

**Agilent B1500A
Semiconductor Device
Analyzer**

Self-paced Training Manual



Agilent Technologies

Notices

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In This Manual

This document is the self-paced training manual to help you to understand what is Agilent B1500A, what functions the B1500A has, how to use the B1500A, and what applications the B1500A contributes to.

CAUTION

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

- Module 1. Introduction

This module explains the product concept and the key features of the B1500A/EasyEXPERT. You will learn about what is the B1500A.

- Module 2. Getting Started

This module explains the basic operations of the B1500A. You will learn about how to launch B1500A/EasyEXPERT and how to perform application test and quick test.

- Module 3. Data Display and Management

This module explains the data display and analysis capabilities of the EasyEXPERT software. You will learn how to use analysis tools, how to change display setup, and how to print/export test result data.

- Module 4. Classic Test Environment

This module explains the classic test mode of the EasyEXPERT. You will learn how to create the classic test setup in the course exercises.

- Module 5. 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 6. Low Current Measurement

This module explains the low current measurement technique. You will learn how to measure the low current in the course exercises.

- Module 7. Measurement Functions

This module explains the measurement functions available with the B1500A. You will learn how to use various measurement functions in the course exercises.

- Module 8. Capacitance Measurement

This module explains the capacitance measurement function. You will learn how to measure the capacitance in a course exercise.

- Module 9. Modifying Application Test Definitions

This module explains a modification example of an application test definition. You will learn how to modify the definition in a course exercise.

- Module 10. Creating Your Test Definitions

This module explains about the application test definition. You will learn how to create your application test definition in a course exercise.

- Module 11. Advanced Definitions and Operations

This module explains how to control external GPIB devices, how to call an execution file, how to perform a repeat measurement, and how to use the prober control script.

- Module 12. Miscellaneous Operations

This module explains what is the status indicator, what is the automatic data export function and the automatic data record function, how to perform selftest and calibration, how to perform SMU zero offset cancel, and such.

Class Exercises

Class exercises use the test setup listed below. The test setup data are only examples and included in the Demo.xpg file stored in the Manual CD-ROM.

Module	Exercise	Device	Test setup/definition/data	Page
Module 1	no exercise			
Module 2	Id-Vd measurement	MOSFET	CMOS: Id-Vd	2-19, 27
	Id-Vg, gm-Vg measurement	MOSFET	CMOS: Vth gmMax	2-19, 27
	B2200 switch control	-	-	2-32
Module 3	Id-Vg, gm-Vg measurement	MOSFET	GMMAX.xtr	3-28
	Using Preview window	-	-	3-31
Module 4	Id-Vd measurement	MOSFET	Trng Id-Vd	4-25
	Multi Channel I/V Sweep Measurement	Bipolar Tr LED	Trng Multi	4-37
	I/V List Sweep Measurement	MOSFET	Trng List	4-51
	I/V-t sampling measurement	0.1 μ F	Trng Sampilng	4-64
	C-V sweep measurement	MOSFET	Trng CV	4-76
	B2200 switch control	-	Trng Switch	4-81
	Direct Control (C-f measurement)	0.1 μ F	Trng C-f	4-88
Module 5	Id-Vd measurement	MOSFET	IDVD, Id-Vd	5-7
	SMU series connection	511 kohm	IRVR	5-24
	SMU parallel connection	1 ohm	Parallel	5-28
	Re measurement, kelvin connection	Bipolar Tr	REKELV	5-38
Module 6	Leak current measurement	-	Zero-check	6-9
	Ultra low current measurement	-	Zero-check-ASU	6-19
	Id-Vg measurement	MOSFET	IDVG	6-20
	Gummel plot	Bipolar Tr	GUMMEL	6-25
Module 7	SMU pulse mode	MOSFET	IDVD-Pulse	7-8
	RC measurement	0.1 μ F and 511 kohm	RC-sampling-log	7-16
	Negative hold time	511 kohm	R-sampl-neg-hold	7-22
	Auto analysis	MOSFET	GMMAX	7-28
	Bias hold function	LED	LED	7-35
	SMU series resistor	0.5 Mohm	IV-res	7-43

Module	Exercise	Device	Test setup/definition/data	Page
Module 8	C-V sweep measurement	MOSFET	CV-1MHz	8-6
Module 9	Modifying application test definition	MOSFET	Trng IdVd Vth.xtd	9-14
			Trng idvd idvg2.xtd	9-32
			Trng idvd idvg3.xtd	9-35
	Using vector data	MOSFET	Trng Cgg-Vg	9-37
Module 10	Creating application test definition	MOSFET	Trng idvd idvg.xtd	10-17
Module 11	no exercise			
Module 12	no exercise			

NOTE

Demo.xpg file

Demo.xpg file is required to create the Demo preset group which contains the test setup data used by the class exercises. And it is stored in the \data folder on the Agilent B1500A Manual CD-ROM, Edition 4 or later.

The Demo preset group should be created before starting the class exercise. To create the 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.

NOTE

.xtd files

The \data folder on the Manual CD-ROM stores some .xtd files. They are the application test definitions used by some class exercises. To use the definition file, import the file by using the Test Definition Import dialog box opened by clicking Library > Import Test Definition. The test definition data are only examples for the class exercises.

NOTE

.xtr files

The \data folder on the Manual CD-ROM 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.

Test Setup for Class Exercises

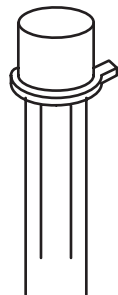
The Demo preset group contains the following test setup. The setup data are only examples for the class exercises. The following table lists the test setup name in alphabetical order.

Test Setup Name	Description
CV-1MHz	MOSFET C _{gs} -V _g measurement
Fowler-Nordheim	Fowler-Nordheim (FN) plot
GMMAX	MOSFET sqrt _{Id} -V _g , PEAK-V _g measurement
GUMMEL	Bipolar transistor gummel plot
IDVD	MOSFET Id-V _d measurement
IDVD-Pulse	MOSFET pulsed Id-V _d measurement
Id-Vd	MOSFET Id-V _d measurement, Application Test
IDVG	MOSFET Id-V _g measurement
IRVR	511 kohm I-V measurement
IV-res	511 kohm I-V measurement with SMU series resistor
LED	LED I-V measurement
Parallel	1 ohm I-V measurement, voltage force and current measurement
RC-sampling-log	RC sampling measurement, log sampling
REKELV	Bipolar transistor Re measurement
R-sampl-neg-hold	511 kohm sampling measurement with negative hold time
Subthreshold	MOSFET subthreshold measurement
Trng C-f	Direct Control (C-f measurement)
Trng Cgg-Vg	Modifying application test definition using vector data
Trng CV	MOSFET C-V measurement
Trng Id-Vd	MOSFET Id-V _d measurement
Trng List	MOSFET V _{th} -gm _{max} measurement using I/V List Sweep
Trng Multi	Multi Channel I/V Sweep (Bipolar transistor and LED)
Trng Sampling	0.1 μF sampling measurement
Trng Switch	B2200 switch setup, Input 1-3-5-7 to Output 1-3-5-7
Zero-check	SMU open measurement
Zero-check-ASU	SMU open measurement with ASU

Required Devices for Class Exercises

To perform the class exercises, you need the device set (Agilent part number 04156-87001) which contains the following devices.

Description	Quantity
N-channel MOSFET	2 ea.
NPN Bipolar Transistor	1 ea.
Red Miniature LED	1 ea.
0.1 μ F Capacitor 50 V	1 ea.
1.0 Ω Resistor 1/8 W	1 ea.
1.1 k Ω Resistor 1/8 W	1 ea.
511 k Ω Resistor 1/8 W	1 ea.



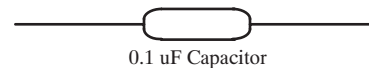
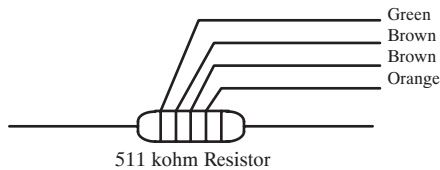
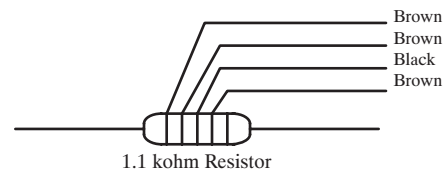
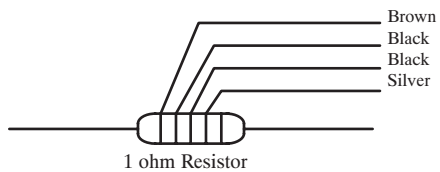
N-ch MOSFET



NPN bipolar Transistor



LED

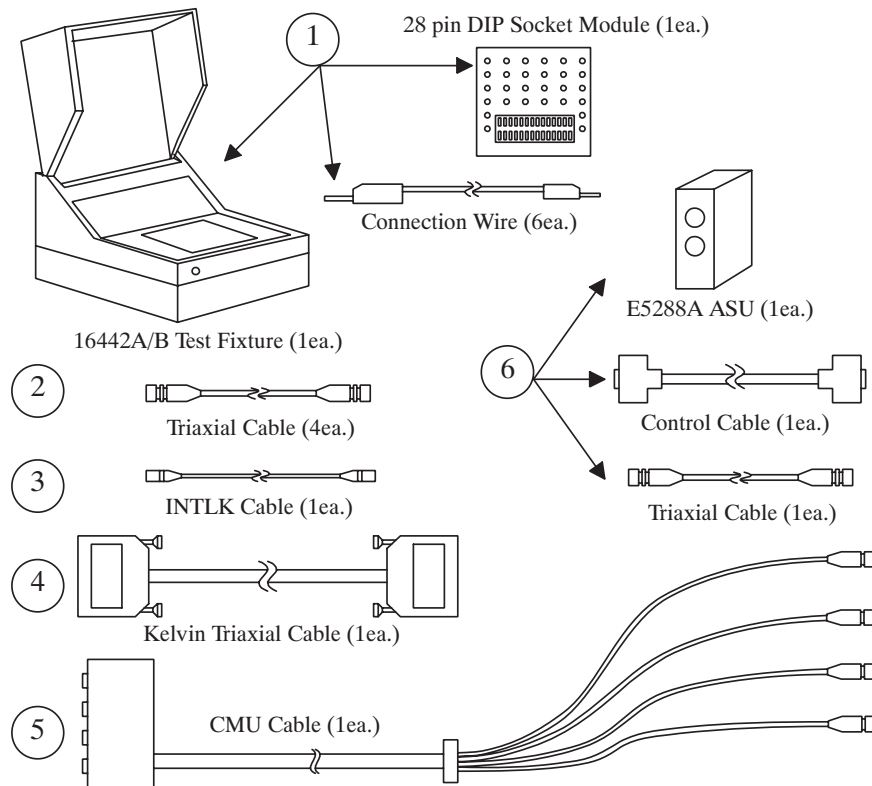


Required Accessories for Class Exercises

To perform the class exercises, you need the following accessories. Prepare the accessories shown below.

Designation	Description	Model No.	Qty.
1	Test Fixture	16442A/B ^a	1 ea.
	28 pin socket module		1 ea.
	Connection wire		6 ea.
2	Triaxial Cable	16494A	4 ea.
3	Interlock Cable	16493J	1 ea.
4	Kelvin Triaxial Cable, for Module 5	16493K	1 ea.
5	CMU Cable, for Module 8	N1300A	1 ea.
6	Atto Sense/Switch Unit, for Module 6	E5288A	1 ea.
	ASU control cable, triax cable, for Module 6	16493M	1 ea.

- a. The 16058A Test Fixture for the 4145A/B may be substituted for the 16442A/B Test Fixture. If you use the 16058A, you also need the 16435A Interlock Adapter.



Module 1. Introduction

- **New Features**
- **EasyEXPERT**
- **To Perform Easy Application Test**
- **User Interface**
- **Modular Mainframe**
- **SCUU/GSWU**
- **ASU**
- **B2200 Switch Control**
- **Desktop EasyEXPERT**



Module 2. Getting Started

- **To Turn on/off B1500A**
- **To Launch EasyEXPERT**
- **To Specify/Create Workspace**
- **To Perform Application Test**
- **To Save/Recall Your Test Setup**
- **To Export/Import Your Preset Group**
- **To Export/Import Test Record**
- **To Perform Quick Test**
- **To Control B2200 Switching Matrix**
- **To Manage Data Display Window**



Module 3. Data Display and Management

- **Data Display window**
- **Graph Analysis Tools**
- **Data Status**
- **To Change Graph/List/Display Setup**
- **To See Print Preview**
- **To Print Display Data**
- **To Copy Graph Plot/List Data**
- **To Save Analysis Result**
- **To Use Preview Window**



Module 4. Classic Test Environment

- **Classic Test Execution Mode**
- **I/V Sweep Measurement**
- **Multi Channel I/V Sweep Measurement**
- **I/V List Sweep Measurement**
- **I/V-t Sampling Measurement**
- **C-V Sweep Measurement**
- **Switching Matrix Control**
- **Direct Control**



Module 5. Basic Measurement

- **SMU Fundamentals**
- **Classic Test Environment**
- **SMUs Connected in Series or Parallel**
- **Cabling and Fixture Issues**
- **Kelvin and Driven Guard**
- **Probes and Prober Connections**
- **Triax and Coax Adapters**
- **Safety Interlock Issues**



Module 6. Low Current Measurement

- **Low-Current Measurement Challenges**
- **Calibration and Zero Cancel**
- **Effect of Cable Movement**
- **ASU for Ultra Low-Current Measurement**
- **Low-Current Subthreshold**
- **Trade-Off Speed Vs Accuracy**
- **Low-Current Gummel Plot**
- **Low-Current Gate Oxide Leakage**



Module 7. Measurement Functions

- **SMU Pulsed Sweep Measurement**
- **I/V-t Sampling Measurement**
- **Negative Hold Time for High Speed Sampling**
- **Auto Analysis**
- **Bias Hold Function**
- **SMU Filter**
- **SMU Series Resistor**
- **Standby Function**



Module 8. Capacitance Measurement

- **CMU Fundamentals**
- **Classic Test Environment**
- **CMU Calibration**
- **SCUU for IV/CV Switching**
- **GSWU for Accurate Capacitance Measurement**
- **ASU for IV/CV Switching**



Module 9. Modifying Application Test Definitions

- **To Open Application Test Definition**
- **To Modify Test Definition**
- **To Use Debug Tools**
- **To Use Built-in Functions**
- **To Add Data Display**
- **To Use Auto Analysis**
- **To Define Test Output**
- **To Use Test Setup Internal Variables**
- **To Use Vector Data to Modify Test Definition**



Module 10. Creating Your Test Definitions

- **What is Test Definition**
- **What is Test Contents**
- **To Open Test Definition Editor**
- **To Define Test Specification**
- **To Define Test Contents**
- **Available Elements**
- **Available Variables**



Module 11. Advanced Definitions and Operations

- **To Control External GPIB Devices**
- **To Call Execution Files**
- **To Perform Repeat Measurements**
- **Prober Control Script**



Module 12. Miscellaneous Operations

- **Function Status Indicator**
- **Automatic Data Export and Data Record**
- **Data Record ON/OFF**
- **Calibration**
- **Configuration**
- **XSLT Samples**
- **To Enable System Controller**
- **To Start Desktop EasyEXPERT**
- **To Use 415x Setup File Converter**



1 Introduction

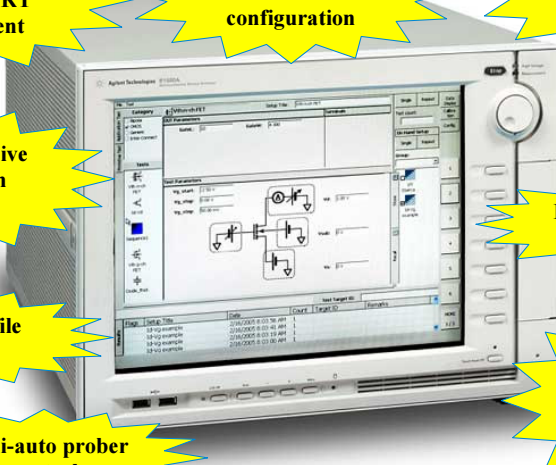
In This Module

- **New Features**
- **EasyEXPERT**
- **To Perform Easy Application Test**
- **User Interface**
- **Modular Mainframe**
- **SCUU/GSWU**
- **ASU**
- **B2200 Switch Control**
- **Desktop EasyEXPERT**




Note:

Agilent B1500A Semiconductor Device Analyzer



The image shows the Agilent B1500A Semiconductor Device Analyzer, a rack-mounted instrument with a large color touch-screen. The screen displays a software interface with various tabs and a central schematic diagram of a power MOSFET circuit. Surrounding the device are eight yellow starburst callouts highlighting key features. At the bottom center is the Agilent Technologies logo.

