

# Keysight Technologies B1505A Power Device Analyzer/Curve Tracer



Self-paced  
Training Manual

# Notices

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Keysight Technologies  
1400 Fountaingrove Parkway  
Santa Rosa, CA 95403

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## **In This Manual**

This document is the self-paced training manual to help you to understand what is Keysight B1505A and how to use the B1505A.

- **Module 1. Introduction**

This module explains the product concept and the key features of the B1505A/EasyEXPERT. You will learn about what is the B1505A.

- **Module 2. Basic Measurement**

This module explains the basic I-V sweep measurement function and the cabling and fixturing issues. You will learn how to measure I-V curves in the course exercises.

- **Module 3. Measurement Examples**

This module describes how to perform high current I-V measurement, high voltage I-V measurement, and high voltage C-V measurement. You will learn them in the course exercises.

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## Class Exercises

Class exercises use the test setup listed below. The test setup data are only examples and included in the Exercise B1505.xpg file stored in the *B1500 Series Product Reference CD*.

Module	Exercise	Device	Test setup/definition/data	Page
Module 1	no exercise			
Module 2	I-V measurement	511 kohm	Tracer 511 kohm	2-7
Module 3	High current measurement	Power BJT	Trace IC-VCE 10 us, 80us	3-6
	High voltage measurement	Power MOSFET	Trace BVDSS	3-13
	High voltage C-V measurement		Cds 1 kV	3-22

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### NOTE

#### Exercise B1505.xpg file

The Exercise B1505.xpg file is required to create the Exercise B1505 preset group which contains the test setup data used by the class exercises. It is stored in the \data\B1505 folder on the *B1500 Series Product Reference CD*.

The Exercise B1505 preset group should be created before starting the class exercise. To create the Exercise B1505 preset group, launch EasyEXPERT and import the file by using the Preset Group Import dialog box opened by clicking My Favorite Setup > Preset Group > Import Preset Group. The test setup data are only examples for the class exercises.

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### NOTE

#### .xtr files

The \data\B1505 folder also stores some .xtr files. They are the sample test results created by executing the test setup which has the same name as the result data. To display these sample test results, import the files by using the Test Result Import dialog box opened by clicking Results > Transport Data > Import.

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### NOTE

#### About sample data

The test setup data described in this manual are only examples. If these example data damage your devices, Keysight is *NOT LIABLE* for the damage.

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## Accessories and Devices Used in Class Exercises

The following tables lists the devices and accessories used in the class exercises described in this document.

**Table 1-1**                      **Devices used in Class Exercises**

Description	Quantity
Power MOSFET	1 ea.
Power BJT	1 ea.
511 k $\Omega$ Resistor	1 ea.

**Table 1-2**                      **Accessories used in Class Exercises**

Model No.	Description	Qty.	
N1259A	Test fixture	1 ea.	
	Inline package device 3 pin socket module	1 ea.	
		8 ea.	
N1254A-512	SHV-SHV test lead	2 ea.	
N1254A-513	SHV-banana adapter	2 ea.	
N1300A	CMU cable, for capacitance measurement	1 ea.	

<b>Model No.</b>	<b>Description</b>	<b>Qty.</b>	
16494A	Triaxial cable	2 ea.	
16493J	Interlock cable	1 ea.	
16493S	HCSMU cable	1 ea.	
16493T	HVSMU cable	1 ea.	

## **Module 1. Introduction**

- **Key Features**
- **EasyEXPERT**
- **User Interface**
- **Modular Mainframe**
- **Accessories**
- **Desktop EasyEXPERT**

## **Module 2. Basic Measurement**

- **SMU Fundamentals**
- **Tracer Test Environment**
- **Classic Test Environment**
- **Application Test Environment**
- **Kelvin and Driven Guard**
- **Connection Overview**
- **Interlock Function**
- **About Connector Type**

### **Module 3. Measurement Examples**

- **Setting Output Limit**
- **High Current Measurement**
- **High Voltage Measurement**
- **CMU Fundamentals**
- **Classic Test Environment**
- **CMU Calibration**
- **High Voltage C-V Measurement**
- **Force and Compliance Side Measurement**
- **Module Selector Control**

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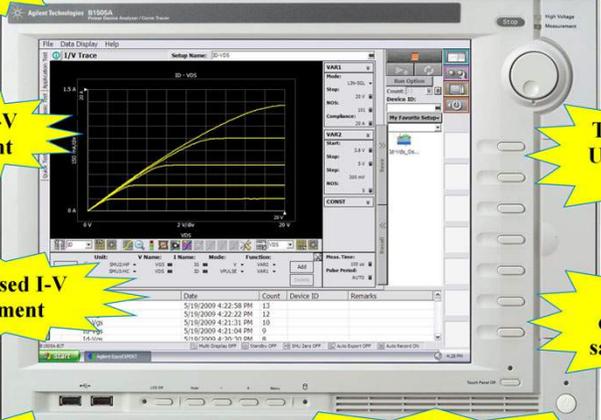
# 1 Introduction

## **In This Module**

- **Key Features**
- **EasyEXPERT**
- **User Interface**
- **Modular Mainframe**
- **Accessories**
- **Desktop EasyEXPERT**

Note:

## Keysight B1505A Power Device Analyzer / Curve Tracer



The image shows the Keysight B1505A Power Device Analyzer / Curve Tracer. The central focus is the device's screen, which displays an I/V trace graph with a yellow curve. The graph axes are labeled with voltage (0 V to 30 V) and current (0 A to 15 A). Below the graph is a table with columns for Date, Count, Device ID, and Remarks. The table contains four rows of data:

Date	Count	Device ID	Remarks
5/16/2009 4:22:58 PM	13		
5/16/2009 4:22:22 PM	12		
5/16/2009 4:21:31 PM	10		
5/16/2009 4:21:04 PM	9		

Surrounding the device are several yellow starburst callouts highlighting key features:

- +/-3000 V I-V measurement**
- EasyEXPERT environment**
- 10 Slots variable module configuration**
- +/-3000 V C-V measurement**
- Touch-screen, USB keyboard & mouse**
- +/-20 A pulsed I-V measurement**
- Test fixture designed for safe operation**
- Semi-auto prober control**
- HV/HC/HPSMU module selector, Bias-T, R-box, Protection adapter**

Note:

## Key Features

- **EasyEXPERT software**
  - **Application test environment (> 40 algorithms)**
  - **Tracer test environment – new concept curve tracer**
  - **Classic test environment – 415x like setup**
  - **Quick test environment – multiple test execution**
  - **Semi-auto prober control**
- **Modular mainframe**
  - **HPSMU, HCSMU, HVSMU for I/V sweep, multi channel I/V sweep, I/V list sweep, I/V-t sampling**
  - **MFCMU for C-V sweep, C-f sweep**
- **HV/HC/HPSMU Module Selector**
  - **Switching module connected to a device terminal**
- **High Voltage Bias-T**
  - **3000 V C-V measurement**
- **Touch-screen, knob, and softkeys**
  - **USB keyboard, mouse, and stylus pen**

### EasyEXPERT software

- Task-oriented, “top-down” approach to device characterization
- Curve tracer like operation
- 415x like operation
- Multiple test execution
- Automatic measurement, auto-analysis functions
- Test sequencing without programming

### Versatile Modular Mainframe

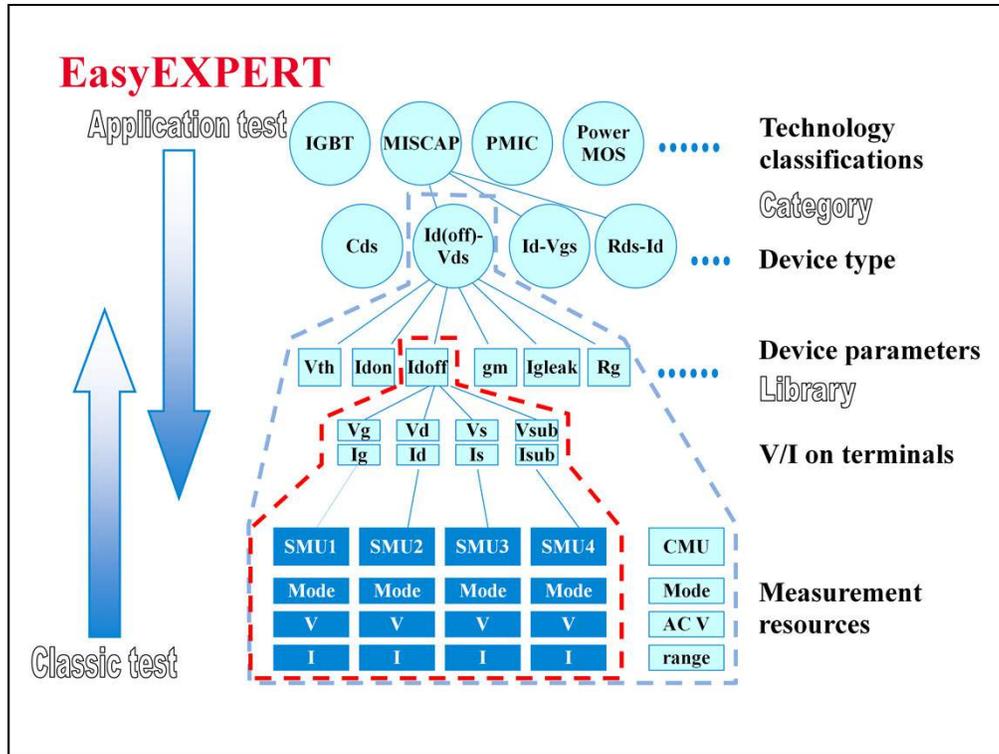
- Flexible & expandable (10 slots)
- Multiple SMU types
- Multi frequency CMU for up to 3000 V C-V measurement with high voltage bias-T
- HV/HC/HPSMU module selector for switching module connected to a device terminal
- 4.2 Amp Ground Unit

### Convenient User Interface

- Touch screen operation (with stylus pen)
- Contextual softkeys & knob control
- USB keyboard & mouse

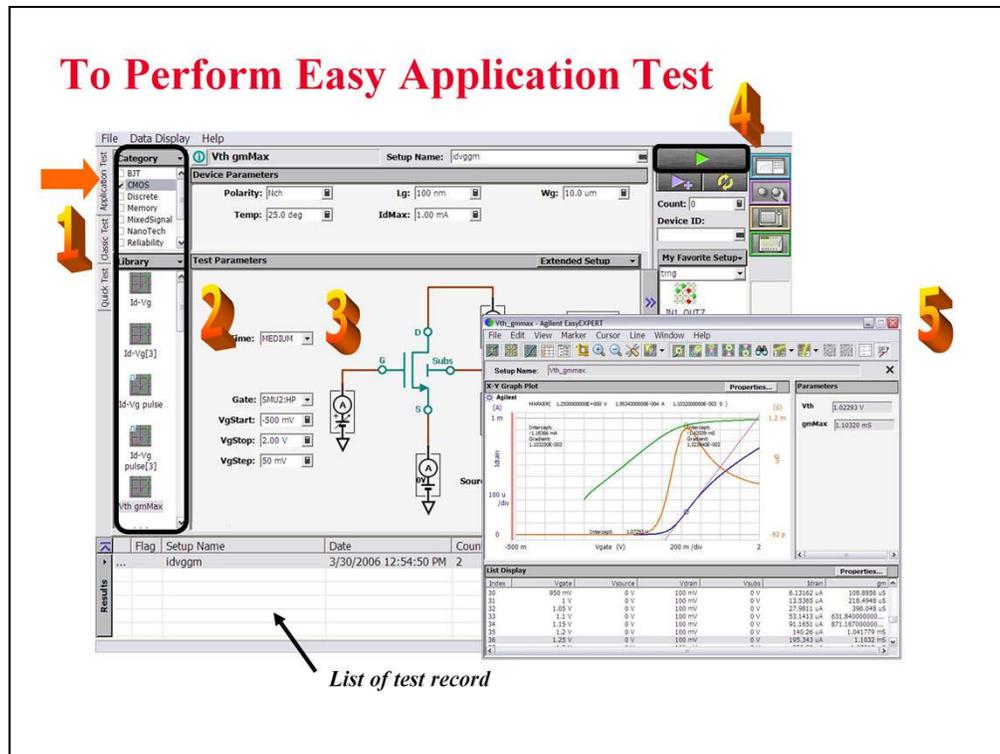
### Desktop EasyEXPERT software

- Controlling B1500A, B1505A, 4155B/C, or 4156B/C by an external computer
- Offline test development and data analysis



Instead of setting up the instrument hardware, the EasyEXPERT software focuses on the real task at hand for the engineer ---device characterization. All that you need to do is to connect the instrument to the device terminals as shown in the EasyEXPERT test parameters area.

The EasyEXPERT software also provides the classic test mode that allows the 4155/4156 like measurement setup operation and the tracer test mode that suggests the new concept curve tracer operation.



Step 1: Click Application Test tab.

Step 2: Select one or more technology categories, and select a desired test from the list of tests associated with the selected technology categories.

Step 3: Change the setup parameters (Device parameters and Test parameters) if you want.

Step 4: Connect DUT, and click the Start button. The B1505A starts the selected test.

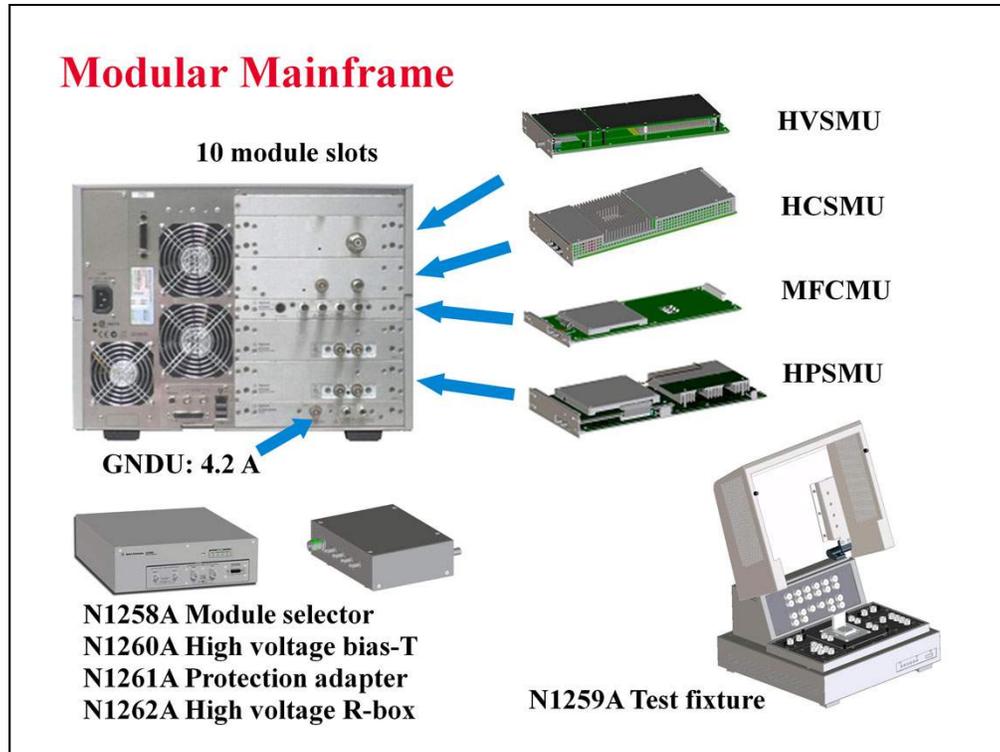
Step 5: Analyze the measurement result data displayed on the Data Display window automatically opened after the test.

The measurement result record is automatically stored in the internal hard disk drive when the Auto Recode mode is ON.

## User Interface

- Touch panel
  - Stylus pen
- Rotary knob
- Softkeys
- USB keyboard
- USB mouse





The following modules and accessories are available for the B1505A:

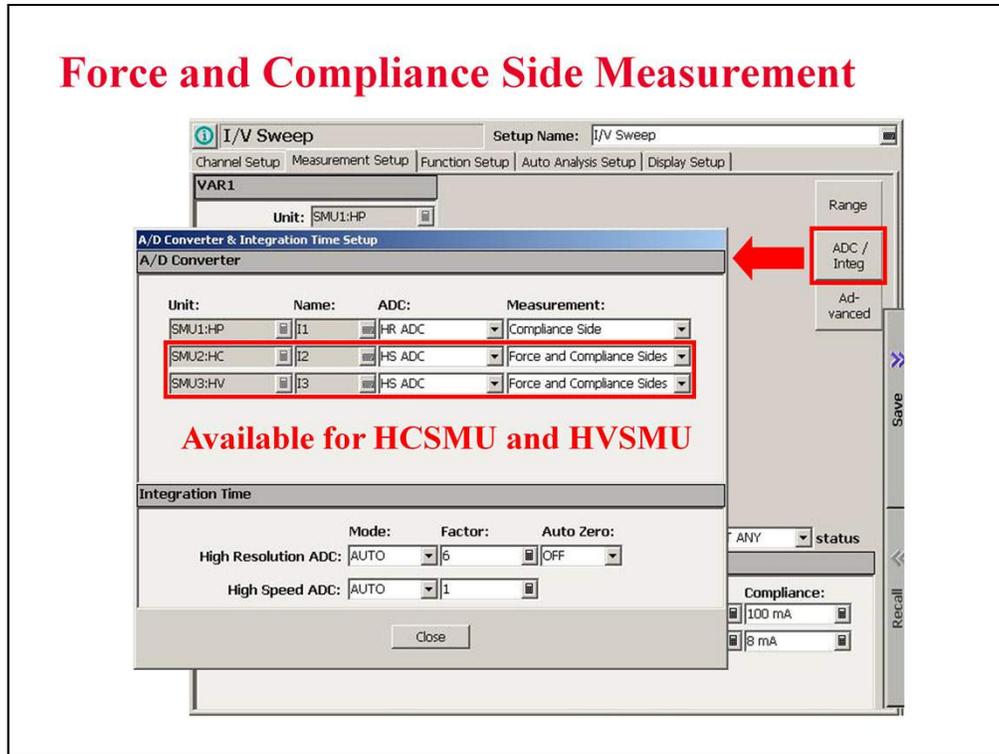
- HVSMU: 3000 V/8 mA force capability, 200 uV/10 fA measurement resolution (2 slot)
- HCSMU: 20 A(pulse)/40 V force capability, 10 pA/200 nV measurement resolution (2 slot), up to 2 modules
- MFCMU: 1 kHz to 5 MHz CV capability (1 slot)
- HPSMU: 1 A/200 V force capability, 10 fA/2 uV measurement resolution (2 slots), up to 2 modules
- Built-in GNDU: 0 V force, maximum 4.2 A sensing
- N1258A: Module selector for switching the module connected to a device terminal
- N1260A: High voltage bias-T for 3000 V C-V measurement
- N1261A: Adapter for protecting HPSMU or GNDU
- N1262A: High voltage R-box for reducing risk of device breakdown
- 16493S-010/011: HCSMU adapter for making the cable connection easily
- N1259A: Test fixture for packaged device measurements

The N1258A, N1260A, N1261A, N1262A, and 16493S are accessories for the measurements without the N1259A.

The N1258A and N1259A install HPSMU protection adapter and GNDU protection adapter.

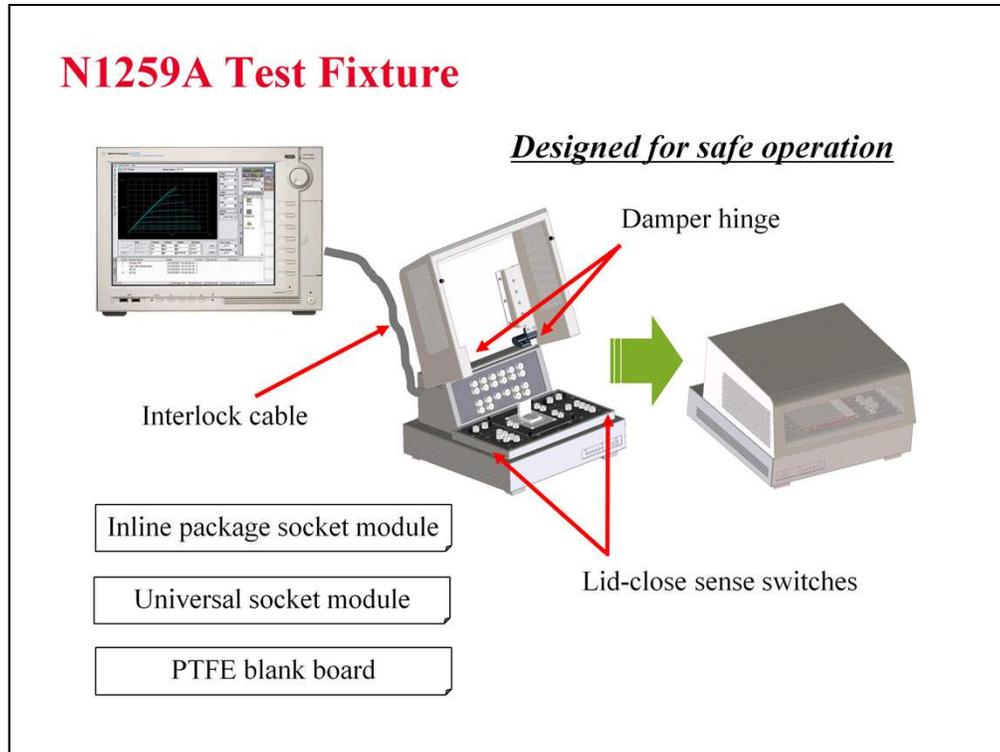
The N1259A can be equipped with the module selector, bias-T, and R-box.

