Parameter Analyzer

Quick Start Guide

HP Part Number
04155-90200
First edition, September 1993
Printed in Japan

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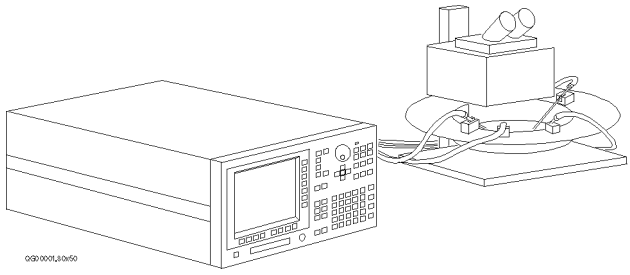
HP 4155A and HP 4156A

HP 4155A Semiconductor Parameter Analyzer and HP 4156A Precision Semiconductor Parameter Analyzer are full automatic and high performance instruments designed to measure, to display graphically, and to analyze the dc parameters and characteristics of semiconductor devices such as diodes, transistors, ICs, solar cells, and wafers during the fabrication process. So you can evaluate device design, process design, fabrication environments, and so on with the HP 4155A/4156A.

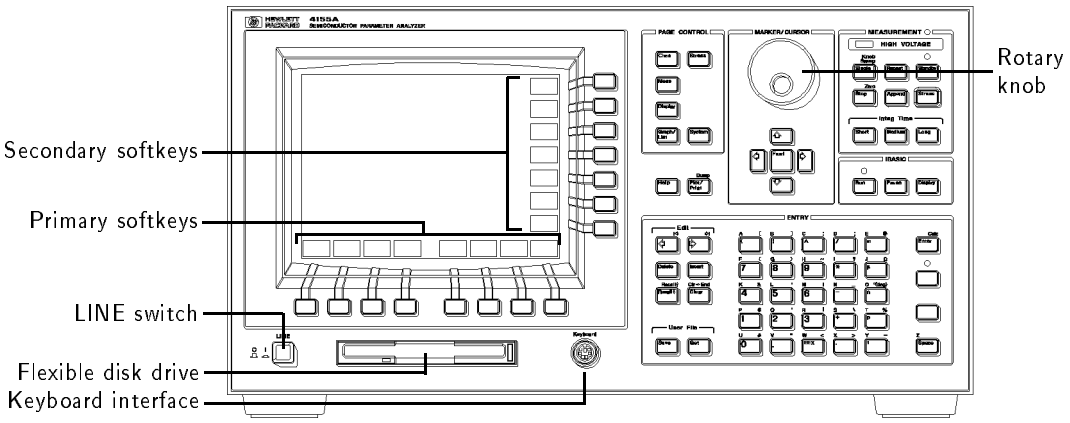
In semiconductor research and development laboratories, the HP 4155A/4156A provides precise characteristics evaluation, which is an important step in the development of new high performance devices, and gives design engineers an easy to use method of device parameter acquisition—an essential element in computer aided design (CAD).

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

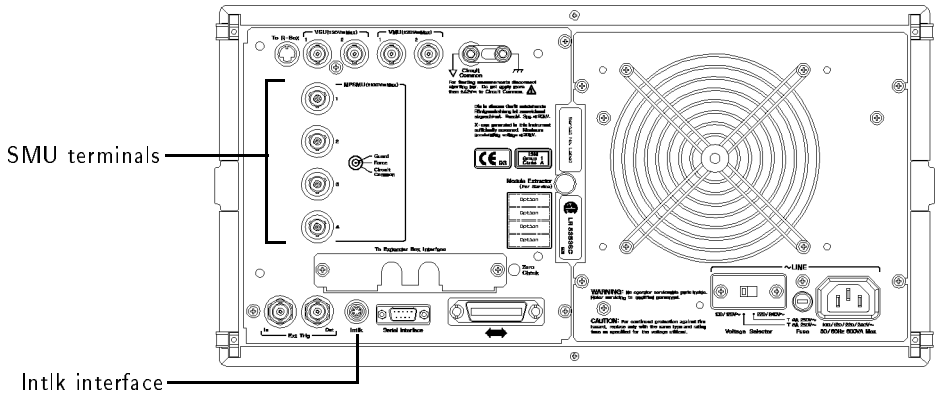
For semiconductor end users, the HP 4155A/4156A is ideal for circuit design applications and incoming inspection.



