Semiconductor Parameter Analyzer

Quick Start Guide

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Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

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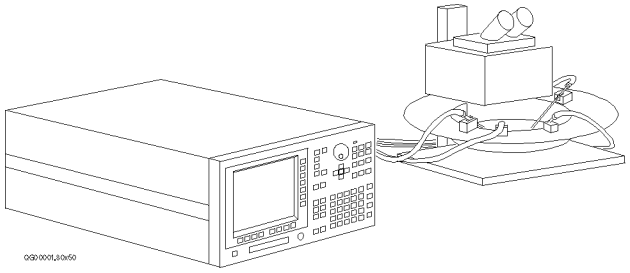
HP 4155B and HP 4156B

The HP 4155B Semiconductor Parameter Analyzer and HP 4156B Precision Semiconductor Parameter Analyzer are fully, automatic, high performance instruments designed to measure, display graphically, and analyze the dc parameters and characteristics of semiconductor devices such as diodes, transistors, ICs, solar cells, and wafers during the fabrication process. You can evaluate device design, process design, production line, and so on by using the HP 4155B/4156B.

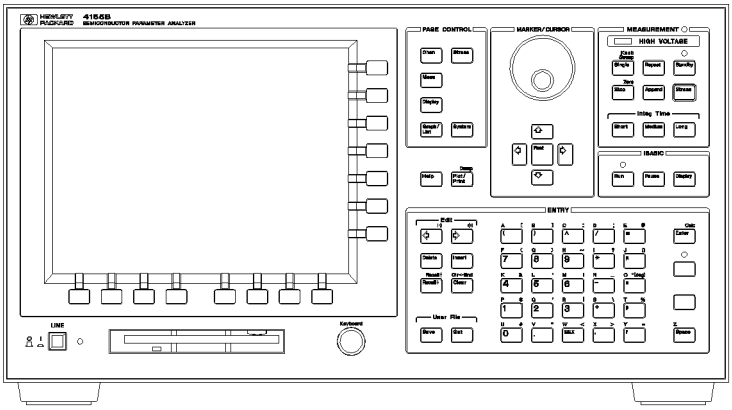
In semiconductor research and development laboratories, the HP 4155B/4156B provides precise characteristics evaluation, which is an important step in the development of new high performance devices, and gives design engineers an easy to use method of device parameter acquisition.

On the production line, the HP 4155B/4156B provides real-time feedback on wafer evaluation to improve the semiconductor process and to increase production yields.

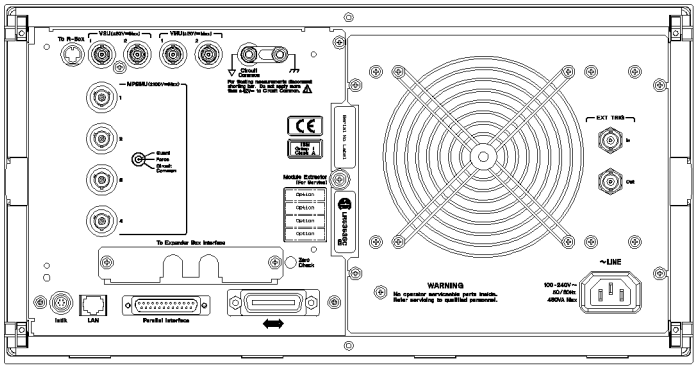
For semiconductor end users, the HP 4155B/4156B is ideal for circuit design applications and incoming inspection.



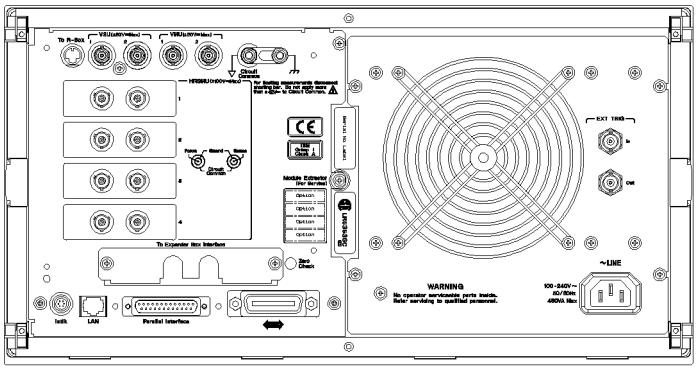
HP 4155B/4156B At a Glance



LINE switch	For applying power.
Flexible disk drive	For inserting a 3.5-inch diskette, which can be used for mass storage.
Keyboard interface	For connecting keyboard. So, you can control HP 4155B/4156B from keyboard as well as from the front-panel keys.
Primary softkeys	For changing pages and secondary softkey menu.
Secondary softkeys	For selecting variable names and alternatives, and changing items.
Rotary knob	For changing values, moving a marker, and performing knob sweep.



HP 4155B



HP 4156B

SMU terminals	Terminals through which voltage and current are forced and measured by SMUs.
Intlk interface	Terminal through which signals for interlock function pass. The interlock function is for preventing electric shock.

In This Guide Book

This guide book is a quick start guide for HP 4155B and HP 4156B. It introduces basic measurement and analysis without a lot of explanation and details. This guide book describes an example for doing the following:

- Measuring Vg–$\sqrt{Id}$ characteristics of a MOS FET.
- Analyzing the results graphically and finding threshold voltage (Vth).

You will find brief instructions for starting measurements with an HP 4155B/4156B.

Text Conventions.
The following text conventions are used in this guide:

Front-panel key	A key that is physically located on the HP 4155B/4156B.
`Softkey`	A softkey displayed on the HP 4155B/4156B.
`Screen Text`	Text displayed on the HP 4155B/4156B.
Italic	Refers to a related document, or is used for emphasis.

Finding Further Information.
This guide book is written for HP 4155B/4156B beginners. See the following books for further information:

HP 4155B/4156B User's Guide Measurement and Analysis provides information on how to use the HP 4155B/4156B for performing measurements and analysis.

HP 4155B/4156B User's Guide General Information provides general information of HP 4155B/4156B.

HP 4155B/4156B Programmer's Guide provides information on how to control the HP 4155B/4156B with remote commands.

HP-IB Command Reference provides reference of HP-IB commands.

SCPI Command Reference provides reference of Standard Commands for Programmable Instruments(SCPI) commands.

HP Instrument BASIC Users Handbook provides information on how to use HP Instrument BASIC, which is programming language built-in the HP 4155B/4156B.