- Revolutionary EasyEXPERT environment
- 10 Slots variable module configuration
- SCUU/GSWU for IV/CV combination
- ASU for 100 aA
- Comprehensive application library
- B2200 switch control
- 415x setup file converter
- Touch-screen w/optional USB keyboard & mouse
- Semi-auto prober control

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The B1500A has many exciting new features and capabilities.

New Features

- EasyEXPERT software
 - Application test environment (> 150 algorithms)
 - Classic test environment – 415x like setup
 - Quick test environment – multiple test execution
 - Semi-auto prober control and B2200 switch control
- Modular mainframe
 - MFCMU for C-V sweep, C-f sweep
 - HPSMU, HRSMU, MPSMU for I/V Sweep, Multi Channel I/V Sweep, I/V List Sweep, I/V-t Sampling
- SMU CMU Unify Unit (SCUU)/Guard Switch Unit (GSWU)
 - switching effortlessly between IV and CV measurement
- Atto Sense/Switch Unit (ASU)
 - 100 aA level low current measurement
- Touch-screen, knob, and softkeys
 - optional USB keyboard, mouse, and stylus pen



The EasyEXPERT software

•Task-oriented, “top-down” approach to device characterization

•Multiple test execution

•Automatic measurement, auto-analysis functions

•Test sequencing without programming

Application Library (>150 algorithms)

•Categorized and organized

•Easy-to-use

415x control by Desktop EasyEXPERT software.

Versatile Modular Mainframe

•Flexible & Expandable (10 slots)

•Multiple SMU types

•Atto-sense and Switch Unit (ASU)

•Multi-Frequency CMU

•SMU CMU Unify Unit for IV/CV Probing

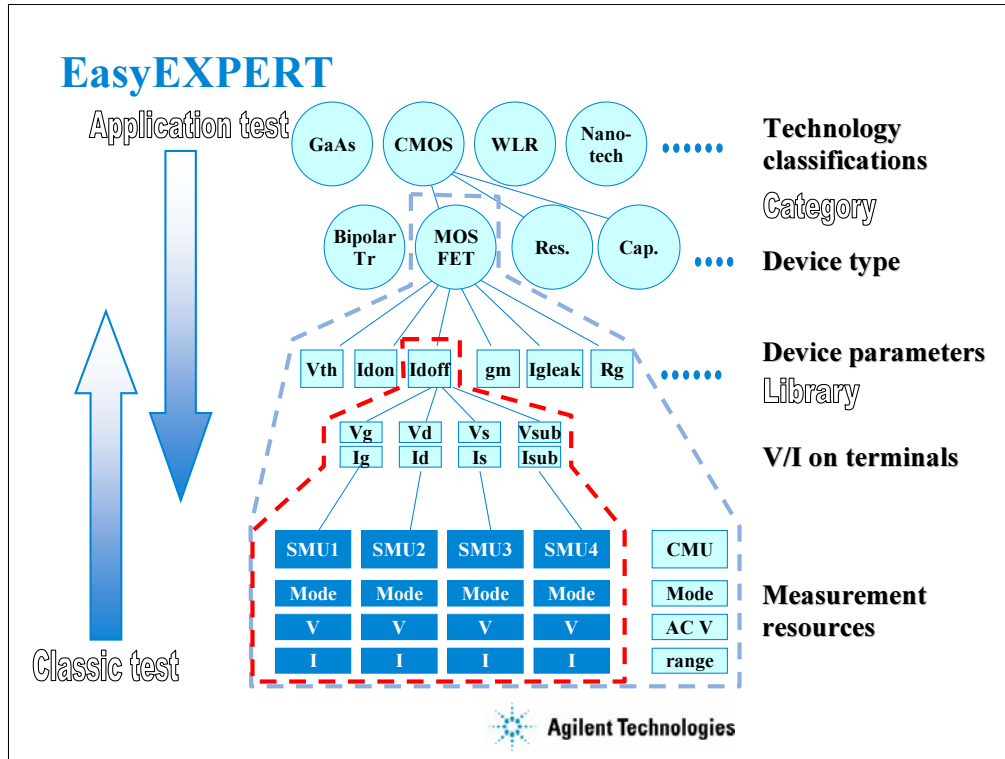
•4.2 Amp Ground Unit

Convenient User Interface

•Touch screen operation (with optional stylus pen)

•Contextual softkeys & knob control

•Optional USB keyboard & mouse



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.

To Perform Easy Application Test

The screenshot shows the Agilent EasyEMPRO software interface. The 'Category' list on the left includes BIT, CMOS, Discrete, Memory, MixedSignal, NanoTech, and Reliability. The 'Device Parameters' section shows settings for Polarity, Temp, Lg, and Wg. The 'Test Parameters' section shows settings for Time, Gate, VgStart, VgStop, Id-Vg pulse, and Vth gmMax. A circuit diagram shows a DUT connected to a source and a sink. The 'K-V Graph Plot' shows a graph of current vs. voltage. The 'List Display' table shows the following data:

Index	Vgate	Vsource	Vdrain	Vbias	Idrain	gmMax
30	850 mV	0 V	100 mV	0 V	6.1162 uA	108.8956 uS
31	1 V	0 V	100 mV	0 V	12.5305 uA	228.4948 uS
32	1.05 V	0 V	100 mV	0 V	27.9813 uA	390.448 uS
33	1.1 V	0 V	100 mV	0 V	53.1412 uA	833.840000000000 uS
34	1.15 V	0 V	100 mV	0 V	81.1852 uA	871.187000000000 uS
35	1.2 V	0 V	100 mV	0 V	249.28 uA	1.045179 mS
36	1.25 V	0 V	100 mV	0 V	393.343 uA	1.1032 mS

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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 B1500A starts the selected test.

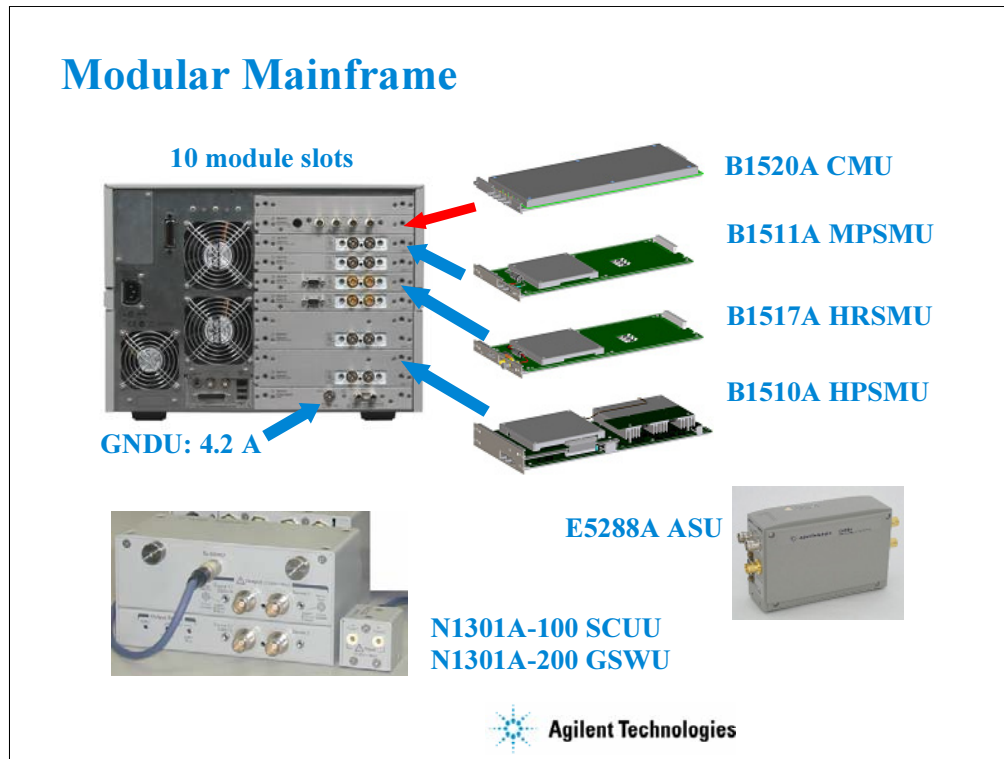
Step 5: Analyze the measurement result data displayed on the Data Display window automatically opened after the test.

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 (option)
- **Rotary knob**
- **Softkeys**
- **USB keyboard (option)**
- **USB mouse (option)**





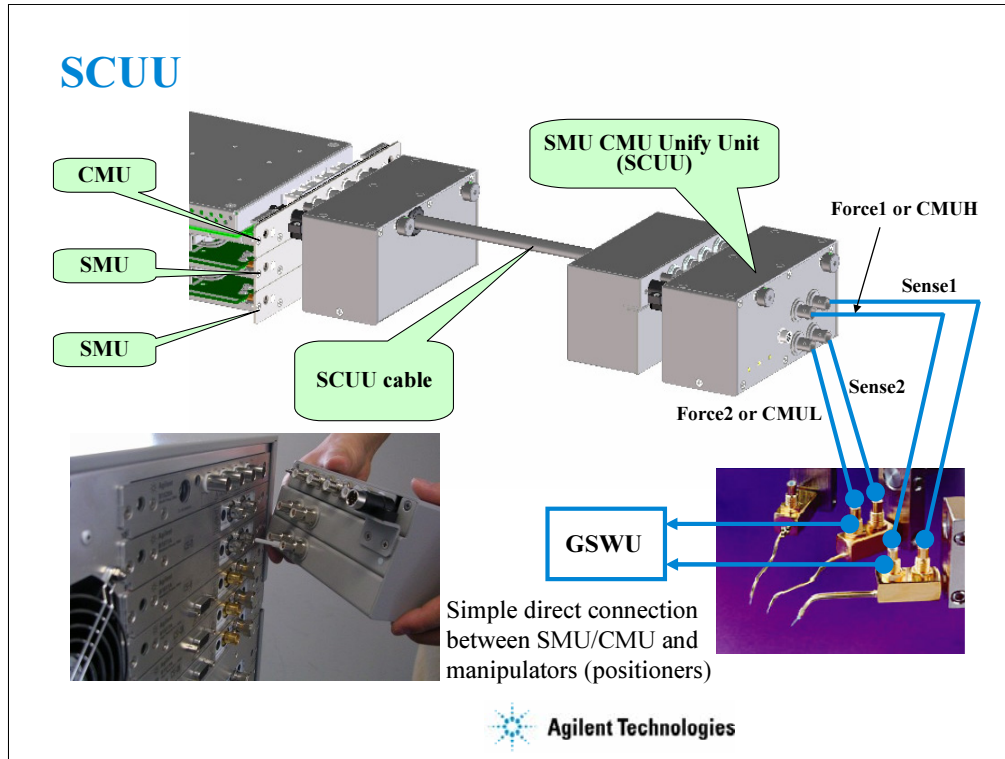
The following modules and accessories are available for the B1500A:

- B1520A CMU: 1 kHz to 5 MHz CV capability (1 slot)
- B1511A MPSMU: 100 mA/100 V force capability, 10 fA/0.5 mV measurement resolution (1 slot)
- B1517A HRSMU: 100 mA/100 V force capability, 1 fA/0.5 mV measurement resolution (1 slot)
- B1510A HPSMU: 1 A/200 V force capability, 10 fA/2 mV measurement resolution (2 slots)
- N1301A-100/102: SMU CMU unify unit (SCUU) & cable assembly
- N1301A-200/201/202: Guard switch unit (GSWU) & cable assembly
- E5288A ASU: 0.1 fA/0.5 mV measurement resolution with support for IV/CV switching

The ASU (Atto sense/switch unit) can be used with the HRSMU calibrated with it.

The SCUU can be used with the CMU (slot N), SMU (slot N-1), and SMU (slot N-2).

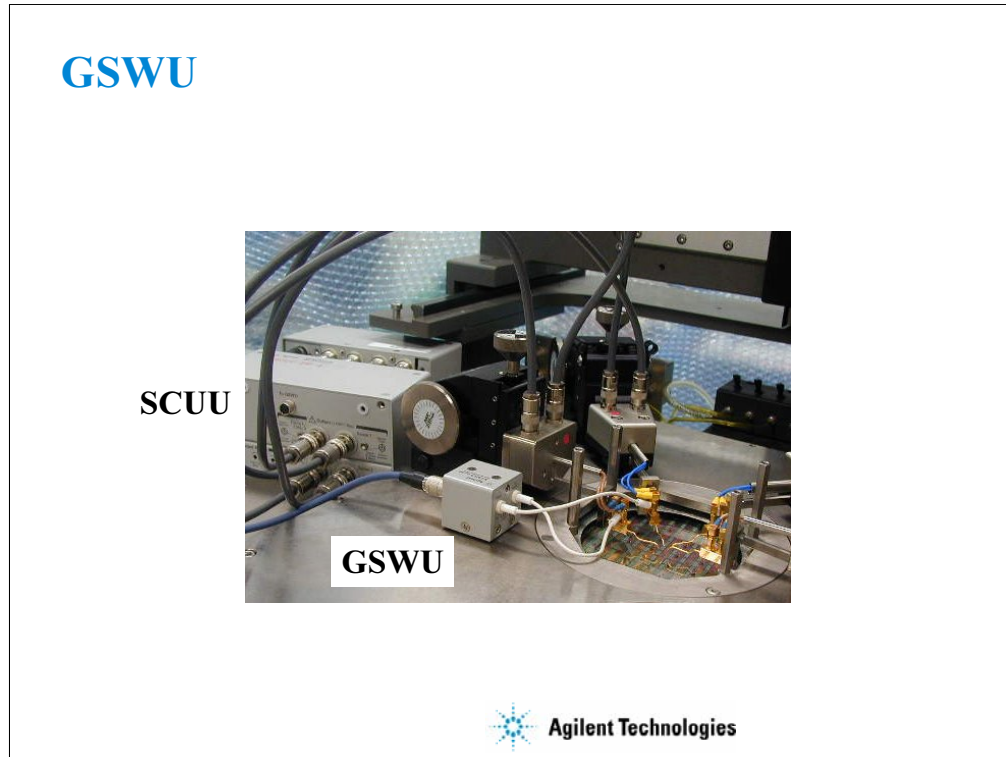
The GSWU can be used with the SCUU.