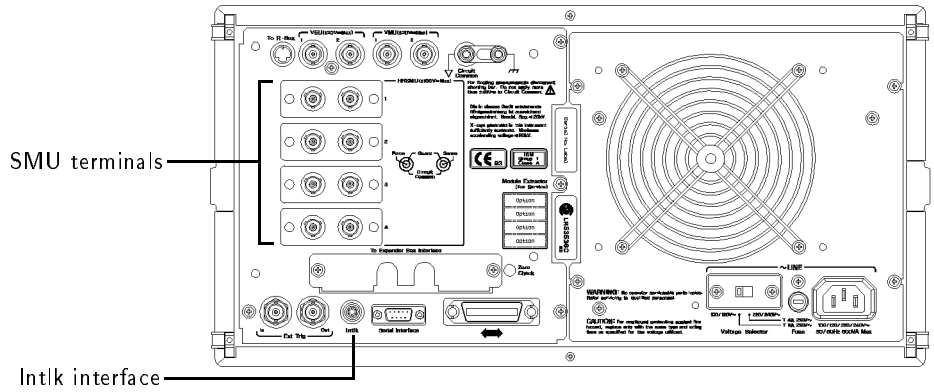
HP 4155A/4156A—At a Glance



LINE switch	You use the LINE switch to apply electric power.
Flexible disk drive	You can use 3.5-inch diskette as the mass storage, which is inserted in this flexible disk drive.
Keyboard interface	You can control the HP 4155A/4156A from keyboard, which is connected to the keyboard interface, as well as from the front-panel keys.
Primary softkeys	You use primary softkeys to move pages and to change the secondary softkey menu.
Secondary softkeys	You use secondary softkeys to select variable names, alternatives, and changing items.
Rotary knob	You use rotary knob to change the setting value and to move a marker.



HP 4155A



HP 4156A

SMU terminals	Either voltage or current output is forced from the SMU terminals, and measurement signal is put to the SMU terminals.
Intlk interface	To prevent you from electric shock, the HP 4155A/4156A has interlock function. The signals for the interlock function go through the Intlk interface.

In This Guide Book

This guide book is a quick start guide for HP 4155A and HP 4156A. It introduces a basic measurement and its analysis without a lot of explanation and details. You can perform the following measurement and analysis through this guide book:

- Measuring Vg-$\sqrt{Id}$ characteristics of a MOS FET.
- Analyzing its graph and finding threshold voltage (Vth).

You will find quick instructions for starting measurements with an HP 4155A/4156A.

Key Conventions.
The following key conventions are used in this guide:

Front-panel key	Text shown like this represents a key physically located on the HP 4155A/4156A.
Softkey	Text shown like this represents a softkey.
`Screen Text`	Text printed in this typeface indicates text displayed on the HP 4155A/4156A.
Bold	Text shown like this indicates a term defined in the glossary.
Italic	Text shown like this referees to a related document, or is used for emphasis.

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

HP 4155A/4156A User's Guide (HP part number 04155-90000) provides information on how to use the HP 4155A/4156A.

HP 4155A/4156A Programmer's Guide (HP part number 04155-90100) provides information on how to control the HP 4155A/4156A with remote commands.

HP Instrument BASIC Users Handbook (HP part number E2083-90000) provides information on how to use HP Instrument BASIC, which is programming language built-in the HP 4155A/4156A.

Getting Started

Getting Started

This guide introduces how to use HP 4155A Semiconductor Parameter Analyzer and HP 4156A Precision Semiconductor Parameter Analyzer. Basic operations of the HP 4155A/4156A 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 4155A or HP 4156A
- HP 16442A test fixture
- Test device (n-channel MOS FET, enhancement type)
  In this guide, the test device used is a Siliconix SD214DE.

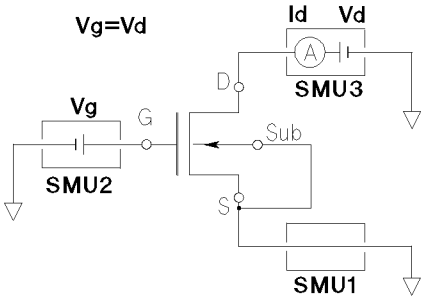
This guide book assumes that you have already installed your HP 4155A/4156A. If not, refer to "Installation" in the *HP 4155A/4156A User's Task Guide.*.

Making a Measurement

In this section, you learn how to execute the measurements with an HP 4155A/4156A 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.



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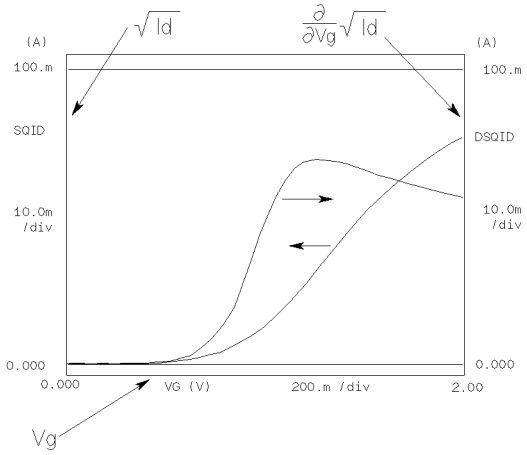


