TABLE (program point table), DATA (measurement data), and PROGRAM (User program). One of these keys must be selected. When the stored files cannot be displayed on the screen, use the [ ] and [ ] keys or the NEXT PAGE and PREV PAGE keys to see the other files that are not being displayed on the present screen. When the GET, RE-SAVE and PURGE keys are pressed, the file name at the top is displayed within " ". If a desired file is moved to the top, it is no longer necessary to press the alphabetic keys.
Recording Measurement Data

Measurement data can be recorded by printing/plotting the data or storing it on the HP 4195A’s internal flexible disc drive (FDD).

Hard Copy

The HP 4195A’s display data can be copied to a printer or HP-GL compatible plotter. When the COPY key is pressed, the softkeys shown in the figure below will be displayed. To produce a hard copy, the analyzer must be in the TALK ONLY mode and the printer or plotter must be in the LISTEN ONLY mode.

- Start or stop the hardcopy function.
- Outputs screen data to plotter.
- Outputs measurement data, program lists, and CAT to the printer.
- Used in the TALK ONLY mode.
- Specifies how data is to be sent to the plotter.

DUMP Procedure

Use the following procedure to dump the current display to an HP-IB printer.

1. Connect the HP-IB printer to the HP 4195A. The printer must be set to LISTEN ONLY or LISTEN ALWAYS mode.
2. Press HP-IB define softkey.
3. Press Talk Only softkey. TLK lamp will turn on.
4. Press return softkey.
5. Press DUMP mode softkey.
6. Press COPY start softkey.
Chapter 2

Transmission Measurements with the HP 4195A

Basic Setup

The following measurement examples use a power splitter or the HP 41952A Transmission/Reflection Test Set (directional bridge or other setup can be used to suit your particular needs). The DUT used in these examples is 145 MHz bandpass filter.

Measuring Insertion Loss (Gain)

**CONFIG**

Press CONFIG key and select NETWORK

**PRESET**

Press the PRESET key to set the analyzer to its initial state.

**CONNECTIONS**

Set up the power splitter as shown in the figure.

**CONTROLS**

1. FORMAT T/R (dB) - θ (Initial state)
2. DISPLAY Rectan X-A&B (Initial state)
3. SWEEP CENTER 145 MHz
   SPAN 100 MHz

**CALIBRATE**

Perform the normalization calibration as described on page 1-10. Connect the output and the input cable to the DL together to create a thru connection. Press the HP 4195A CAL key, select the TRANS CAL menu, and press the NO MALIZE (THRU) softkey. Then press the THRU softkey and the ENTER/EXECUTE key to perform normalization.

After measuring a thru, press CORRECTN on/off softkey.

**DEVICE UNDER TEST**

Connect the DUT as shown in the figure, and press TRIG RST key to initiate a sweep.

**AUTOSCALE**

Press the SCALE REF key and select the AUTO SCAL softkey. The measurement result shown in the figure will then be displayed. The yellow trace (trace A) indicates the amplitude ratio of the two inputs (dB) and the light blue trace (trace B) indicates the phase difference (θ).

**Insertion Loss**

Use the MKR-MAX softkey to read the insertion loss at the frequency.
3 dB Bandwidth

The bandwidth can easily be determined with the marker and line-cursor.

1. Press the MODE key and select the oMKR&LCURS softkey.
2. Press the MKR→MAX softkey.
3. Press the Δ mode on/off softkey.
4. Press the more 1/2 softkey, then press the Δ VALUE entry softkey. DLCURS= will be displayed.
5. Enter -3 dB.
6. Set the WIDTH on/off softkey to on/off, the -3 dB bandwidth is displayed at WIDTH on the upper right corner of the screen.

Out-of-Band Rejection

Use the double marker mode (o&-MKRS) to determine out-of-band rejection.

1. Press the MODE key and select the o&-MKRS softkey.
2. Press the MKR→MAX softkey. • MKR moves to the MAX position.
3. Set the Δ mode on/off softkey to on/off the difference between o MKR and • MKR will be displayed on the screen.
4. Press the active oMKR/-MKR softkey to make the oMKR active.
5. Press the MKR→MIN softkey and the oMKR will seek the point of greatest insertion loss. The Δ T/R shown here is the out-of-band rejection (dB).

Passband Ripple

Passband ripple can be measured when a partial analysis function is used (The figure shows an example of a filter with ripple).

1. Enter the double marker mode (o&-MKRS) and alternately move the two markers to within the passband region with the rotary knob as shown in the figure to the left.
2. Press the SPECIAL FUNCTION MORE key, select the ANA RANGE softkey and the softkeys shown in the figure to the left will appear.
3. Press the STORE ANA RNG softkey, set the PART ANA on/off softkey to ON (on/off), and the Δ symbols appear at the bottom of the screen. The area indicated by these symbols is subjected to the partial analysis.
4. Make the o MKR active, press the MKR→MAX softkey, make also • MKR active and perform MKR→MIN. When the Δ mode is set to ON, the magnitude of the ripple is displayed as Δ T/R(dB).
Measuring Phase Characteristics

The HP 4195A's vector network measurement function makes it possible to measure phase characteristics at the same time as amplitude ratio measurements are performed. The phase measurement data is displayed on trace B, as shown in the figure to the left. Trace B data can be phase extended to more than ±180°. Also the phase unit can be changed to radians. In the next section, we will measure group delay, important in determining phase distortion.

Group Delay Measurement

Group delay (τ) is defined as follows.

\[
\tau = \frac{\Delta \theta \text{ (radian)}}{\Delta \omega} = \frac{\Delta \theta \text{ (°)}}{360° - \Delta F}
\]

ΔF is the frequency difference between the two frequencies and Δθ is the phase difference between the two frequencies. Thus the group delay is the degree of change in phase relative to a change in frequency. When the group delay is constant, the phase change is linear or there is no phase distortion. ΔF is called aperture and expressed as a percentage of measurement frequency range (SPAN frequency).