You have a very hard time switching between CV and IV measurements (you may actually devote separate probe stations to CV and IV just to avoid having to change cables). In addition, great care has to be taken when cabling to a capacitance meter to insure that all of the capacitance measurements are properly compensated. The SCUU removes all of these worries and makes connection simple and easy. In addition, the B1500A software automatically takes care of the multiplexing based upon the type of algorithm selected from the front panel.

To install the SCUU near the manipulators/positioners, use the N1301A-102 SCUU cable.

To realize accurate capacitance measurement, use the N1301A-200/201/202 GSWU & cable.



The GSWU must be connected to the outer conductors of the manipulators/positioners connected to the Force1/CMUH and Force2/CMUL connectors of the SCUU. And the GSWU control cable must be connected between the GSWU and the SCUU.

When the SMU paths are available for the manipulators/positioners, the GSWU opens between the outer conductors. However, when the MFCMU paths are available, the GSWU shorts them together to make the return path of measurement current. This will reduce the signal path impedance. And this is effective for the accurate capacitance measurement.

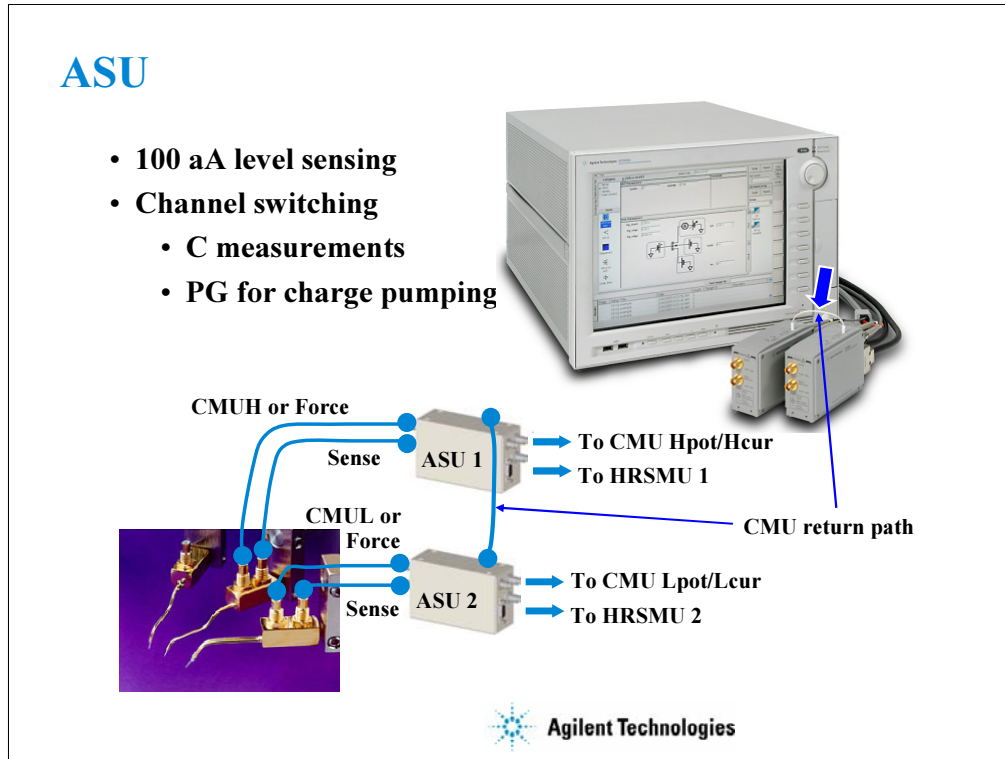
By using the EasyEXPERT software, cable length between the CMU and the SCUU is automatically detected, and the GSWU switch control is automatically performed. Also, capacitance error compensation is also automatically performed if the compensation data are available.

The GSWU is effective for

- reducing the residual inductance of the measurement cable
 - stabilizing the residual inductance when measurement cable distance is changed (moved)
- It's roughly 1/10 to 1/30 when used with two 80 cm cable.

Note:

When the SMU paths are available for the manipulators/positioners, the connection between the outer conductors must be broken because they are connected to the SMU guard terminals separately and the guard terminals must be opened at the end of the extension.



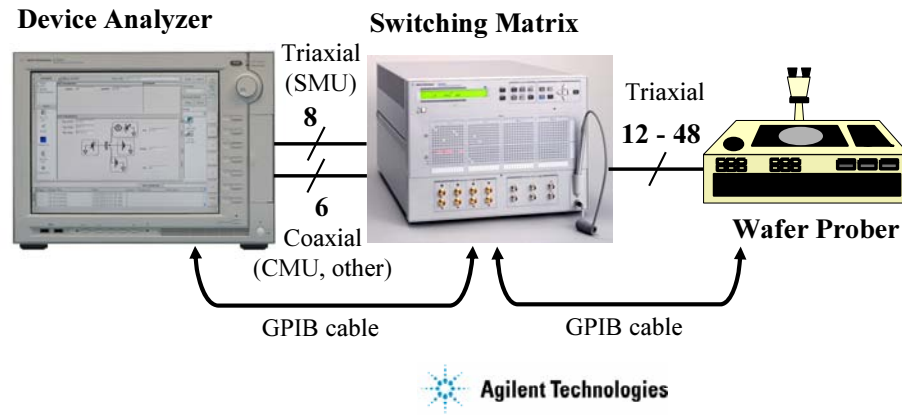
The high-resolution SMU (HRSMU) has an innate 1 fA & 0.5 mV measurement resolution. The optional ASU extends the HRSMU measurement resolution to 0.1 fA.

The ASU has another feature, built-in switching capability. It can switch between the SMU and an auxiliary input (AUX input, two BNC).

If the CMU is connected to the AUX inputs, the ASU can switch between the low current and CV measurements. Then connect a wire between the CMU return terminals of ASUs to make the return path of measurement current. This is effective for accurate capacitance measurement. However, you need to perform capacitance compensation by yourself.

B2200 Switch Control

- Allows use of a probe card to facilitate probing of standardized device modules (usually 24-pin configuration)
- Enables easy multiplexing between the triaxial outputs of SMUs and the coaxial outputs of other (BNC-based) instruments and modules

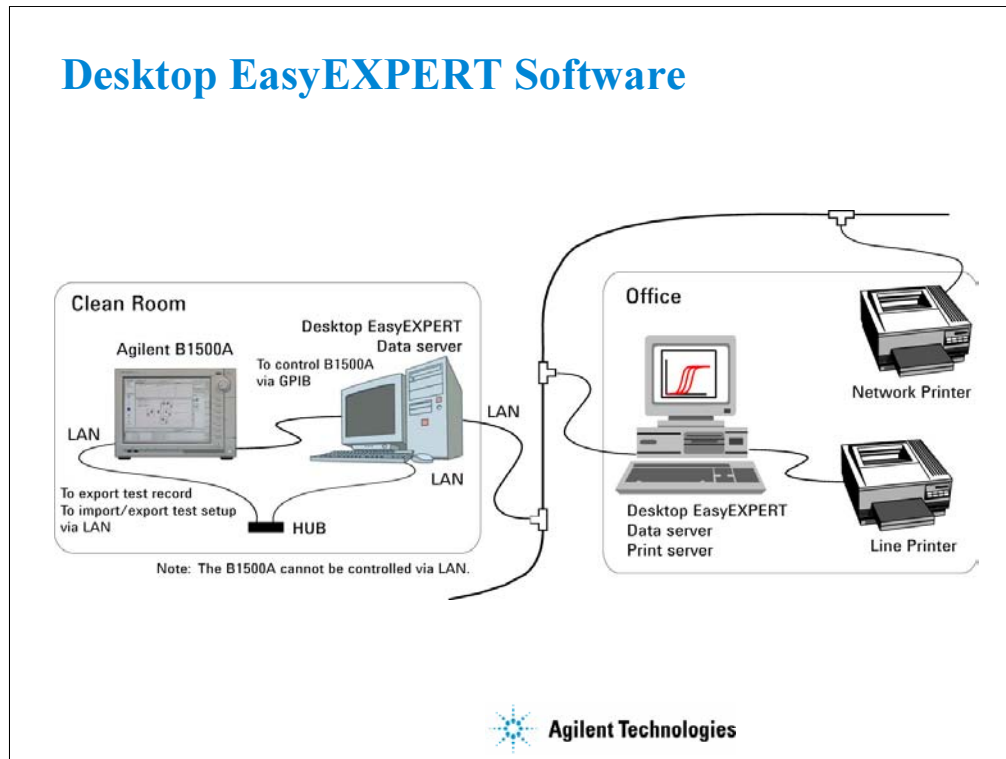


Agilent B2200A/B2201A switching matrix can be controlled by B1500A/EasyEXPERT via GPIB. EasyEXPERT provides the Switching Matrix Operation Panel for interactive control of B2200 independent from the test execution mode of B1500. And switch setup can be saved to a classic test setup data. In the classic test, the switch setup is sent to B2200 when a measurement start button is clicked.

B1500A/EasyEXPERT also provides the semi-auto prober control script. The semi-auto prober can be controlled without programming. The prober control script supports the die move operation by using the following first three procedures in the repeat measurement setup and adds the subsite move operation by using the Subsite procedure in the quick test setup.

Prober control script:

- Start procedure
- Iteration procedure
- Final procedure
- Subsite procedure



The Desktop EasyEXPERT software provides the following additional advantages to the B1500A, allowing you to minimize the amount of offline tasks performed on B1500A and increase the working ratio for measurements.

- Allows B1500A 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.
- Allows 415X to be controlled from an external computer via GPIB while online.

To start Desktop EasyEXPERT, see Module 12.





2 Getting Started



In This Module

- **To Turn on/off B1500A**
- **To Launch EasyEXPERT**
- **To Specify/Create Workspace**
- **To Perform Application Test**
- **To Save/Recall Your Test Setup**
- **To Export/Import Your Preset Group**
- **To Export/Import Test Record**
- **To Perform Quick Test**
- **To Control B2200 Switching Matrix**
- **To Manage Data Display Window**



This section explains the above tasks. You will understand how to launch B1500A/EasyEXPERT, how to perform application test and quick test, and how to create your test setups and preset groups.

To Turn on/off B1500A

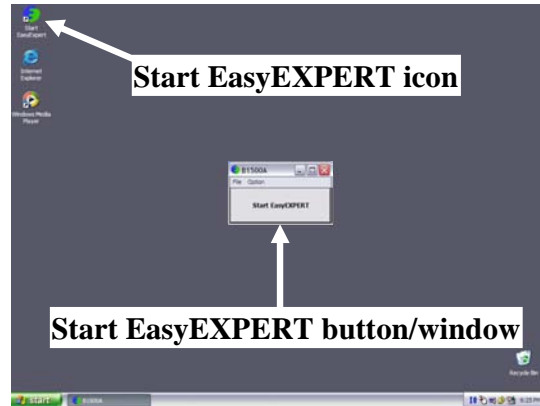


The Standby button works to turn on the B1500A when it is turned off. When the B1500A is turned on, the Standby button works to terminate the EasyEXPERT software, Windows, and turn off the B1500A.

After the B1500A is turned on, log on Windows.

The default user is Agilent B1500 User with no password.

To Launch EasyEXPERT



After logging on, click Start EasyEXPERT button to launch the EasyEXPERT software.

If you do not see the Start EasyEXPERT button, double click the Start EasyEXPERT icon to open the Start EasyEXPERT window.

This window has the File menu and the Option menu. The File menu is used to close this window. The Option menu provides the following functions.

Backup EasyEXPERT Database: Used to make backup of the EasyEXPERT database.

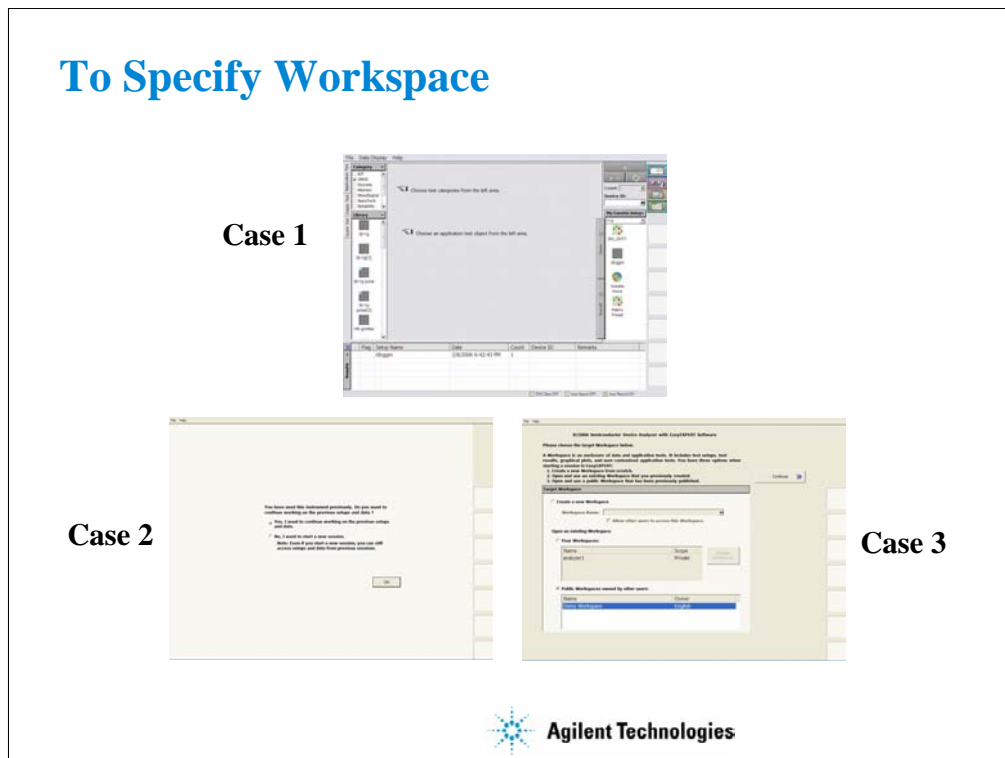
Restore EasyEXPERT Database: Used to restore the EasyEXPERT database.

Note:

Desktop EasyEXPERT provides the following additional functions in the Option menu.

Execution Mode: Used to change the software execution mode.

Move EasyEXPERT Database: Used to move the EasyEXPERT database.



After launching the EasyEXPERT, you will see one of the above screens.

Case 1: If this is the first time to launch the EasyEXPERT

The LCD displays the EasyEXPERT main screen.