HP 4155B/4156B Sample Application Programs' Guide Book provides description on some sample application programs and setup files.

HP 4155B/4156B VXIplug&play Driver User's Guide provides description on the HP 4155B/4156B VXIplug&play driver and the furnished application program and reference of the HP 4155B/4156B and HP E5250A VXIplug&play driver's functions.

1

Getting Started

This guide introduces how to use HP 4155B Semiconductor Parameter Analyzer and HP 4156B Precision Semiconductor Parameter Analyzer. Basic operations of the HP 4155B/4156B are provided.

This guide consists of the following three sections:

- **Making a measurement**: preparing for measurements and measuring a sample device (MOS FET).
- **Analyzing a result**: analyzing the results graphically and searching for the threshold voltage (Vth) of the MOS FET.
- **If you have a problem**: providing solutions to problems you may encounter while using this guide.

Before going to the next page, make sure you have prepared the following:

- HP 4155B or HP 4156B
- HP 16442A test fixture
- Test device (n-channel MOS FET, enhancement type)
  In this guide, the test device used is a Siliconix SD214DE.

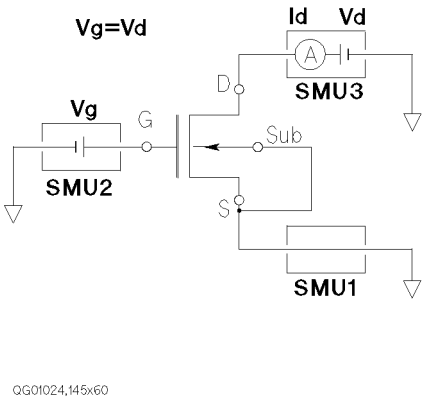
This guide book assumes that you have already installed your HP 4155B/4156B. If not, refer to "Installation" in the *HP 4155B/4156B User's Guide General Information*.

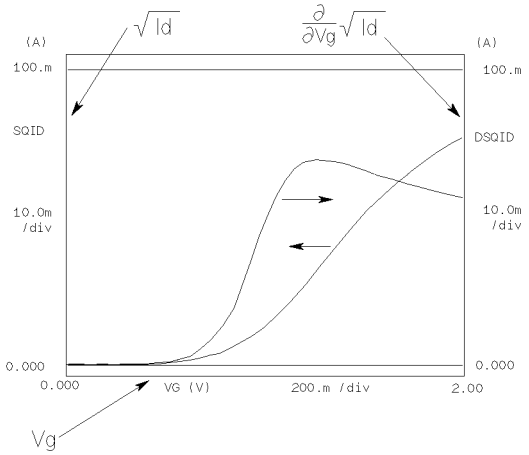
Making a Measurement

In this section, you learn how to execute the measurements with an HP 4155B/4156B and to display the measurement results graphically. Id-Vg measurement of a MOS FET is provided as an example. You learn step-by-step how to perform this measurement.

You measure the device under test (DUT) by using the measurement circuit as shown in the following diagram. SMU2 and SMU3 sweep the same voltage to the gate and drain. SMU3 measures the drain current (Id). The source and substrate are connected to circuit common.

You should get result similar to the following figure. Gate voltage Vg (swept from 0 V to 2 V) is assigned to X axis, $\sqrt{Id}$ is assigned to Y1 axis, and $\frac{\partial}{\partial Vg}\sqrt{Id}$ is assigned to Y2 axis.





Step 1. Prepare for the measurement

Before executing measurement, configure HP 4155B/4156B and accessories.

1. Make sure that the HP 4155B/4156B is off.
2. Connect the HP 16442A test fixture to HP 4155B/4156B. See next figure.
3. If you use the keyboard, connect it to the HP 4155B/4156B.

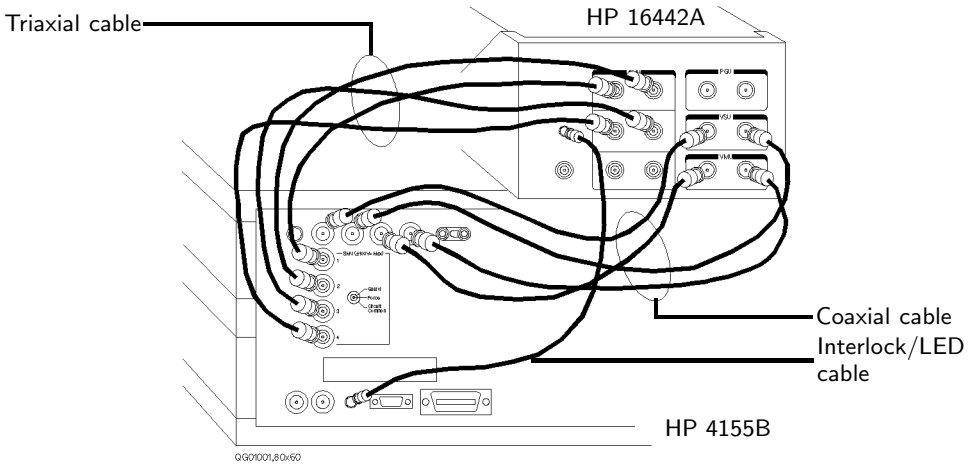
When you use the HP 4155B, connect as follows:

HP 4155B	cable	HP 16442A	HP 4155B	cable	HP 16442A
Intlk	⇐Interlock/LED[1]⇒	Intlk	SMU 4	⇐Triaxial[2]⇒	SMU 4
SMU 1	⇐Triaxial[2]⇒	SMU 1			(blue label)
		(blue label)	VSU 1	⇐Coaxial[3]⇒	VSU 1
SMU 2	⇐Triaxial[2]⇒	SMU 2	VSU 2	⇐Coaxial[3]⇒	VSU 2
		(blue label)	VMU 1	⇐Coaxial[3]⇒	VMU 1
SMU 3	⇐Triaxial[2]⇒	SMU 3	VMU 2	⇐Coaxial[3]⇒	VMU 2
		(blue label)			