CONFIG NETWORK

PRESET Press the PRESET key.

CONNECTIONS Used the same connections used for measuring insertion loss.

CONTROLS

1. FORMAT Select T/R - τ
2. DISPLAY Rectan X-A&B (Initial state)
3. Sweep CENTER 145 MHz SPAN 20 MHz

CALIBRATE Setup the analyzer in thru connection and conduct a normalization calibration (same as insertion loss).

DEVICE UNDER TEST Connect the DUT as shown in the figure to the left, a press the TRIG/RST key.

AUTOSCALE Press the SCALE REF key, and select SCALE for A and B AUTO SCALE softkeys.

2-3
The default aperture value for group delay measurements is 0.5% of the frequency span width. It can be changed up to maximum of 100%. To set the aperture, press the FORMAT key, select the APERTURE entry softkey. When DFREQ= is displayed, enter a value between 0.5 and 100.

The figure to the left shows the effect of different aperture settings on group delay measurements. The trace will gradually become smoother as the aperture span width is increased from 0.5%, to 1% and then 2%. The aperture setting must be made with care when group delay measurements are performed, because it influences the measurement values and the resolution. When the aperture is increased, measurement resolution increases, but the accuracy along the lateral axis (frequency) decreases. In group delay measurements it is necessary to know at which aperture a measurement value was obtained.
Measuring Gain Compression

All measurements so far have been frequency swept measures. However, signal source output (OSC level and DC bias can also be swept and measured with the H 4195A. In the following the OSC level will be swept to obtain the maximum input level at which the output level does not change linearly (Gain Compression).

**CONFIG**

**NETWORK**

**PRESET**
Press the PRESET key.

**CONNECTIONS**
Set up as shown in the figure on the left.

**CONTROLS**
1. FORMAT T/R (dB) - θ (Initial State)
2. DISPLAY rectan X-A&B (Initial State)
3. SWEEP Press the MENU key and the PRMTR key
   Select OSC LVL (dBm).
   START -26 dBm
   STOP 0 dBm

**CALIBRATE**
Make a thru connection and perform a normalization calibration as described in the first setup in this chapter (insertion loss measurements).

**DEVICE UNDER TEST**
Connect the DUT (amplifier) as shown in the figure on the left, and press TRIG/RST key.

**AUTOSCALE**
Press the AUTO SCALE softkey.

The amplifier's characteristics are shown in the figure on the left. (The figure shows trace A only.) In this measurement, the spot frequency was 10 MHz. The frequency can be changed by pressing the SWEEP MENU key to select the PRMTR menu and using the SPOT FREQ softkey.

The 1 dB gain compression point of the amplifier can be obtained by the following operation sequence.

1. Press the MODE key and select the o MKR&LCUI softkey.
2. Press the MKR+MAX softkey.
3. Set the Δ mode on/off softkey to ON (on/off).
4. Press the more key and select the Δ VALUE en softkey. DCURS= will appear on the screen, enter and the input level at which the gain is reduced by 1 dB can be determined.
Chapter 3

Reflection Measurements with the HP 4195A

Chapter 2 demonstrated how to use the HP 4195A analyzer for transmission measurements. This chapter will describe how to use the HP 4195A to make reflection measurements, another important aspect of network analysis.

To measure reflection parameters, a directional coupler or bridge is required to pick up the reflected signal. A power splitter is also required to feed the signal to both the reference channel and the directional coupler (bridge). The setup is for this measurement is accomplished by connecting the HP 41952A/B Transmission/Reflection test set as illustrated in the figure at the left. The HP 85044A is used in the measurement examples given in this chapter.

The reflection characteristics of a device is normally measured in the form of return loss, reflection coefficient, and SWR. The relationship between these three factors is as follows.

\[
\text{Reflection Coefficient (} \Gamma \text{)} = \frac{\text{Reflection Voltage}}{\text{Input Voltage}}
\]

\[
= S_{11} \text{ (or } S_{22} \text{)} = \rho < \theta
\]

(\( \rho \) is the absolute value of \( \Gamma \), and \( \theta \) is phase angle)

Return loss (dB) = -20 log (\( \rho \))

\[
\text{SWR} = \frac{1 + \rho}{1 - \rho}
\]

An example of a reflection measurement is given next.
CONFIG

S11 of S-PARAMTR

Make sure to select S-parameter S11 with the CONFIG key. Parameters indicating reflection such as RL - $\theta$, $|\Gamma| - 1$, $\Gamma_x - \Gamma_y$, SWR - $\theta$ can only be used when S11 or S22 measurements are made.

PRESET

Press the PRESET key to initialize the analyzer.

CONNECTIONS

Connect the HP 41952A as shown in the figure on the left.

1. FORMAT RL - $\theta$ (Initial state)
2. DISPLAY rectan X-A&B (Initial state)
3. SWEEP CENTER 145 MHz
   SPAN 100 MHz

CALIBRATE

Perform 1-port Full Calibration as follows. Press the CAL key and select the S-PRMTR CAL menu softkey. The press the ONE PORT FULL CAL softkey. Connect an OPEN, SHORT and 50 $\Omega$ standard in sequence to the HP 85044A's test PORT and press the corresponding softkey and the ENTER/EXECUTE key. Then press the return softkey to display previous softkeys and press the COF RECTION on/off softkey.

DEVICE UNDER TEST

Connect the DUT (a 145 MHz bandpass filter) as shown in the figure and press TRIG/RST key.

AUTOSCALE

Press the SCALE REF key and select the AUTO SCAL softkey.

Measuring Return Loss

The figure to the left indicates the return loss for the 145 MHz bandpass filter with previously measured transmission characteristics.

Measuring Reflection coefficient

Press the FORMAT key and select the $|\Gamma| - \theta$ softkey to start the reflection coefficient measurement.