## Force and Compliance Side Measurement



The HVSMU and HCSMU can perform the measurements for both force side and compliance side simultaneously. This means that the HVSMU/HCSMU can measure both voltage and current when it performs voltage or current output.

The Force and Compliance Sides measurement mode is not available for the HPSMU.



N1259A test fixture supports the following DUT interface for DUT connection.

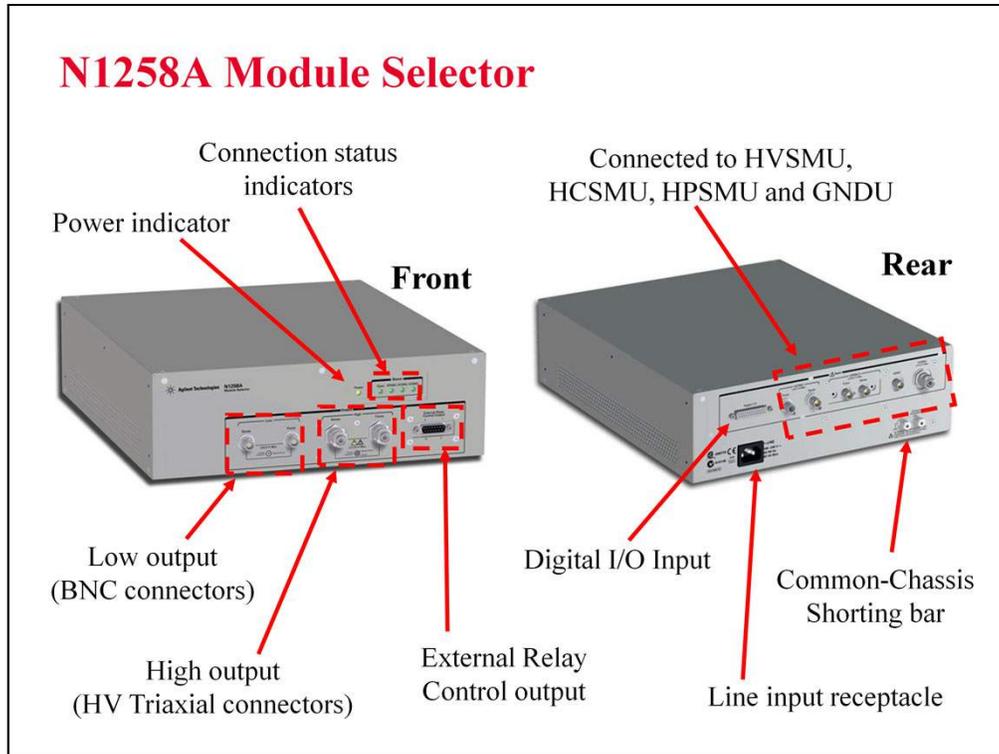
- Inline package socket module
- Universal socket module for supporting variety of packaged devices
- PTFE blank board for placing DUT

Interlock to Prevent Electrical Shock

Voltages greater than 42 V are not allowed when an interlock sense switch is open.

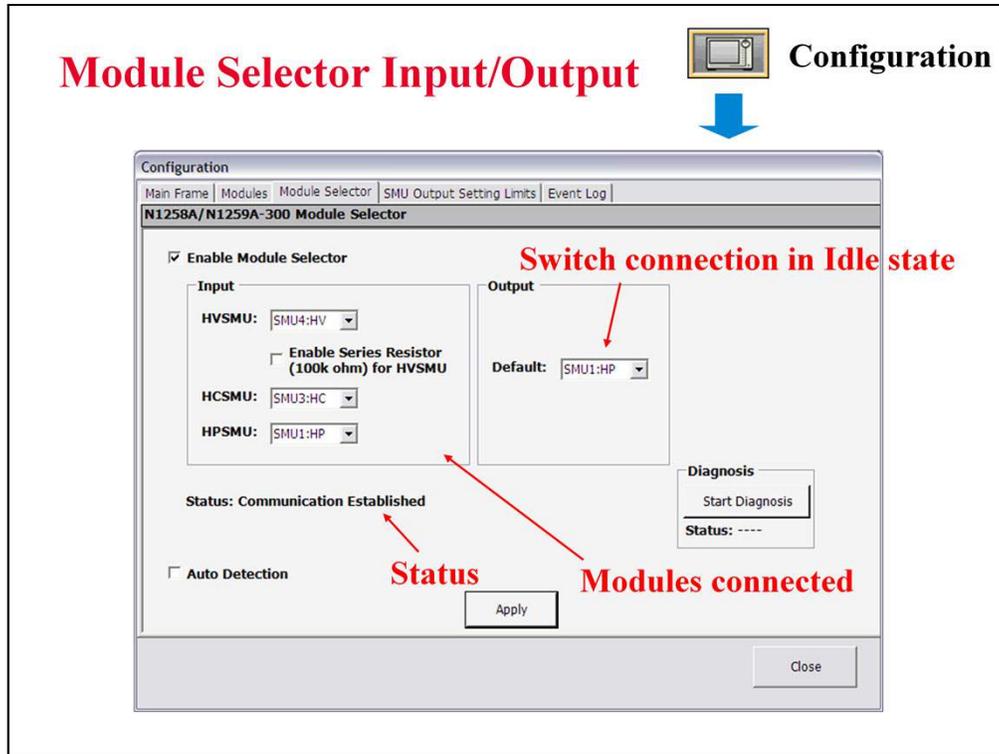
Pinch Point Prevention

Heavily damped lid hinges protect fingers and hands from injury due to the heavy lid suddenly slamming down.



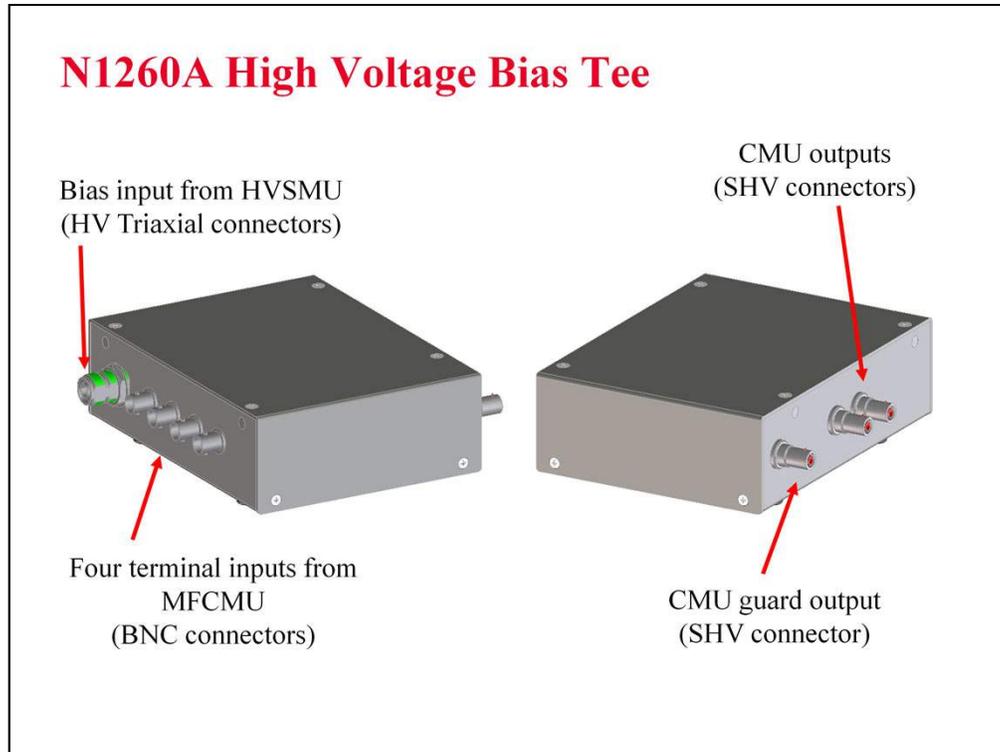
Module selector is used to switch the measurement resource connected to the device under test (DUT) automatically. The measurement resource will be HPSMU, HVSMU, or HCSMU. One selector provides one switching channel.

The N1258A is used with a DUT interface such as your own test fixture and prober station, not N1259A fixture.



The Configuration window Module Selector tab screen is used to specify the input connections and the default setting of the module selector.

The modules connected to the module selector inputs must be specified by the Input fields. And the default setting of the module selector internal switch must be set by the Default field. The default setting means the module selector internal switch connection in the idle state. The switch connection is automatically controlled by the EasyEXPERT software. The connection depends on the measurement module actually used in the test setup.

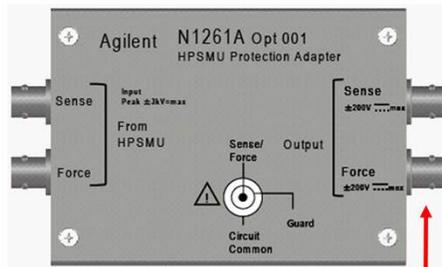


High voltage bias-T is used to perform the high voltage C-V measurement. The C-V measurement up to 3000 Vdc can be realized by using the bias-T, MFCMU, and HVSMU.

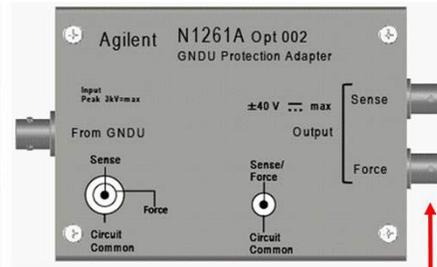
The N1260A is used with a DUT interface such as your own test fixture and prober station, not the N1259A test fixture.

## N1261A Protection Adapter

### HPSMU Protection Adapter



### GNDU Protection Adapter



Triax output connectors for N1261A-001  
HV output connectors for N1261A-003

BNC output connectors for N1261A-002  
SHV output connectors for N1261A-004

Protection adapter is used for protecting GNDU or HPSMU module from high voltage.

The N1261A is used with a DUT interface such as your own test fixture and prober station, not the N1259A test fixture.

N1261A-001: HPSMU protection adapter with Triaxial(f) output connectors

N1261A-002: GNDU protection adapter with BNC(f) output connectors

N1261A-003: HPSMU protection adapter with HV(jack) output connectors

N1261A-004: GNDU protection adapter with SHV(jack) output connectors

## N1262A High Voltage Resistor Box



	Resistance	Connector type	
		Input	Output
<b>N1262A-001</b>	<b>1 Mohm</b>	<b>HV</b>	<b>SHV</b>
<b>N1262A-002</b>	<b>100 kohm</b>	<b>HV</b>	<b>SHV</b>
<b>N1262A-010</b>	<b>1 kohm</b>	<b>Triax</b>	<b>Triax</b>
<b>N1262A-011</b>	<b>1 kohm</b>	<b>HV</b>	<b>SHV</b>

Resistor box is used for reducing the risk of device breakdown or preventing SMU from oscillation. 1 k $\Omega$  ( $\pm$  200 Vdc), 1 k $\Omega$  ( $\pm$  3000 Vdc), 100 k $\Omega$  ( $\pm$  3000 Vdc), or 1 M $\Omega$  ( $\pm$  3000 Vdc).

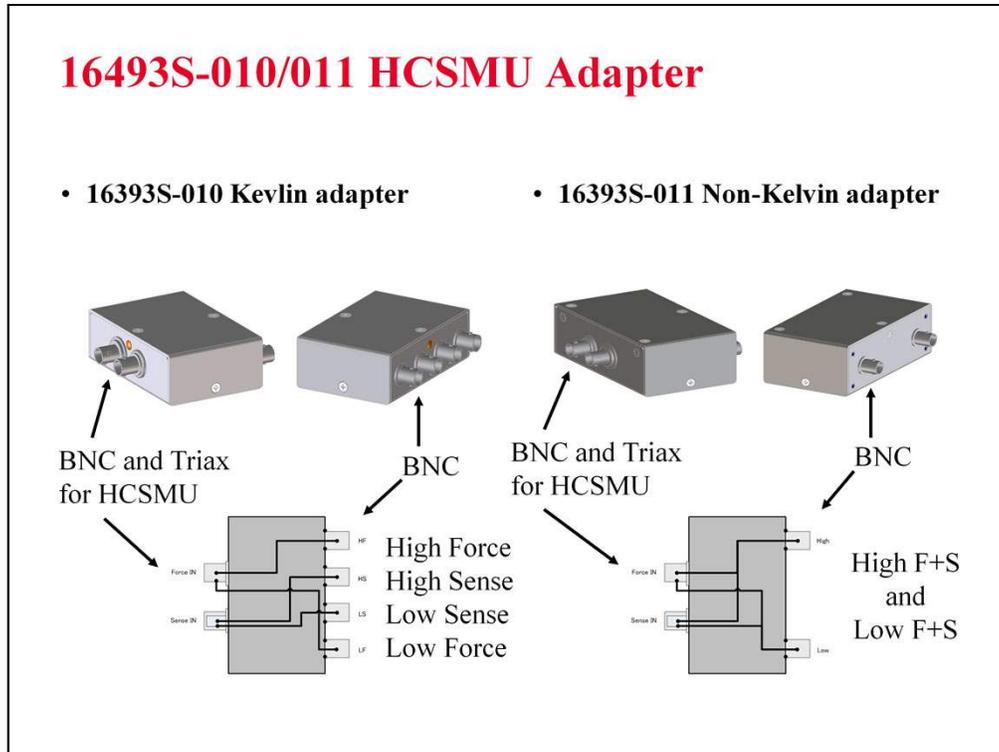
The N1262A is used with a DUT interface such as your own test fixture and prober station, not the N1259A test fixture.

N1262A-001: 1 M $\Omega$  ( $\pm$  3000 Vdc) resistor with SHV(jack) output connector

N1262A-002: 100 k $\Omega$  ( $\pm$  3000 Vdc) resistor with SHV(jack) output connector

N1262A-010: 1 k $\Omega$  ( $\pm$  200 Vdc) resistor with Triaxial(f) output connector

N1262A-011: 1 k $\Omega$  ( $\pm$  3000 Vdc) resistor with SHV(jack) output connector

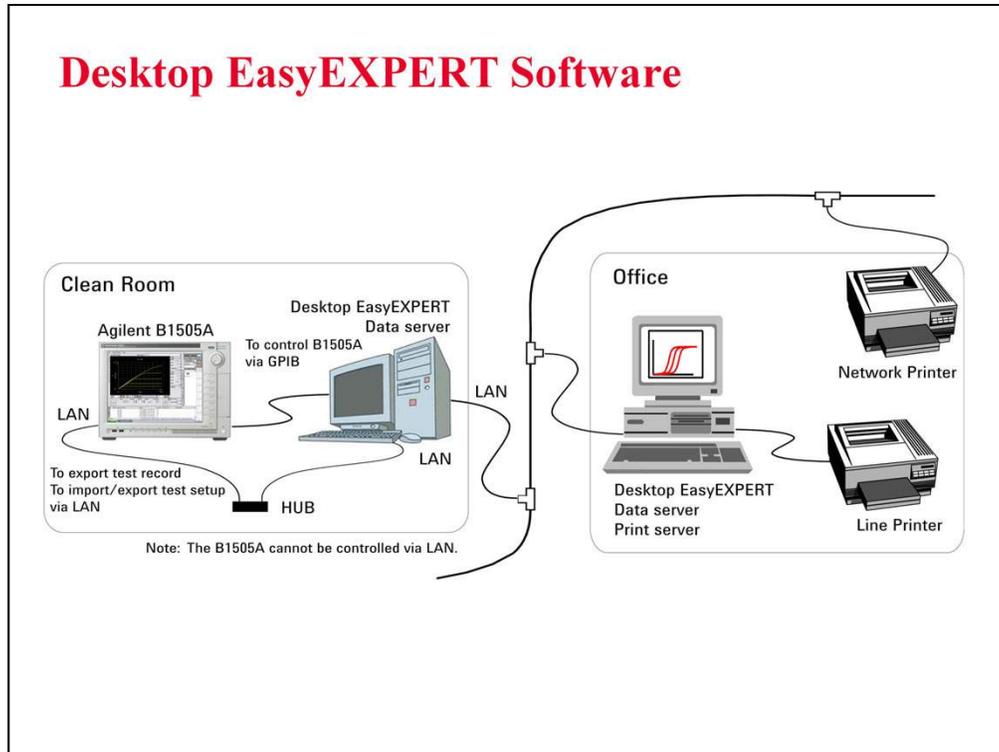


HCSMU adapter is used to convert the HCSMU Force and Sense connectors to the High and Low BNC connectors.

The 16493S is used with a DUT interface such as your own test fixture and prober station, not the N1259A test fixture.

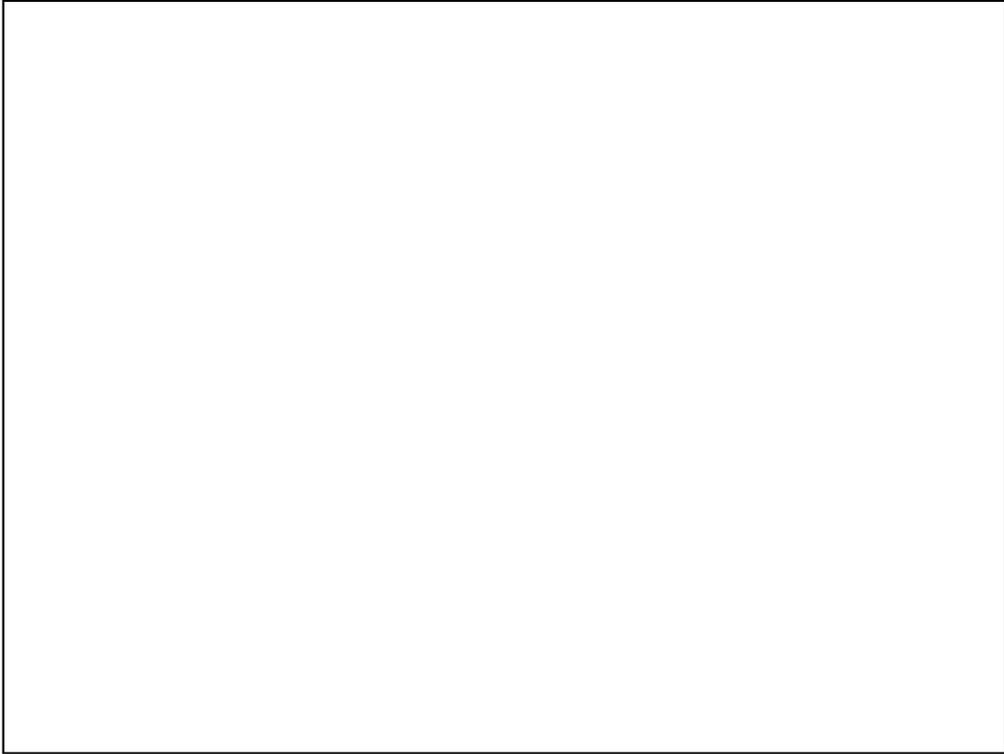
16493S-010: Adapter for making the Kelvin connection of HCSMU path

16493S-011: Adapter for making the non-Kelvin connection of HCSMU path



The Desktop EasyEXPERT software provides the following additional advantages to the B1505A, allowing you to minimize the amount of offline tasks performed on B1505A and increase the working ratio for measurements.

- Allows B1500A/B1505A/4155B/4155C/4156B/4156C to be controlled from an external computer via GPIB while online.
- Allows test setup to be created on an external computer while offline.
- Allows data analysis to be performed on an external computer while offline.