1 Interlock/LED cable: HP 16493J

2 Triaxial cable: HP 16493C. You do not need to connect SMU4 for this measurement.

3 Coaxial cable: HP 16493B. You do not need to connect VSUs and VMUs for this measurement.



Connecting HP 4155B to HP 16442A Test Fixture

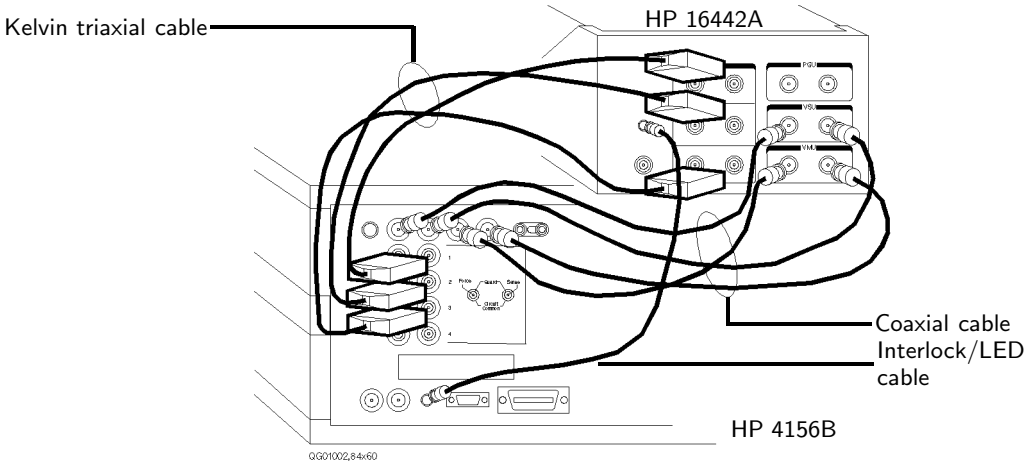
When you use the HP 4156B, connect as follows:

HP 4156B	cable	HP 16442A	HP 4156B	cable	HP 16442A
Intlk	⇐Interlock/LED[1]⇒	Intlk	VSU 1	⇐Coaxial[3]⇒	VSU 1
SMU 1	⇐Kelvin triaxial[2]⇒	SMU 1	VSU 2	⇐Coaxial[3]⇒	VSU 2
SMU 2	⇐Kelvin triaxial[2]⇒	SMU 2	VMU 1	⇐Coaxial[3]⇒	VMU 1
SMU 3	⇐Kelvin triaxial[2]⇒	SMU 3	VMU 2	⇐Coaxial[3]⇒	VMU 2

1 Interlock/LED cable: HP 16493J

2 Kelvin triaxial cable: HP part number 04155-61602

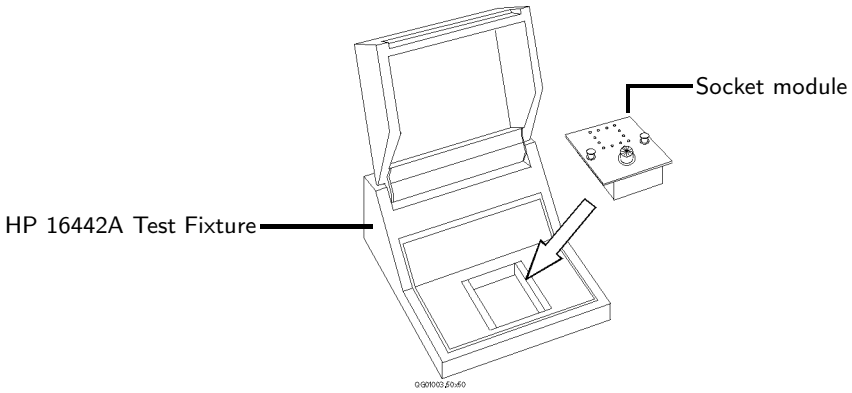
3 Coaxial cable: HP 16493B. You do not need to connect VSUs and VMUs for this measurement.



Connecting HP 4156B to HP 16442A Test Fixture

Step 2. Mount your DUT on the test fixture

1. Select a suitable socket module for your DUT.
2. Mount the socket module on the test fixture.

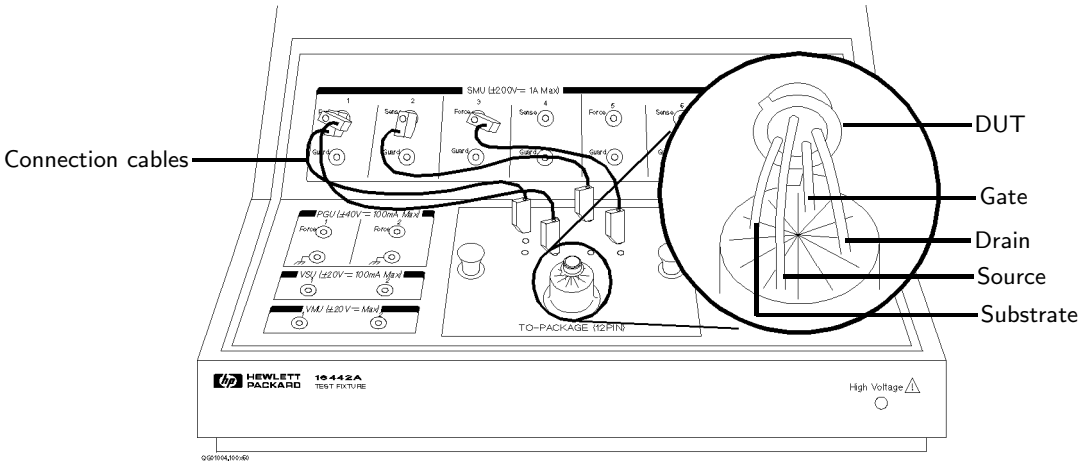


3. Mount your DUT on the socket module.
4. Make connections with four connection cables (miniature banana – pin plug).

   You make the following connections:

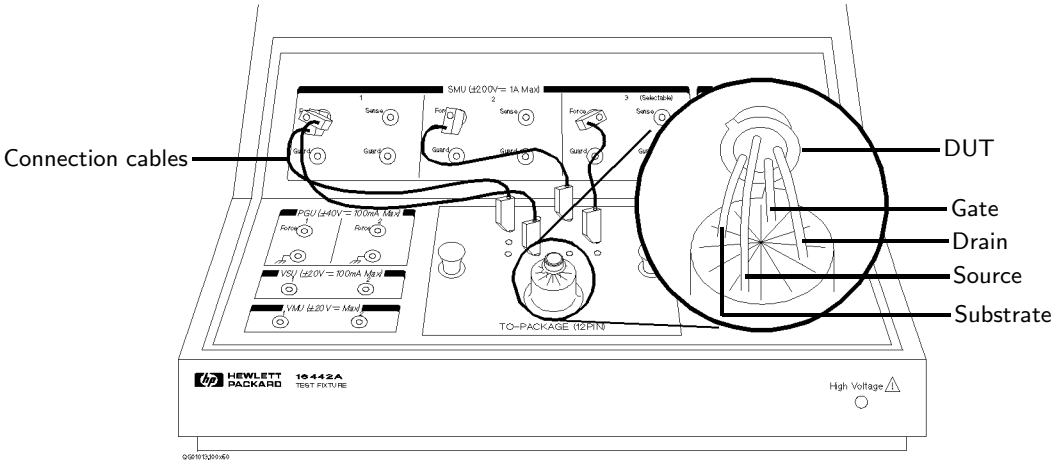
   Source—SMU1
   Gate—SMU2
   Drain—SMU3
   Substrate—SMU1

   Both the source and substrate terminals are connected to SMU1.
5. After finishing connections, shut the lid of the test fixture.