Measuring SWR

Press the FORMAT key and select the SWR - $\theta$ softkey to start the SWR measurement.
Measuring S-Parameters

S-parameters (S11, S21, S12, S22) characterize a two port device. Measurements of S-parameters can be made only by terminating the circuit with a resistor. This facilitates measurements of incident and reflection voltages as the circuit need not be opened or shorted, as in the case of h-parameters. These advantages make them specially suited to measure circuit systems at high frequencies. Each S-parameter can be defined as follows.

<table>
<thead>
<tr>
<th>S-parameter</th>
<th>Definition</th>
<th>Significance</th>
<th>Direction</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>S11</td>
<td>b1</td>
<td>Reflection</td>
<td>Forward</td>
<td>T1/R1</td>
</tr>
<tr>
<td>S21</td>
<td>b2</td>
<td>Gain (loss)</td>
<td>Forward</td>
<td>T2/R1</td>
</tr>
<tr>
<td>S12</td>
<td>b1</td>
<td>Gain (loss)</td>
<td>Reverse</td>
<td>T1/R2</td>
</tr>
<tr>
<td>S22</td>
<td>b1</td>
<td>Reflection</td>
<td>Reverse</td>
<td>T2/R2</td>
</tr>
</tbody>
</table>

S11 Measurements

S11 can be measured using the following procedure.

**CONFIG**
S-PRMTR, S11

**PRESET**
PRESET key

**CONNECTIONS**
Connect the HP 41952A as shown in the figure on the left.

**CONTROLS**
1. FORMAT \( \Gamma_x - \Gamma_y \) (When POLAR or SMITH is selected, it is automatically selected.)
2. DISPLAY POLAR
3. SWEEP CENTER 145 MHz
   SPAN 10 MHz

**CALIBRATE**
Perform a 1-port full CAL. Use the same procedure as described in the previous setup. Connect the standards to the left test set.

**DEVICE UNDER TEST**
Connect the DUT (145 MHz bandpass filter) as shown in the figure and press TRIB/RST key.

**AUTOSCALE**
Press the SCALE REF key and select the AUTO SCALE softkey. The figure to the left shows a POLAR display of the 145 MHz bandpass filter's S11 characteristics. Each point of the measurement trace indicate the phase and amplitude of the reflection coefficient \( \Gamma \) of the DUT. The display of the reflection coefficient in the center of the POLAR display is 0 which indicates that there is no reflection at all. The outermost circle is \( |\Gamma|=1 \) which indicates that all of the signal is being reflected back from the device (100% reflection).
To measure S22, press the CONFIG key and select the S22 softkey. Perform a 1-port full CAL, the same as for the S11 measurement. Connect the standards to the right test point. The characteristics shown in the figure on the left are displayed. Measuring the S21 or S12 can be performed by pressing respective softkey, however it would be necessary to first setup the DUT for a thru connection and then perform a normalize calibration.

Once the reflection coefficient \( \Gamma \) has been measured, the DUT’s impedance is easily determined. Use the same setup as used to measure the S11 and S22 parameters, so the display to Smith chart, then the R-X value, inductance (\( L \)) and capacitance (\( C \)) can be read from the Smith Chart by using the marker. The figure on the left shows the 145 MHz bandpass filter measured input impedance.
Chapter 4

Spectrum Measurements with the HP 4195A

In chapters 2 and 3 the relationship between input, output, and reflected waveforms were measured using a sine wave, in which only the amplitude or phase differed. In an actual circuit, pure sine waves are seldom realized due to the circuit non-linearity, (i.e. distortion or noise). Non-linear circuits are widely used for modulation and mixing. The HP 4195A’s spectrum analysis function is used to measure such non-linearity. This chapter will describe level, distortion and noise measurement using the HP 4195A’s spectrum analysis function.

Basic Setup

No external test sets are required to perform spectrum measurements. The DUT is connected directly to one of the HP 4195A’s four input ports: R1, R2, T1 or T2. An RF amplifier is used for the DUT in the examples. Modify the instrument setups shown to suit the DUT being measured. In the case of measurements involving amplifiers, use an attenuator if the amplifier output exceeds +20 dBm.

Switching Between Input Ports

Press the CONFIG key and select the PORT SELECT soft-key to switch the HP 4195A’s input ports. Then select port R1, T1, R2 or T2.

Level Measurements

The HP 4195A’s spectrum function measures the absolute value of the input level. In the following example we will measure an amplifier’s output level. The measurement sequence is as follows.

CONFIG SPECTRUM
PRESET

Press the PRESET key to set the analyzer to an initial state.

CONNECTIONS

Set up as shown in the figure on the left.

1. FORMAT dBm
2. DISPLAY rectan X-A&B (Initial state)
3. SWEEP CENTER 145 MHz
   SPAN 100 MHz
Press the SCALE REF key and select the AUTO SCALE softkey.

When the measurement results shown in the figure to the left are displayed, press the MKR+ key and select the MKR+MAX softkey. The marker (oMKR) on the trace moves to the peak point on the displayed trace. The absolute amplitude level (dBm), and the frequency at the marker position are displayed in the upper right corner of the screen. Press the ATTEN key of the input port being used to change the setting of the attenuator so the waveform displayed will be measured with the maximum dynamic range.

Measuring Noise Level

By using the HP 4195A's noise marker function the spectrum density of the normalized noise at a bandwidth of Hz can be read directly. The measurement is performed as follows:

1. Set the marker to the desired frequency.
2. Press the MKR+ key, and select the more 1/2 softkey to display the more 2/2 menu.
3. Set the NOISE on/off softkey to ON (on/off), to start reading the noise levels.
Measuring Total Harmonic Distortion

**CONFIG**
SPECTRUM

**PRESET**
Press the PRESET key to initialize the HP 4195A.

**CONNECTIONS**
Set up as shown in the figure on the left.

**CONTROLS**
1. FORMAT dBm (Initial state)
2. DISPLAY rectan X-A&B (Initial state)
3. SWEEP START 100 MHz
   STOP 450 MHz

**AUTOSCALE**
Press the SCALE REF key and select the AUTO SCALE softkey.

Operate the marker as described in the following sequence.