Case 2: If the B1500A has one workspace only

Select Yes, and click OK if you use the existing workspace.

The EasyEXPERT main screen is displayed.

Select No, and click Next if you want to create a new workspace.

See next slide.

Case 3: If the B1500A has some workspaces (more than one)

Select workspace you want to use, and click Continue.

The EasyEXPERT main screen is displayed.

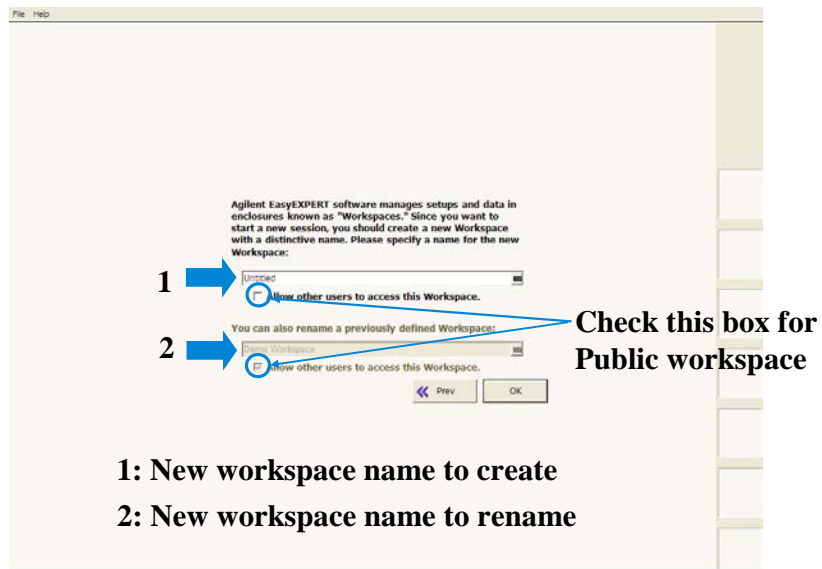
If you create workspace, check the Create a new Workspace radio button, and click Continue.

To create a public workspace, check the *Allow other users to access this workspace* box. The public workspace can be used by all users.

To create a private workspace, delete the check from the *Allow other users to access this workspace* box.

Workspace is the space created in the Agilent B1500A's internal hard disk drive, and is used to store the test setup, measurement result data, and so on. The workspace can be created and allocated for each user.

To Create Workspace



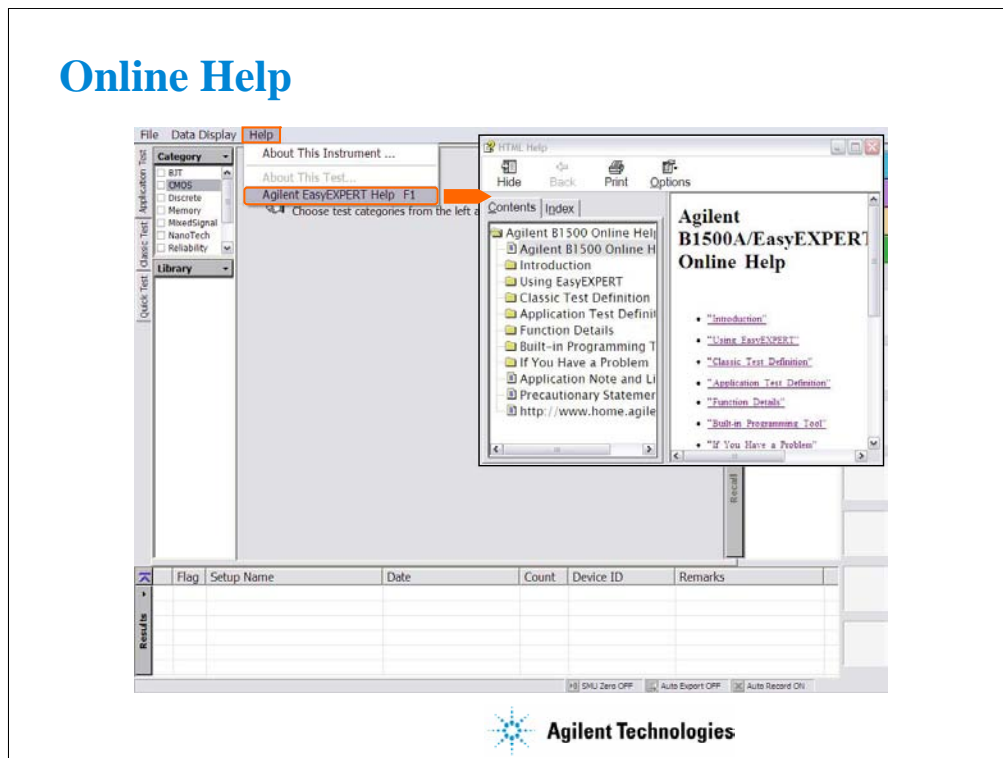
Enter the workspace name and click OK to create/rename the workspace.

If you want to create a public workspace, check the *Allow other users to access this workspace* box.

The public workspace can be used by all users.

If you want to create a private workspace, delete the check from the *Allow other users to access this workspace* box.

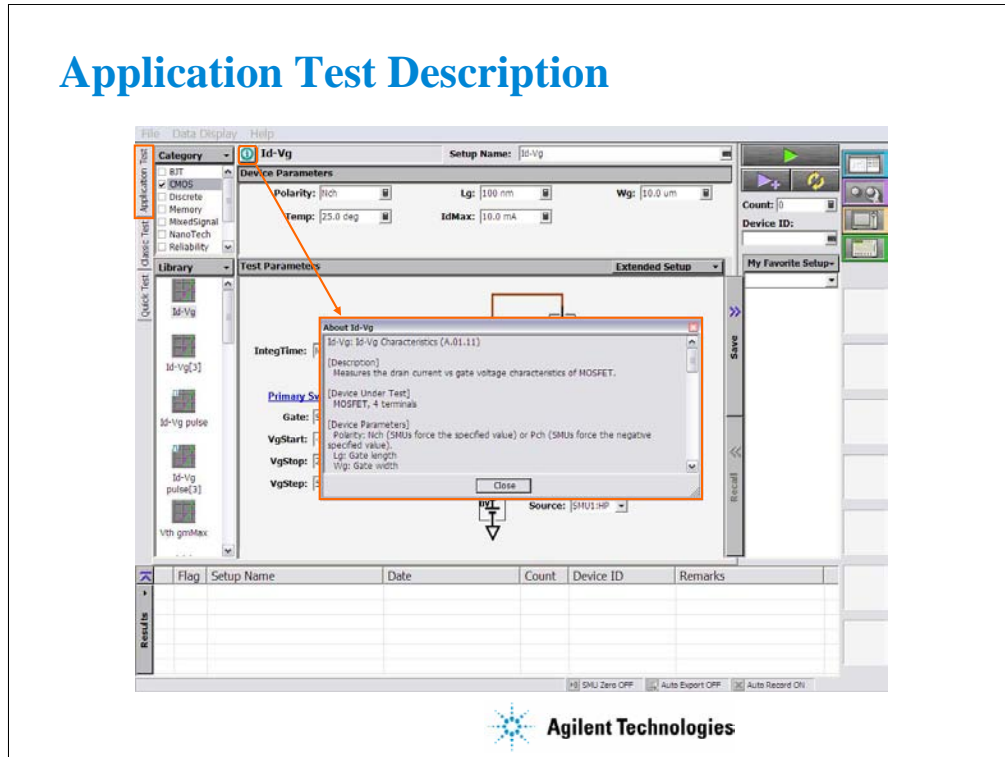
Online Help



Online Help is available for the B1500A and EasyEXPERT. Select Help > Agilent EasyExpert Help menu to display the online help window. The online help provides the following information.

- Introduction describes overview, front view, rear view, and measurement units of the Agilent B1500A.
- Using EasyEXPERT provides the reference information of the Agilent EasyEXPERT software.
- Function Details explains the measurement functions of the B1500A with EasyEXPERT.
- Built-in Programming Tool provides the reference information of the built-in function, read out functions, and script programming statements.
- If You Have a Problem describes the problem solving information, the B1500A system maintenance information, and the error messages.

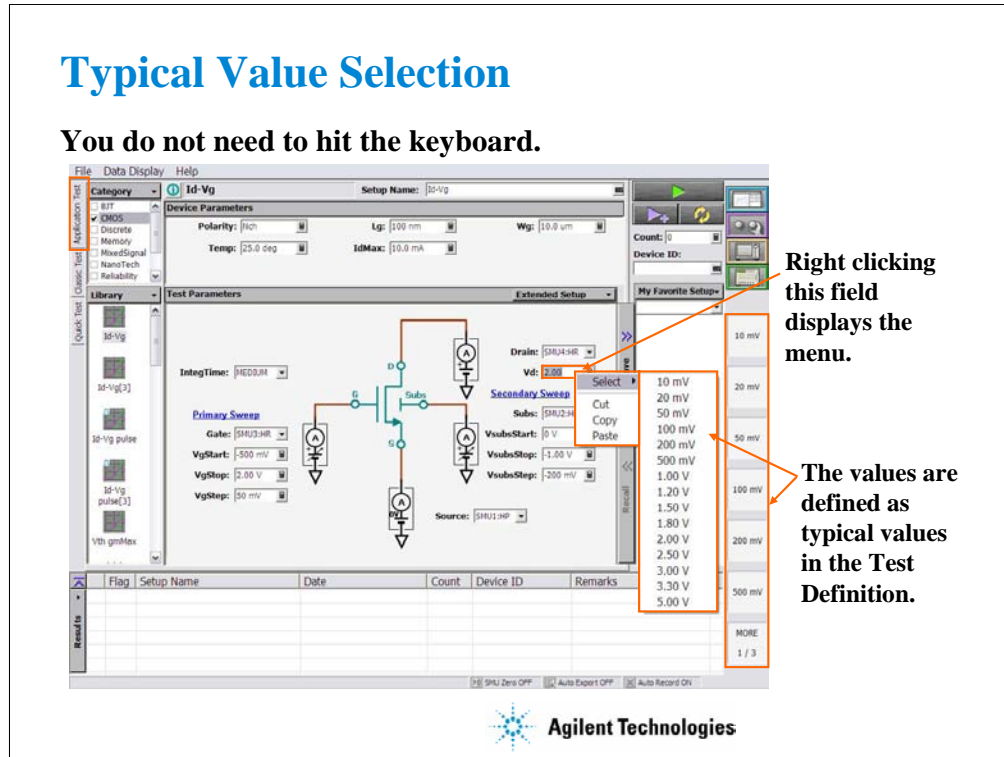
Application Test Description



To know about the application test, click the (i) icon. This icon displays the message box that explains the application test definition. This function will help you to know what is and how to use the application test.

Typical Value Selection

You do not need to hit the keyboard.



When you set a test condition of application test, you do not need to use keyboard. You can select the value from the typical values as shown below.

- Click the entry field of a setup parameter by using the touch screen or the mouse. This displays the typical values for the specified parameter on the softkeys.
- Select one of the softkeys.

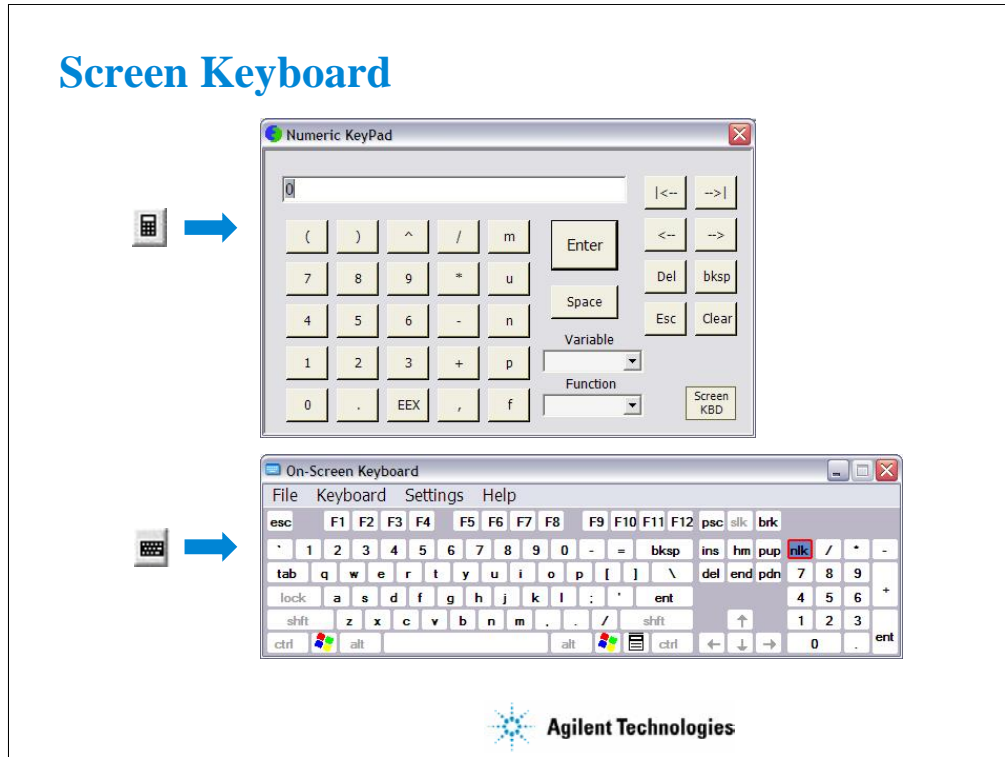
Also you can use the following manner.

- Point the entry field of a setup parameter by using the mouse.
- Right click the mouse to display the popup menu.
- Click the Select menu to display the typical values for the specified parameter.
- Select one from the typical values.

Note:

The typical values are defined in the test definition. And you can change the values by using the Define typical values window opened by clicking the Typical Values button on the Test Specification screen of the Test Definition window. For the Test Definition window, see Module 9.