Step 1. Prepare for the measurement

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

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

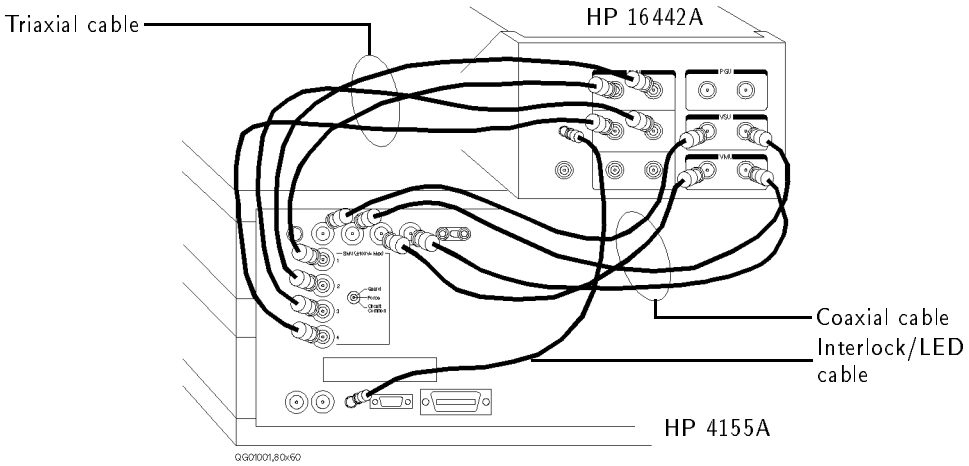
When you use the HP 4155A, connect as follows:

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

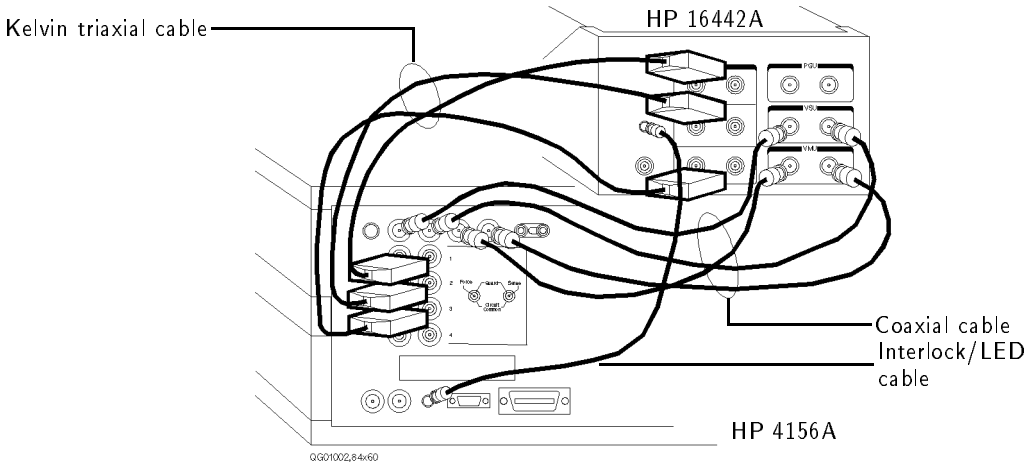
When you use the HP 4156A, connect as follows:

HP 4156A	cable	HP 16442A	HP 4156A	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

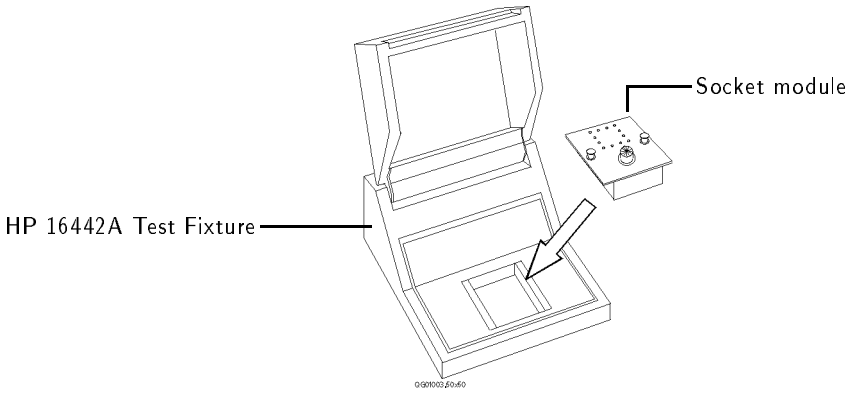
3 Coaxial cable: HP 16493B. You do not need to connect VSUs and VMUs for this measurement.



Connecting HP 4156A 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.