1. Press the MKR→ key and select the MKR→MAX softkey.
2. Type R1=MKRA and press the ENTER key. The amplitude value of the fundamental is assigned to variable register R1.
3. Select the NEXT PEAK softkey.
4. Type R2=MKRA and press the ENTER key. The amplitude of the second harmonic is assigned to register R2.
5. Select the NEXT PEAK softkey.
6. Type R3=MKRA and press the ENTER key. The amplitude of the third harmonic is assigned to register R3.
7. Type as follows and press the ENTER key.

\[
\text{SQR} \left(10^\pi (R2-2/20)+10^\pi (R3-2/20))/10^\pi (R1/20)-100\right)
\]

The ratio of distortion (%) of the second and third harmonic is displayed at the bottom of the screen.

Operations 1 – 7 above can be programmed to be executed by using the user program function. Refer to the example given in APPENDIX B.
The HP 4195A can switch between the four input ports to spectrum measurements, eliminating the need for reconnecting to different points on a circuit. The HP 4195A can display a maximum of four traces simultaneously. The setup shown on the left permits simultaneous display of two spectrum waveforms.

Proceed as follows.

1. Press the PRESET key, the CONFIG key, and select the SPECTRUM softkey. The measurement result made by R1 port is displayed. R1 Port is selected when the analyzer is initialized.

2. Press the DISPLAY key, and set the TRACE B on/off softkey to ON (on/off).

3. Type B=A and press the ENTER key. The measurement data in register A is transferred to register B, and the result is displayed as trace B (light blue).

4. Press the CONFIG key, select the PORT SELECT softkey, and press the T1 softkey to make port T1 the measurement port.

5. The signal input to port T1 is displayed as trace C (yellow). At this time, note that trace A looks like it being overwritten on every sweep, but actually it maintains the same data.

6. Press the SCALE REF key and input the value with the REF LEVEL or /DIV softkeys or modify the value with the [ ] and [ ] keys to display trace A in the top half of the screen. Then press the SCALE for A/B softkey and use the same manner to display trace B in the lower half of the screen.

Note: Traces C and D can be used when 3 or 4 trace displays are required. Refer to APPENDIX C, page C-3, for four trace display.
Chapter 5

Impedance Measurements with the HP 4195A

When the HP 41951A impedance test kit is used with the HP 4195A, a devices impedance parameters between 100 kHz and 500 MHz (|Z|, |Y|, θ, R, X, C, L, Q, D etc.) can be displayed directly. In this chapter, a crystal resonator with a resonant frequency of 80 MHz will be measured.

Basic Setup

To perform impedance measurements, the HP 41951A impedance test kit and a test fixture suitable for the DUT are required. The HP 16092A clip test fixture is used in this example.

CONFIG

IMPEDANCE

PRESET

Press the PRESET key to initialize the 4195A.

CONNECTIONS

Connect the HP 41951A adaptor as shown in the figure. Do not connect the HP 16092A test fixture.

CONTROLS

1. FORMAT |Z|-9 (initial state)
2. DISPLAY rectan X-A&B (initial state)
3. SWEEP CENTER 80.0014 MHz
   SPAN 10 kHz

CALIBRATE

Calibration must be performed to remove measurement errors induced by the 41951A test kit. Perform a 1-port full CAL by connecting 0 Ω, 0 S, 50 Ω standards respectively to the 7 mm connector of the Impedance Test Adapter.

COMPENSATION

To obtain the best accuracy, the test fixture residuals should be compensated for. Connect the HP 16092A test fixture and perform OPEN/SHORT offset compensation.

DEVICE UNDER TEST

Connect the DUT to the HP 16092A and press TRIG/RST key.

AUTOSCALE

Press the SCALE REF key and select the AUTO SCALE softkey. The measurement results are displayed as shown in the figure to the left. Trace A displays the absolute value of impedance |Z| and trace B displays the phase angle θ.
With the equivalent circuit function of the HP 4195A, parameters L, R, Ca and Cb of the crystal resonator's equivalent circuit are automatically calculated by the HP 4195A. The calculation is performed using the measured impedance data.

Proceed as follows to perform the calculation.

1. Press the MORE key in the SPECIAL FUNCTION section, and select the EQV CKT softkey.

2. Press the CKT E softkey. (Because the DUT is a crystal. In case of an inductor, select CKT A or B. In case of a capacitor, select CKT D.)

3. When the CALC EQV para softkey is pressed, a beep generated to indicate that the equivalent circuit values displayed in the lower part of the screen (as shown in the figure on the left).

The equivalent circuit analysis function is used to simulate impedance and admittance frequency-dependent characteristics. Proceed as follows.

1. Select the EQV para entry softkey.

2. Enter the value of each equivalent circuit parameter and press the return softkey.

3. When the SIMULATE f-char softkey is pressed, the HP 4195A beeps as the simulated frequency characteristics (traces C and D) are displayed with traces A and B (and D display are simulated results, A and B are actual measurements).

Turn off traces A and B to more clearly view traces C and D. To turn off traces A and B, press the DISPLAY key and set the TRACE A on/off and TRACE B on/off softkeys OFF (on/off). To turn off traces C and D, press the VIEW key and set the VIEW C on/off and VIEW D on/off softkeys to OFF (on/off).
APPENDIX A

INTERNAL REGISTERS

An HP 4195A "Internal Register" is a memory location to or from which the user can write or read numeric data. By using these registers, the HP 4195A can easily solve various measurement and computational problems. Refer to APPENDIX F for the internal register listing.