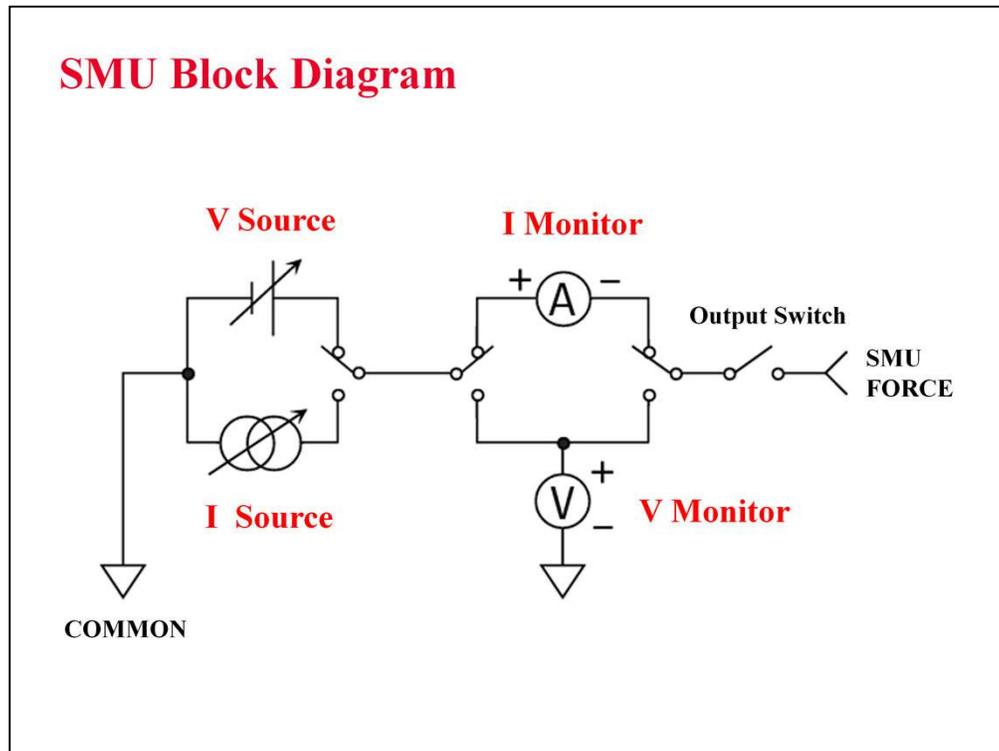
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## 2 Basic Measurement

## **In This Module**

- **SMU Fundamentals**
- **Tracer Test Environment**
- **Classic Test Environment**
- **Application Test Environment**
- **Kelvin and Driven Guard**
- **Connection Overview**
- **Interlock Function**
- **About Connector Type**

Note:



The source monitor unit (SMU) can function in the following modes:

- Voltage source while monitoring current (compliance side measurement)
- Voltage source while monitoring voltage (force side measurement)
- Current source while monitoring current (force side measurement)
- Current source while monitoring voltage (compliance side measurement)

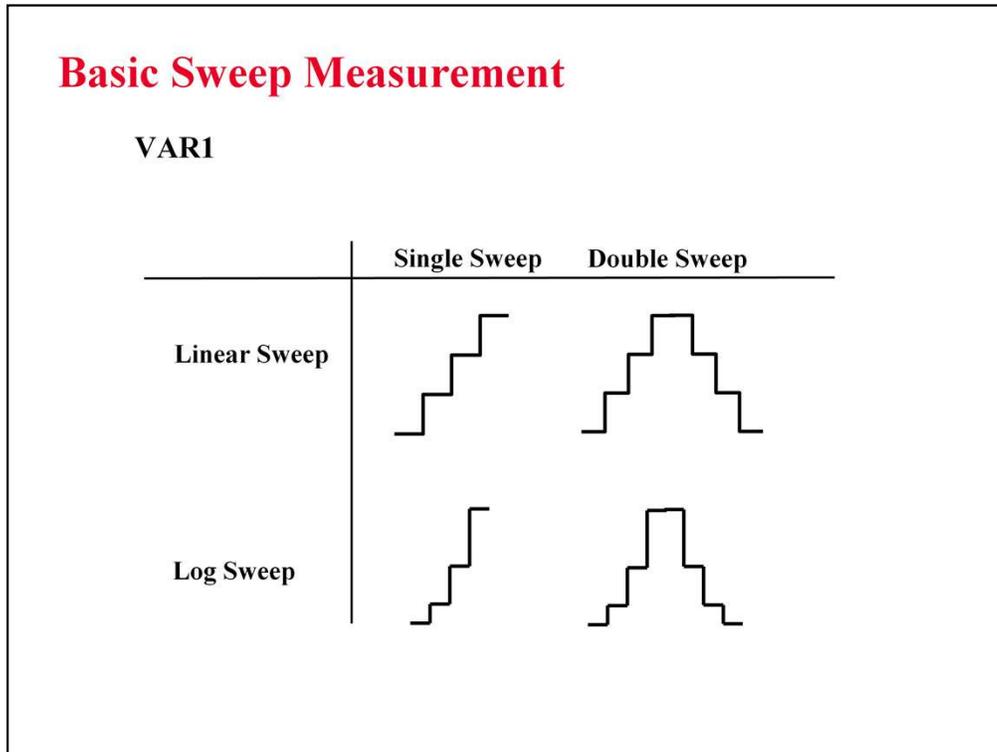
The force side measurement is available for HVSMU and HCSMU. In the GPIB remote mode, it is available for all SMU.

The SMU can output V or I in constant, linear sweep, logarithmic sweep or pulsed modes.

Constant V or I mode could be used for “spot” measurements or biases.

Swept output is used to trace a curve. A second SMU can be swept subordinately to measure a “family of curves.”

Pulsed mode is used during swept measurements to reduce the effects of thermal stress on the device under test (DUT).



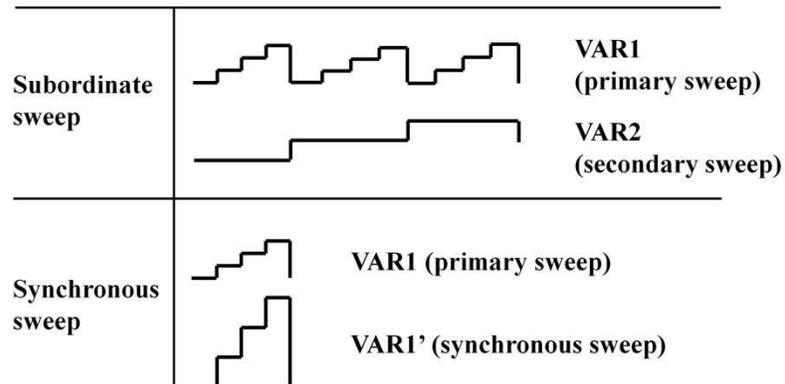
The SMUs can now sweep up to a value and then back down (double sweep). This feature is useful when the device must be tested without abruptly removing the forcing condition.

Log sweeps are required any time the measurement results span many decades, such as a MOS subthreshold curve.

The variable used to set the SMU to a basic sweep is VAR1. It may be called the primary sweep.

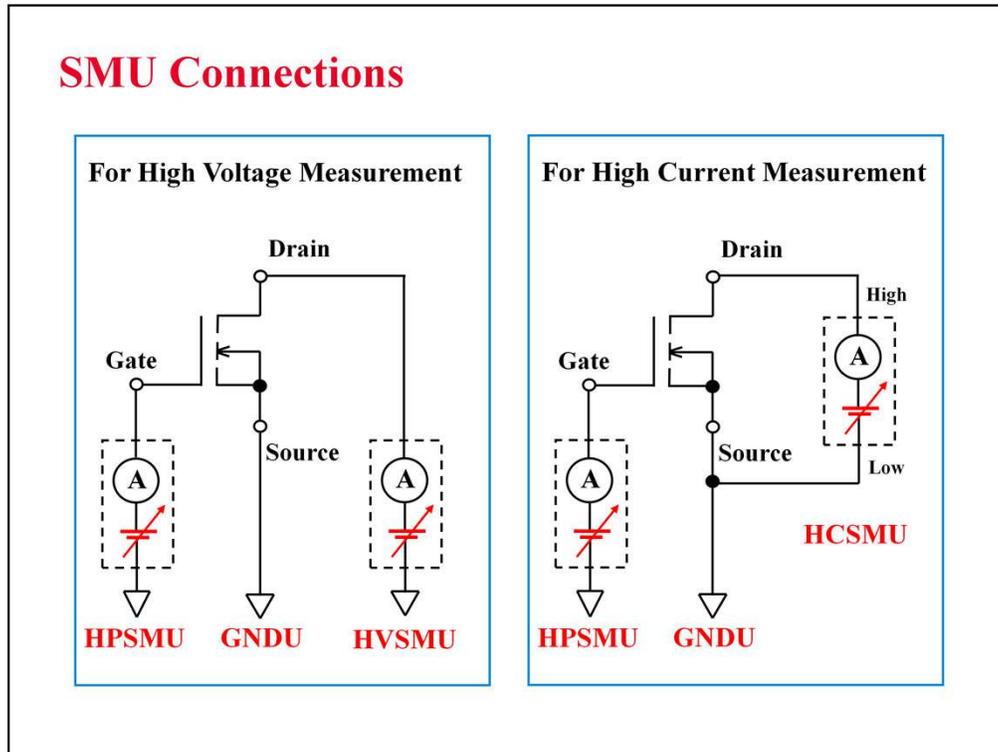
## Sweep Measurement Modes

### Combining VAR1, VAR1', VAR2



A subordinate sweep variable (VAR2) may be combined with the basic sweep variable (VAR1). This corresponds to the step knob and sweep knob of a curve tracer. This produces a family of curves. VAR2 may be called the secondary sweep.

Another useful combination is a synchronous sweep. Here VAR1 and VAR1' are in-step. VAR1' defaults to a gain of 1, which means it exactly tracks VAR1. You can also vary the initial offset between VAR1 and VAR1'. These features are useful for bipolar gummel plots, op-amp differential input tests, etc.



Before performing measurement, choose appropriate SMU type for connecting to the device terminal.

The above example shows the typical connections for measuring a power MOSFET which has 3 terminals. HPSMU and GNDU are connected to Gate and Source respectively. And HVSMU will be connected to Drain for the high voltage measurement. Or HCSMU High and Low will be connected to Drain and Source respectively for the high current measurement.

Kelvin connection is available for the HPSMU, HCSMU, and GNDU. To make the Kelvin connection, connect the SMU/GNDU Force and Sense terminals together at the point as close as possible to the device terminal. The Kelvin connection is effective for low resistance or high current measurement.

## **Class Exercise**

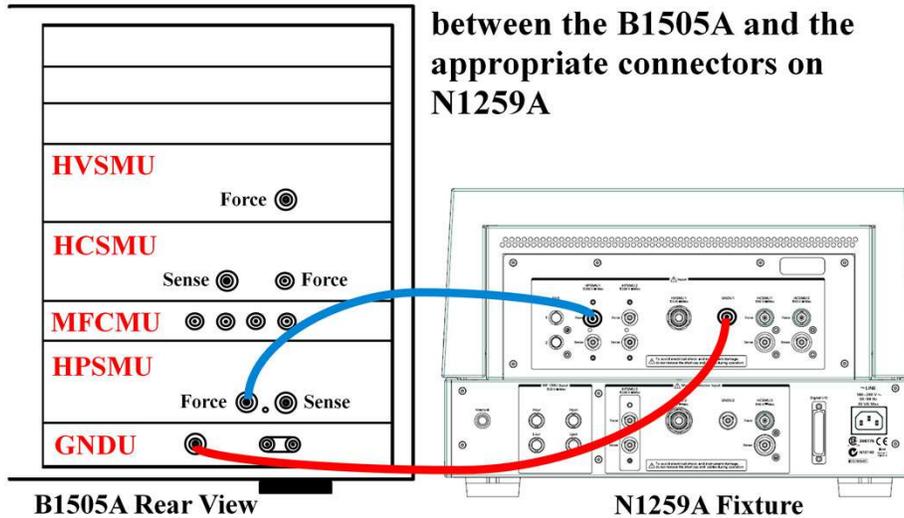
### **Perform Resistance Measurement**

- 1. Connect the B1505A and the test fixture.**
- 2. Display Tracer Test screen.**
- 3. Set the measurement condition (output value, etc.)**
- 4. Create your preset group, and save your setup.**
- 5. Connect device (resistor).**
- 6. Click  button to start a single measurement, or click  button to start a repeat measurement.**

Note:

## Connecting N1259A Test Fixture

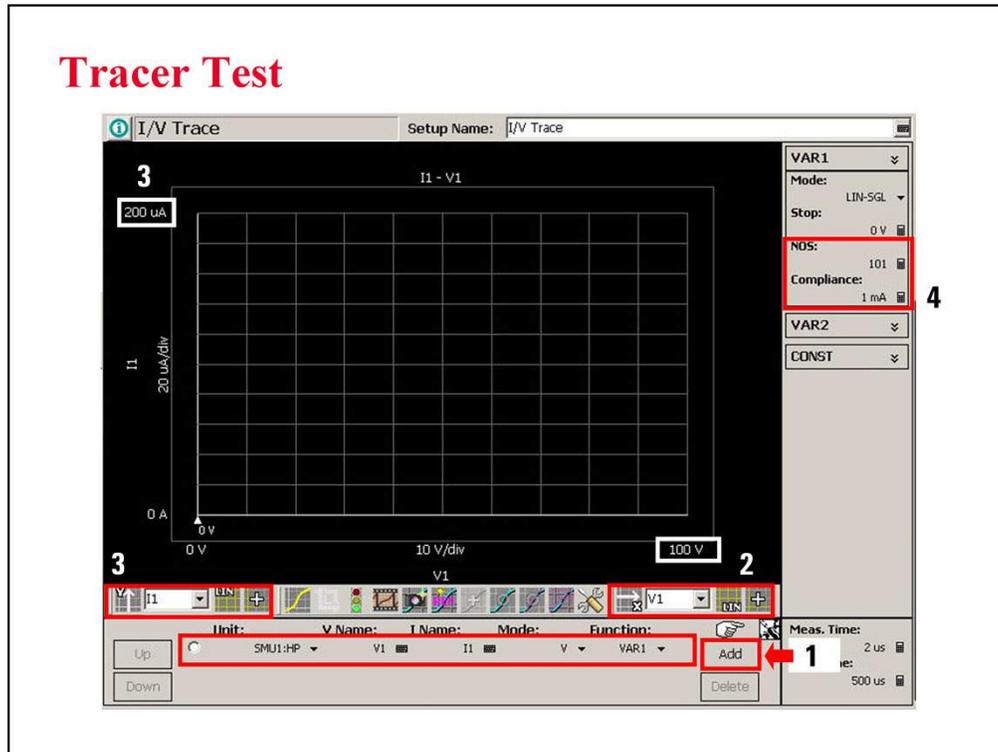
Connect the dedicated cables between the B1505A and the appropriate connectors on N1259A



Required equipment and accessories:

- B1505A with HPSMU
- N1259A test fixture
- 16493L GNDU cable for connecting GNDU
- 16494A Triaxial cable for connecting HPSMU

## Tracer Test



Tracer Test is the best way for performing I-V measurement easily and quickly.

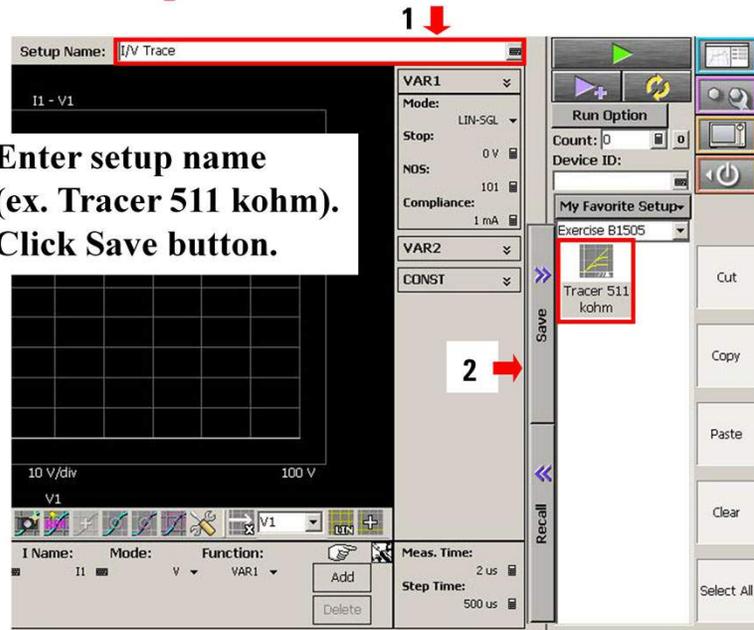
Display the Tracer Test screen and set the measurement condition.

You can finish the setup by the following four steps only.

1. Click Add button to add a SMU channel setup line.
2. Set the X axis and maximum value.
3. Set the Y axis and maximum value.
4. Set the NOS and Compliance values.

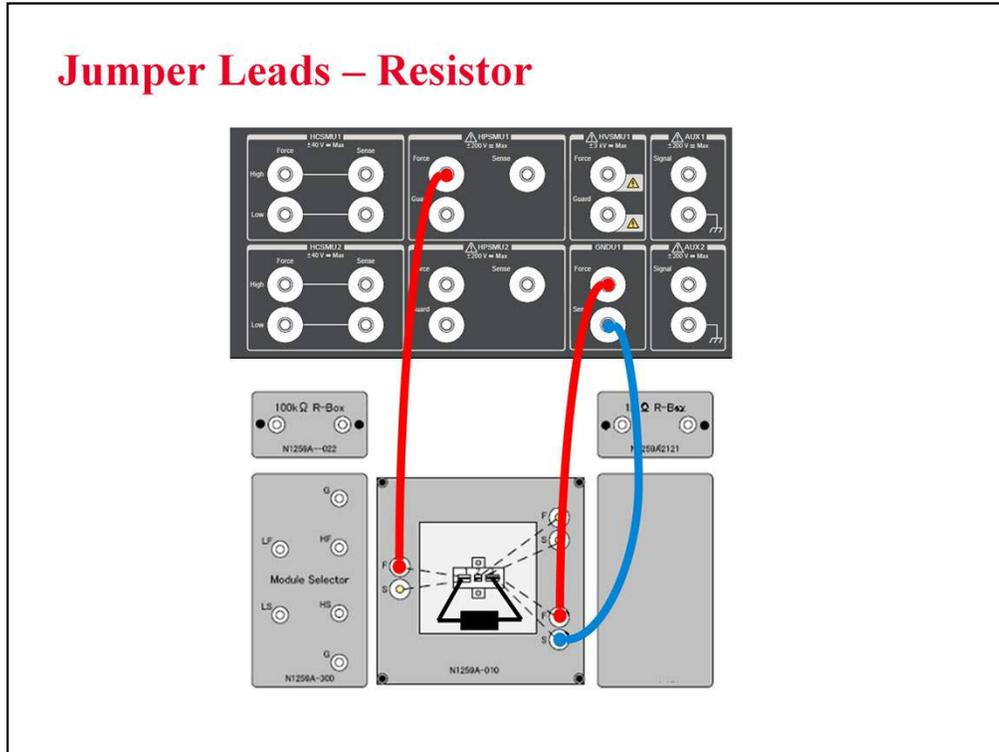
## To Save Setup Data

1. Enter setup name (ex. Tracer 511 kohm).
2. Click Save button.



Note:

## Jumper Leads – Resistor



Required parts:

- Inline package socket module
- Connection wire, 3 ea.

## To Perform Repeat Measurement

1. Highlight the VAR1 Stop entry field and leave it.
2. Click  button to start measurement.
3. Rotate the rotary knob to change sweep range.