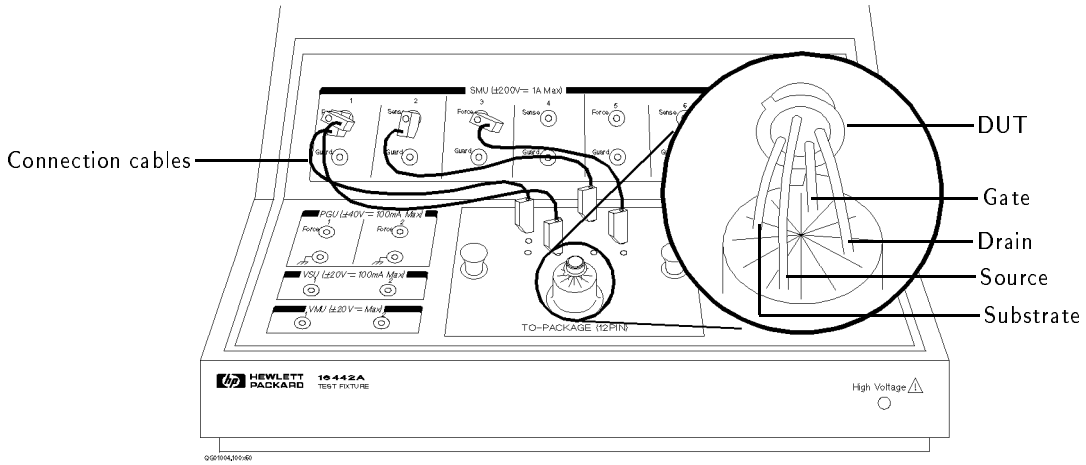


3. Mount your DUT on the socket module.
4. Make connections with four connection cables (miniature banana - pin plug).

   You make the following connections:

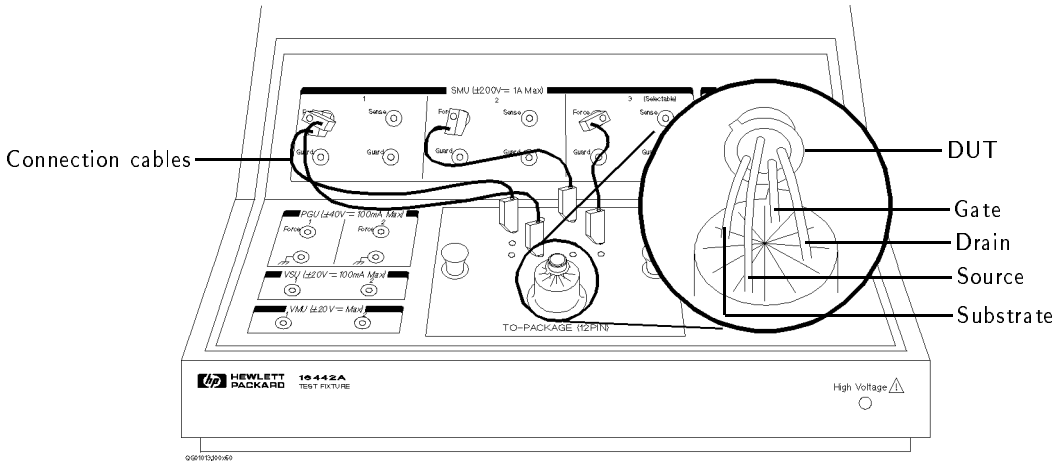
   Source—SMU1
   Gate—SMU2
   Drain—SMU3
   Substrate—SMU1

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



Wiring for HP 4155A

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

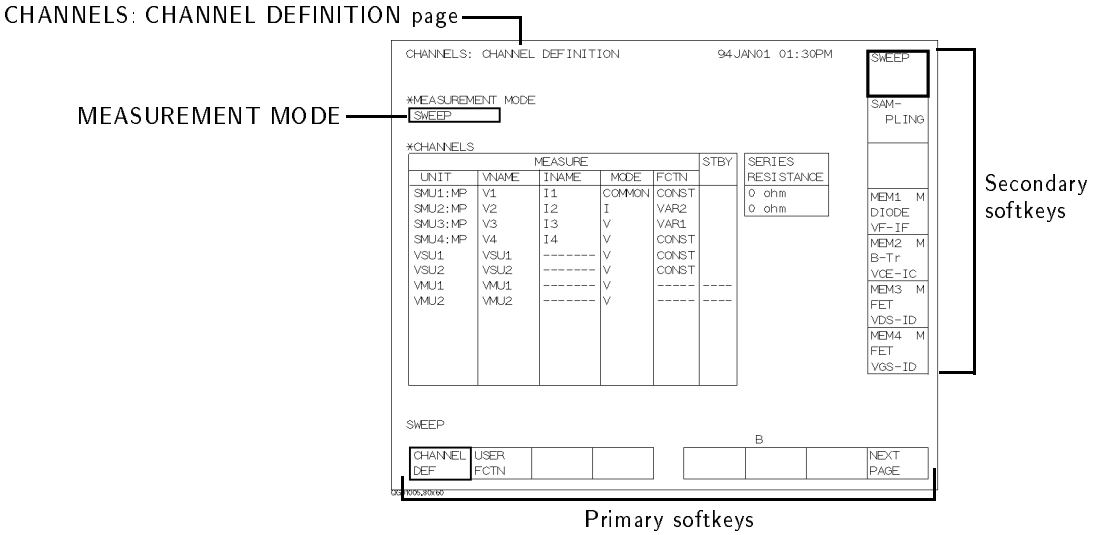


Wiring for HP 4156A

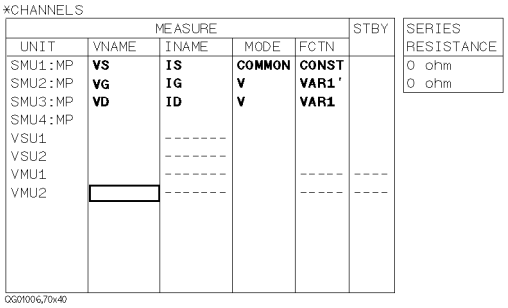
Step 3. Define the channel assignments

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

1. Switch on the HP 4155A/4156A. Self-test starts.
2. After self-test is finished, make sure that CHANNELS: CHANNEL DEFINITION page appears on the screen of the HP 4155A/4156A. 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:



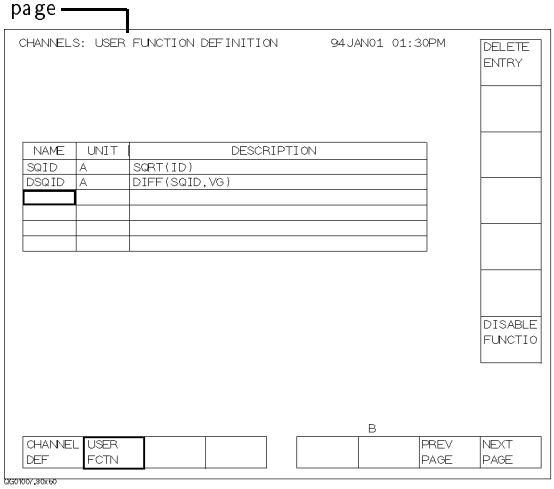
Action	on Front Panel	on Keyboard
To move the pointer,	use ⇐, ⇒, ⇑, or ⇓ of MARKER/CURSOR area.	use ◀, ▶, ▲, or ▼.
To move the cursor to edit in display area,	use ⇐ or ⇒ of Edit area.	use Backspace key.
To enter "VS" in VNAME field,	press V ., ", S +, \, then Enter.	type VS, then press Enter.
To enter "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.

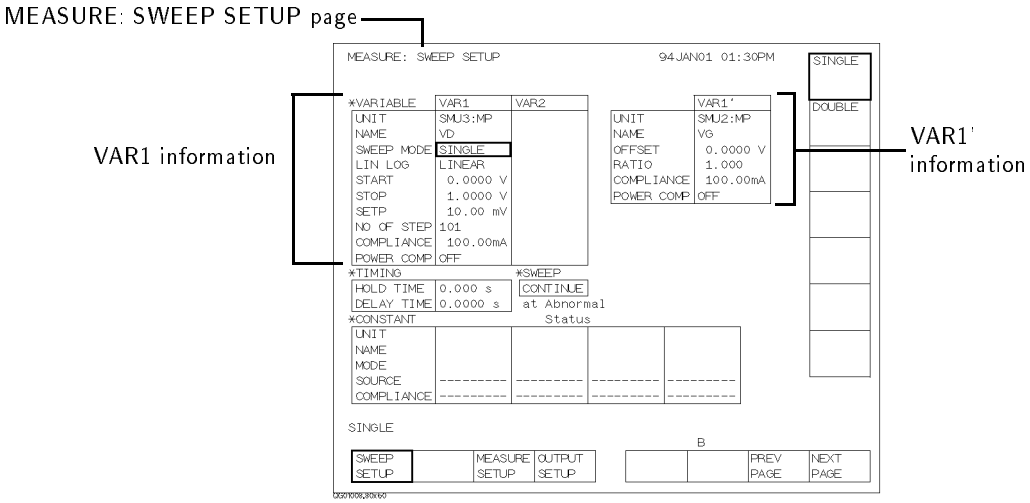
1 Square root operator |$\sqrt{}$| is defined by "SQRT" built-in function.

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

0G01010,40x30

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

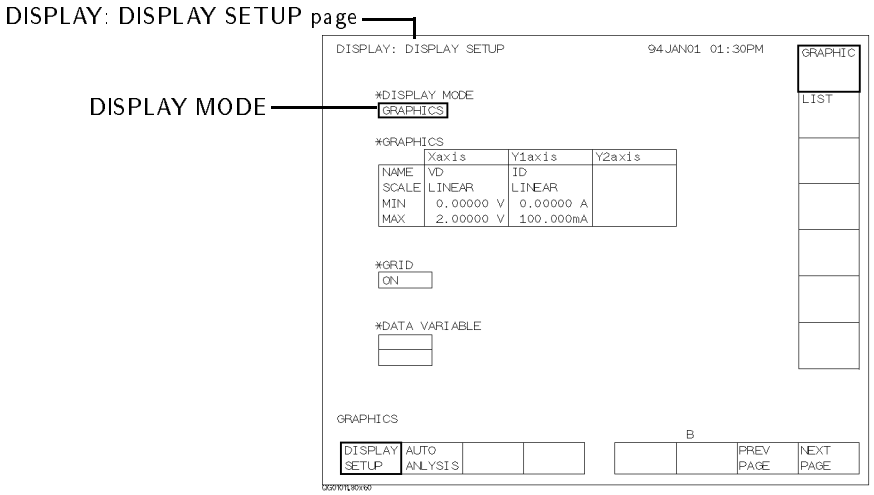
$$(VAR1' \; output) = RATIO \times (VAR1 \; output) + OFFSET$$