Wiring for HP 4155B

For this measurement by the HP 4156B, non-Kelvin connections are used. So, connect only the force terminals as shown in the following figure:

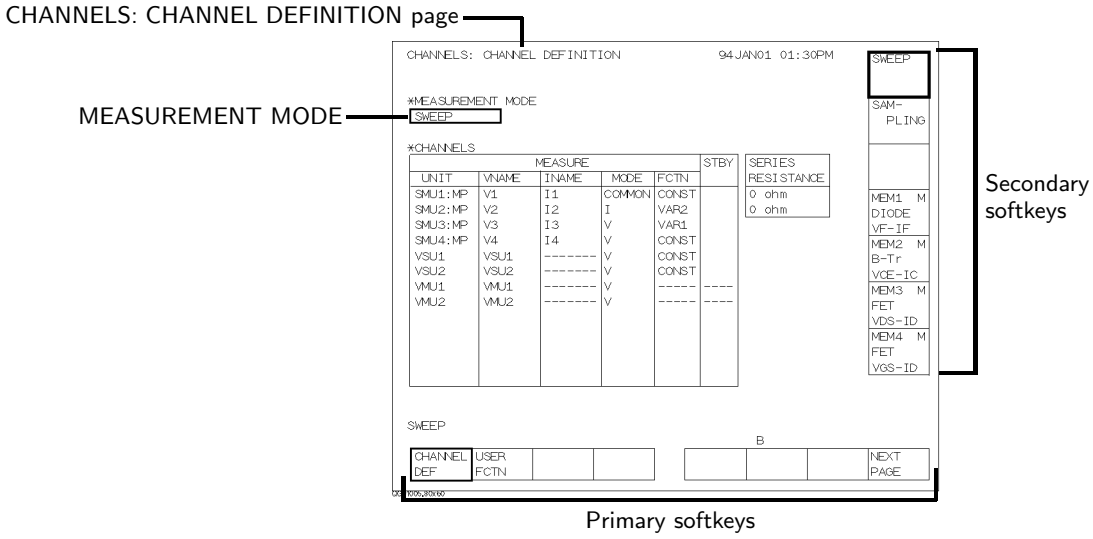


Wiring for HP 4156B

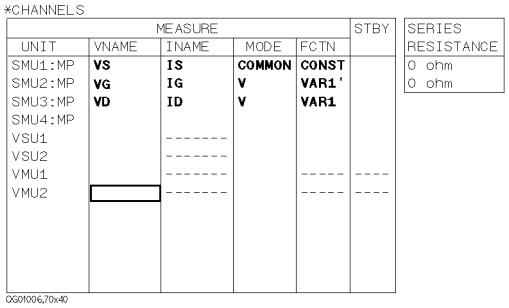
Step 3. Define the channel assignments

You set the connection information on the CHANNELS: CHANNEL DEFINITION page.

1. Switch on the HP 4155B/4156B. Self-test starts.
2. After self-test is finished, make sure that CHANNELS: CHANNEL DEFINITION page appears on the screen of the HP 4155B/4156B. If not, press Chan front-panel key.



3. Make sure that SWEEP is displayed in the MEASUREMENT MODE field. If not, select SWEEP secondary softkey in the MEASUREMENT MODE field.
4. Set the connection information in the CHANNELS table as follows:



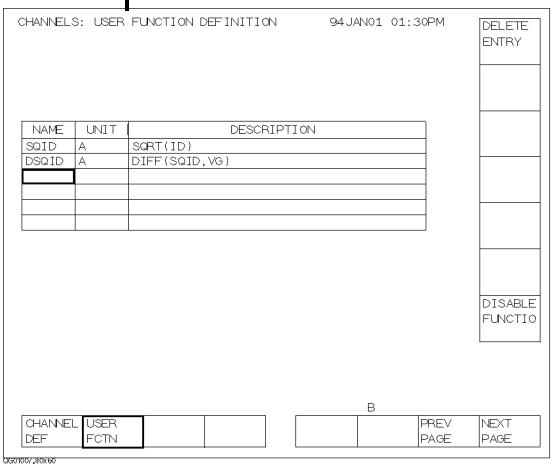
Action	on Front Panel	on Keyboard
To move the pointer,	use ⇐, ⇒, ⇑, or ⇓ of MARKER/CURSOR area.	use ◀, ▶, ▲, or ▼.
To move the cursor to edit in display area,	use ⇐ or ⇒ of Edit area.	use Backspace key.
To enter "VS" in VNAME field,	press V . ", S + \, then Enter.	type VS, then press Enter.
To enter "IS" in INAME field,	press I * ?, S + \, then Enter.	type IS, then press Enter.
To set "V" in the MODE field,	select V secondary softkey.	press Shift-F1 keys.
To set "VAR1'" in FCTN field,	select VAR1' secondary softkey.	press Shift-F4 keys.
To set "VAR1" in FCTN field,	select VAR1 secondary softkey.	press Shift-F2 keys.
To disable a unit,	select DISABLE UNIT secondary softkey.	press Shift-F7 keys.

Step 4. Define the user functions

You define the user functions on the CHANNELS: USER FUNCTION DEFINITION page.

1. Select `USER FCTN` primary softkey. The CHANNELS: USER FUNCTION DEFINITION page appears.
2. Enter the user function information in the table as follows:

CHANNELS: USER FUNCTION DEFINITION page



You enter the following two user functions:

$$\mathrm{SQID} = \sqrt{\mathrm{Id}}$$

$$\mathrm{DSQID} = \frac{\partial}{\partial \mathrm{Vg}}\mathrm{SQID} = \frac{\partial}{\partial \mathrm{Vg}}\sqrt{\mathrm{Id}}$$

Where, *Id* is drain current and *Vg* is gate voltage.