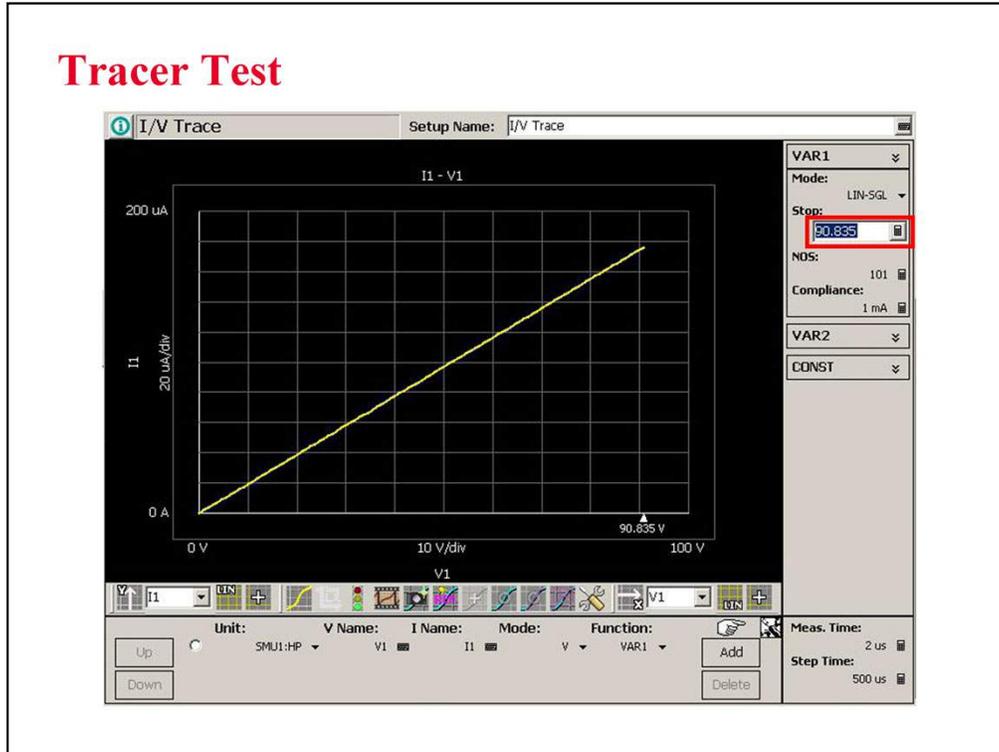


3



Note:

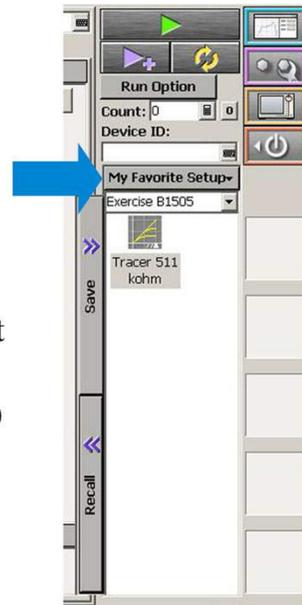
## Tracer Test



Note:

## To Import Demo Data

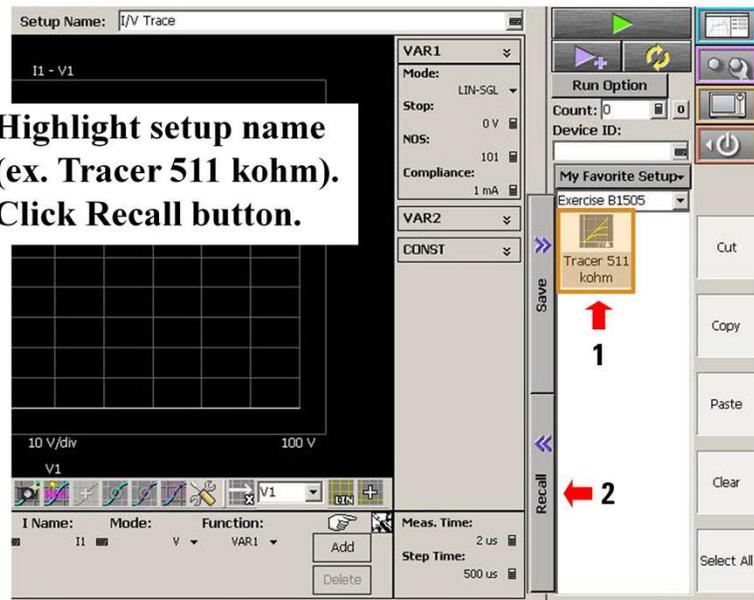
1. Prepare the Keysight B1500 Series Manual CD
2. Insert the CD into the B1505A built-in CD-ROM drive
3. Click My Favorite Setup button
4. Click Preset Group > Import Preset Group ...
5. Import the preset group files (.xpg) in the ¥data folder on the CD



The Keysight B1500 Series Manual CD stores demo data for this class exercise. Insert the CD and import the demo data to the EasyEXPERT database. The Exercise B1505.xpg file contains the test setup data used in this class exercise.

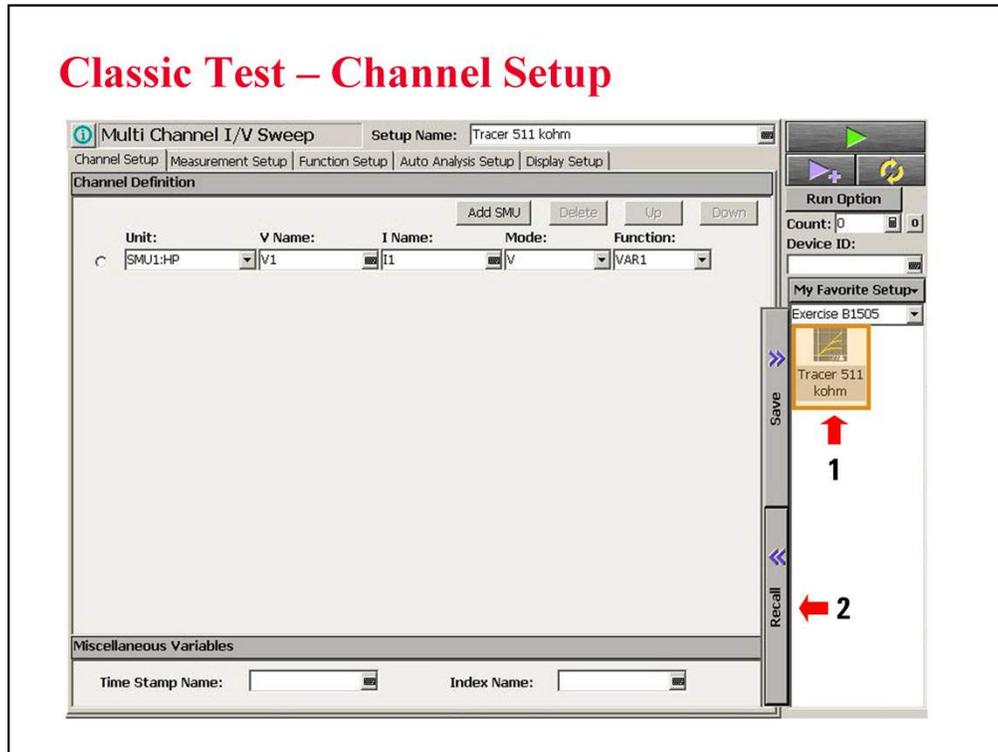
## To Get Setup Data

1. Highlight setup name (ex. Tracer 511 kohm).
2. Click Recall button.



Note:

## Classic Test – Channel Setup



The Tracer Test setup can be recalled in the Tracer Test mode as shown in the previous page. Also it can be recalled and used in the Classic Test mode.

Change the test mode to Classic Test, and perform the procedure shown in the previous page.

Display the Measurement Setup, Display Setup, and so on. And check the conversion result of the setup data. Also change the setup as you desire. You can set the details of measurement conditions which are not supported by the Tracer Test mode.

For the functions of Tracer Test and Classic Test, see Keysight EasyEXPERT Self-paced Training Manual.

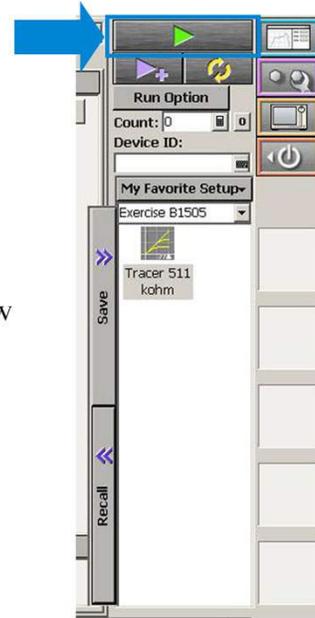
## To Start Measurement

1. Click Single button

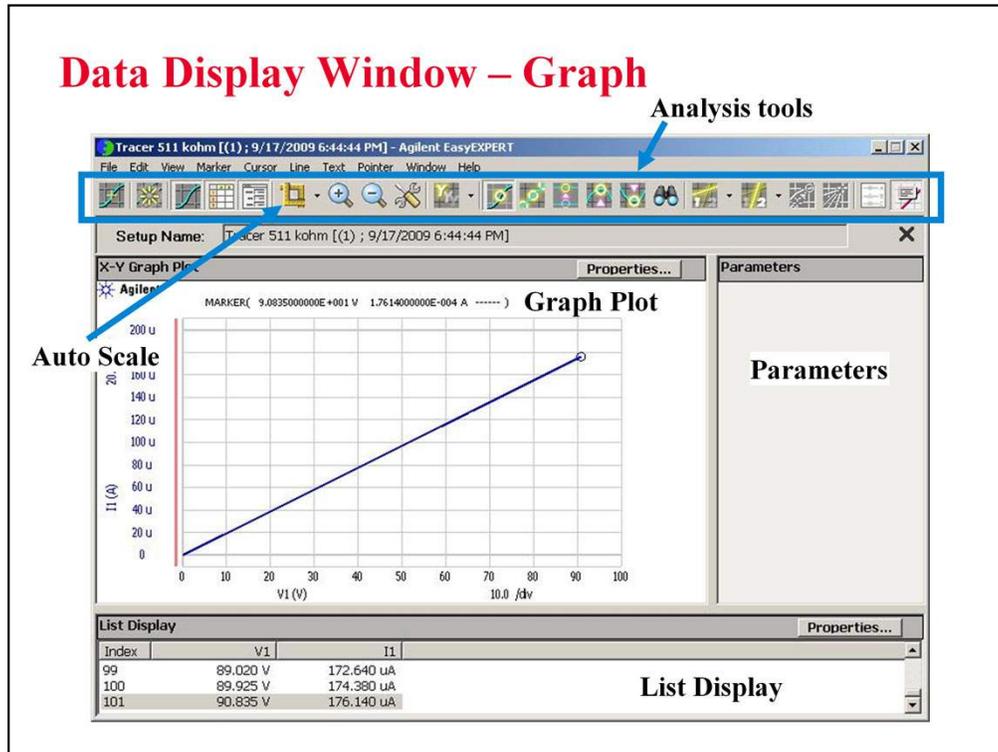


This opens the Data Display window and starts measurement.

The Data Display window shows measurement result data graph/list.



Note:



This window displays measurement result graph, list, and parameter values.

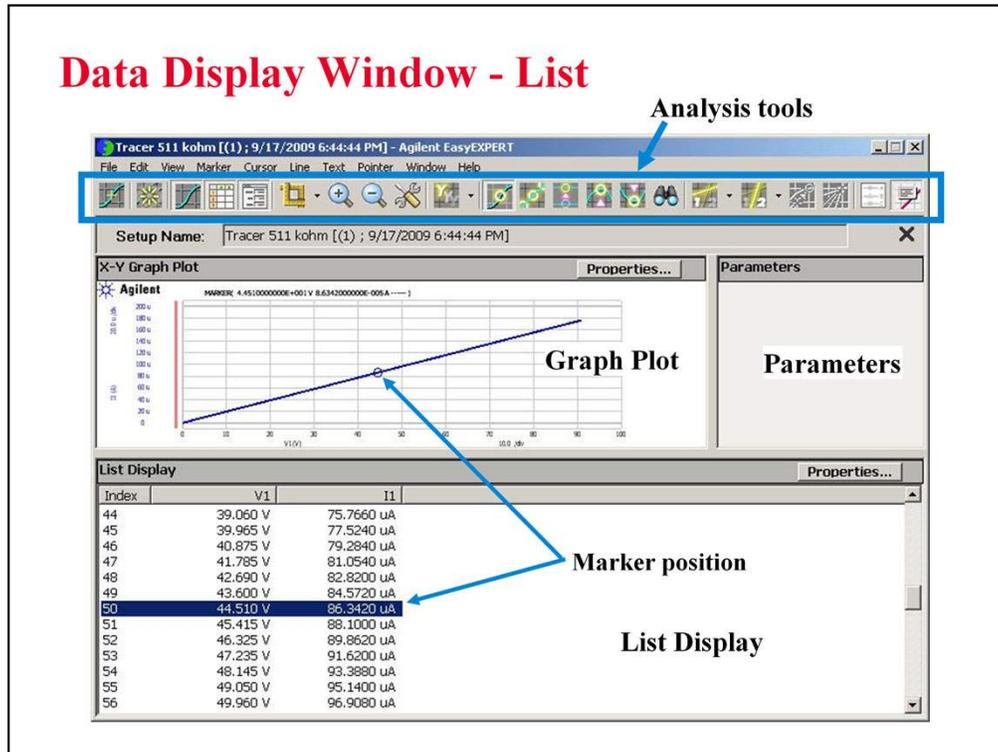
Markers are used to traverse the actual measurement data. Markers cannot be placed anywhere on the screen except on an actual measurement trace. They are denoted with a small circle. One moves the markers with the front panel rotary pulse generator (RPG) knob, mouse, or touch screen.

Cursor may be used anywhere on the screen and are denoted by a small cross. The cursor is moved using mouse, touch screen, or an arrow key.

The line function may be selected to draw one of four types of lines: line between cursors, gradient line, tangent line, regression line.

One of the most used interactive functions on this window is the autoscale feature which is applied by clicking the icon of yardsticks.

## Data Display Window - List



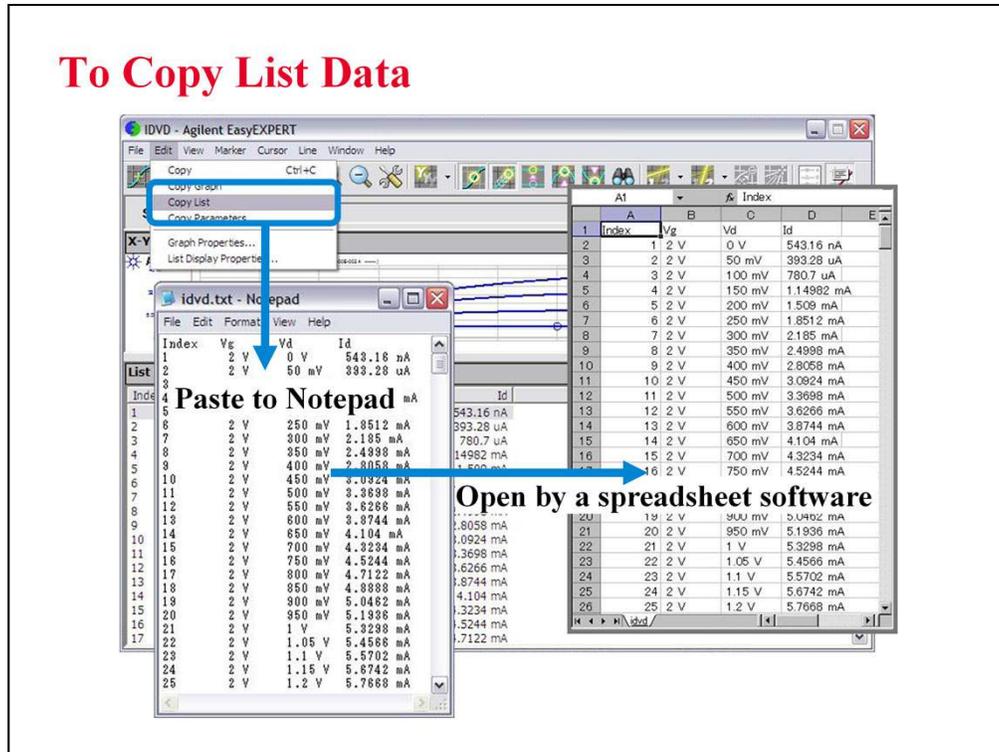
The List Display corresponds exactly with the Graph Plot. Even the highlighted line of data corresponds to the marker position on the Graph Plot.

Up to twenty columns of data can be set on the List Display. Note that the Graph Plot can only plot nine columns (X, Y1 to Y8).

The list data can be copied to a spreadsheet software easily. Click Edit > Copy List. This copies all of the list data into the clipboard.

On the Notepad, paste it and save it as a text file. The file can be opened as a tab separated value data by using a spreadsheet software. See the next page.

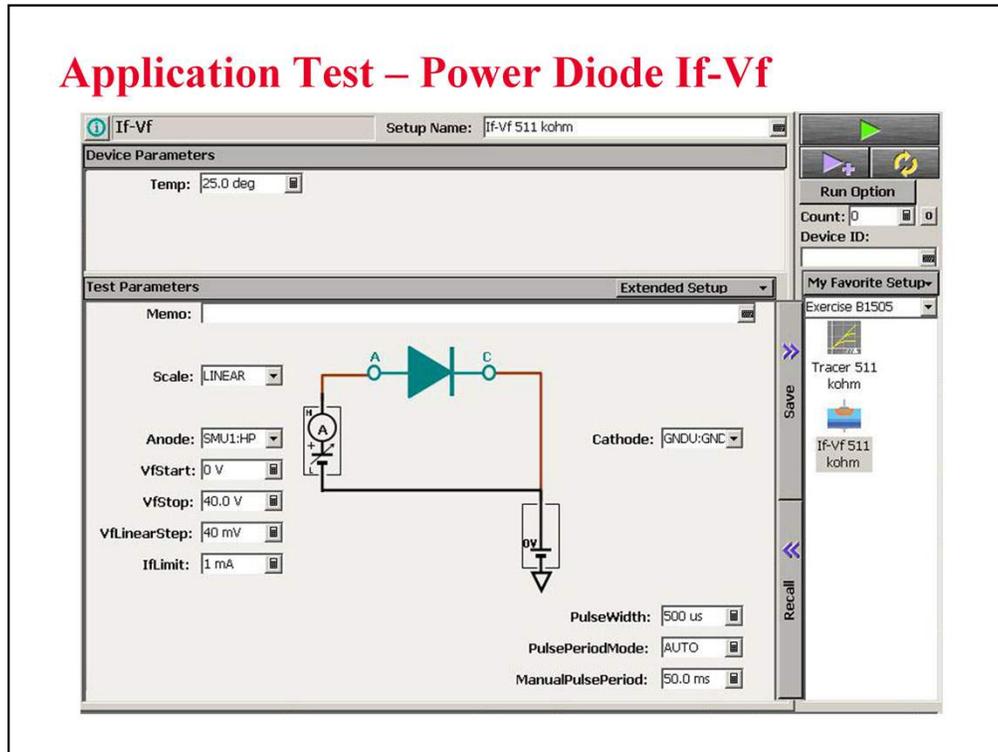
## To Copy List Data



You can read the measurement result on a spreadsheet software.

1. Click Edit > Copy List on the Data Display window.
2. Click Edit > Paste on the Notepad window.
3. Save the data as a CSV file.
4. Open the CSV file on your spreadsheet software.

## Application Test – Power Diode If-Vf



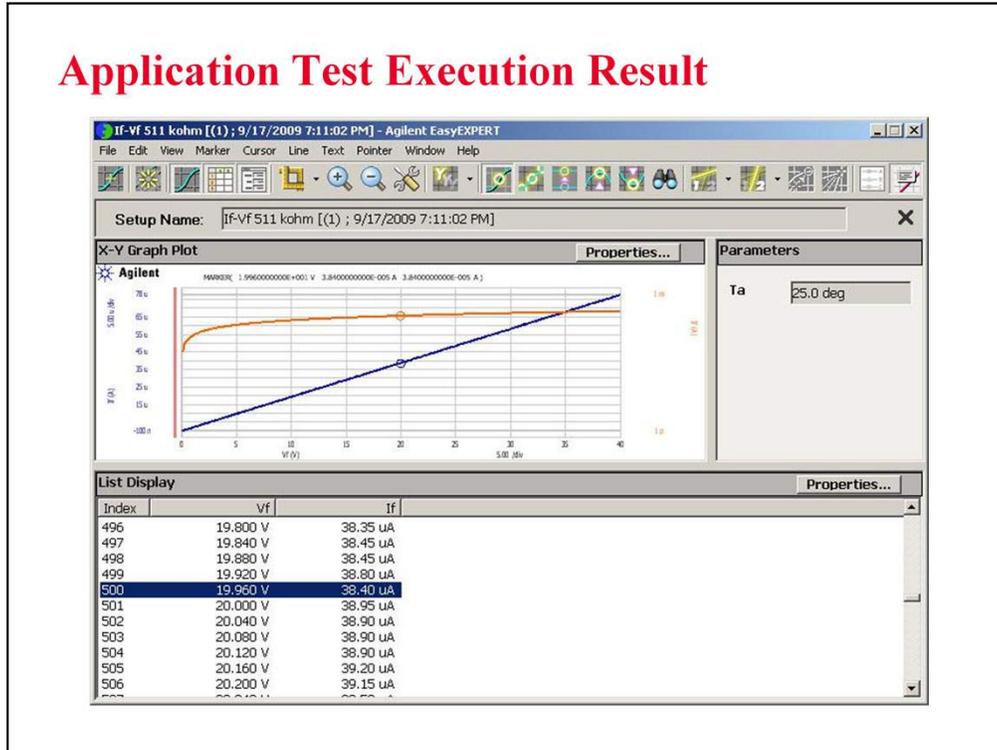
Open If-Vf application test in the Power Diode category. This test can be used for resistance measurement.

Set Anode to the available SMU (ex. SMU1:HP) and change VfStop value to 40 V which is the maximum value of this parameter. And execute the measurement. You can see the test result as shown in the next page.

Device Parameters area allows the user to set device parameters. In the If-Vf setup, the device parameter is temperature only.

Extended Setup button opens the Extended Setup dialog box which shows the extra setup parameters. In the If-Vf setup, the extended test parameters are hold time, If zero, measurement time, pulse base value, and pulse averaging count.