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:

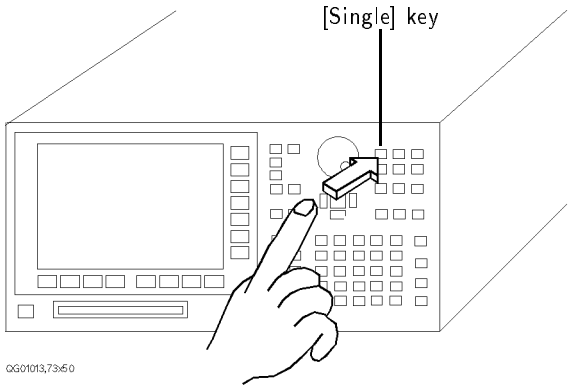
*GRAPHICS

	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**

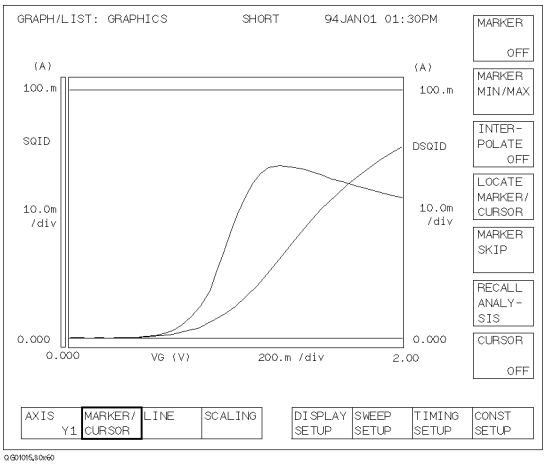
Action	on Front Panel	on Keyboard
To enter "VG" in NAME field,	select VG secondary softkey.	press Shift-F3 keys.
To set "LINEAR" in SCALE field,	select LINEAR secondary softkey.	press Shift-F1 keys.
To enter "0.00000 V" in MIN field,	press U0#, then Enter.	type 0, then press Enter.
To enter "2.00000 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.



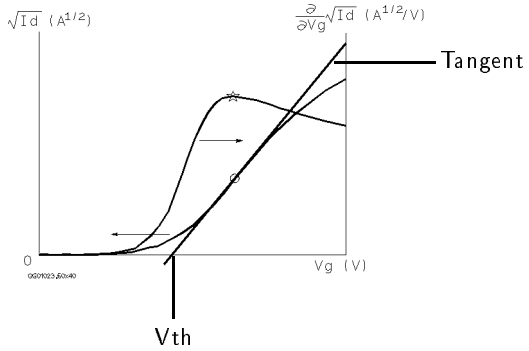
Analyzing the Results

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.

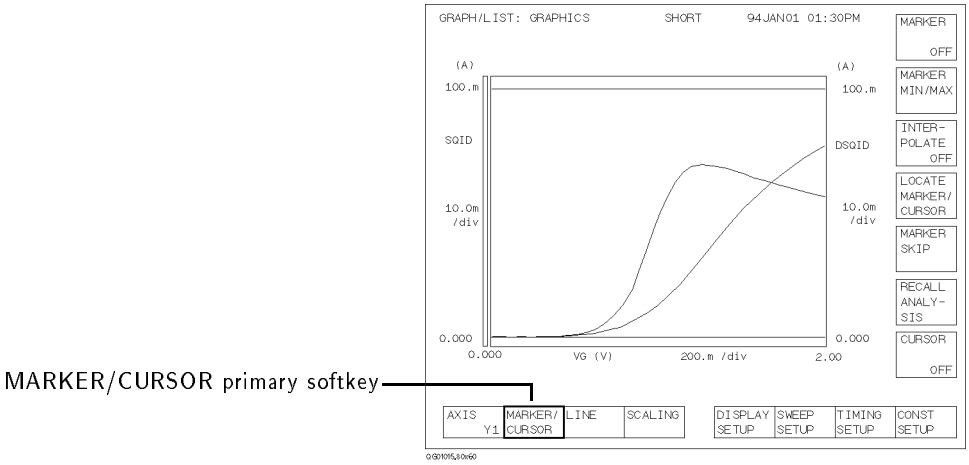
The basic algorithm to search for the threshold voltage is:

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).