Action	on Front Panel	on Keyboard
To move the pointer,	use ⇐, ⇒, ⇑, or ⇓ of MARKER/CURSOR area.	use ◀, ▶, ▲, or ▼.
To move the cursor to edit in display area,	use ⇐ or ⇒ of Edit area.	use Backspace key.
To enter "SQID" in NAME field,	press S(+)\, Q2', I*?, D/;, then Enter.	type SQID, then press Enter.
To enter "SQRT(ID)"[1] in DEFINITION field,	press S(+)\, Q2', R3|, Tp%, ␣ (blue key), A(␣[, ID, B)␣], then Enter.	type SQRT(ID), then press Enter.
To enter "DSQID" in NAME field,	press D/;, S(+)\, Q2', I*?, D/;, then Enter.	type DSQID, then press Enter.
To enter "DIFF(SQID,VG)"[2] in DEFINITION field,	press D/;, I*?, F7{, F7{, ␣ (blue key), A(␣[, ␣ (blue key), S(+)\, Q2', I*?, D/;, ␣ (blue key), X,␣>, VG, B)␣], then Enter.	type DIFF(SQID,VG), then press Enter.
To disable a user function,	select DISABLE FUNCTION secondary softkey.	press Shift-F7 key.

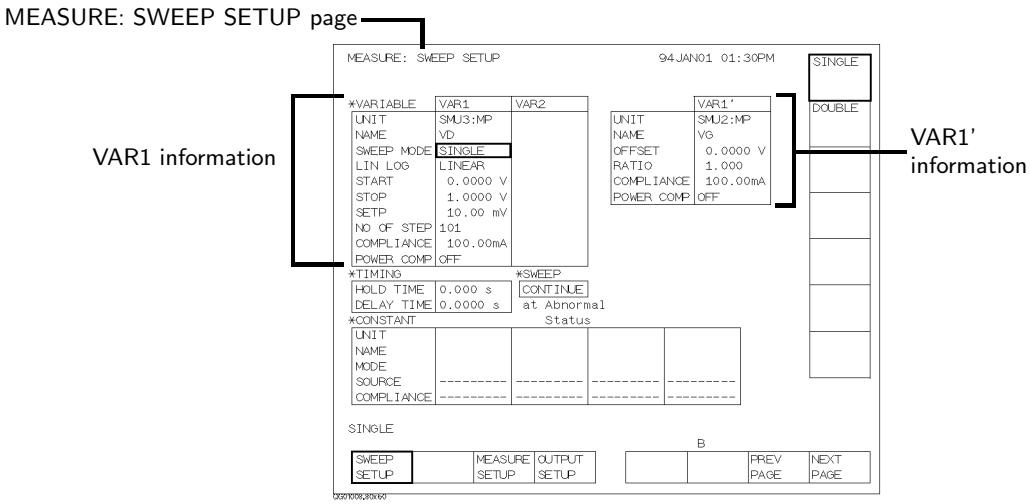
1 Square root operator ($\sqrt{\ }$) is defined by "SQRT" built-in function.

2 Partial difference ($\frac{\partial}{\partial}$) is defined by "DIFF" built-in function.

Step 5. Set up the measurement parameters

You set the output parameters on the MEASURE: SWEEP SETUP page.

1. Press (Meas) front-panel key. The MEASURE: SWEEP SETUP page appears.



2. Set the VAR1 information as follows:

*VARIABLE	VAR1	VAR2
UNIT	SMU3:MP	
NAME	VD	
SWEEP MODE	**SINGLE**	
LIN LOG	**LINEAR**	
START	**0.0000 V**	
STOP	**2.0000 V**	
SETP	**10.00 mV**	
NO OF STEP	101	
COMPLIANCE	**100.00mA**	
POWER COMP	**OFF**	

Drain voltage sweeps from 0 V to 2 V with 10 mV step. The current compliance is set to 100 mA.

Action	on Front Panel	on Keyboard
To move the pointer,	use (←), (→), (↑), or (↓).	use (◀), (▶), (▲), or (▼).
To set "SINGLE" in SWEEP MODE field,	select SINGLE secondary softkey.	press (Shift)-(F1) keys.
To set "LINEAR" in LIN/LOG field,	select LINEAR secondary softkey.	press (Shift)-(F1) keys.
To enter "2.000 V" in STOP field,	press Q(2)', then (Enter).	type 2, then press (Enter).
To enter "10.00 mV" in STEP field,	press P(1)$, U(0)#, E(m)@, then (Enter).	type 10m, then press (Enter).

3. Set the VAR1' information as follows:

	VAR1'
UNIT	SMU2:MP
NAME	VG
OFFSET	0.0000 V
RATIO	1.000
COMPLIANCE	100.00mA
POWER COMP	OFF

QG01010,40x30

To force the same voltage to the drain and gate, set $RATIO = 1$ and $OFFSET = 0$. Because VAR1' is defined as follows:

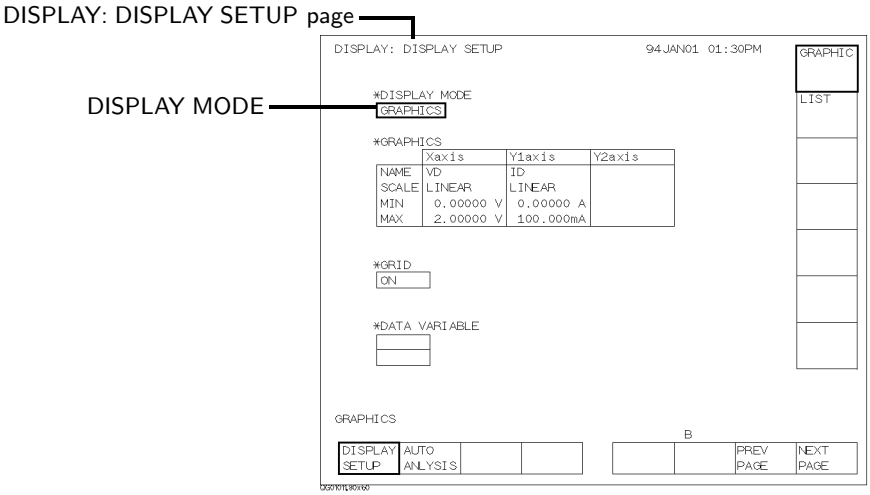
$$(VAR1' \; output) = RATIO \times (VAR1 \; output) + OFFSET$$

Action	on Front Panel	on Keyboard
To enter "`0.000 V`" in OFFSET field,	press U(0)#, then (Enter).	type `0`, then press (Enter).
To enter "`1.000`" in RATIO field,	press P(1)$, then (Enter).	type `1`, then press (Enter).