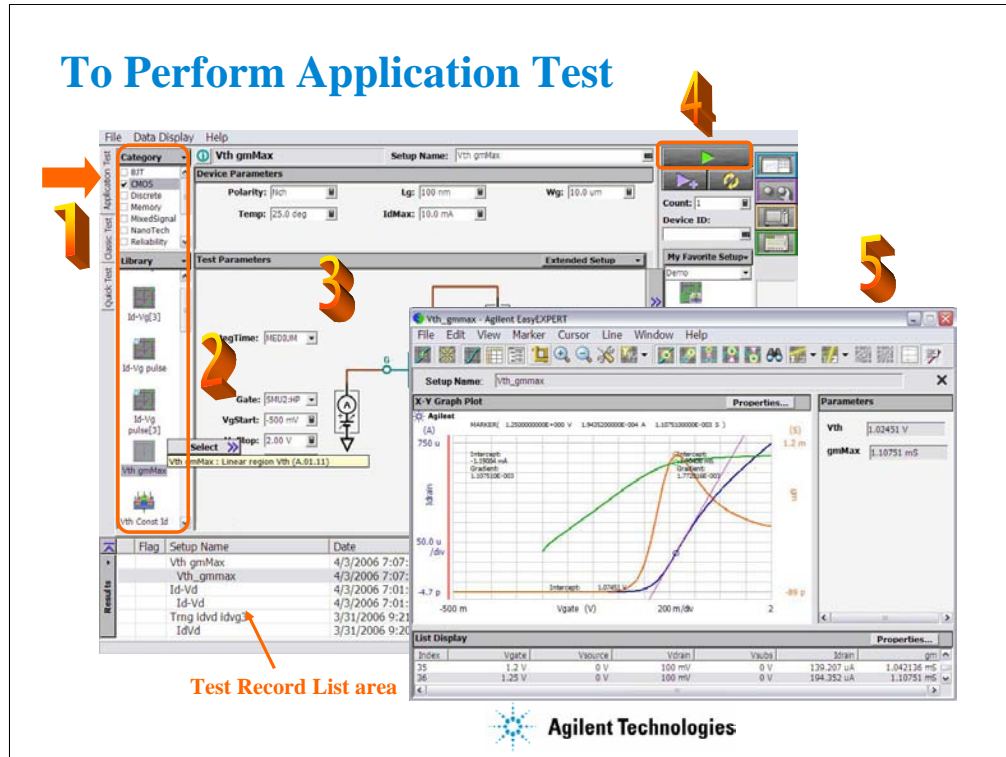
Screen Keyboard



When you need to enter numeric characters in an entry field, you will see the icon at the right side of the entry field. This icon opens the Numeric Keypad. You can use this screen keypad instead of the USB keyboard.

When you need to enter alphabetic characters in an entry field, you will see the icon at the right side of the entry field. This icon opens the On Screen Keyboard. You can use this screen keyboard instead of the USB keyboard.

To Perform Application Test



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.

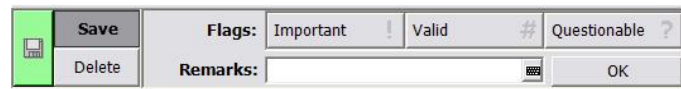
Step 4: Connect DUT, and click the Single button. The B1500A starts the selected test.

After the test, the test result data is displayed on the Data Display window. And the Test Result Editor is also displayed on the lower left area of the B1500 screen. See the next page.

Step 5: Analyze the measurement result data.

The measurement result record is automatically stored in the internal hard disk drive.

Test Result Editor



- **Save/Delete**
- **! Important**
- **# Valid**
- **? Questionable**
- **Remarks**
- **OK**



The Test Result Editor provides the following GUI to set a flag and remarks to the test result record. Set the flag and remarks to the test record.

•Save button and Delete button

Divides test records into groups, Save and Delete.

Test records in Save-group are always listed in the lower area of the EasyEXPERT main screen.

Test records in Delete-group can be listed when Results > Filter > Show Deleted Data is checked.

•Flags buttons

The following buttons are available. You can set one of the following flags.

•Important ! Button

Sets the important flag (!) to the test result record.

•Valid # button

Sets the valid flag (#) to the test result record.

•Questionable ? Button

Sets the questionable flag (?) to the test result record.

•Remarks field

You can enter characters into this field. The characters will be recorded as the Remarks value of the test result record.

•OK button

Applies the setup on the Test Result Editor, and closes this dialog box.

Test Record List Area

Results > Filter > Show Deleted Data

Flag	Setup Name
...	# Vth gmMax
...	ID-VD1
!	Vth gmMax
*	ID-VD1

Expand Application Test Results

Flag	Setup Name
...	# Vth gmMax
...	# Vth gmMax
...	ID-VD1
...	ID-VD1
!	Vth gmMax
!	Vth gmMax
*	ID-VD1

Show All Append Data

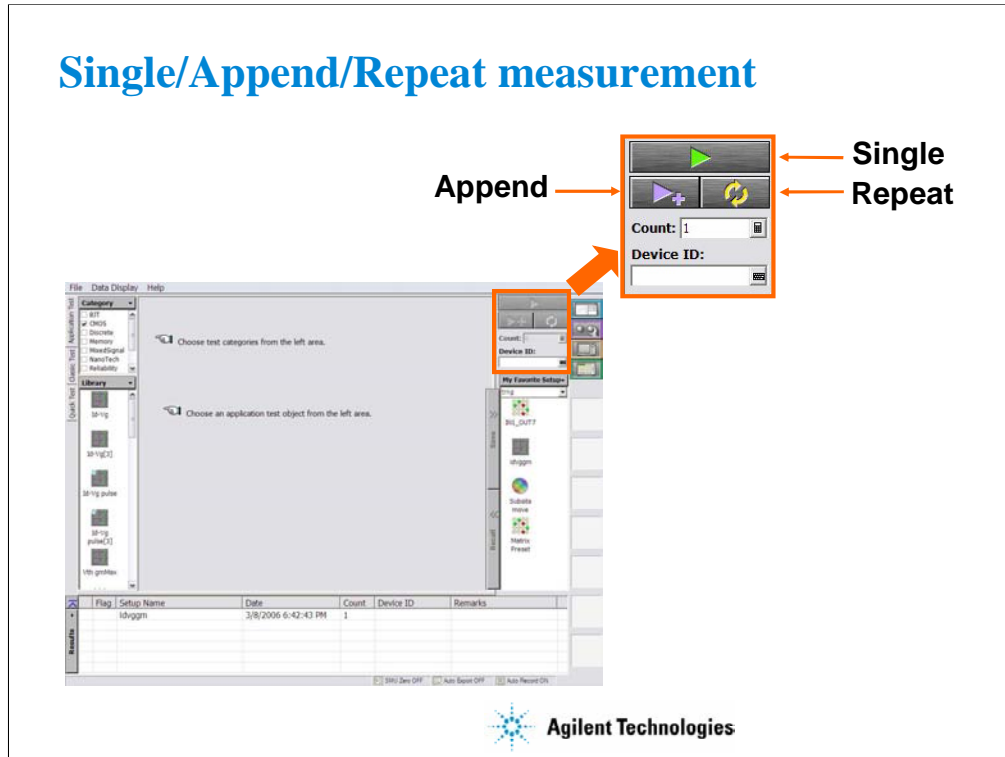
Flag	Setup Name
A	# Vth gmMax
A	# Vth gmMax
S	? Vth gmMax
S	? Vth gmMax
A	ID-VD1
A	ID-VD1
S	ID-VD1
!	Vth gmMax
!	Vth gmMax
*	ID-VD1

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The test result records are listed in the test record list area. The area also lists the following data.

- Append measurement data marked with ...
- Deleted data marked with * if Results > Filter > Show Deleted Data is checked
- Test name defined in the application test definition if Results > Filter > Expand Application Test Results is checked

If Results > Filter > Show All Append Data is checked, all append data will be listed and the symbol will be changed to A for the data obtained by the Append measurement or S for the data obtained by the Single measurement.



The EasyEXPERT provides three execution modes, Single, Append, and Repeat.

Single button triggers a single measurement.

Append button triggers an append measurement. The measurement results will be appended to the Data Display window that shows the previous measurement results. The Data Display window can have maximum 10 layers for displaying measurement results.

Repeat button opens the Repeat Measurement Setup dialog box used to set the repeat measurement condition. To perform the repeat measurement, see Module 11.

To abort measurement, click Stop button that appears instead of the Single button.

To Save/Recall Your Test Setup

My Favorite Setup button

Preset Group name. Use this field to select preset group.

Flag	Setup Name	Date	Count	Device ID	Remarks
	Vth gmMax	4/3/2006 7:07:37 PM	1		
	Vth_gmmax	4/3/2006 7:07:35 PM	1		
	Id-Vd	4/3/2006 7:01:40 PM	1		
	Id-Vd	4/3/2006 7:01:38 PM	1		
	Trng Idvd Idvg3	3/31/2006 9:21:00 PM	1		
	IdVd	3/31/2006 9:20:55 PM	1		

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The test setups you create or modify **MUST** be saved in a preset group (My Favorite Setup).

To save the setup, click the Save button.

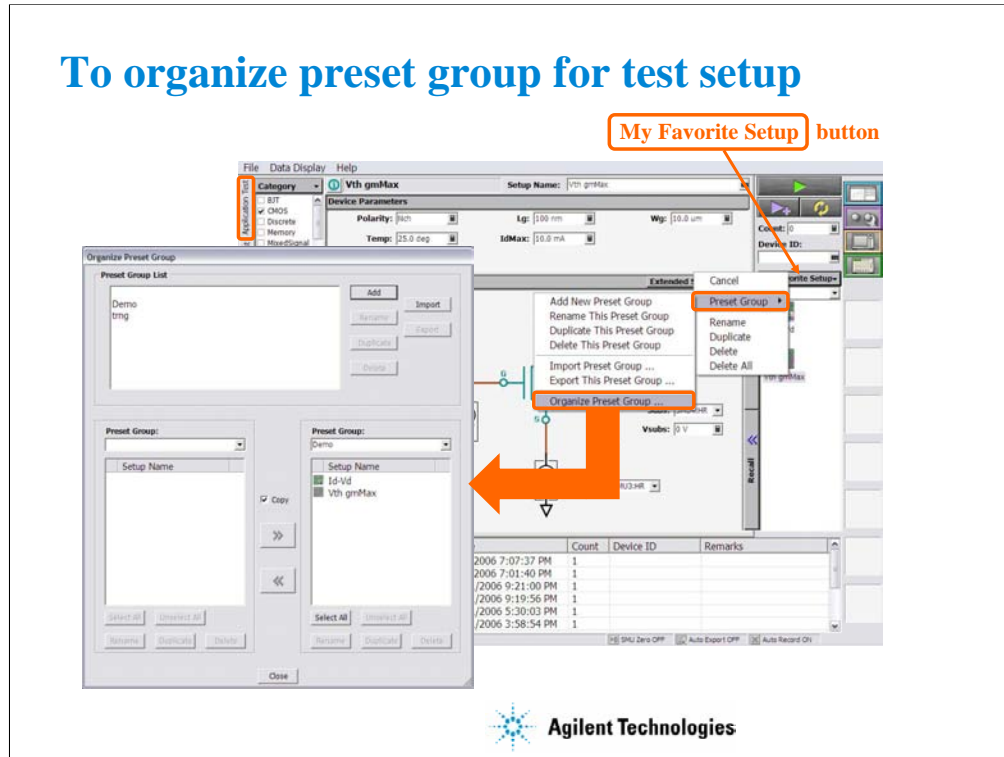
To recall the setup, click the Recall button.

You can organize the setups by using the My Favorite Setup button.

To select the available preset group, use the field below the My Favorite Setup button. In the above example, the Demo group is selected and listed in the My Favorite Setup list.

To rename, duplicate, or delete the setups, and to add, rename, duplicate, delete, import, or export the preset group, use the function of the My Favorite Setup button menu or the Organize Preset Group dialog box shown in the next page.

To organize preset group for test setup



This dialog box is opened by selecting the Organize Preset Group function of the My Favorite Setup button menu, and is used to organize the preset group.

- Preset Group List

Lists the preset groups saved in the workspace. The Add, Rename, Duplicate, Delete, Import, and Export buttons are available to organize the preset groups.

- Copy

Sets the operation of the >> button and the << button. They work as Copy when this check box is checked, and as Move when this check box is blank.

- >>

Copies or moves the preset setup selected in the left Preset Group box to the right Preset Group box.

- <<

Copies or moves the preset setup selected in the right Preset Group box to the left Preset Group box.

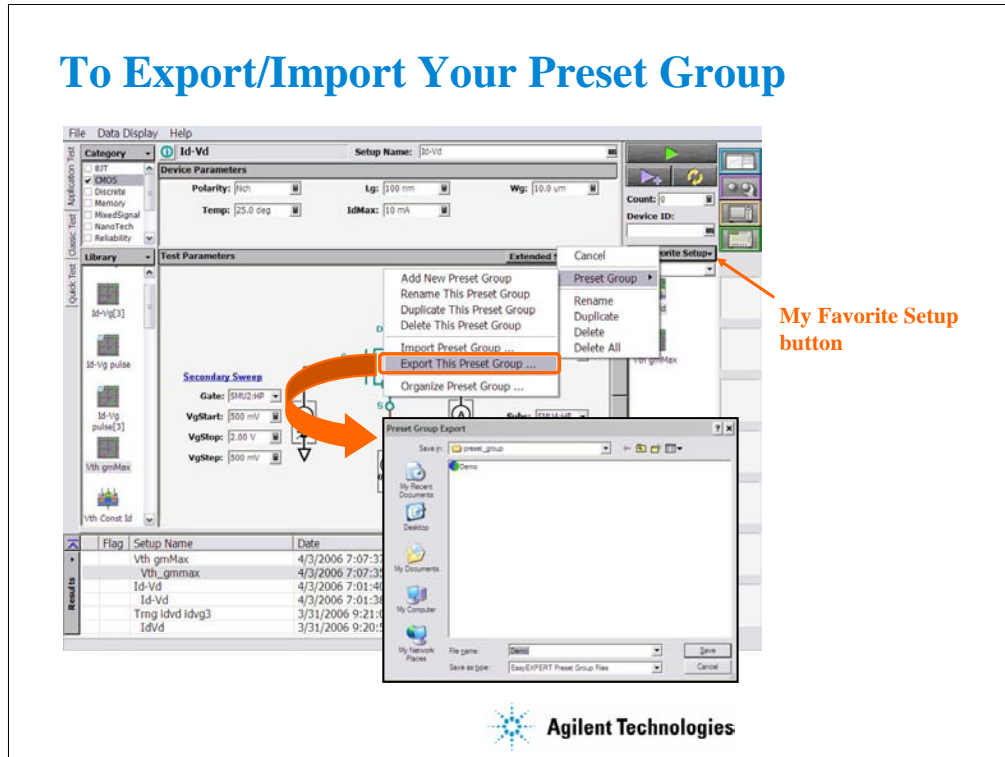
- Close

Closes the Organize Preset Group dialog box.

- Preset Group

Lists the preset setups saved in the preset group. The Select All, Unselect All, Rename, Duplicate, and Delete buttons are available to select or organize the setups saved in the preset group.

To Export/Import Your Preset Group



You can export/import your preset group.

To export the present preset group, click the My Favorite Setup button, select Export, and specify the folder and the name of the preset group to export.

To import the preset group, click the My Favorite Setup button, select Import, and specify the preset group to import.

To Export/Import Test Record

The screenshot shows the Agilent EasyExpert interface. The 'Results' pane is open, displaying a list of test records. The record 'Id-Vd' is selected, and a context menu is open over it. The 'Export As' option is visible in the menu. An orange arrow points to the 'Id-Vd' record in the list. In the background, a circuit diagram and a Microsoft Excel spreadsheet are visible. The spreadsheet shows the following data:

1	A	B	C	D	E	F	G	H	I
2	Setup File	Id-Vd							
3	Application	Id-Vd	Public						
4	TestParam Name	Gate	Source	Drain	Subs	VgStart	VgStop	VgStep	Vs
5	TestParam Value	SMU2 HP	SMU3 HR	SMU1 HP	SMU4 HR	0.5	2	0.5	
6	DutParam Name	Polarity	Lg	Wg	Temp	IdMax			
7	DutParam Value	1	1.00E-07	1.00E-05	25	0.002			
8	MetaData	TestReco	true						
9	MetaData	TestReco	04/07/2006 12:43:56						
10	MetaData	TestReco							
11	MetaData	TestReco	2						
12	MetaData	TestReco	true						
13	MetaData	TestReco							
14	MetaData	TestReco							
15	MetaData	TestReco	3f887e65-9d37-4f44-a313-c17e01d83b47						

1. Select data record to export, and right click.
 2. Select Transport Data > Export As xxxx.
- To export multiple data, select Transport Data > Folder Export.