Registers Types

The 4195A has the following four types of registers:

<table>
<thead>
<tr>
<th></th>
<th>Array Register</th>
<th>Single Register</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Contains 401</td>
<td>Contains only one element (value)</td>
</tr>
<tr>
<td></td>
<td>elements (values)</td>
<td></td>
</tr>
<tr>
<td><strong>General Purpose</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open to users. The HP 4195A will not change the data in these registers.</td>
<td>E – J, RA – RF</td>
<td>R0 – R99</td>
</tr>
<tr>
<td><strong>Limited Purpose</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opened to users but their application are limited. The HP 4195A may change the data or may be changed by the data in these registers.</td>
<td>Examples: A – D, MA, MB, X</td>
<td>Examples MKR, MKRA, CENTER</td>
</tr>
</tbody>
</table>

Data Storage

The typical applications for the registers are the storage of measurement data. Array Registers C thru J and RA thru RJ are suitable to this purpose because each of them has a maximum of 401 elements. To store or recall the data, use register operation described below. Also, Example 4) shows an example of storing/recalling the data.

Register Operations

Mathematical operations can be performed using the registers. The syntax for operations is similar to that found in BASIC.

Example)

\[ A = I + J \]

<table>
<thead>
<tr>
<th>Result</th>
<th>Source</th>
<th>Destination</th>
<th>Arguments</th>
</tr>
</thead>
</table>

Register operations can be performed from the front panel, in a User Program, in a User Defined Function and in with User Math. During front panel execution, the ENTER key should be pressed to execute the operation. Front panel execution is simple, but note that when the SWEEP mode is set to CONT, the data in registers A and B are refreshed during each sweep. The following are examples of array registers operations and marker-related single registers definition.
Example 1) Mathematical Operation

Mathematical operation can be performed for either a) Individual element of array register or b) Entire element of array register.

CONFIG .... SPECTRUM
PRESET
TRIG/RST..... SINGLE mode


a) Elements within array register can be changed individually.

A(100) = -15 ENTER

b) Entire register array can be changed very simply.

A = -15 ENTER

Example 2) Simulation of two filters connected in series

A = C + D ENTER

Example 3) Simulation of transmission characteristic of RC filter

\[ T(\omega) = 20 \log \left( \frac{V_2}{V_1} \right) = 20 \log \left( \frac{1}{\sqrt{1+(\omega RC)^2}} \right) \]

HP 4195A Register Operation:

A=20+LOG(1/\text{SQRT}(1+(2*\text{PI}*X\times1E3+1E-10)*+2)) ENTER

Where PI: Single Register containing π value
X: Array register containing freq.values
Example 4) Using register E as a waveform memory

CONFIG: SPECTRUM

Marker/Cursor Related Registers

E = A

CONFIG: NETWORK

SWEEP Mode: SINGLE

B = E

Autoscale for B
APPENDIX B

USER PROGRAM

User Programs can control almost all HP 4195A functions. These User Programs enable automated measurements, complicated calculations and analysis to be performed quickly and easily. How to write a program, and sample programs are covered next.

How to Write a User Program

Writing User Programs is easy. User programs are created and modified in the "Editor mode". Once you are in the editor, the HP 4195A will automatically generate the command in the program when you push the function keys. You create a User Program in the same way you would perform a manual measurement. The following example is a procedure to write and run a simple program.

Sample Procedure for making and running a program:

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Key Strokes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Scratch the current program</td>
<td>PROGRAM SCRATCH ENTER</td>
</tr>
<tr>
<td>2. Select the Editor</td>
<td>EDIT EXECUTE</td>
</tr>
<tr>
<td>3. Select Spectrum mode</td>
<td>CONFIG SPECTRUM ENTER</td>
</tr>
<tr>
<td>4. Preset</td>
<td>PRESET ENTER</td>
</tr>
<tr>
<td>5. Select the input port</td>
<td>PORT SELECT SPECTRUM T1 ENTER</td>
</tr>
<tr>
<td>6. Select frequency</td>
<td>START 50MHZ ENTER</td>
</tr>
<tr>
<td></td>
<td>STOP 250MHZ ENTER</td>
</tr>
<tr>
<td>7. Trigger</td>
<td>TRIG/RST ENTER</td>
</tr>
<tr>
<td>8. Move the marker to the higher peak</td>
<td>MKR→ menu oMKR MKR→ MAX ENTER</td>
</tr>
<tr>
<td>9. End the program</td>
<td>PROGRAM END ENTER</td>
</tr>
<tr>
<td>10. Quit the Editor</td>
<td>QUIT EDITOR</td>
</tr>
<tr>
<td>11. Run the Program</td>
<td>RUN</td>
</tr>
</tbody>
</table>
Sample Programs

The following programs show typical applications of user Programs. Although the key strokes are not given for these programs, commands are entered by pressing the related keys. Also refer to APPENDIX E where the commands are given with corresponding softkeys.

Example 1) Alternate Transmission/Reflection measurement

This program changes the measurement port for every sweep and is suitable for the measurement setup given on page 3-2.

10 FNC1  // Select Network Measurement
  20 RST  // Preset the 4195A
  30 CENTER=145 MHZ  // Set center frequency to 145MHz
  40 SPAN=100 MHZ  // Set span frequency to 100MHz
  50 PORT1  // Select port T1/R1 for reflection measurement
  60 SWTRG  // Initiate a sweep (Sweep Trigger)
  70 PORT2  // Select port T2/R1 for transmission measurement
  80 SWTRG  // Initiate a sweep (Sweep Trigger)
  90 GOTO 50
  100 END

Example 2) SIN wave, COS wave display

10 SWM2  // Select sweep mode to SINGLE
  20 NOP=360  // Set number of displayed points to 360
  30 FOR R0=1 TO 360
  40 A(R0)=SIN(R0)  // Substitute SIN value for the R0th element of A register
  50 B(R0)=COS(R0)  // Substitute COS value for the R0th element of B register
  60 NEXT R0
  70 SCL1  // Scale for A
  80 AUTO  // Autoscale
  90 SCL2  // Scale for B
  100 AUTO  // Autoscale
  110 END

When you run the program, SIN and COS waves are displayed on the CRT. It will take more than 1 min. to complete this program, because traces A and B are re-written each time as are the A and B registers. The following program shortens the time by using register operations. This program also uses multi-statement technique to shorten execution time and program length.