Step 6. Set up the results display

You set the results display information on the DISPLAY: DISPLAY SETUP page.

1. Press (Display) front-panel key. The DISPLAY: DISPLAY SETUP page appears.



2. Make sure GRAPHICS is displayed in the DISPLAY MODE field. If not, select GRAPHIC secondary softkey in the DISPLAY MODE field.
3. Set the X-, Y1-, and Y2-axes information as follows:

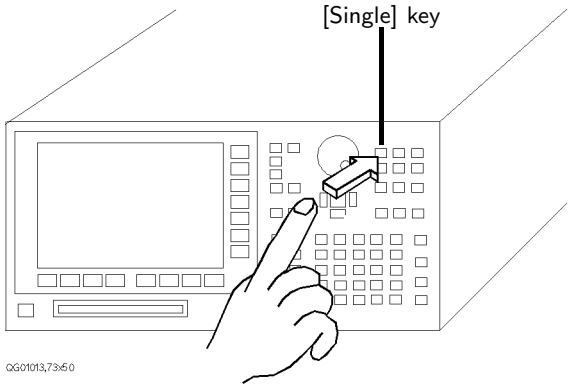
*GRAPHICS

	Xaxis	Y1axis	Y2axis
NAME	VG	SQID	DSQID
SCALE	LINEAR	LINEAR	LINEAR
MIN	0.00000 V	0.00000 A	0.00000 A
MAX	2.00000 V	100.000mA	100.000mA

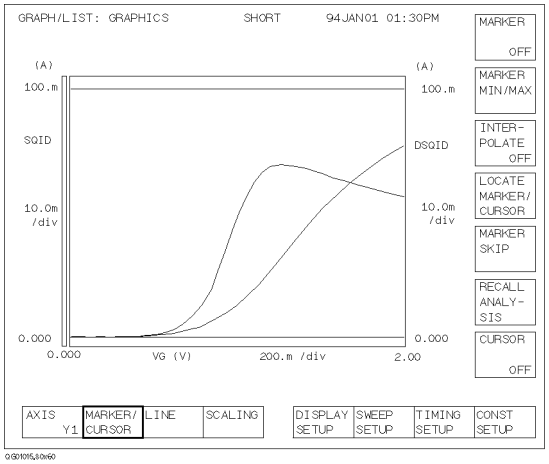
Action	on Front Panel	on Keyboard
To enter "VG" in NAME field,	select VG secondary softkey.	press Shift-F3 keys.
To set "LINEAR" in SCALE field,	select LINEAR secondary softkey.	press Shift-F1 keys.
To enter "0.00000 V" in MIN field,	press U0#, then Enter.	type 0, then press Enter.
To enter "2.00000 V" in MAX field,	press Q2', then Enter.	type 2, then press Enter.
To enter "SQID" in NAME field,	select MORE 1/2, then SQID secondary softkeys.	press Shift-F7 keys, then Shift-F3 keys.
To enter "0.00000 A" in MIN field,	press U0#, then Enter.	type 0, then press Enter.
To enter "100.000mA" in MAX field,	press P1$, U0#, U0#, Em@, then Enter.	type 100m, then press Enter.
To enter "DSQID" in NAME field,	select MORE 1/2, then DSQID secondary softkeys.	press Shift-F7 keys, then Shift-F4 keys.

Step 7. Execute the measurement

- Press (Single) front-panel key to execute the measurement.



You should get measurement results similar to the following figure.



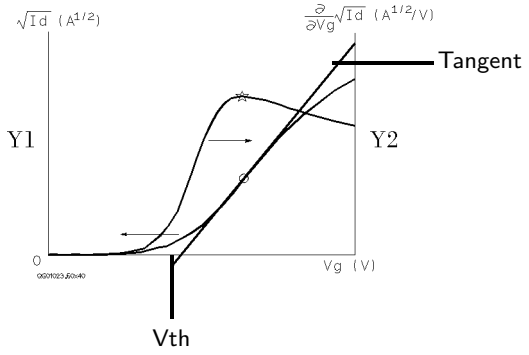
Analyzing the Results

In the previous section, you measured the drain current (Id) while performing a synchronous sweep of the gate voltage (Vg) and drain voltage (Vd). And the measurement results were drawn graphically on the screen.

In this section, you analyze the measurement results on the graph and search threshold voltage (Vth) of the DUT.

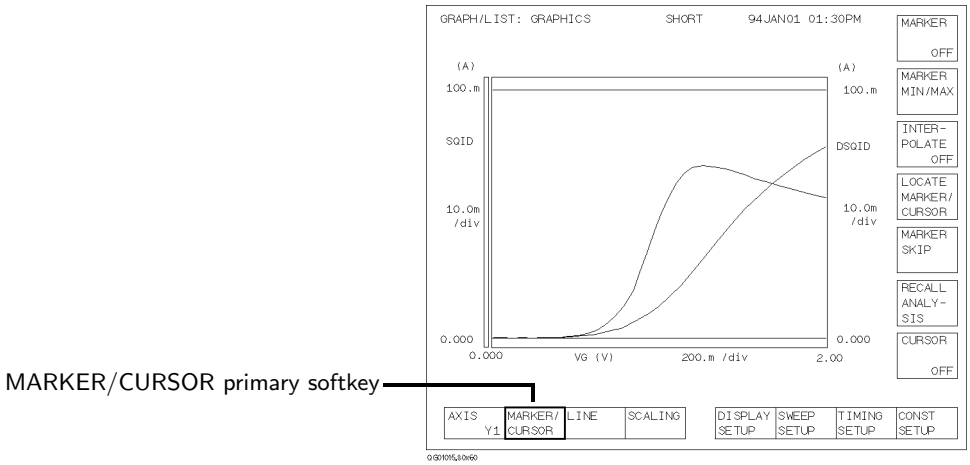
The basic algorithm to search for the threshold voltage is:

1. Assign gate voltage (Vg) to X-axis, $\sqrt{Id}$ to Y1-axis, and $\frac{\partial}{\partial Vg}\sqrt{Id}$ to Y2-axis.
2. Search for the maximum value of $\frac{\partial}{\partial Vg}\sqrt{Id}$ curve, which is also the point where the gradient of $\sqrt{Id}$ curve is maximum.
3. Draw a tangent line to the point where the gradient of $\sqrt{Id}$ curve is maximum.
4. Read the X-coordinate value where the tangent line crosses the X-axis. This value is threshold value (Vth).