To export the test result record, specify the data records and select the Transport Data > Export As xxxx menu.

You can save the data records as an EasyEXPERT file, a CSV file, a XML spreadsheet file, or a XML file created by using the specified XML style sheet.

You can import the data record exported as the EasyEXPERT file or the XML spreadsheet file.

To import the file, select the Transport Data > Import... Then the Test Result Import dialog box is opened. On the dialog box, select the file to import.


You can read by using a text editor or a spreadsheet software as shown above. This example reads a test record exported to a CSV file.

Note:

To export multiple test records, select Transport Data > Folder Export..., and specify the destination folder and file names automatically set. Then the multiple test records can be exported to the specified folder.

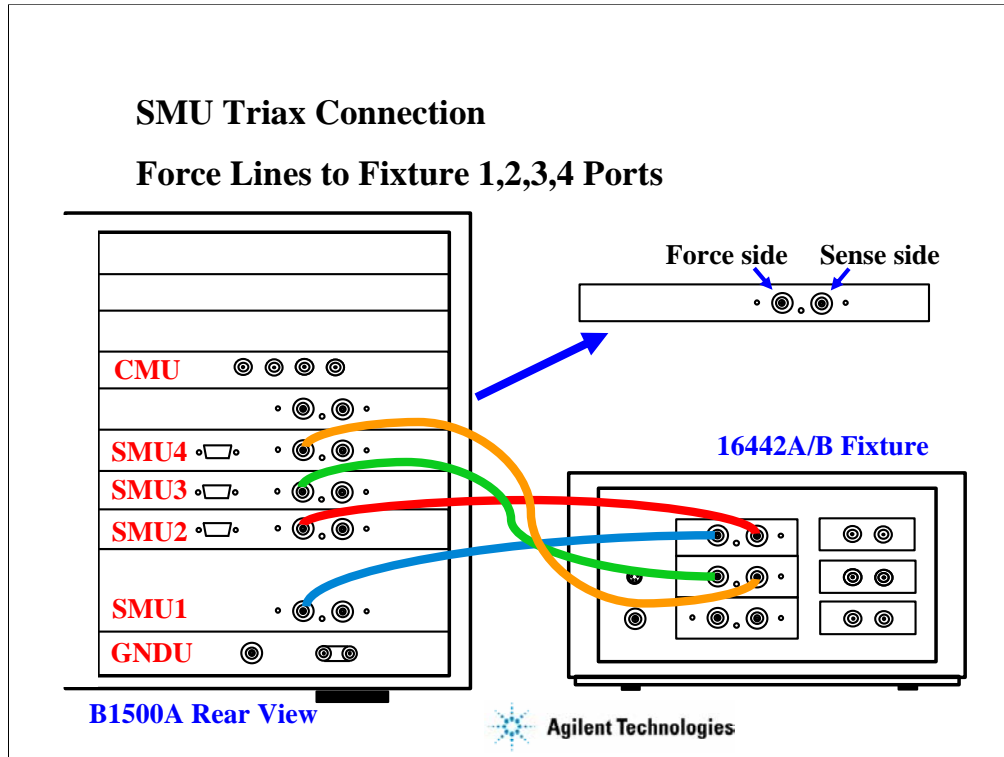
Class Exercise

Perform Application Test.

1. **Connect device (MOSFET). See the following pages.**
2. **Open Id-Vd test definition in the CMOS library.**
3. **Change the setup (SMU, output value, etc.)**
4. **Create your preset group, and save your setup.**
5. **Click  button to start a single measurement.**
6. **Perform this exercise for the Vth gmMax test definition.**



Note:

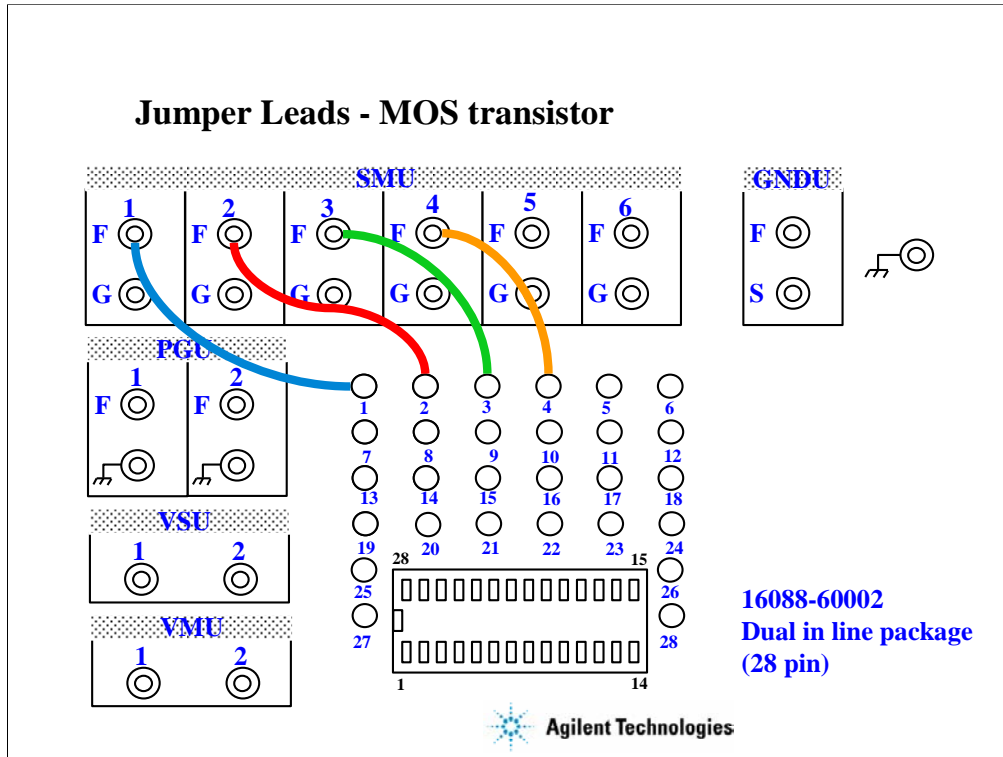


For the non-Kelvin connections, connect only the Force lines, leaving the Sense lines open.

Connect corresponding numbers. On the 16442A/B fixture use the numbers labeled 1 - 6, not 1 - 3.

Your B1500A may not match the SMU configuration shown in this figure. Note that SMU1 is the module top of the GNDU (ground unit). The SMU number become large from bottom to top as shown.


This is the SMU cable setup that will be used in the remainder of the class exercises.



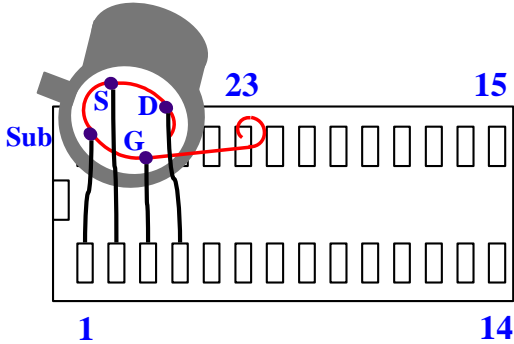
For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme. On older fixtures, this scheme is shown in light blue lettering. In newer fixtures, this scheme is shown in white reverse background lettering.


Device Orientation and Insertion



CAUTION



1: Substrate
2: Source
3: Gate
4: Drain



The MOS FET leads must be re-arranged into a straight line as shown.

IMPORTANT:

The MOS FET is highly sensitive to electrostatic damage. Touching the bare leads can definitely destroy the device. The device comes with a special shorting wire attached. Bend the leads the way you want, insert the device in the socket, and then remove the shorting wire. The wire has a tab. Just grab the tab and pull straight out. The wire will spiral out as you pull.

Once the shorting wire is removed, you must use a wrist strap when handling the device.

Setup Example

1. check

2. select

3. change

3. change

3. change

3. change

3. change

4. create

5. save

Test result data (record) is automatically saved after measurement.

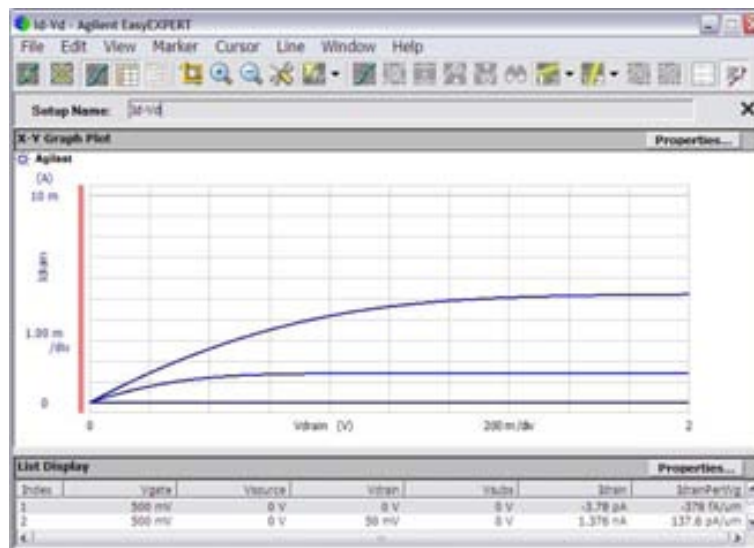
Flag	Setup Name	Date	Count	Device ID	Remarks
	Id-Vd	4/3/2006 7:01:40 PM	1		
	mg Idvd Idvg3	4/3/2006 7:01:38 PM	1		
	dvd	3/31/2006 9:21:00 PM	1		
	dvg	3/31/2006 9:20:41 PM	1		
	mg Idvd Idvg2	3/31/2006 9:19:56 PM	1		

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1. Check the CMOS check box.
2. Select Id-Vd (or Vth gmMax) and click the Select button.
3. Change the SMU setting as follows.
 - Substrate: SMU1
 - Source: SMU2
 - Gate: SMU3
 - Drain: SMU4
4. Create your preset group (ex. Exercise).
5. Save the changed setup to your preset group.

After this class exercise, the Id-Vd setup and the Vth gmMax setup will be saved in your preset group.

Result Example



This is the Id-Vd measurement result example of the following source setup.

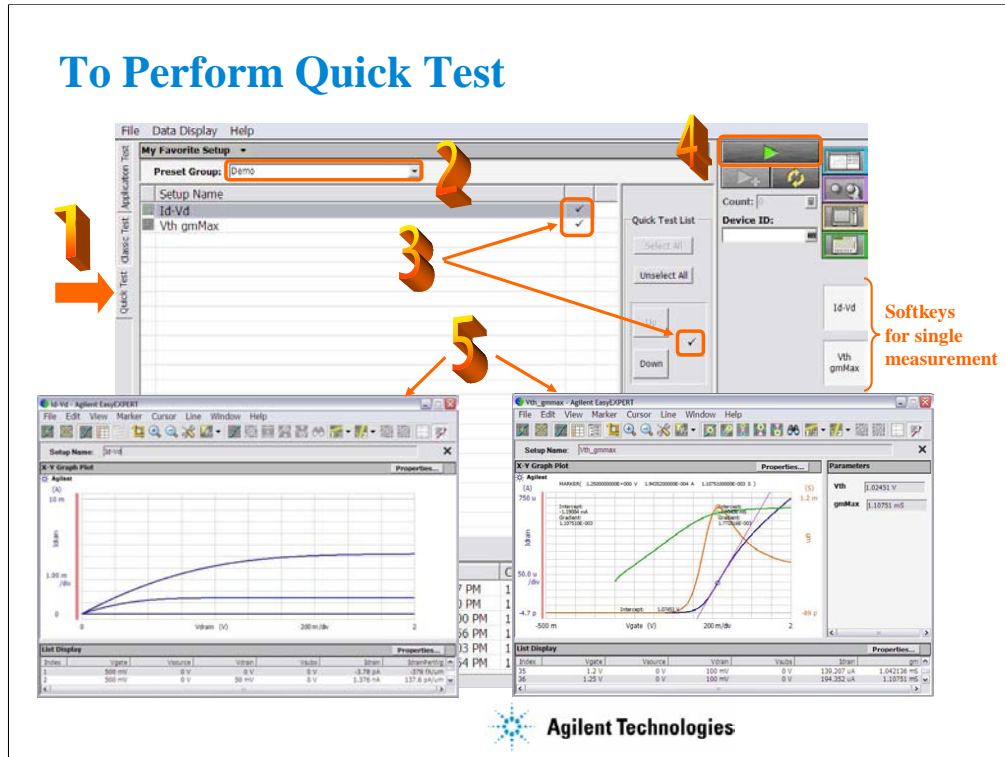
Gate voltage: 0.5 V to 2 V, 0.5 V step

Drain voltage: 0 V to 2 V, 0.05 V step

Source voltage: 0 V

Substrate voltage: 0 V

To Perform Quick Test



Step 1: Click Quick Test tab.

Step 2: Select the Preset Group.

Step 3: Mark (check) the test setups to be executed while the Quick Test is executed.

Step 4: Connect DUT, and click the Single button. The B1500A starts the selected tests from top to bottom in the list.

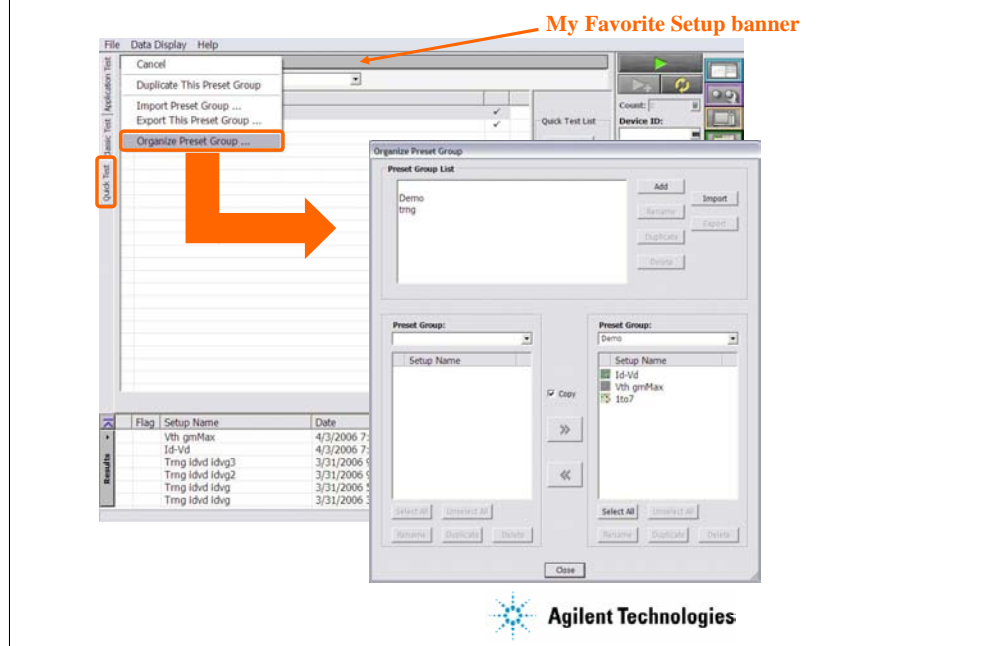
After the test, the test result data is displayed on the Data Display window. And the Test Result Editor is also displayed on the lower left area of the B1500 screen.