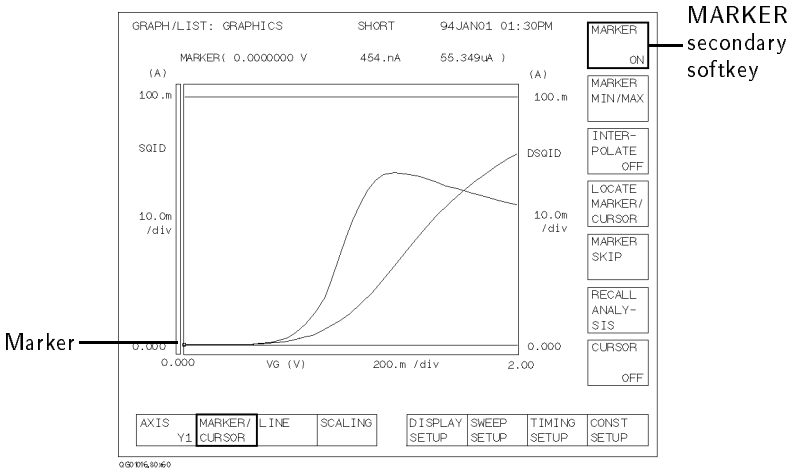
Find the threshold voltage

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

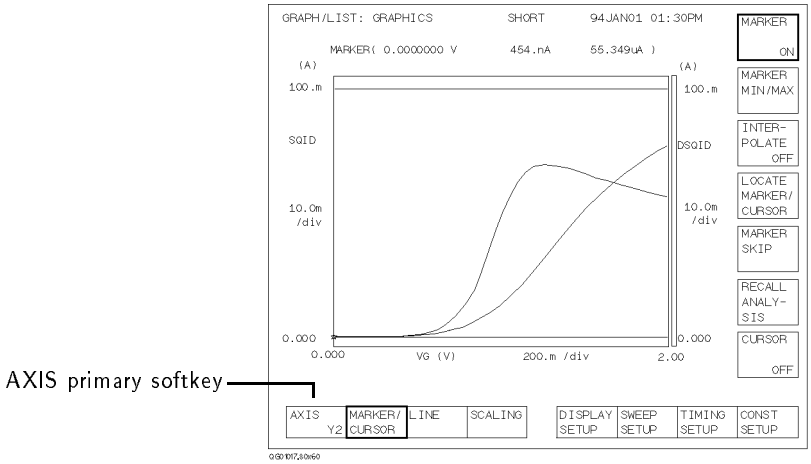


2. Select `MARKER` secondary softkey so that `ON` appears on the softkey.

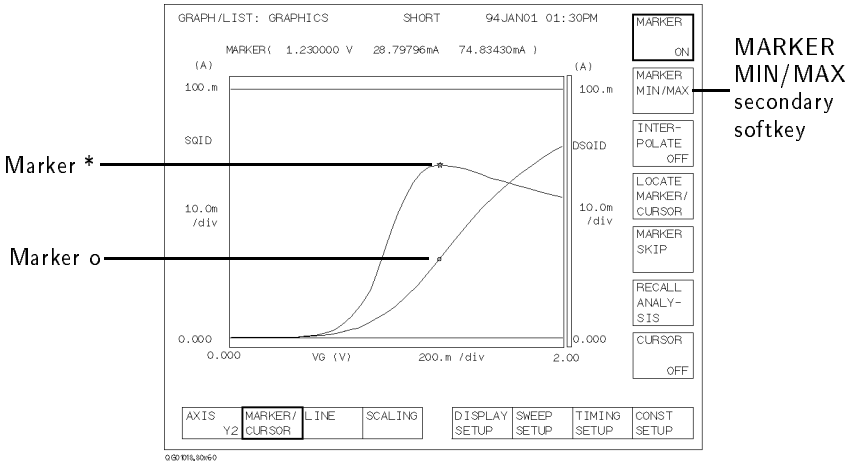
   The `MARKER` softkey is highlighted, and the markers appears on the measurement curve.



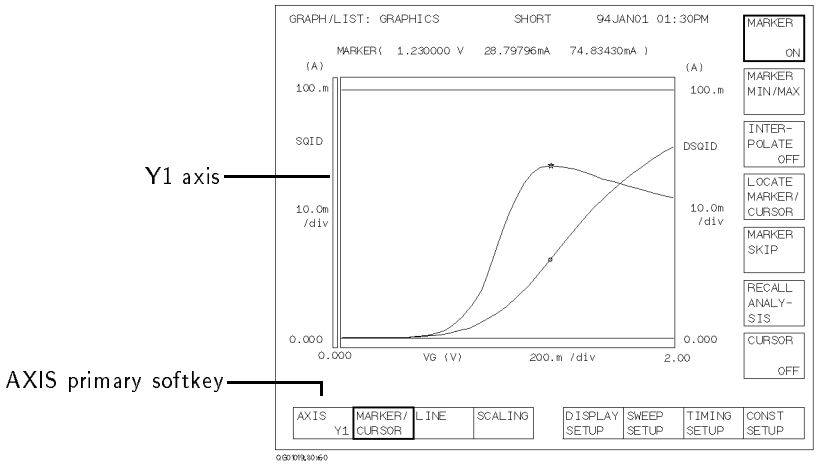
3. Select `AXIS` primary softkey so that `Y2` appears on the softkey. The Y2 axis is highlighted.