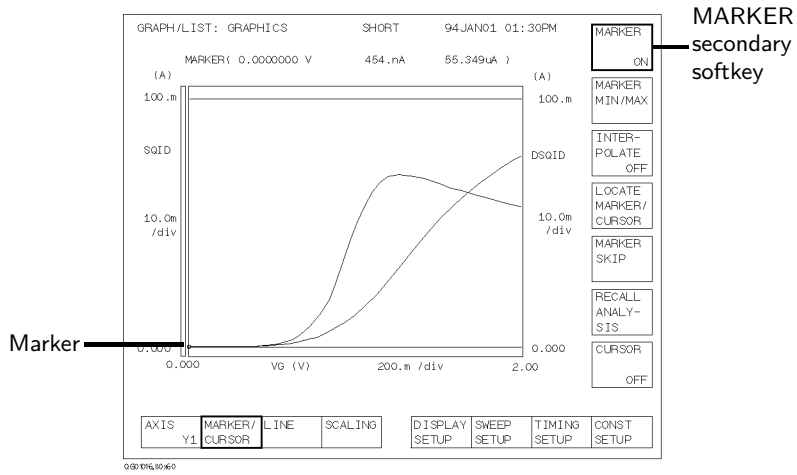


Find the threshold voltage

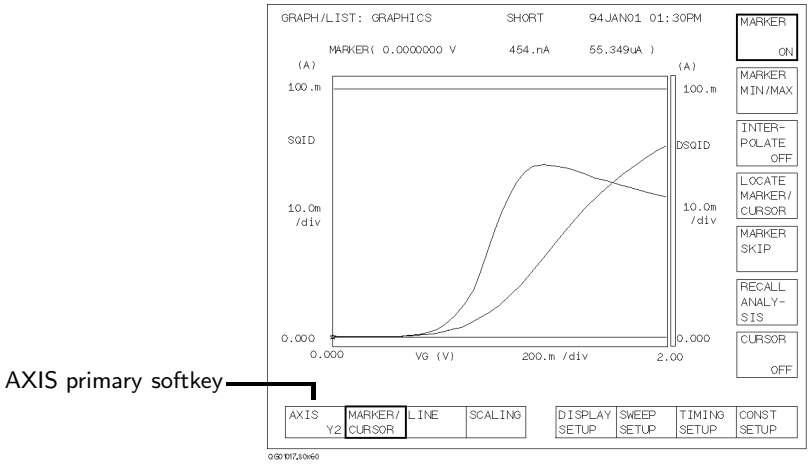
1. Make sure that `MARKER/CURSOR` primary softkey is highlighted. If not, select the `MARKER/CURSOR` primary softkey.



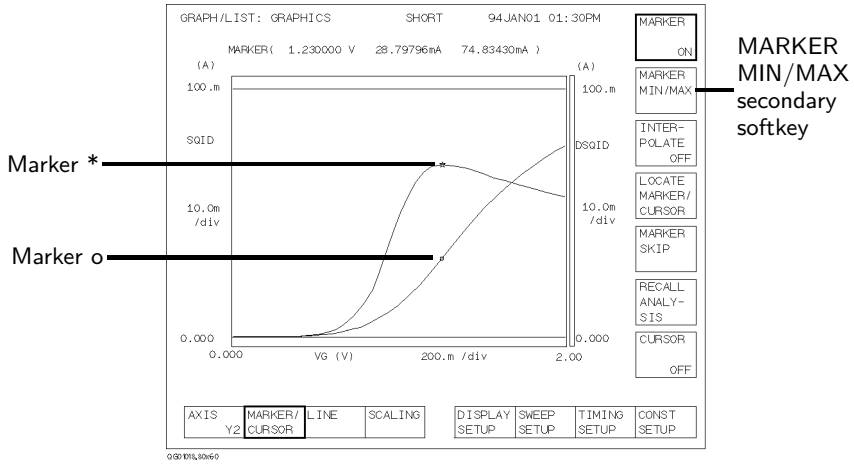
2. Select `MARKER` secondary softkey so that `ON` appears on the softkey. The `MARKER` softkey is highlighted, and the markers appears on the measurement curve.



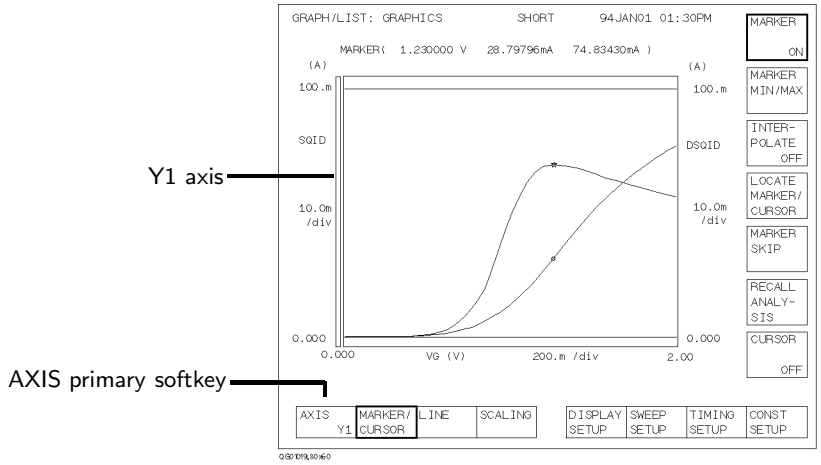
3. Select `AXIS` primary softkey so that `Y2` appears on the softkey. The Y2 axis is highlighted.