10 SWM2;NOP=360
  20 FOR R0=1 TO 360
  30 RA(R0)=SIN(R0);RB(R0)=COS(R0)
  40 NEXT R0
  50 A=RA;B=RB;SCL1;AUTO;SCL2;AUTO
  60 END
Example 3) 3 dB Bandwidth of the filter

This program measures and displays the 3dB Bandwidth value. Refer to pages 2-1 and 2-2 for measurement sequence.

10 FNC1 ! Select Network Measurement
20 RST ! Preset the 4195A
30 CENTER=145 MHZ,SPAN=100 MHZ
40 SWTRG ! Initiate a sweep (Sweep Trigger)
50 MCF4 ! Select marker and line cursor mode
60 MKMX ! Marker to MAX
70 DELT1 ! Delta mode ON
80 MKACT0 ! Enable line cursor
90 DLCURS=-3 ! Move line cursor to -3dB down from marker
100 R0=WID ! Input -3dB bandwidth into R0
110 DISP '3 DB BANDWIDTH (HZ)'='R0
120 END

Example 4) Total Harmonic Distortion

This program calculates 2nd and 3rd harmonic distortion. Refer to page 4-1 for measurement setup and sequence.

10 MCF1 ! Select single marker mode
20 MKMX1 R1=MKRA ! Marker to MAX (Fundamental)
30 NRTKP1 R2=MKRA ! Search the next peak (2nd Harmonics)
40 NRTKP1 R3=MKRA ! Search the next peak (3rd Harmonics)
50 R0=SQR((10**2*R2/20)+10**((2*R3/20))/10**((R1/20)*100
60 DISP 'THD (%)'='R0
70 END

SPECTRUM

THD (%) = 0.05566127%05E-01

DIV DIV CENTER 300 000 000.000 Hz
10.00 10.00 SPAN 300 000 000.000 Hz
THD (%) = 0.05566127%05E-01

B-3
Example 5) Go/No-Go Testing with Limit Line

This program specifies upper/lower limit lines +20 dB apart from the actual measurement value (Line No. 40 ~ 100), and checks if the measured value exceeds the limit (Line No. 120 ~ 240). Decision is made by checking if register B (not displayed), which contains difference between the actual value and limit value, has any negative value (Line No. 130 ~ 160).

10!
20: GO/NO-GO WITH LIMIT LINE
30:
40 FNC1
50 RST
60 CENTER=145 MHZ; SPAN=50 MHZ; NOP=51; OPB0
70 SWTRG
80 SPSTR; DPA0; AUTO
90 SCL1; R0=REF; R1=DIV; ECL2; R0=DIV; R1
100 C=A+20; D=A-20; DPA1; SPD1; SPD1; MKCRZ
110!
120 SWTRG
130 B=C-A; MKMN
140 IF MKRB<0 THEN GOTO 210
150 B=A-D; MKMN
160 IF MKRB<0 THEN GOTO 210
170!
180 DISP "PASS"
190 GOTO 120
200!
210 BEEP
220 DISP "*** FAIL *** PRESS CONT"
230 PAUSE
240 GOTO 120
250 END
APPENDIX C
USER DEFINED FUNCTION

The HP 4195A's User Defined Function can be used to define a softkey which will perform a sequence of key strokes. This reduces key strokes needed to obtain Total Harmonic Distortion, for instance. Five softkeys can be individually defined. In addition, three SE (Sweep End Function) softkeys can be used for operations at the end of every sweep. These SE softkeys are used for applications such as Signal Tracking and Alternate Sweep. The following example shows how to define a "3 dB Bandwidth" softkey.

Defining Procedure:

1. Press USER DEFINED key.
2. Press the DEFINE FCTN softkey.
3. Select the FCTN1 softkey.
   DF1"
   will be displayed at the bottom of the CRT.
4. Define a softkey to obtain the -3 dB bandwidth. Refer to page 2-2 for the required key strokes. Each command should be separated by a ";".
5. The following commands should be displayed.
   DF1" MCF4;MKMX;DELT1;DLCURS=-3;WIDTH1"
6. Press the ENTER key.

Notes:

1. To define SE softkeys, press SWP END FCTN softkey and then press DEFINE SE  fctn softkey.
2. Up to 85 characters can be defined for one softkey.
3. The syntax for User Defined Functions is the same as that of a user Program. This means that execution commands such as RST and SWTRG cannot be used in combination with other commands.

Execution:

Preset the HP 4195A and measure the transmission characteristics of the bandpass filter. Refer to page 2-1 for the measurement procedure. Press the USER DEFINE key and the softkey numbered "1". The -3 dB bandwidth is displayed as the WIDTH value.
Entering Key Labels:

Any key label (name) can be assigned to a User Defined key. The following procedure shows how to label softkey #1 as "3DB BW".

1. Press the USER DEFINE key.

2. Press the KEL LBL entry softkey.

3. Select the fctn 1 KEY LBL softkey

   LBL1"

   will be displayed.

4. Input the following using alphanumeric keys

   LBL1" 3DB BW"

   Up to 15 characters can be used for a label.