Step 5: Analyze the measurement result data.

The measurement result record is automatically stored in the internal hard disk drive.

The softkeys placed right side of the LCD are used to trigger a single measurement of the associated test.

To organize preset group for test setup



This dialog box is opened by selecting the Organize Preset Group function of the My Favorite Setup banner menu, and is used to organize the test preset group.

- Preset Group List

Lists the preset groups saved in the workspace. The Add, Rename, Duplicate, Delete, Import, and Export buttons are available to organize the preset groups.

- Copy

Sets the operation of the >> button and the << button. They work as Copy when this check box is checked, and as Move when this check box is blank.

- >>

Copies or moves the preset setup selected in the left Preset Group box to the right Preset Group box.

- <<

Copies or moves the preset setup selected in the right Preset Group box to the left Preset Group box.

- Close

Closes the Organize Preset Group dialog box.

- Preset Group

Lists the preset setups saved in the preset group. The Select All, Unselect All, Rename, Duplicate, and Delete buttons are available to select or organize the setups saved in the preset group.

Class Exercise

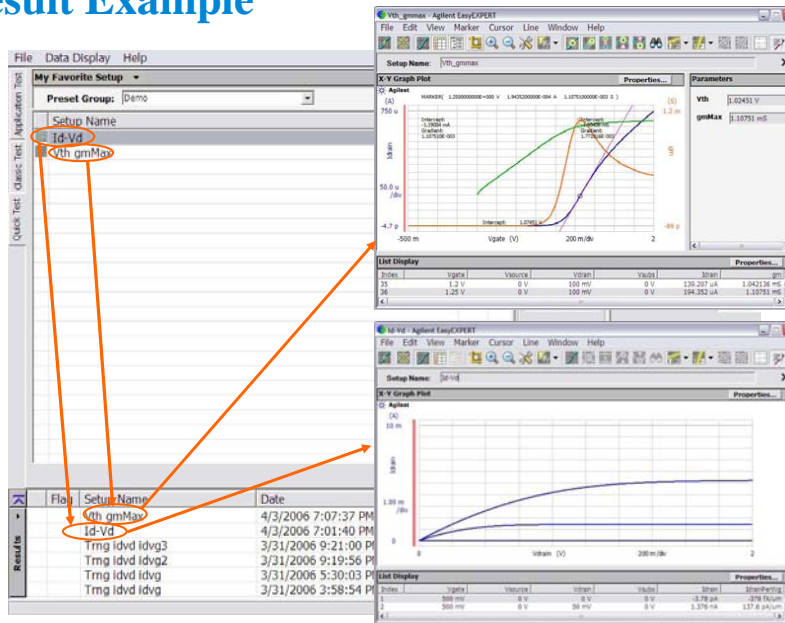
Perform Quick Test.

1. Use the device connection of the previous exercise.
2. Open your preset group.
3. Edit your preset group as you want (changing the test execution order etc.).
4. Save your preset group.
5. Perform Quick Test.

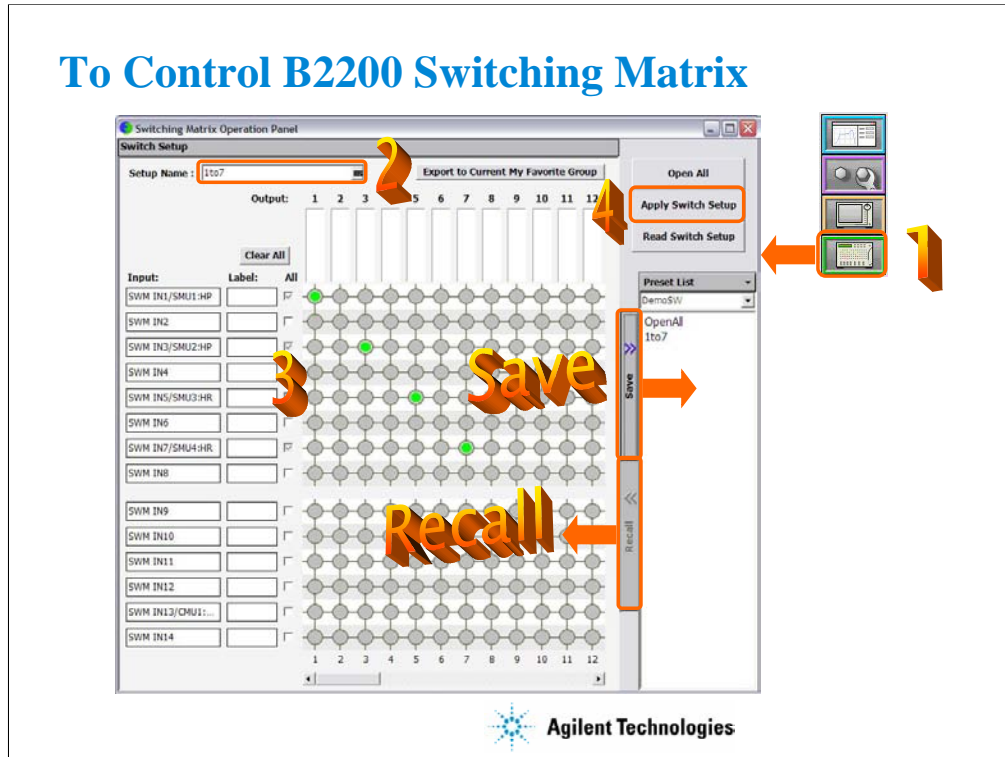


Note:

Result Example



Note:



Step 1: Click Switching Matrix button to open the Switching Matrix Operation Panel.

Step 2: Enter the switch setup name.

Step 3: Define the switch setup by using the matrix on the operation panel window. Label can be set to input ports and output channels.

Step 4: Click the Apply Switch Setup button to send the switch setup to the B2200 switching matrix.

Note:

Before clicking this button, connect the B2200 to the B1500 via GPIB, and set the configuration. To set the configuration, see Module 12.

The switch setups you create or modify MUST be saved in a preset group.

To save the setup, click the Save button.

To recall the setup, click the Recall button.

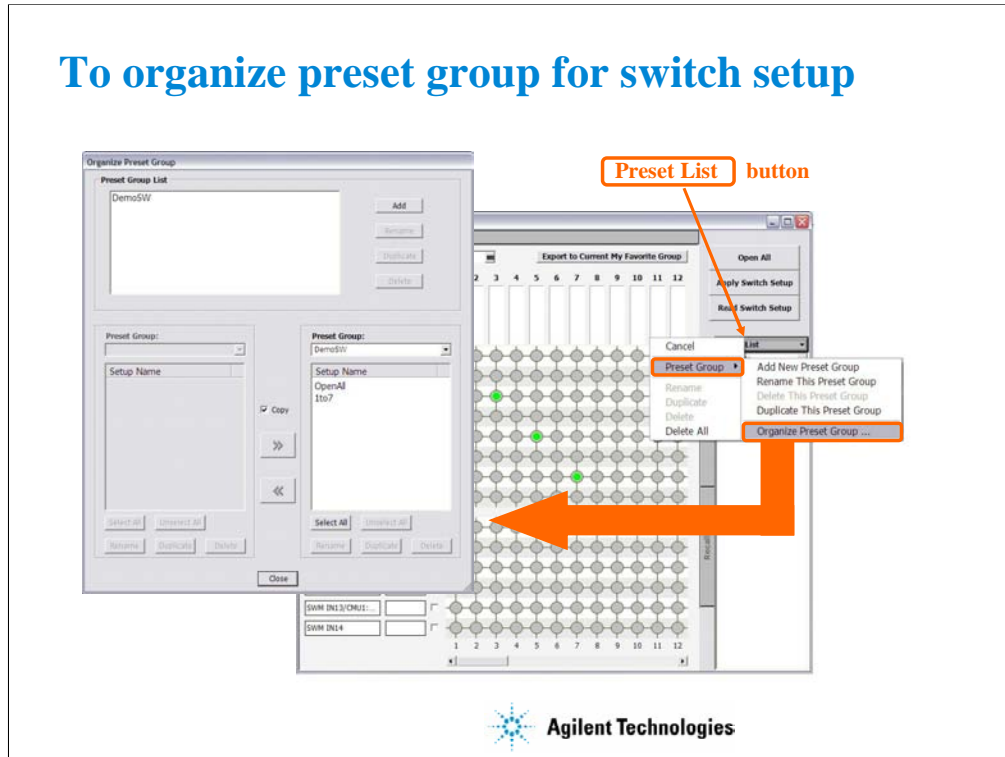
You can organize the setups by using the Preset List button.

To select the available preset group, use the field below the Preset List button. In the above example, the DemoSW group is selected and listed in the Preset List list.

To rename, duplicate, or delete the setups, and to add, rename, duplicate, or delete the preset group, use the function of the Preset List button menu or the Organize Preset Group dialog box shown in the next page.

Read Switch Setup: Read switch setup from B2200 via GP-IB and show it on the operation panel window.

To organize preset group for switch setup



This dialog box is opened by selecting the Organize Preset Group function of the Preset List button menu, and is used to organize the switch preset group.

- Preset Group List

Lists the preset groups saved in the workspace. The Add, Rename, Duplicate, and Delete buttons are available to organize the preset groups.

- Copy

Sets the operation of the >> button and the << button. They work as Copy when this check box is checked, and as Move when this check box is blank.

- >>

Copies or moves the preset setup selected in the left Preset Group box to the right Preset Group box.

- <<

Copies or moves the preset setup selected in the right Preset Group box to the left Preset Group box.

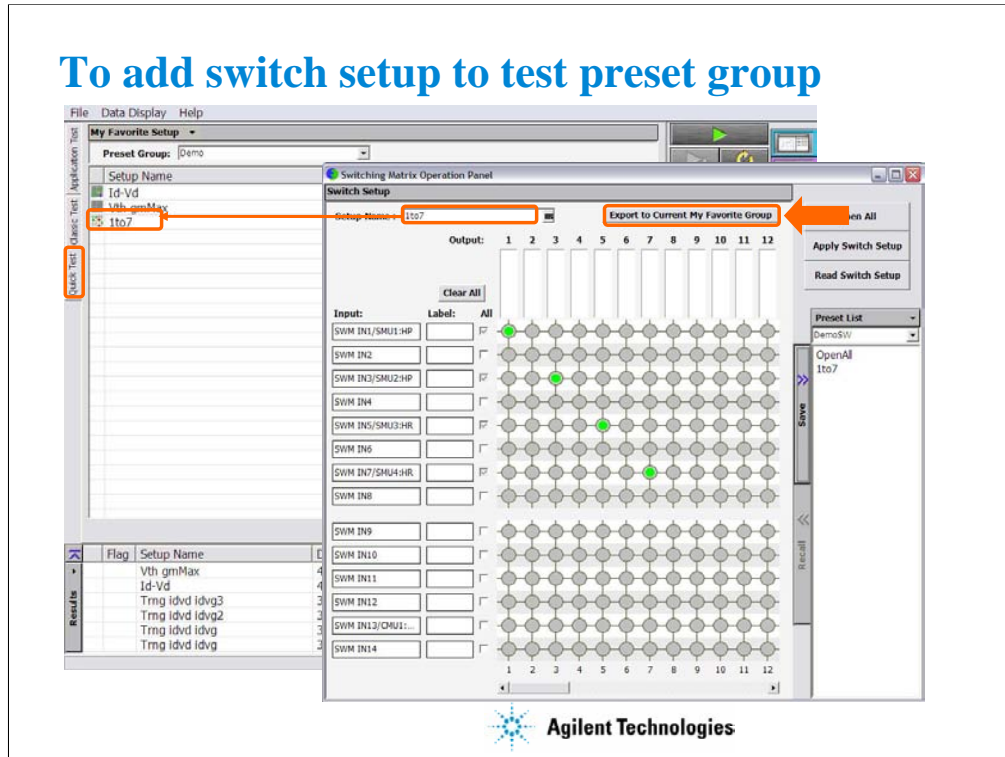
- Close

Closes the Organize Preset Group dialog box.

- Preset Group

Lists the preset setups saved in the preset group. The Select All, Unselect All, Rename, Duplicate, and Delete buttons are available to select or organize the setups saved in the preset group.

To add switch setup to test preset group



Switch setups can be saved in the preset group for test setups.

Click the Export to Current My Favorite Group button. The switch setup will be converted to a classic test setup and saved in the My Favorite Setup group opened in the main screen.

To select the available preset group, use the Preset Group field. In the above example, the Demo group is selected and listed in the quick test setup list.

To duplicate, import, or export the preset group, use the function of the My Favorite Setup banner menu or the Organize Preset Group dialog box shown in the next page.

Class Exercise

Add switch setup to test preset group.

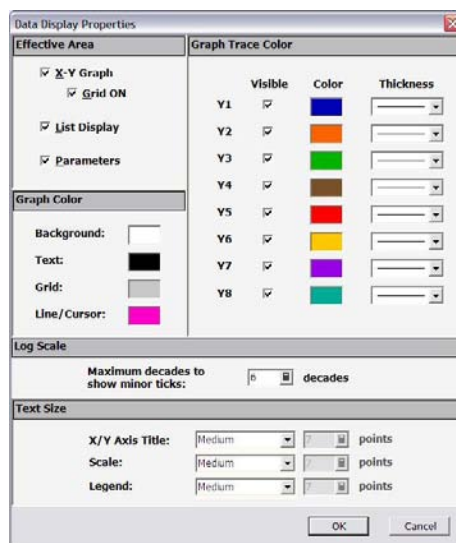
1. Create a switch setup.
2. Create your switch preset group, and save your setup.
3. Add the switch setup to your test preset group.
4. Save your test preset group.



Note:

To Manage Data Display Window

Data Display > Default Data Display Properties...



The Data Display Properties window is used to set the default setting of the Data Display window. This window is opened by selecting the Data Display > Default Data Display Properties... menu of the main screen.

The Effective Area is used to select the area effective when the Data Display window is opened, and provides the following check box.

- X-Y Graph: Check this box to enable the X-Y Graph area.
- Grid ON: Check this box to display the grid in the X-Y Graph.
- List Display: Check this box to enable the List Display area.
- Parameters: Check this box to enable the Parameters area.

The Graph Color area is used to set the color map for the Data Display window. You can change the color of the background, text, graph grid, and line. The color palette is opened by clicking the pattern of the item.

The Graph Trace Color area is used to set visibility, color, and thickness of the data traces Y1 to Y8 plotted on the graph.