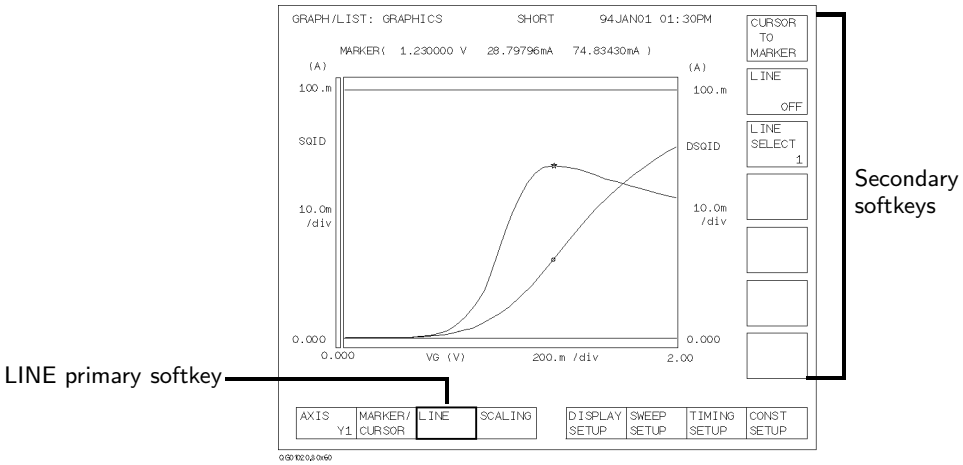
4. Select `MARKER MIN/MAX` secondary softkey until the * marker moves to the maximum point on the Y2 curve. The o marker (on Y1 curve) also moves to same X-axis point, which is maximum gradient of Y1 curve.



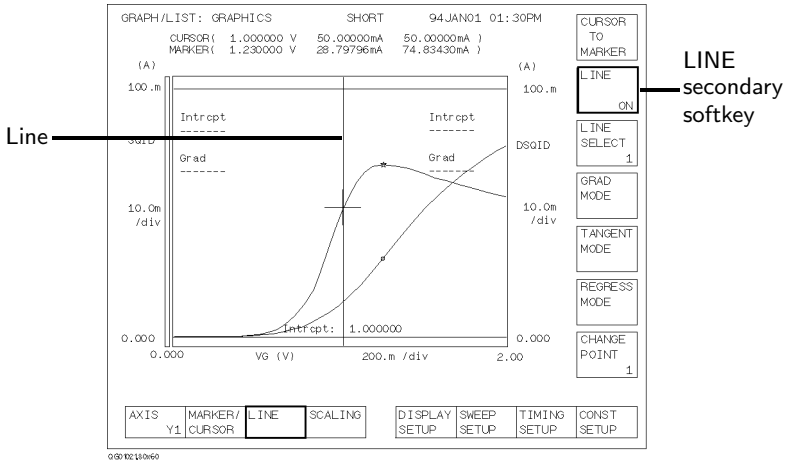
5. Select `AXIS` primary softkey so that Y1 appears on the softkey. The Y1 axis is highlighted.



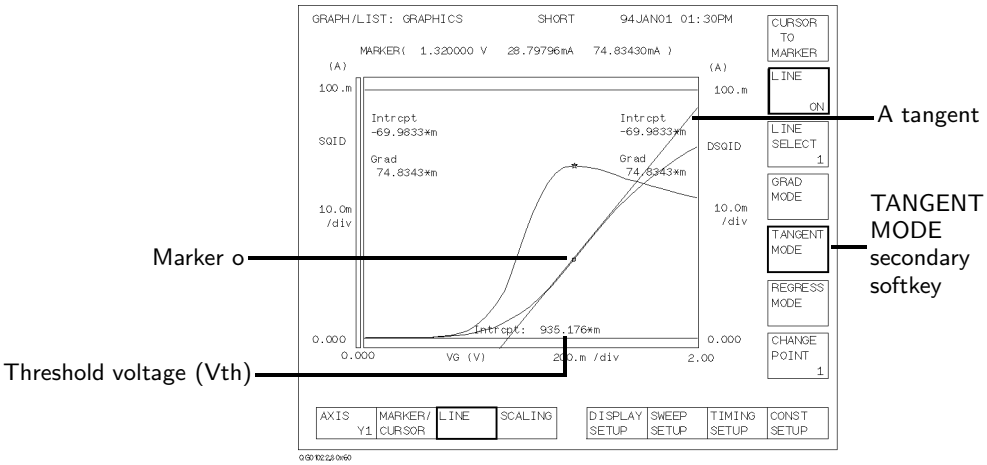
6. Select `LINE` primary softkey. The secondary softkey menu changes.



7. Select `LINE` secondary softkey so that `ON` appears on the softkey. The `LINE` softkey is highlighted, and a vertical line appears in the center of the plotting area.



8. Select `TANGENT MODE` secondary softkey. The line becomes tangent to the o marker of the Y1 curve.



Read the X-axis intercept value of the tangent line. This is the threshold voltage (Vth). In the example above, Vth is 935 mV.

If You Have a Problem

This section describes how to solve the following unexpected problems:

- If HP 4155B/4156B cannot be powered on
- If display page does not appear after applying power
- If HP 16442A test fixture is not stable

If HP 4155B/4156B cannot be powered on

- Check that the power cable is firmly connected to HP 4155B/4156B and to power outlet.
- Check that the front-panel LINE switch is on.
- Check that the voltage selector switch is set properly.

  The voltage selector switch is located in the lower-right corner of the rear panel. The following table shows the line voltage selector setting.

Line Voltage	Position
84-124 Vac	left
200-248 Vac	right

- Check that the fuse is good.

  The fuse holders located in the lower-right corner of the rear panel.

1. Turn the HP 4155B/4156B off and disconnect the power cable from the power outlet.
2. Unscrew the fuse holder on the rear panel.
3. Inspect that the correct fuse is installed, and wire inside the fuse is *not* broken by using a rester.

Line	Fuse Type	HP Part Number
110/120 Vac	Time-delay type 8A, 250 Vac	2110-0383
220/240 Vac	Time-delay type 4A, 250 Vac	2110-0014

4. Replace the fuse, if necessary. Then, screw in the fuse holder.
5. Turn the HP 4155B/4156B on.

If display page does not appear after applying power

- If HP 41501 is installed, *first* turn on the HP 41501, *then* turn on HP 4155B/4156B.
- If the self-test fails, see "If You Have a Problem" in the *HP 4155B/4156B User's Guide General Information*.

If HP 16442A test fixture is not stable

- Install stabilizers on the HP 16442A.

  For this procedure, see "Installation" in the *HP 4155B/4156B User's Guide General Information*.
- If you use the HP 16442A test fixture with HP 16440A selector or HP 16441A R-BOX, attach HP 16442A to HP 16440A or HP 16441A by using plates and screws.

  For this procedure, see "Installation" in the *HP 4155B/4156B User's Guide General Information*.