5. Press the ENTER key.

Examples

Example 1) Filter Parameters

   DF1"MCF1;MKMX"
   DF2"MCF4;MKMX;DELT1;DLCURS=-3;WIDTH1;R2=WID;R0=LCURSL;R1=LCURSR"
   DF3"MCF2;MKACT1;MKMX;DELT1;MKACT0;DMKR=20 KHZ"
   DF4"MCF4;MKMX;DELT1;DLCURS=-60;WIDTH1;R3=WID/R2;DISP 'SHAPE FACTOR=',R3"
   DF5"MCF2;MKR=R0;5MKR=R1;ARSTR;ANA1;LMX(A);ARSTR;MKACT1;MKMX;MKACT0;MKMN;ANA0"

   LBL1"INSERTN LOSS "
   LBL2"3dB BW"
   LBL3"OUTBAND REJEC "
   LBL4"SHAPE FACTOR "
   LBL5"PASSBAND RIPPLE "

Example 2) Signal Track (Application of Sweep End Function)

   DFA"MKMX;MKCTR"

   LBLA"SIGNAL TRACK "
Example 3)  Alternate Transmission/Reflection Measurement (Application of Sweep End Function)

DFA"SPCHG;PORT1;SEFA0;SEFB1"
DFB"SPCHG;PORT2;SEFB0;SEFA1"

Example 4)  Four-channel Spectrum Measurement (Defined by User Program)

If the User Defined Functions are defined by a User Program, there are several merits for the user.

1)  Setup of the 4195A can be made easily.

2)  User Defined Functions can be stored as an ASP file on the flexible disc. This saves disc space when compared with a STATE file.

3)  User Program Editor can be used to edit keys.

When you run the following program, instrument setup and key definition are made in one time.

10  FNC2
20  RST
30  CENTER=145 MHZ ; SPAN=100 MHZ ; DIV=40 ; SCL2 ; DIV=40 ; DFB1 ; SPC1 ; SPD1
100  DF1"PORT1 ; SCL1 ; REF=0 ; C=A-200 ; DMA=MA ; DMB=B ; MTHA1 ; MTHB1 ; PRMA' R1""
110  DFZ"PORTZ ; SCL2 ; REF=100 ; D=B-200 ; DMB=MA ; DMA=A ; MTHA1 ; MTHB1 ; PRMB' T1""
120  DF3"PORT3 ; SCL1 ; REF=200 ; C=A+200 ; DMA=MA ; DMB=B ; MTHA1 ; MTHB1 ; PRMA' RZ""
130  DF4"PORT4 ; SCL2 ; REF=300 ; D=B+200 ; DMB=MA ; DMA=A ; MTHA1 ; MTHB1 ; PRMB' T2""
140  DF5"""
150  LBL1"R1"
160  LBL2"T1"
170  LBL3"RZ"
180  LBL4"T2"
190  LBL5"""
210  SUM1;UNITA"DBM";UNITB"DBM"
220  END

SPECTRUM
<table>
<thead>
<tr>
<th>REF</th>
<th>B</th>
<th>GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

(CDM | 1DBM | 1 | 1) -10.5225 DBM
APPENDIX D

USER MATH FUNCTION

The User Math Function of the HP 4195A enables the displayed data to be as a function of the measurement data. This facilitates applications which require real-time calculations such as unit conversion, MAX HOLD, and compensation of external attenuators. The figure below shows an example of a +15 dB offset being applied to the measurement value by using the User Math function.

Defining Procedure:

1. Press the DEFINE MATH key.
2. Press the DEFINE MATH A softkey.
   
   DMA=

   is displayed on the bottom of the CRT.

3. Input the following using the alphanumeric keys.
   
   DMA=MA+15

   Where DMA (Defined Math A) means displayed data and MA means measured data.

4. Press the ENTER key.
Execution:

Press the DEFINE MATH key and set the MATH->A on/off softkey to ON (on/off). "Math" is displayed on the top line of the CRT and the displayed data is offset by +15 dB.

Sample Definitions

Example 1) Max Hold

\[ DMA = MA \]
\[ DMB = \max(\text{MA, B}) \]

( Display B ON )

Example 2) Averaging

Averaging 4 times:

\[ DMA = A \cdot 3/4 + MA/4 \]

Averaging 128 times

\[ DMA = A \cdot 127/128 + MA/128 \]
Example 3) 75Ω Environment Measurement

When the HP 4195A is used with an HP 11852B Minimum Loss Pad (5.7 dB Loss) to convert 50 Ω to 75 Ω, it is necessary to set dBm referenced to 75 Ω. Following equation converts measured dBm (in 50 Ω) to dBm in 75 Ω.

\[ \text{DMA} = \text{MA} + 5.7 \]

Example 4) Vp-p Measurement

While the HP 4195A measures voltage in Vrms, it can be converted into Vp-p using the following equation.

\[ \text{DMA} = 2 \times \sqrt{2} \times \text{MA} \]

Also unit should be changed as follows.

UNITA“Vp-p”
APPENDIX F
INTERNAL REGISTER/COMMAND LISTING

The following are frequently-used registers and commands. This listing does not cover all registers and commands used in the HP 4195A. Refer to APPENDIX E for complete listing of softkey-related registers and commands.

**ARRAY REGISTERS**

A  Measurement data register displayed on the CRT as a bright yellow trace.
B  Measurement data register displayed on the CRT as a bright cyan trace.
C  Superimpose data register. Displayed when View C is set to ON.
D  Superimpose data register. Displayed when View D is set to ON.
E - J, RA - RF  General purpose registers.
MA  Measurement data registers for the User Math Function.
MB  Measurement data registers for the User Math Function.
X  Contains the sweep point data.