## Application Test Execution Result



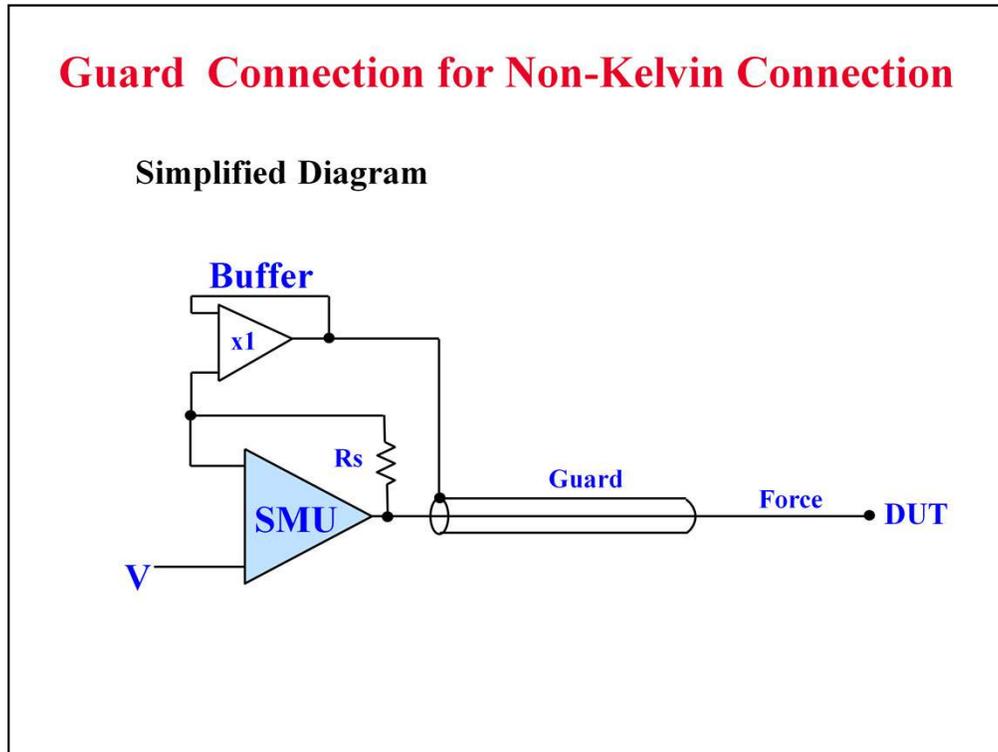
Note:

## Cabling and Fixturing Issues

- **Guard connection**
- **Kelvin connection**
- **Accessory connection**
- **Connection cables**
- **Interlock function**



The B1505A is a precision instrument. However, the ability to make precise and reliable measurements may be compromised by your fixturing to the device. The following section provides some theory and hints for making sense out of cabling and fixturing issues.

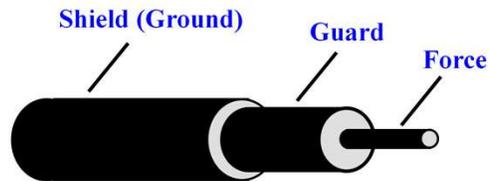


The guard connection is needed for the high voltage measurement and the measurement  $< 1$  nA. Below 1 nA a regular coax cable's capacitance dominates over the DUT (device under test) capacitance. What you see is cable charging current.  $I = C(dv/dt)$  where  $dv/dt$  is the rate of change of SMU voltage from one step to the next of a coax cable with no guard.  $C$  is the total capacitance of the cable.

The above diagram shows how the cable capacitance is eliminated with a triaxial cable. The guard is driven at the same voltage as the force center conductor. No current can flow between guard and force when they are held at the same potential. Guard and force are isolated by a buffer amplifier. They can never be shorted together.

The guard is effective for HPSMU and HVSMU.

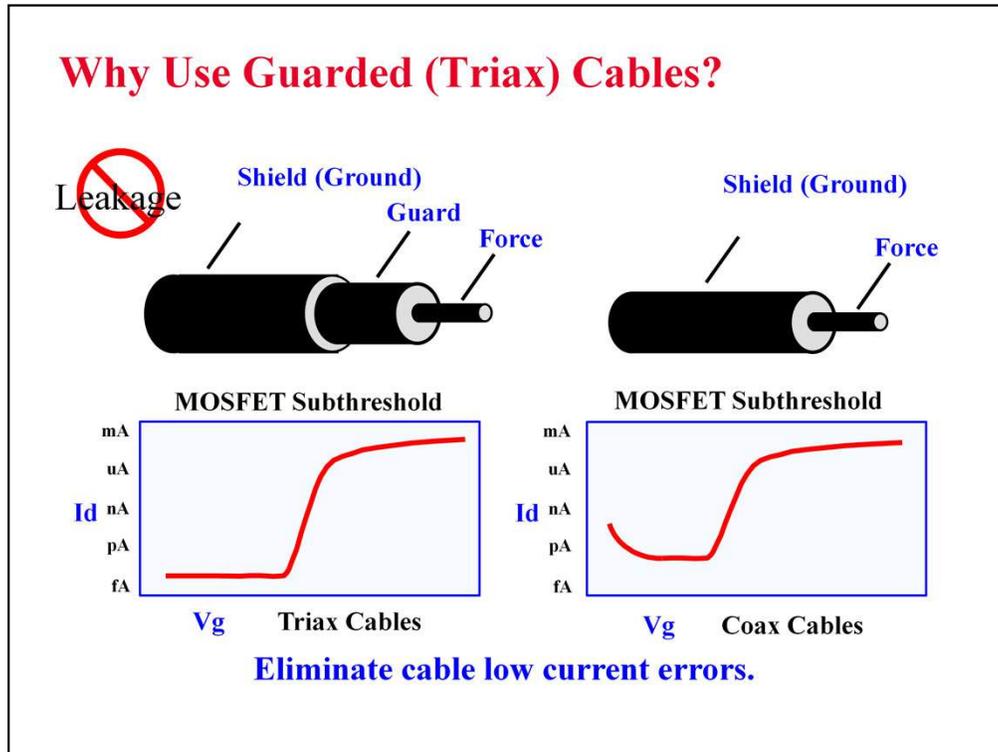
## Triaxial Cable for Non-Kelvin connection



	16494A-001 (1.5 m)	16494A-002 (3.0 m)
Shield Capacitance	900 pF	1800 pF
Guard Capacitance	130 pF	240 pF
Force Resistance	160m ohm	320m ohm

Shown above are typical capacitance and series resistance of the force line. If cables are too long, high capacitance may cause the SMU to oscillate. Keep the force-guard cable capacitance less than 600 pF. Similarly, the guard-shield capacitance must be less than 5000 pF.

Note the rather high force resistance. Kelvin connections must be used to eliminate this cable error.



The triax cable is a special low dielectric loss, high impedance cable. This cable may be used down to fA levels when properly used with a guarded probe. The guard voltage tracks the force voltage exactly, so that no voltage drop can exist between guard and force. This eliminates the capacitive loading that would otherwise limit low current measurements.

If low impedance coax cables are used with outer layer at ground potential, two limitations will be immediately apparent. The cable leakage will limit the low current measurement floor. In addition, when the voltage is swept, the sudden change will cause additional cable charging. This distorts the low current portion of a MOS subthreshold curve as shown.

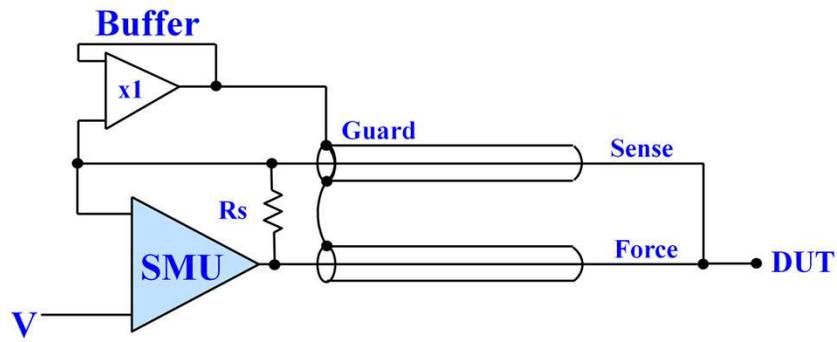
**RULES:**

Unguarded coax cable is OK for measurements above 1 nA.

Triax cable or coax with outer layer at guard potential should be used for measurements below 1 nA.

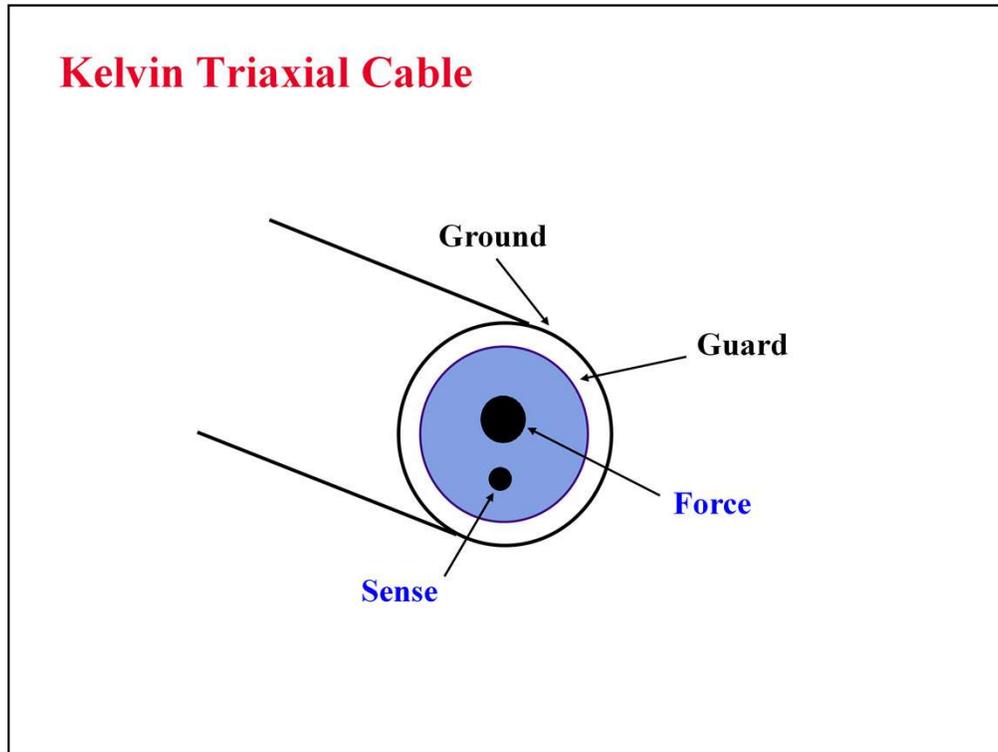
## Guard Connection for Kelvin connection

### Simplified Diagram



With the Kelvin connection, sensing is done at the DUT, eliminating the fraction of an ohm of cable resistance. The internal sensing resistor  $R_s$  is the only feedback path without the Kelvin connection.

Note that the B1505A operates just fine without the sense cable. This is important to know because in general you do not need the sensing Kelvin connection. Most MOS measurements are high impedance and the residual cable loss is insignificant.



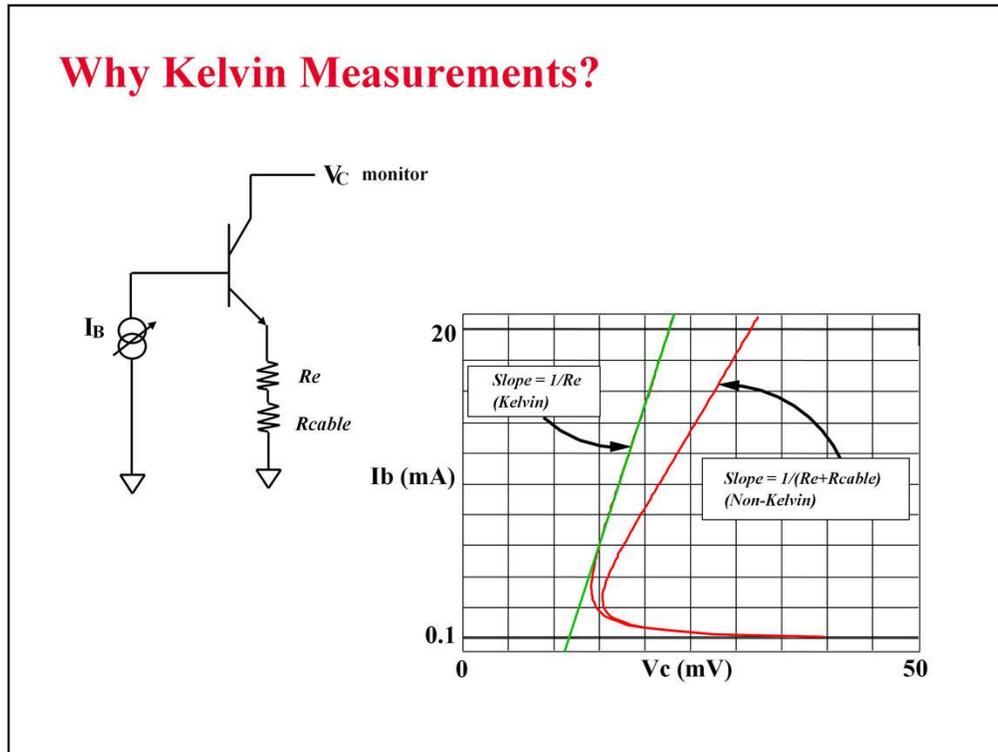
The triaxial cables are good for low current measurements. However, two cables are necessary for low resistance Kelvin measurements.

Keysight Technologies designed a special Kelvin triaxial cable for the precision semiconductor parameter analyzers. This cable is optimized for both low current and low resistance measurement. Both force and sense lines are held rigidly in the same PTFE cable. Friction is reduced and the cable is less sensitive to noise caused by moving the cable. This cable can be used for connecting the HPSMU installed in the B1505A.

Kelvin triaxial cable assemblies are available with two connector options:

16494B	B1500A/4156 compatible on one end; 4142 compatible on the other end
16493K	B1500A/4156 compatible on both ends (standard option)

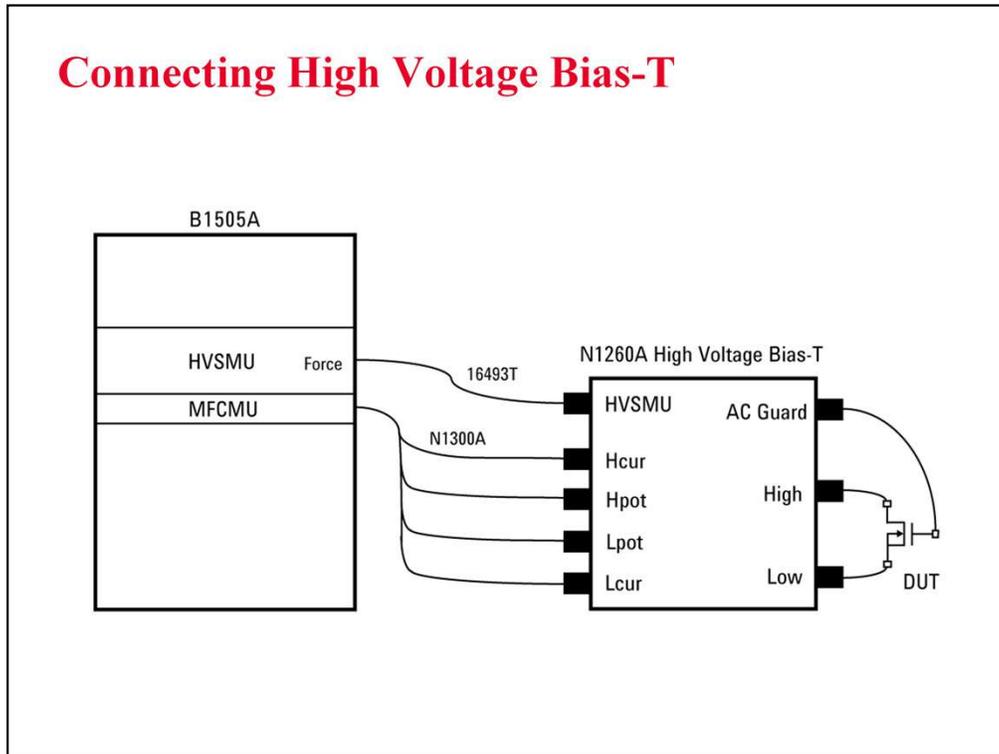
For connecting the HCSMU and HVSMU, use 16493S and 16493T respectively.



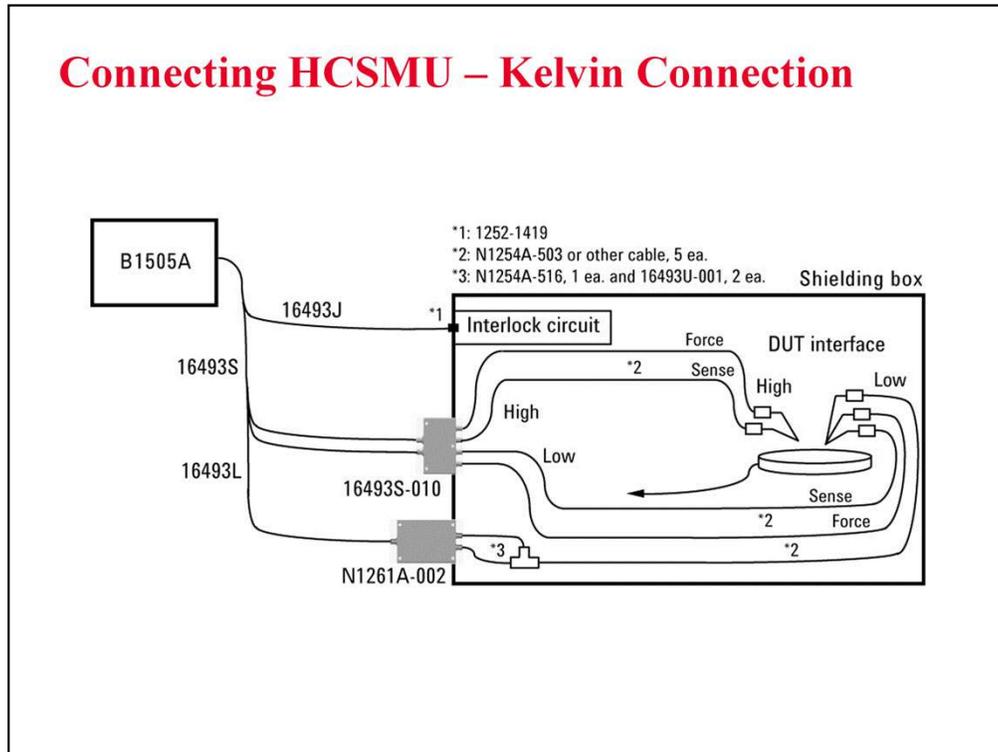
In the example above, the device is connected with a SMU on the base sweeping current, a voltmeter on the collector, and the emitter is grounded with a Kelvin SMU. The base SMU does not have to be Kelvin since we are only forcing current and do not care about measuring the cable loss in the base. Also, the collector SMU is being used only as a high impedance voltmeter, so there is no cable loss in this lead.

The emitter on the other hand, must be connected to a Kelvin SMU. Because of this, we can compensate for the  $R_{cable}$  ohm path through the cable and fixture. From the graph we can see the emitter resistance is  $R_e$  ohm when compensated using the Kelvin connection. Non-Kelvin resistance is  $R_e + R_{cable}$  ohm, due to the extra  $R_{cable}$  ohm cable and fixture resistance error.





The high voltage bias-T is required for the up to 3000 V high voltage C-V measurement. The B1505A and DUT should be connected as shown.



The 16493S-010 HCSMU Kelvin adapter converts the HCSMU connectors to four BNC connectors High Sense, High Force, Low Sense, and Low Force. This adapter must be used for the high current measurement to reduce the effect of the residual resistance.

The GNDU Force and Sense must be connected to the device low terminal. Then use a BNC-T adapter, two BNC cables, and N1254A-503 or other cable. To extend the accurate 0 V point as close as possible to the device terminal, extend the GNDU Kelvin connection to the device terminal.

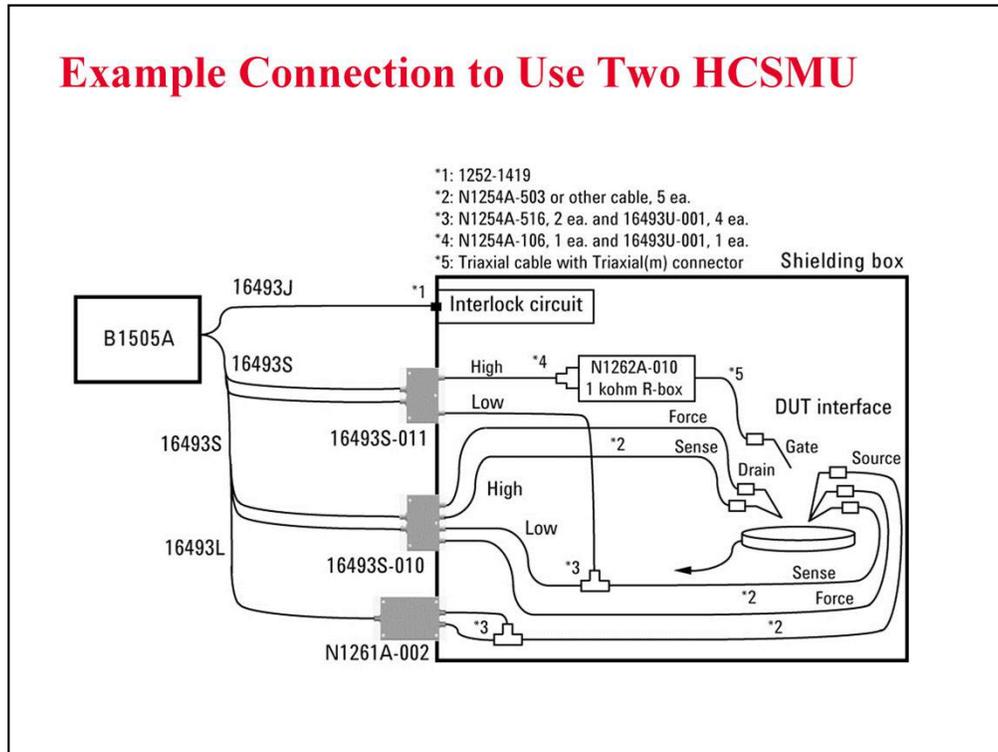
If you want to simplify the connections, prepare the following parts instead of the parts between the N1261A-002 and the device shown above.