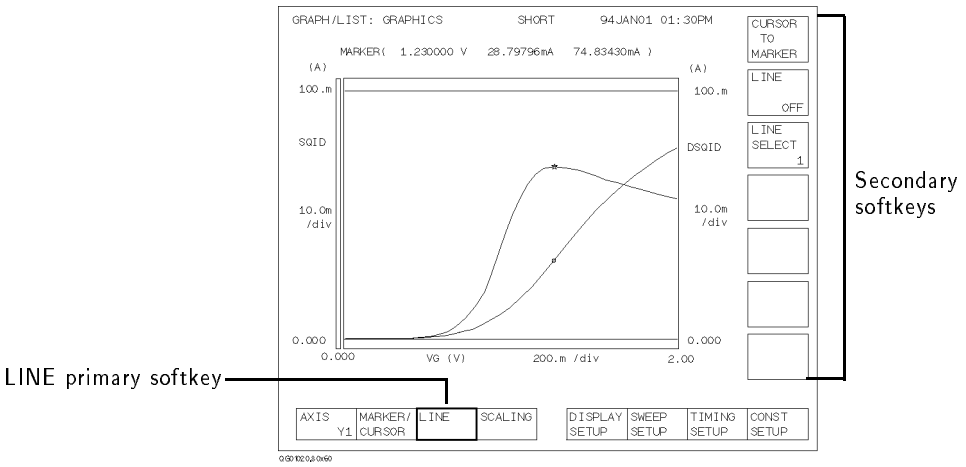
4. Select `MARKER MIN/MAX` secondary softkey until the * marker moves to the maximum point on the Y2 curve. The o marker (on Y1 curve) also moves to same X-axis point, which is maximum gradient of Y1 curve.



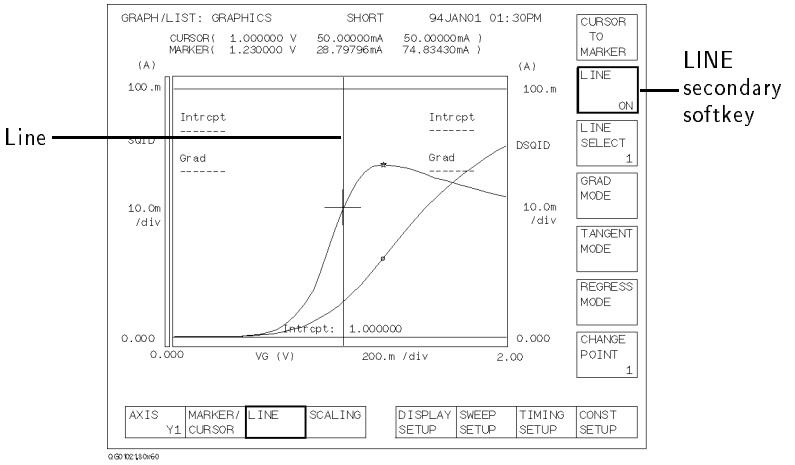
5. Select `AXIS` primary softkey so that Y1 appears on the softkey. The Y1 axis is highlighted.



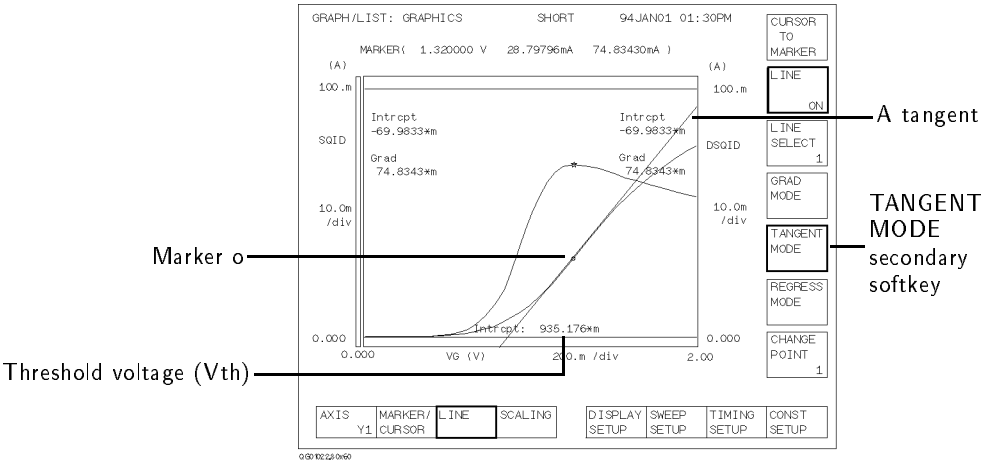
6. Select `LINE` primary softkey. The secondary softkey menu changes.



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

If HP 4155A/4156A cannot be powered on

- Check that the power cable is firmly connected to HP 4155A/4156A 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 4155A/4156A 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 4155A/4156A 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 4155A/4156A.
- If the self-test fails, see "If You Have a Problem" in the *HP 4155A/4156A User's Task Guide*.

If HP 16442A test fixture is not stable

- Install stabilizers on the HP 16442A.

  For this procedure, see "Installation" in the *HP 4155A/4156A User's Task Guide*.
- 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 4155A/4156A User's Task Guide*.

If You Have a Problem