**SINGLE REGISTERS**

ATR1  Contains R1 attenuator value.
ATR2  Contains R2 attenuator value.
ATT1  Contains T1 attenuator value.
ATT2  Contains T2 attenuator value.
BTM  Contains the bottom of the display scale.
CENTER  Contains CENTER value.
DFREQ  Contains APERTURE value.
DIV  Contains scale division value.
DLCURS  Contains the difference value between MKRA and LCURS. Refer to page A-3.
DMKR  Contains the difference value between MKR and SMKR. Refer to page A-3.
DMKRA  Contains the difference value between MKRA and SMKRA. Refer to page A-3.
DMKRB  Contains the difference value between MKRB and SMKRB.
LCURS  Contains the LINE CURSOR position (height) value. Refer to page A-3.
LCURSL  Contains the value of left most intersect point. Refer to page A-3.
LCURSR  Contains the value of right most intersect point. Refer to page A-3.
MANUAL  Contains manual sweep point value.
MKR  Contains the value of o MARKER position in horizontal axis. Refer to page A-3.
MKRA  Contains data A value specified with the o MARKER. Refer to page A-3.
MKRB  Contains data B value specified with the o MARKER.
NOP  Contains number of sweep points.
PI  Contains value of 3.14159265359.
QV  Contains Q value.
R0 ( - R99)  General purpose single registers.
RBW  Contains RBW value.
REF  Contains the top of the display scale.
SMKR  Contains the value of * MARKER position in vertical axis. Refer to page A-3.
SMKRA  Contains data A value specified with the * MARKER. Refer to page A-3.
SMKRB  Contains data B value specified with the * MARKER.
SPAN  Contains SPAN value.
START  Contains START value.
STOP  Contains STOP value.
WID  Contains width value (=LCURSR-LCURS). Refer to page A-3.
Z  Contains numeric value resultant from front-panel mathematical operation.
COMANDS

ANA1/ANA0  Partial Analysis ON/OFF.
ARSTR  Store Partial Analysis range.
AUTO  Autoscale to the active scale.
CMT  Comment.
COPY  Starts or aborts hardcopy operation.
CORR1/CORR0  Correction ON/OFF.
DELT1/DELT0  Delta (Δ) mode ON/OFF.
DF1 (− DF5)  Defines User Defined Function #1 (− #5).
DFA (− DFC)  Defines the Sweep End Function #A (− #C).
DISP  Displays a character string, R0 − R99 register data or both.
DMA (DMB)  Defines User Math A (or B) equation.
DPA1/DPA0  Trace A ON/OFF.
DPB1/DPB0  Trace B ON/OFF.
DSP1 (− DSP5)  Selects the rectan X-A&B (or other) display format.
FNC1  Selects the Network configuration.
FNC2  Selects the Spectrum configuration.
FNC3  Selects the Impedance configuration.
FNC4 − FNC7  Selects the S-Parameter configuration.
GPP1 (− GPP4)  Selects T/R-θ (or other) format.
HADM1/HADM2  HP-IB Addressable/Talk-only.
IMP1 (− IMP12)  Selects the |Z|−θ (or other) format.
LBL1 (− LBL5)  Defines the User Defined Function #1 (− #3) softkey label.
LBLA (− LBLC)  Defines the Sweep End Function #A (− #C) softkey label.
LMN  Moves the markers to the local-minimum points.
LMX  Moves the markers to the local-maximum points.
MCF0  Turns MARKER function off.
MCF1  Selects the o MARKER mode.
MCF2  Selects the o and * MARKERS mode.
MCF3  Selects the LINE CURSOR mode.
MCF4  Selects the o–CURS mode.
MKACT0  Selects the active marker to * MARKER.
MKACT1  Selects the active marker to o MARKER.
MKACT2  Selects the LCURS to active.
MKCR1  Selects the MARKER or LCURS reading object to data A (for A).
MKCR2  Selects the MARKER or LCURS reading object to data B (for B).
MKCTR  MKRS + CENTER
MKEXP  MKRS + SPAN
MKMN  MKR + MIN
MKMX  MKR + MAX
MKREF  MKR + REF
MKSP  MKR + STOP
MKST  MKR + START
MTHA1/MTHA0  Math A ON/OFF.
MTHB1/MTHB0  Math B ON/OFF.
NXTPK  NEXT PEAK.
PORT1 (− PORT5)  Selects input port.
PRMA (PRMB)  Enters the User Math A (or B) label.
RST  PRESET.
OVAL  Calculates C value at the LINE CURSOR.
REV?  Displays the firmware revision code.
SAP1 (− SAP6)  Selects dBm (or other) format.
SCL1  Selects the active scale change data to data A (SCALE for A).
SCL2  Selects the active scale change data to data B (SCALE for B).
SCL3  Selects the active scale change data to data B (SCALE for B).
SCT1 (SCT2)  Selects the linear (or log) scale display.
SEFA1/SEFA0  Sweep End Function #A ON/OFF.
SEFB1/SEFB0  Sweep End Function #B ON/OFF.
SEFC1/SEFC0  Sweep End Function #C ON/OFF.
SPC1/SPC0  View C ON/OFF.
SPCH0  A,B ↔ C,D
SPD1/SPD0  View D ON/OFF.
SPI1 (− SPI4)  Selects RL-θ (or other) format.
SPSTR  STORE A,B → C,D.
SRSTR  Store Partial Sweep range.
SWM1  CONT sweep mode.
SWM2  SINGLE sweep mode.
SWM3  MANUAL sweep mode.
SWP1 (− SWP5)  Selects Frequency (or other) sweep.
SWR1/SWR0  Partial Sweep ON/OFF.
SWT1 (SWT2)  Selects linear (or log) sweep.
SWTRIG  Sweep Trigger (→TRIG/RST).
TRIG1/FRIG2  Trigger mode int (ext).
TRIG  Triggers when trigger mode is set to ext.
UNITA (UNITB)  Enters User Math A (or B) unit label.
WIDTH1/WIDTH0  WIDTH ON/OFF.
VFTR1/VFTR0  Video Filler ON/OFF.
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May, 1990
Reorder No. or Manual Part No.
5950-2942

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Printed in Japan

Manufacturing Part No.
5950-2942