Two BNC(m)-(f)-(f) adapters to be directly connected to the 16493S Low Force and Sense.

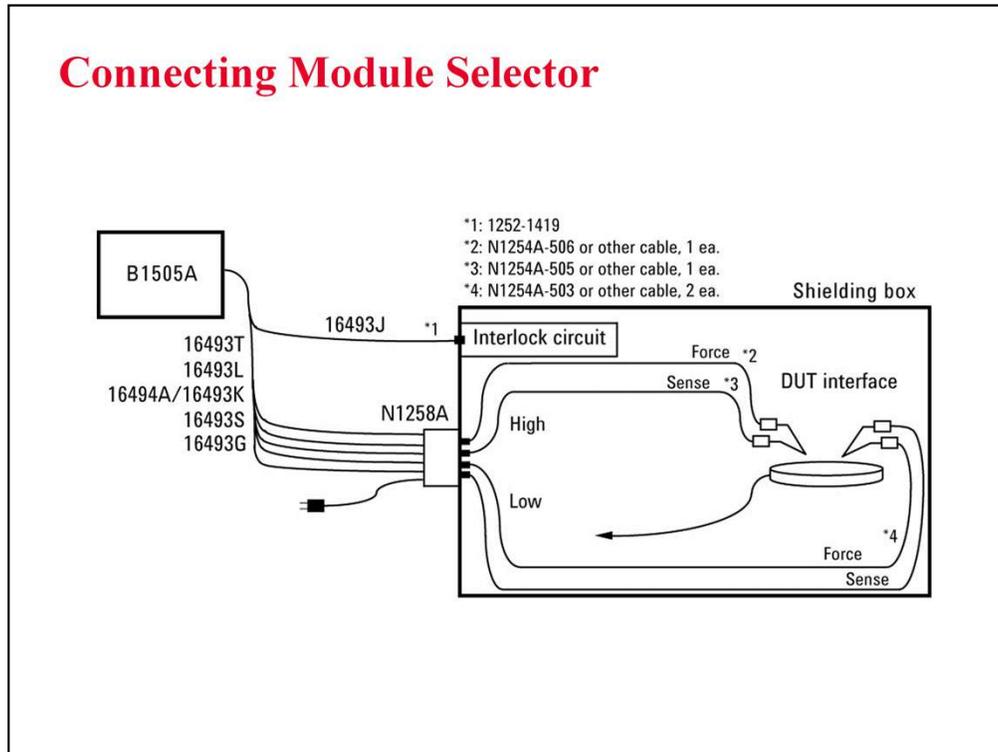
Two BNC cables to be connected between the N1261A Force/Sense and the 16493S Low Force/Sense.

This connection can save one probing pin or needle for the GNDU and can make the connection easy. However it may cause small noise on the measurement result.

## Example Connection to Use Two HCSMU



If the additional HCSMU is used for the measurement of the low current terminal such as MOSFET Gate, the 16493S-011 HCSMU Non-Kelvin adapter can be used instead of the 16493S-010 Kelvin adapter. The Non-Kelvin adapter converts the HCSMU connectors to two BNC connectors High and Low.

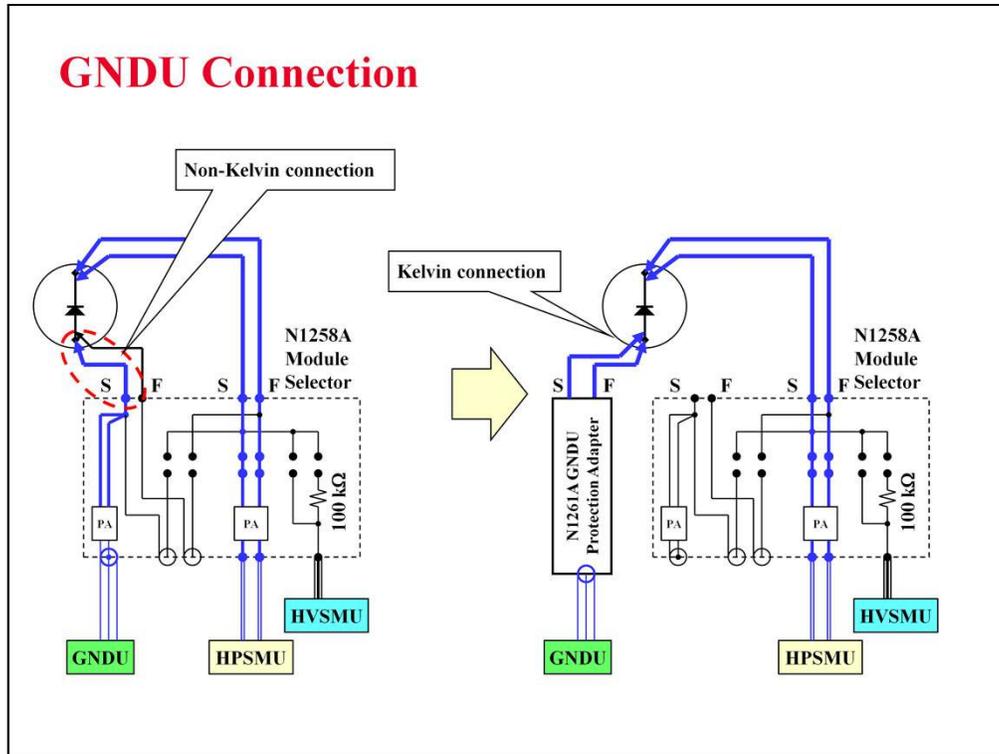


The module selector is used for the automatic switching of the measurement resources connected to DUT. The measurement resources are the HPSMU, HVSMU, HCSMU, and GNDU.

The module selector Low Sense and Force are internally connected to the HCSMU Low Sense and Force respectively also the Low Sense is connected to both GNDU Sense and Force. And the High Sense and Force connections are switched.

The module selector requires the AC power and the control signal via the B1505A Digital I/O connector.

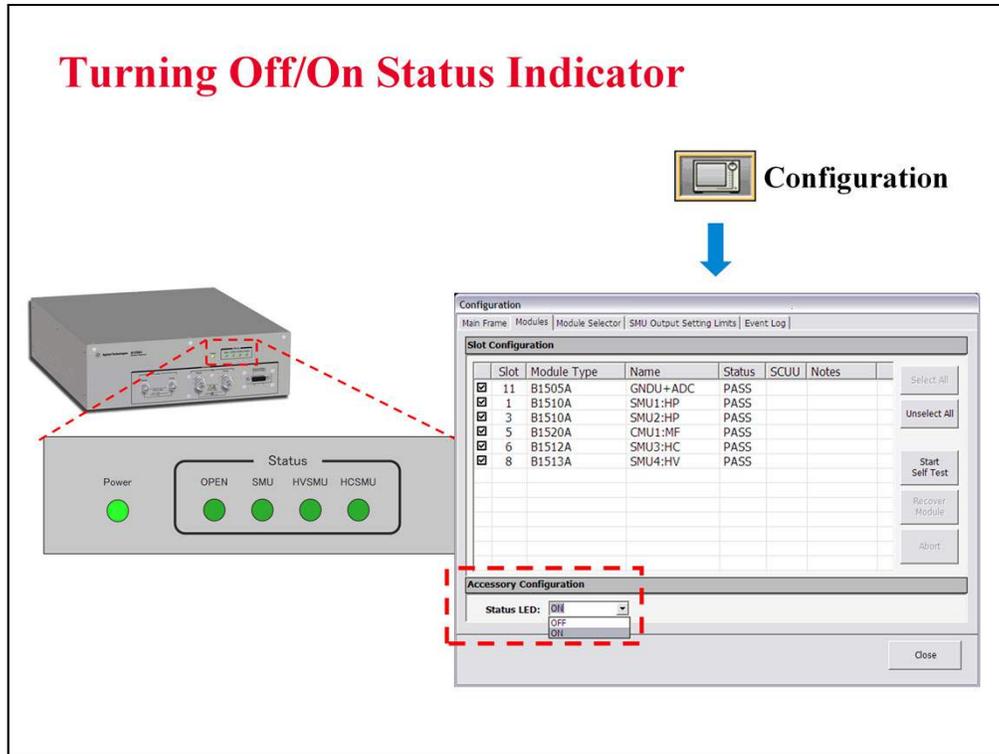
The module selector installs the HPSMU protection adapter and the GNDU protection adapter.



For the measurement using the module selector, the GNDU can be connected to the module selector GNDU input. This connection is especially effective for the measurement using the HCSMU because it makes cabling easy although it ends the Kelvin connection of GNDU in the module selector. This is no problem for the measurement with the HCSMU as no current flows to the GNDU.

This connection is also available for the measurement using the HPSMU or the HVSMU. However for the accurate measurement over 10 mA, use the N1261A-002/004 GNDU protection adapter to extend the Kelvin connection as close as possible to the device terminal.

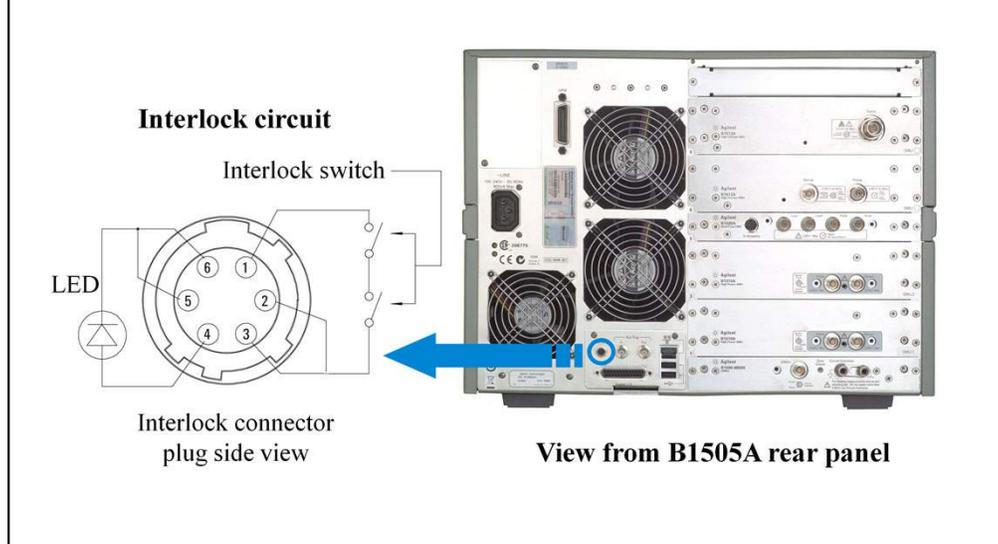
## Turning Off/On Status Indicator



To make complete dark condition in the prober shielding box, the status indicator must be OFF.  
The Power LED and Status indicator are disabled by setting Status LED to OFF on the Configuration window Module Selector tab screen.

## Interlock Function

- For measurements above 42 Volts
- For program control using program memory



To prevent shock hazard, the B1505A will not operate above 42 V, unless you connect the interlock circuit.

The interlock connection is required when the voltage exceeds 42 V or when the program memory is used in a control program.

The N1259A test fixture has the interlock circuit internally which makes this short by closing a lid activated switch.

You must make the circuit to your prober to comply with US OSHA safety standards. The switch on the prober should be mounted into the access door of the shield box.

If you want to wire your own cable or fixture, these Keysight part numbers may be used:

1252-1419 Female 6-pin plug connector

1252-1418 Male 6-pin cable connector

## Connector Compatibility

General Type		High Voltage Type	
Triaxial	BNC	SHV (Safe High Voltage)	MHV (Miniature High Voltage)
			
Max. 250 VDC	Max. 500 VDC Max. 500 VAC	Max. 5000 VDC Max. 3500 VAC	Max. 1600 VAC

SHV connectors are opposite male/female against the BNC, and it is easy to see incompatibility with others.

MHV connectors are similar to BNC connectors, and are often mistaken to be BNC connectors.

To connect the HVSMU, the SHV connector must be used. The other connectors do not support up to 3000 V.

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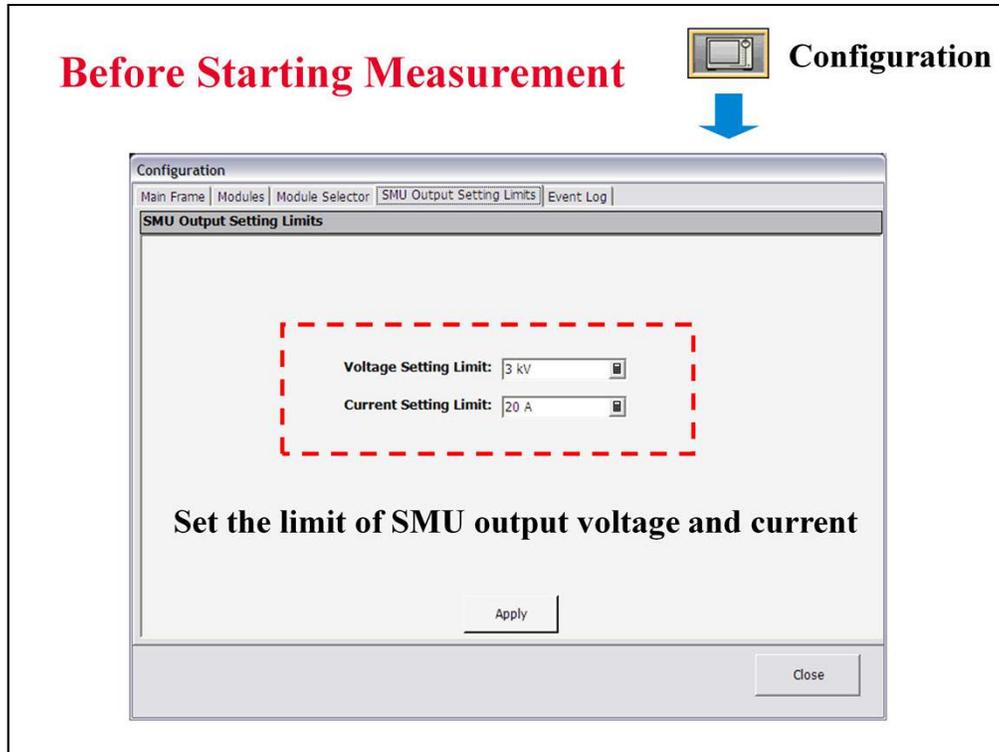
**3**

## **Measurement Examples**

### **In This Module**

- **Setting Output Limit**
- **High Current Measurement**
- **High Voltage Measurement**
- **CMU Fundamentals**
- **Classic Test Environment**
- **CMU Calibration**
- **High Voltage C-V Measurement**

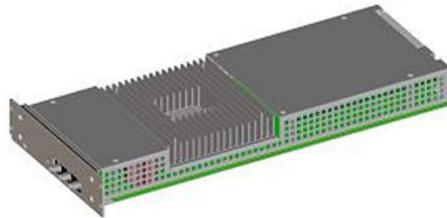
Note:



The HVSMU and HCSMU output can be limited by using the Configuration window SMU Output Setting Limits tab screen. This is effective for preventing the probe tip from burning out.

## High Current SMU

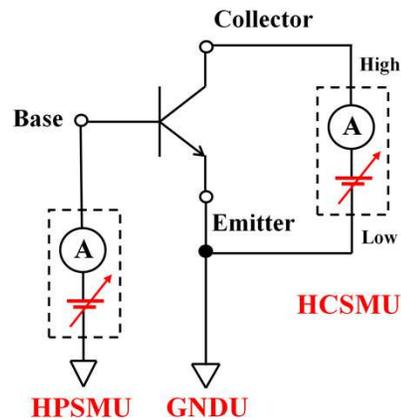
- Occupies 2 slots of B1505A
- 20 A/20 V pulse output
- 1 A/40 V DC/pulse output
- 1/1,000,000 set/measurement resolution
- DC sweep, Pulsed sweep
- Minimum 50  $\mu$ s pulse width
- Faster measurement time



Note:

## High Current Measurement

### SMU Connection



HPSMU can be used for the measurement up to 1 A. And HCSMU supports the high current measurement up to 20 A.

The above example shows the typical connections for measuring a power bipolar junction transistor which has 3 terminals. HPSMU and GNDU are connected to Base and Emitter respectively. And HCSMU High and Low will be connected to Collector and Emitter respectively for the high current measurement.

Kelvin connection is available for the HPSMU, HCSMU, and GNDU. To make the Kelvin connection, connect the Force and Sense terminals together at the point as close as possible to the device terminal. The Kelvin connection is effective for low resistance or high current measurement.

## **Class Exercise**

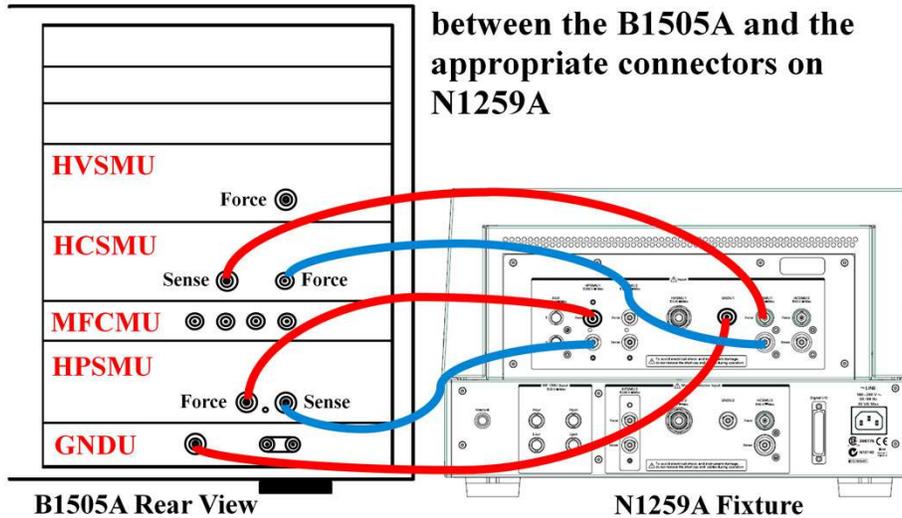
### **Perform Ic-Vce Measurement**

- 1. Connect the B1505A and the test fixture.**
- 2. Display Tracer Test screen.**
- 3. Set the measurement condition (output value, etc.)**
- 4. Create your preset group, and save your setup.**
- 5. Connect device (Power BJT).**
- 6. Click  button to start a single measurement, or click  button to start a repeat measurement.**

Note:

## Connecting N1259A Test Fixture

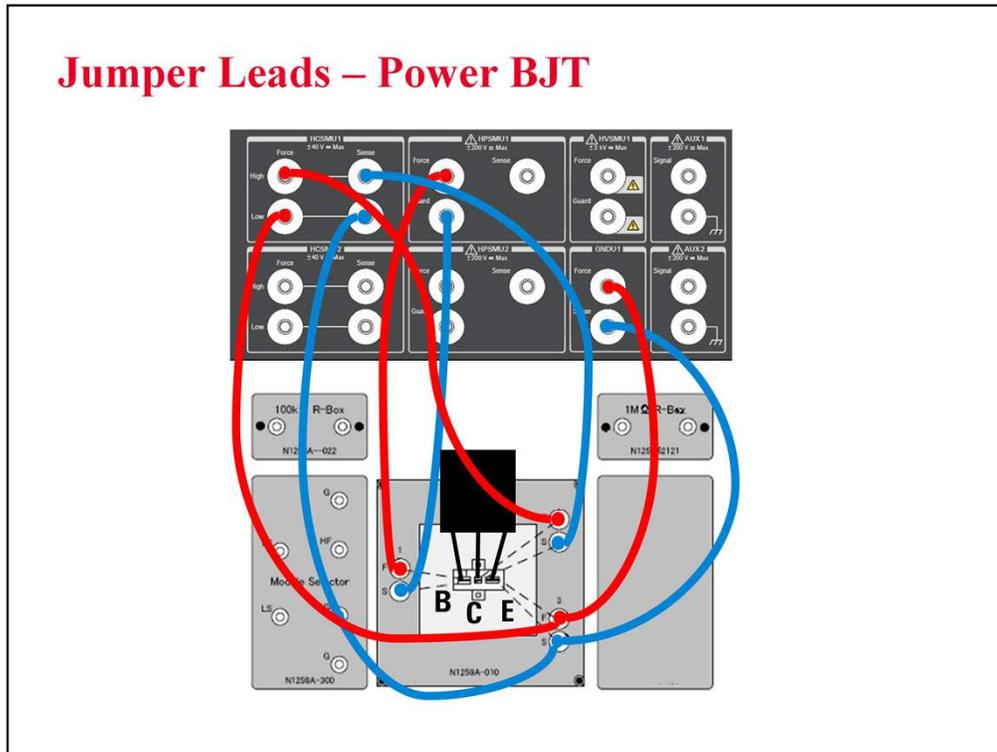
Connect the dedicated cables between the B1505A and the appropriate connectors on N1259A



Required equipment and accessories:

- B1505A with HCSMU and HPSMU
- N1259A test fixture
- 16493L GNDU cable for connecting GNDU
- 16494A Triaxial cable, 2 ea. for connecting HPSMU
- 16493S HCSMU cable for connecting HCSMU

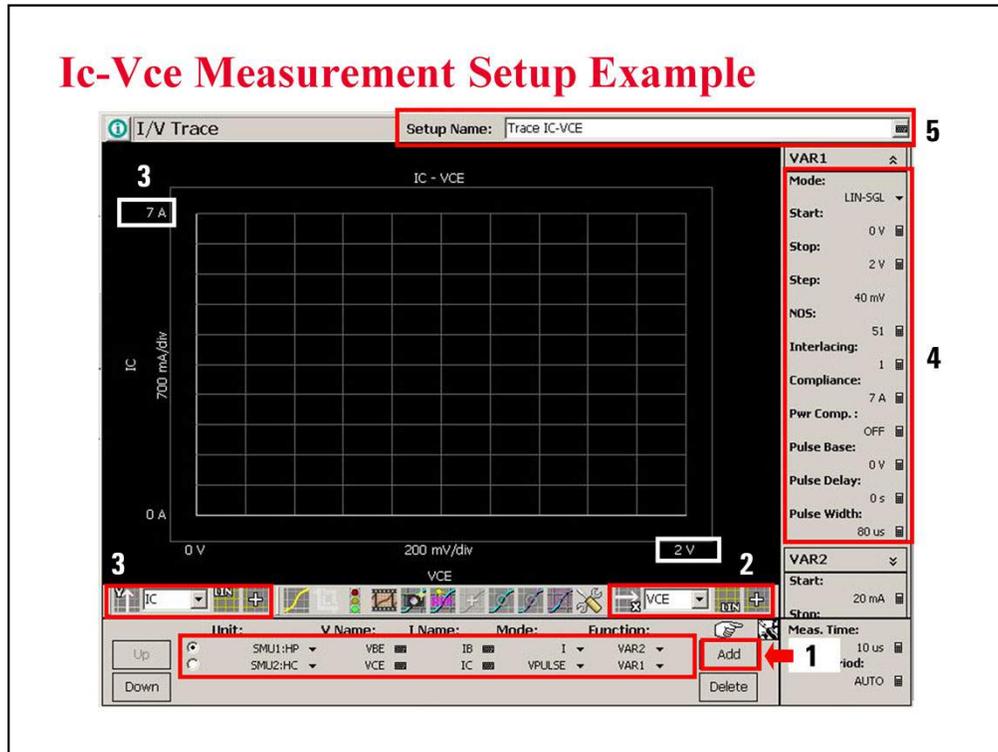
## Jumper Leads – Power BJT



Required parts:

- Inline package socket module
- Connection wire, 8 ea.

## Ic-Vce Measurement Setup Example



Display the Tracer Test screen and set the measurement condition.

You can finish the setup as follows.

1. Click Add button to add SMU channel setup lines. And set the channel definitions.
2. Set the X axis and maximum value.
3. Set the Y axis and maximum value.
4. Set the VAR1 output condition.
5. Set the Setup Name. For example, enter Trace IC-VCE.

Channel definition example:

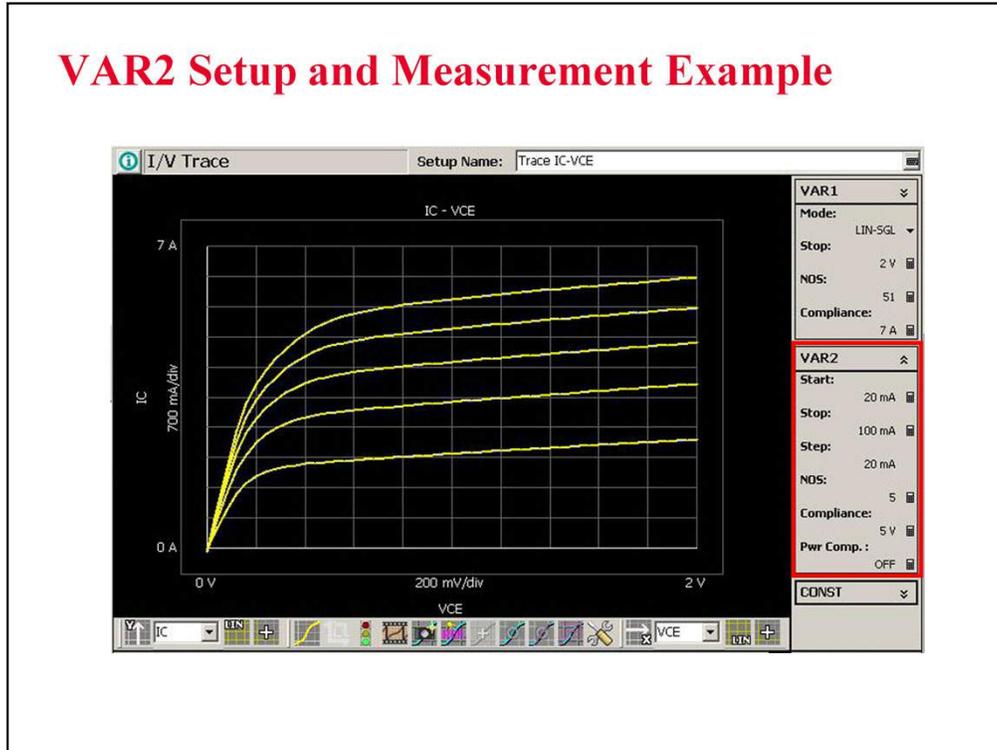
SMU1:HP V Name=VBE, I Name=IB, Mode=I, Function=VAR2

SMU2:HC V Name=VCE, I Name=IC, Mode=VPULSE, Function=VAR1

Source setup example:

VAR1 Mode=LIN-SGL, Start=0 V, Stop=2 V, Step=40 mV, NOS=51, Interlacing=1, Compliance=7 A, Pwr Comp.=OFF, Pulse Base=0 V, Pulse Delay=0 s, Pulse Width=80 us

## VAR2 Setup and Measurement Example



Set the VAR2 output condition.

VAR2 Start=20 mA, Stop=100 mA, Step=20 mA, NOS=5, Compliance=5 V, Pwr Comp.=OFF

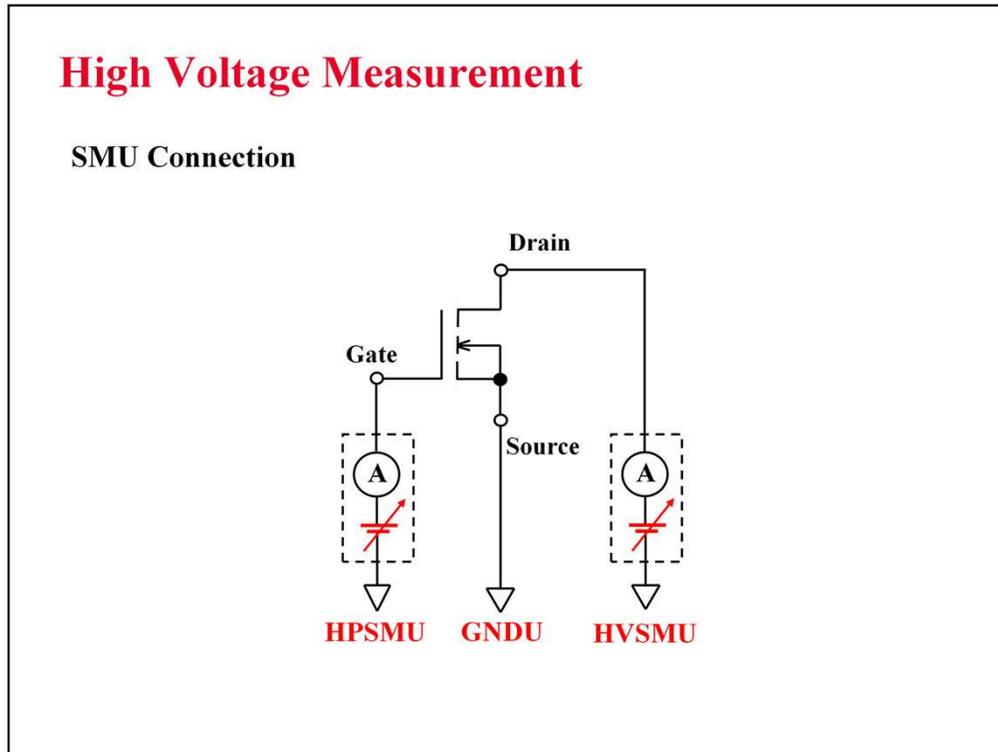
After that, perform measurement. The graph area will show the measurement result as shown in this example.

## High Voltage SMU

- Occupies 2 slots of B1505A
- 3000 V/4 mA or -3000 V/-4 mA output
- 1500 V/8 mA or -1500 V/-8 mA output
- 1/1,000,000 set/measurement resolution
- DC sweep, Pulsed sweep
- Faster measurement time



Note:



HPSMU can be used for the measurement up to 200 V. And HVSMU supports the high voltage measurement up to 3000 V.

The above example shows the typical connections for measuring a power MOSFET which has 3 terminals. HPSMU and GNDU are connected to Gate and Source respectively. And HVSMU will be connected to Drain for the high voltage measurement.

Kelvin connection is available for the HPSMU and GNDU. To make the Kelvin connection, connect the Force and Sense terminals together at the point as close as possible to the device terminal. The Kelvin connection is effective for low resistance or high current measurement.

## **Class Exercise**

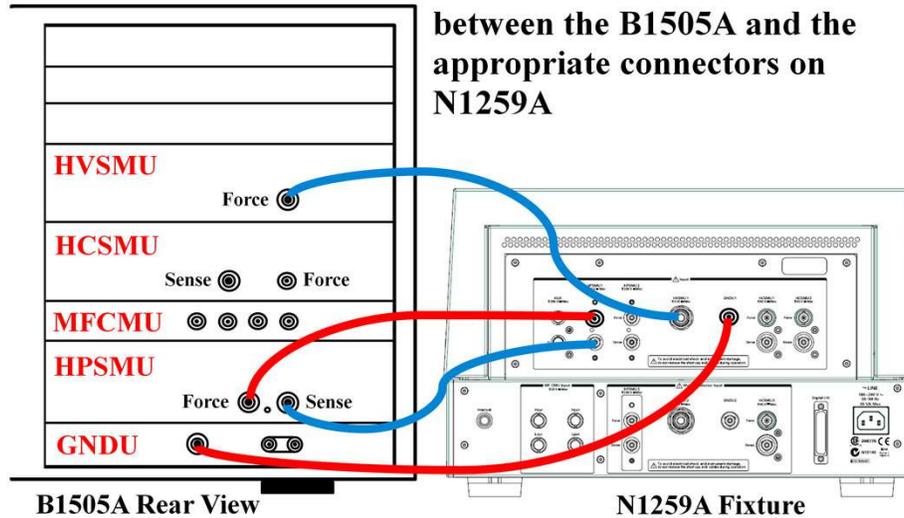
### **Perform Id-Vds Measurement**

- 1. Connect the B1505A and the test fixture.**
- 2. Display Tracer Test screen.**
- 3. Set the measurement condition (output value, etc.)**
- 4. Create your preset group, and save your setup.**
- 5. Connect device (Power MOSFET).**
- 6. Click  button to start a single measurement, or click  button to start a repeat measurement.**

Note:

## Connecting N1259A Test Fixture

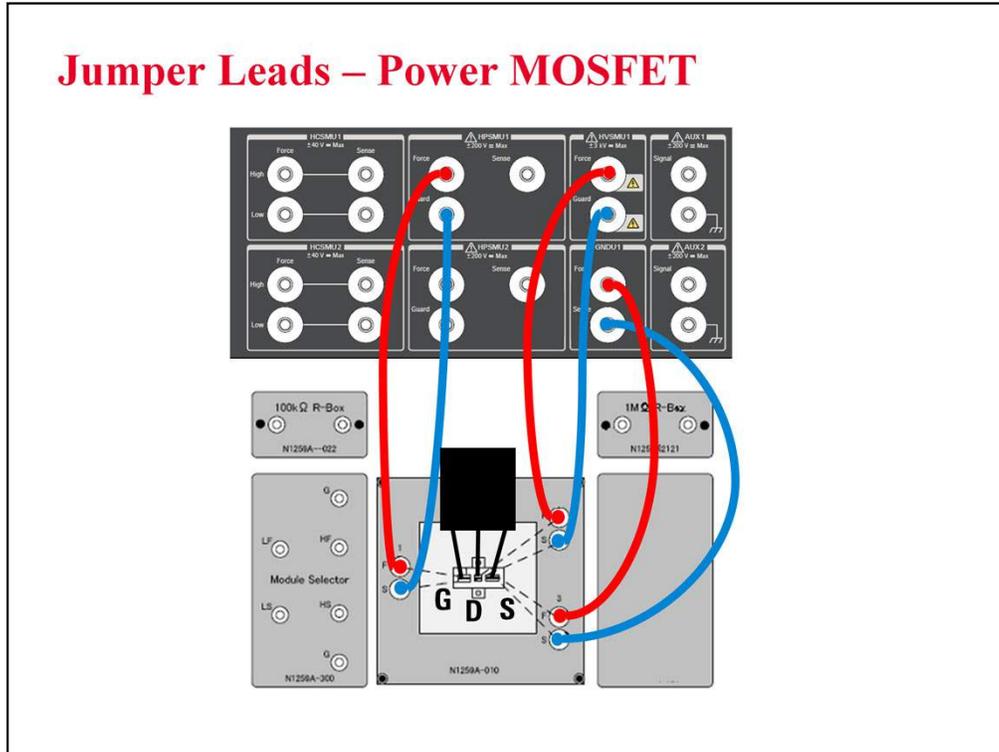
Connect the dedicated cables between the B1505A and the appropriate connectors on N1259A



Required equipment and accessories:

- B1505A with HVSMU and HPSMU
- N1259A test fixture
- 16493L GNDU cable for connecting GNDU
- 16494A Triaxial cable, 2 ea. for connecting HPSMU
- 16493T HVSMU cable for connecting HVSMU

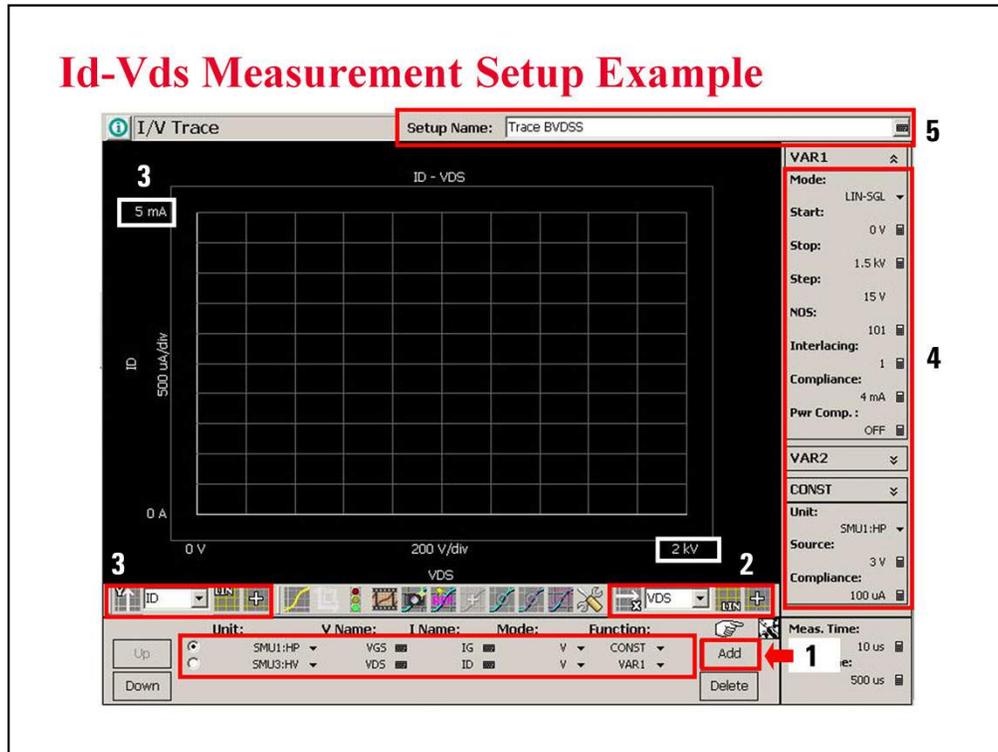
## Jumper Leads – Power MOSFET



Required parts:

- Inline package socket module
- Connection wire, 6 ea.

## Id-Vds Measurement Setup Example



Display the Tracer Test screen and set the measurement condition.

You can finish the setup as follows.

1. Click Add button to add SMU channel setup lines. And set the channel definitions.
2. Set the X axis and maximum value.
3. Set the Y axis and maximum value.
4. Set the VAR1 and CONST output conditions.
5. Set the Setup Name. For example, enter Trace BVDSS.

Channel definition example:

SMU1:HP V Name=VGS, I Name=IG, Mode=V, Function=CONST

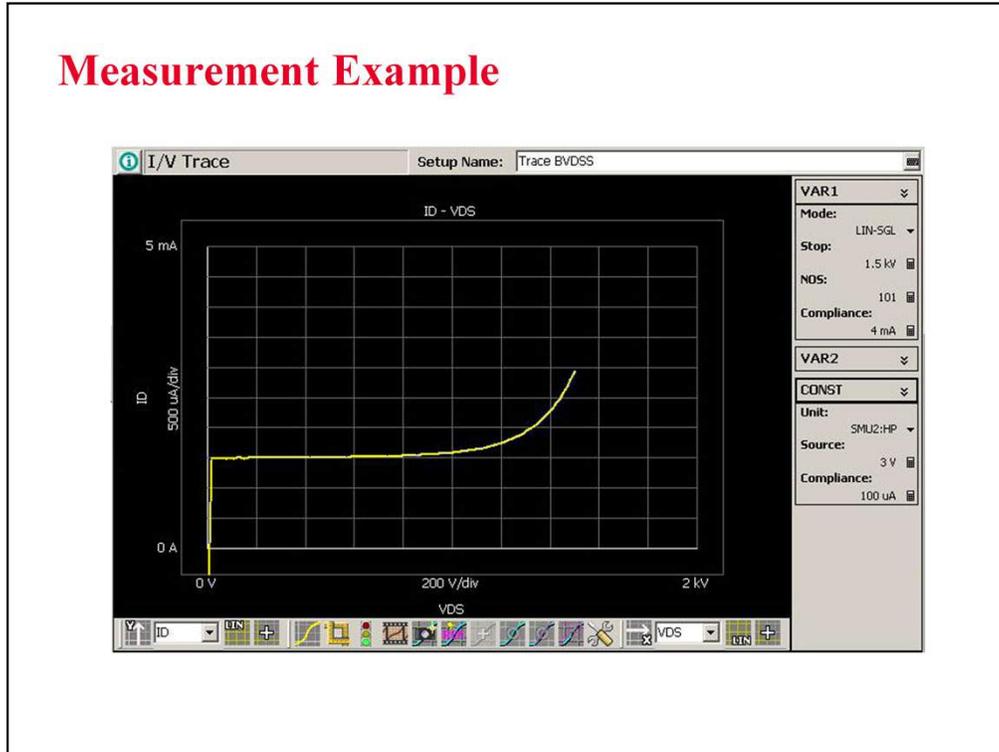
SMU3:HV V Name=VDS, I Name=ID, Mode=V, Function=VAR1

Source setup example:

VAR1 Mode=LIN-SGL, Start=0 V, Stop=1.5 kV, Step=15 V, NOS=101, Interlacing=1, Compliance=4 mA, Pwr Comp.=OFF

CONST Source=3 V, Compliance=100 uA

## Measurement Example



Perform measurement. The graph area will show the measurement result as shown in this example.

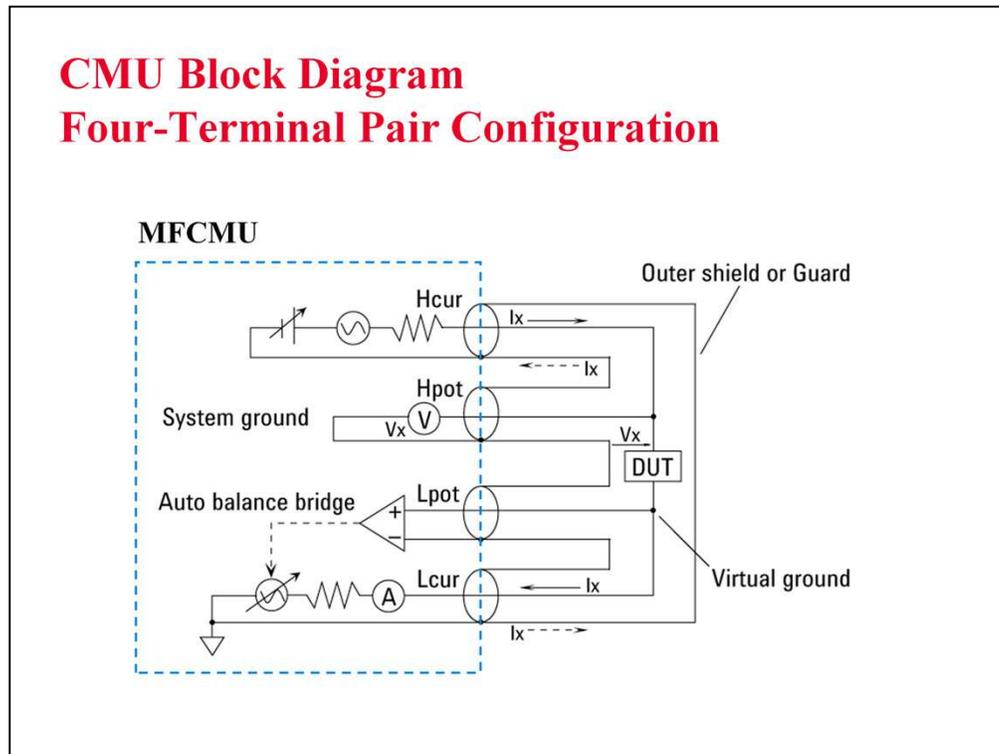
## Multi Frequency CMU



- Occupies 1 slot of B1505A
- Four terminal pair configuration
- Spot & Sweep measurements
- Faster measurement time
- 1 kHz to 5 MHz frequency range
- +/-25 V DC bias  
(+/-3000 V with HVSMU and Bias-T)
- Cable length auto detection (1.5 or 3 m)
- Higher accuracy below 100 pF

Note:

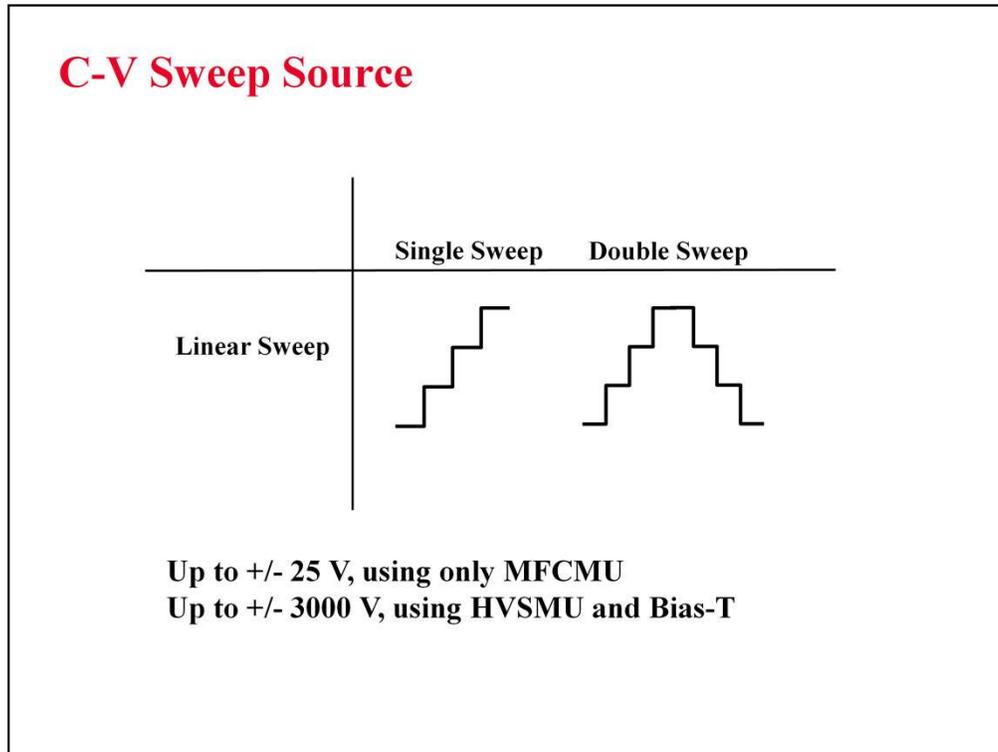
## CMU Block Diagram Four-Terminal Pair Configuration



Generally, any mutual inductance, interference of the measurement signals, and unwanted residual factors in the connection method incidental to ordinary termination methods will have significant effects on the measurements, especially at a high frequency. The MFCMU employs the four-terminal pair (4TP) measurement configuration which permits easy, stable, and accurate measurements and avoids the measurement limitations inherent to such factors.

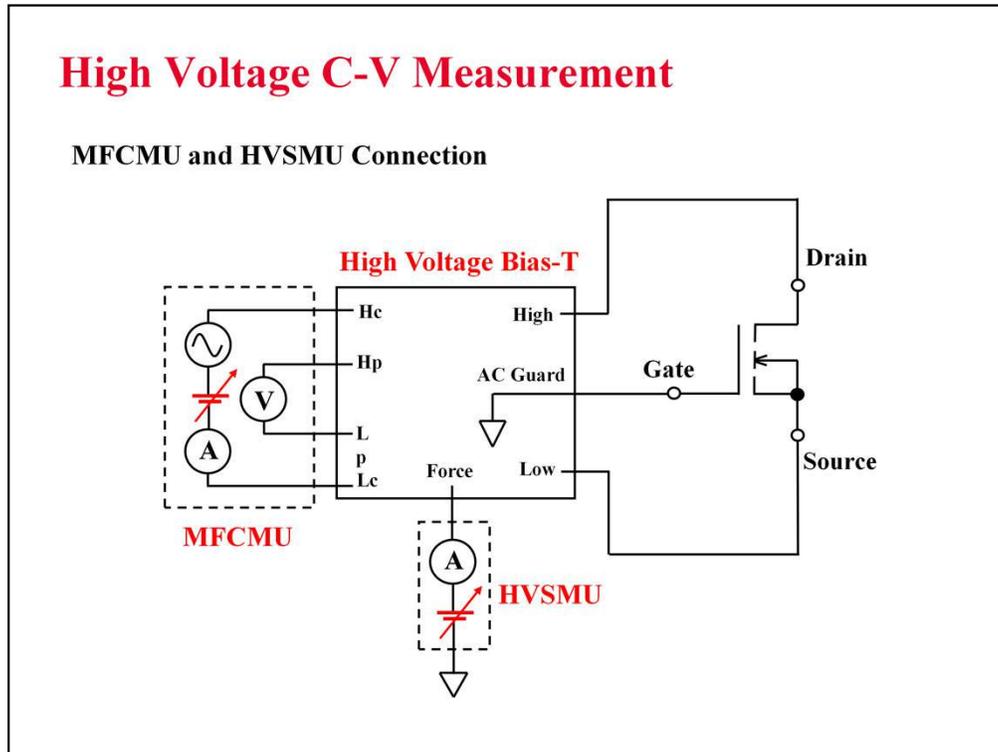
The above figure shows the four-terminal pair measurement principle. The measurement terminals consist of the following four coaxial connectors.

- Hcur: High current
- Hpot: High potential
- Lpot: Low potential
- Lcur: Low current



MFCMU supports the linear single sweep and the linear double sweep. The MFCMU can sweep up to a value and then back down (double sweep). This feature is useful when the device must be tested without abruptly removing the forcing condition.

The MFCMU can force up to 25 V DC bias. The DC bias can be expanded up to 3000 V by using the HVSMU and the high voltage Bias-T.



The above example shows the connections for measuring a power MOSFET C<sub>ds</sub>-V<sub>ds</sub> characteristics. MFCMU and HVSMU are connected to the high voltage bias-T as shown. And High, Low, and AC Guard are connected to Drain, Source, and Gate respectively.

## **Class Exercise**

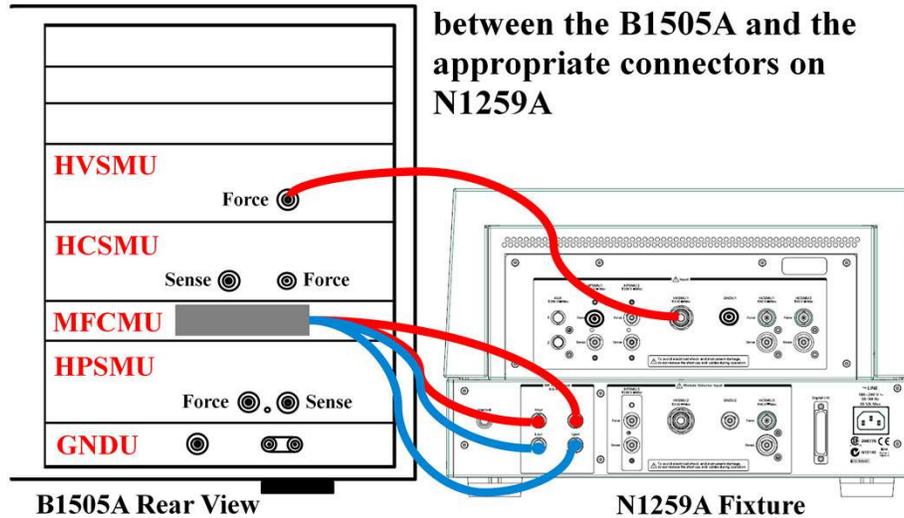
### **Perform Cds-Vds Measurement**

- 1. Connect the B1505A and the test fixture.**
- 2. Open Cds application test.**
- 3. Set the measurement condition (output value, etc.)**
- 4. Create your preset group, and save your setup.**
- 5. Perform CMU calibration**
- 6. Connect device (Power MOSFET).**
- 7. Click  button to start a single measurement.**

Note:

## Connecting N1259A Test Fixture

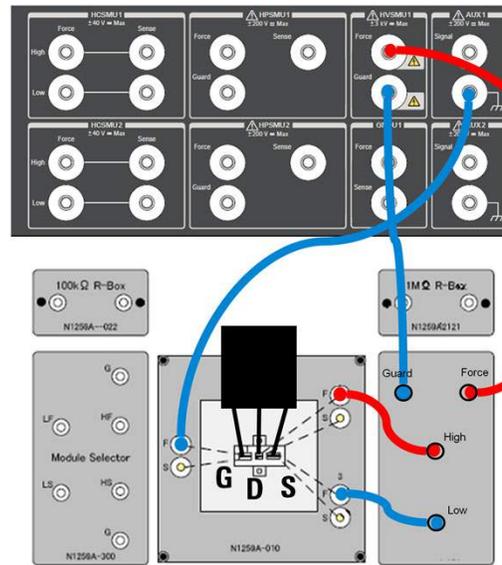
Connect the dedicated cables between the B1505A and the appropriate connectors on N1259A



Required equipment and accessories:

- B1505A with MFCMU and HVSMU
- N1259A test fixture
- N1300A CMU cable for connecting MFCMU
- 16493T HVSMU cable for connecting HVSMU

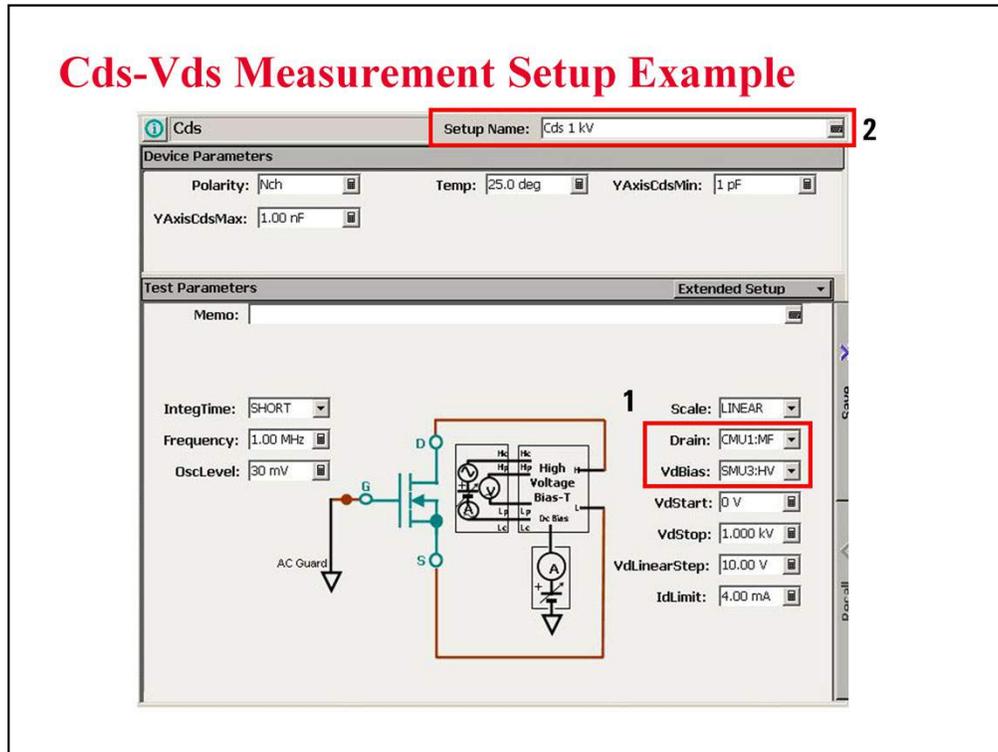
## Jumper Leads – Cds-Vds Measurement



Required parts:

- Inline package socket module
- Connection wire, 3 ea.
- SHV to SHV test lead, 2 ea. for connecting Bias-T High and Low
- SHV to banana adapter, 2 ea. for connecting Bias-T High and Low

## Cds-Vds Measurement Setup Example



- Open the Cds application test from the Power MOSFET category.
1. Specify the correct units for the MFCMU and HVSMU.
  2. Set the Setup Name. For example, enter Cds 1 kV.
- Change the value of the other setup parameters if you want.

## CMU Calibration

Type	Effectiveness	Measurement terminals
Phase Compensation <i>Perform before measurement</i>	Corrects phase error caused by extending measurement cables.	Open terminals
Open Correction <i>Perform before measurement</i>	Corrects for stray admittance. Effective for high impedance measurement.	Open terminals
Short Correction <i>Recommended</i>	Corrects for residual impedance. Effective for low impedance measurement.	Connect terminals together
Load Correction <i>Recommended</i>	Corrects any error by using the working standard.	Connect standard

MFCMU is equipped with the error correction function used to realize accurate impedance measurements. The correction function minimizes the effects of the error elements in the extension cables and the DUT interface such as manipulator and probe card.

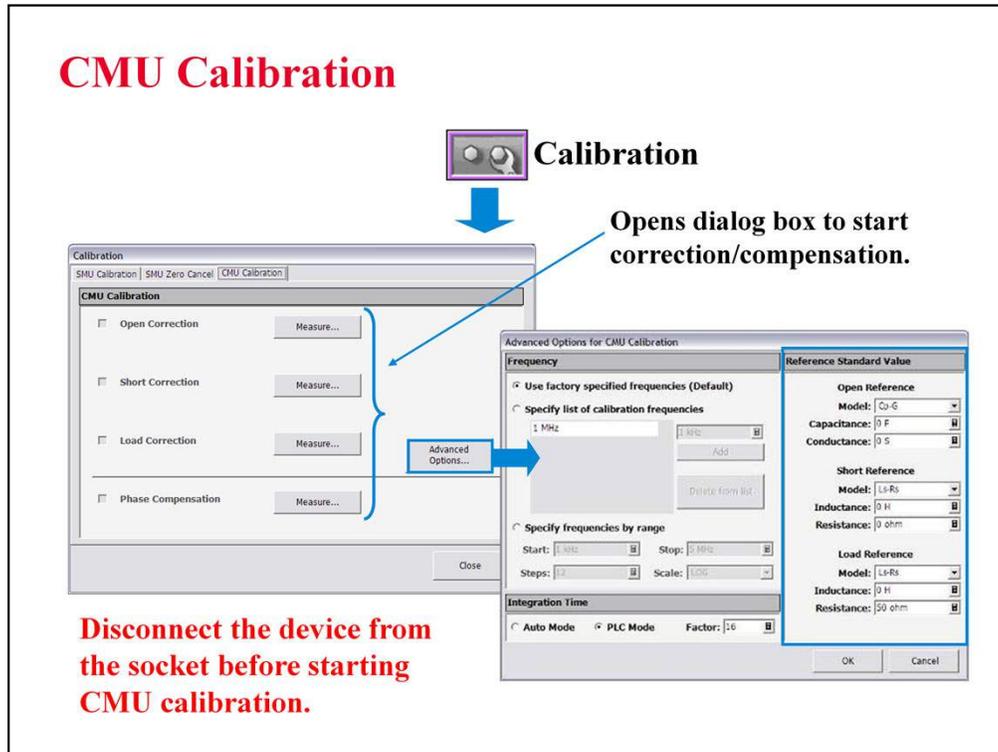
At least perform the phase compensation and the open correction. They only need to open the measurement terminals.

Performing the short correction and the load correction is recommended.

If it is easy to make the short condition in your test environment, perform the short correction.

If you have the load standard, perform the load correction.

The standard must have the reference value. And the reference value must be defined in the Advanced Options for CMU Calibration window. This window is opened by clicking the Advanced Options... button. See the next page.



Open the Calibration window and click the CMU Calibration tab to perform the CMU calibration.

At first, open the MFCMU high and low terminals at the device end (socket), and perform the Phase Compensation by clicking the Measure... button.

After the phase compensation, perform the Open Correction by clicking the Measure... button.

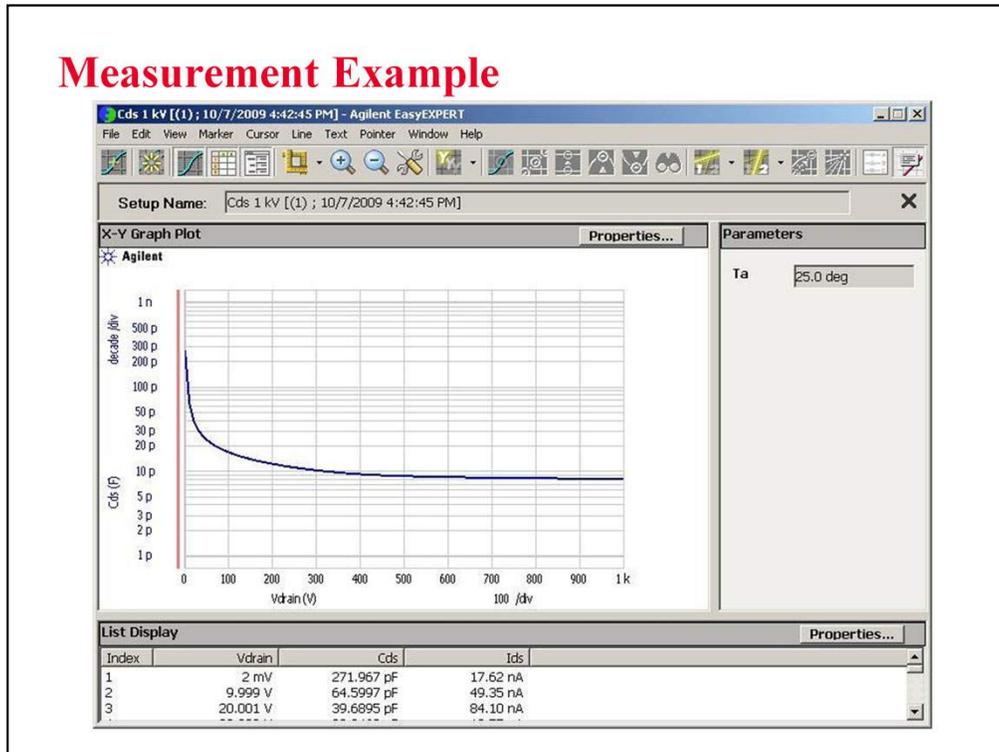
If you can make the short condition, short the measurement terminals, and perform the Short Correction.

If you have the load standard, connect it, and perform the Load Correction.

Note:

If you use the calibration standard, define the reference data before starting the calibration. It must be defined in the Reference Standard Value on the Advanced Options for CMU Calibration window.

## Measurement Example



Perform measurement. The Data Display window will show the measurement result as shown in this example.



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