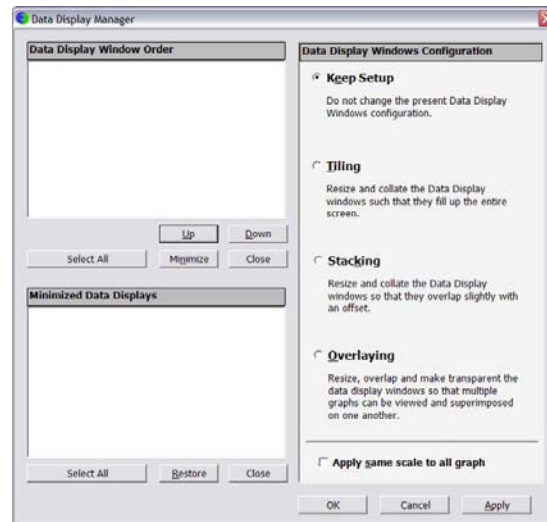
The Log Scale area is used to set the maximum number of decades to show the minor ticks for the log axis. If the number of graph decades is less than or equal to the entered value, the minor ticks are displayed. If it is greater than the entered value, the minor ticks are not displayed.

The Text Size area is used to set the font size for the graph. The available settings are Largest, Large, Medium, Small, Smallest, and Fixed. For settings other than Fixed, the appropriate size is automatically selected. For Fixed, a font size entry field is provided, and the specified font size is always applied.

- X/Y Axis Title: Font size for the axis title
- Scale: Font size for the X and Y coordinate values
- Legend: Font size for the graph legend

To Manage Data Display Window

Data Display > Manage Data Display...



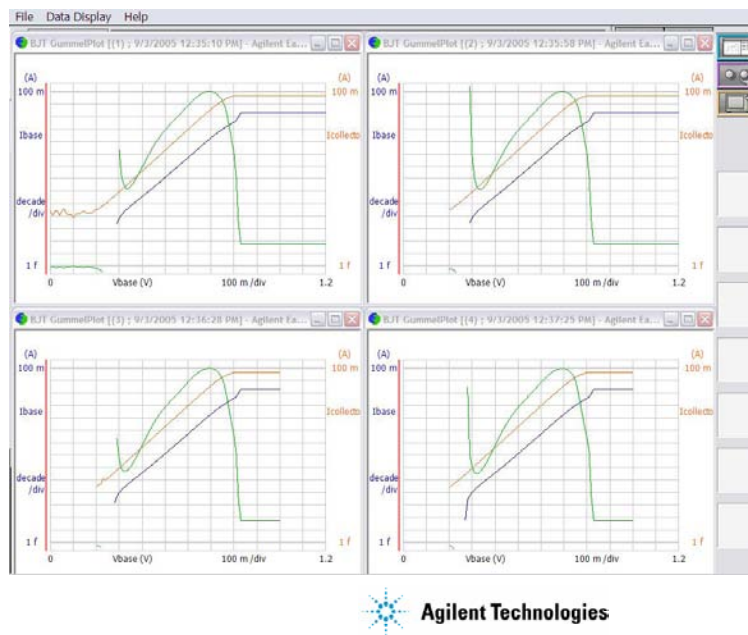
The Data Display Manager is used to control the appearances of the Data Display windows. This window is opened by selecting the Data Display > Manage Data Display... menu of the main screen. The Data Display Window Order area lists the Setup Name of the Data Display windows opened. The list items from top to bottom correspond to the windows from front to back in the screen image. The Minimized Data Displays area lists the Setup Name of the Data Display windows minimized. The Data Display Window Configuration area provides the following radio buttons and a check box to change the appearances of the Data Display windows. All functions are available for the opened windows. See following slides for the display examples.

- Keep Setup: Keeps the present configuration of the Data Display windows.
- Tiling: Resize and collate the data display windows such that they fill up the entire screen.
- Stacking: Resize and collate the data display windows so that they overlap slightly with an offset.
- Overlaying: Resize, overlap, and make transparent the data display windows so that multiple graphs can be viewed and superimposed on one another.

The following check box must be checked to apply the same graph scale to all graphs.

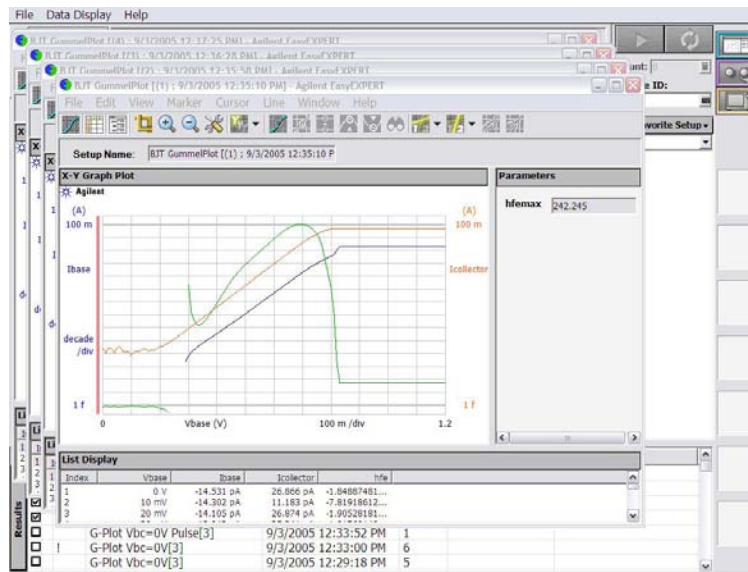
- Apply same scale to all graph

Tiling



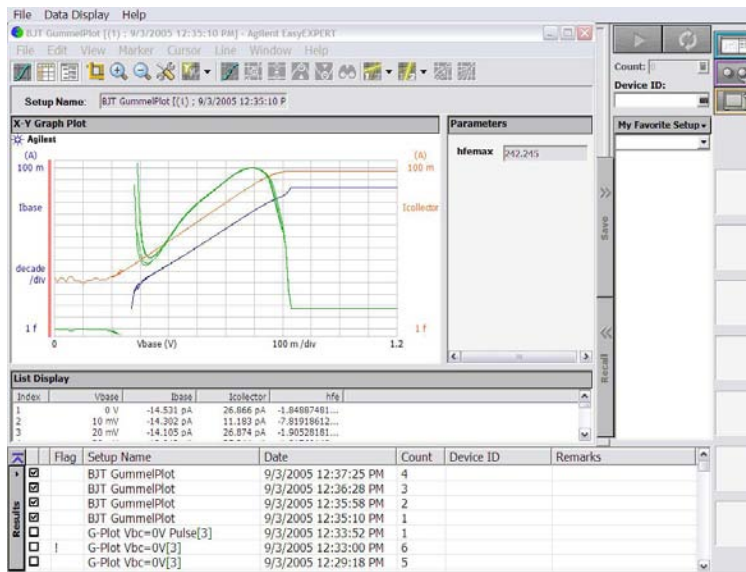
This is a display example of Tiling.

Stacking

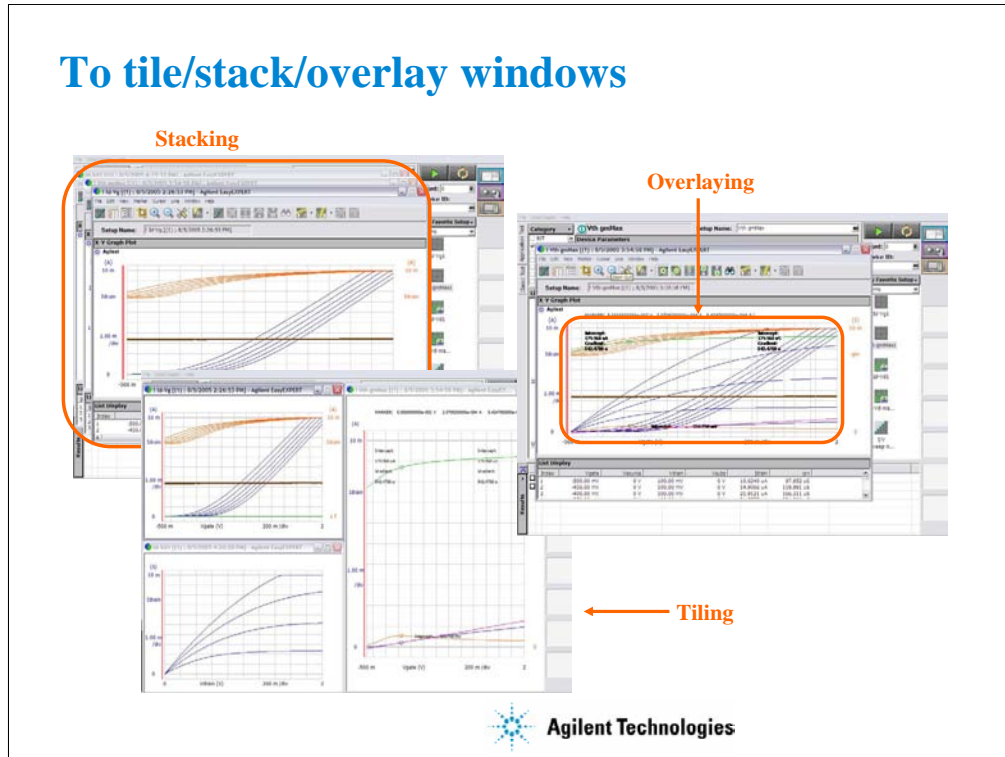


This is a display example of Stacking.

Overlaying



This is a display example of Overlaying.



When some Data Display windows are opened, the following Windows menu functions are useful.

Tiling

Tiles all Data Display windows on the screen.

Stacking

Stacks all Data Display windows on the screen.

Overlaying

Overlays all Data Display windows on the screen. Then the position, window size, and visibility of the most front window are applied to all windows on the screen.

The background of the X-Y Graph area is cleared except for the most back window.

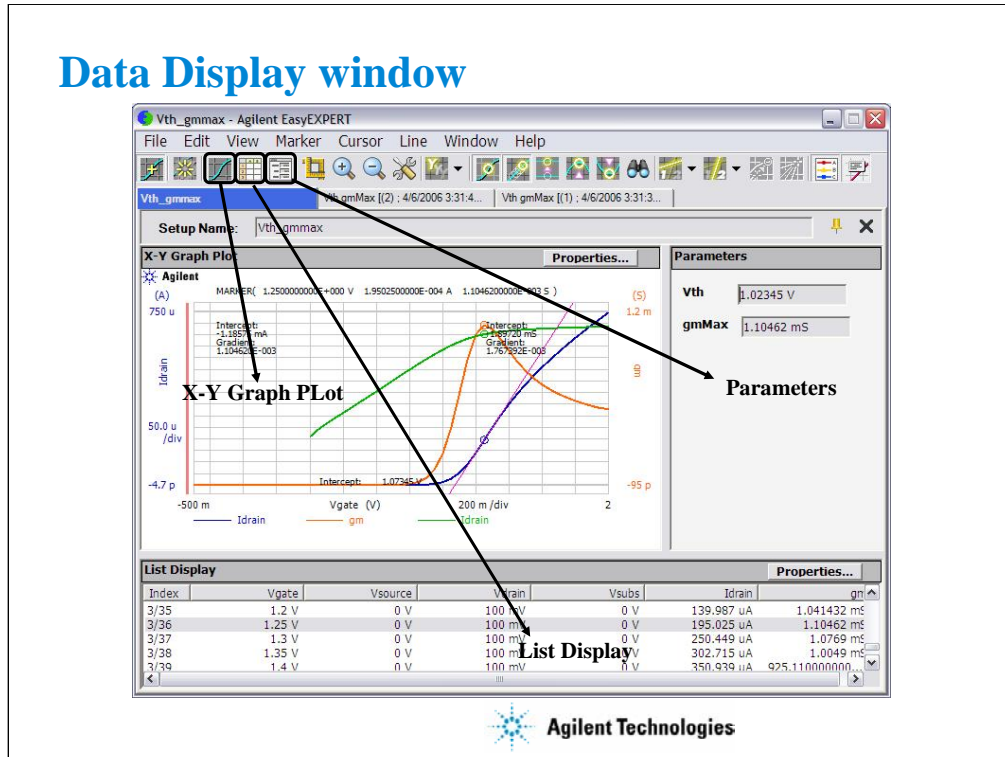
In This Module

- **Data Display window**
- **Graph Analysis Tools**
- **Data Status**
- **To Change Graph/List/Display Setup**
- **To See Print Preview**
- **To Print Display Data**
- **To Copy Graph Plot/List Data**
- **To Save Analysis Result**
- **To Use Preview Window**



This section describes the above topics. You will understand how to use analysis tools, how to change display setup, and how to print/export test result data.

Data Display window



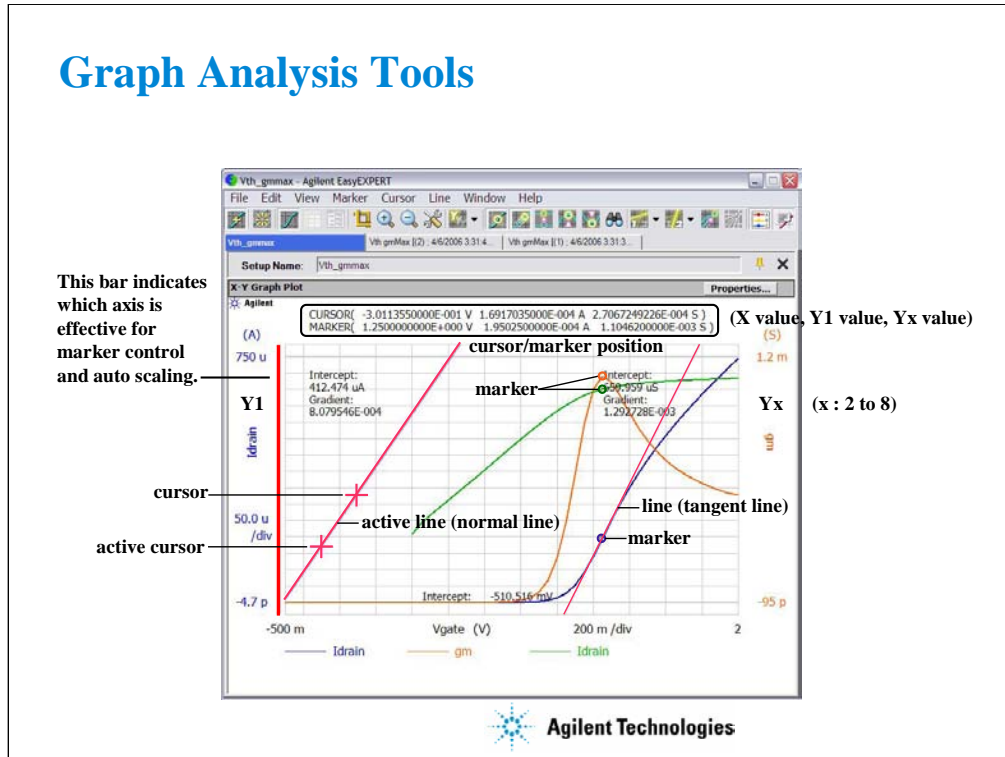
The Data Display window is opened after measurement automatically, or by clicking the Data Display button. And the window is used to display measurement data and analyze the data.

The Show X-Y Graph icon displays/hides the X-Y Graph Plot area. This is the same as the View > X-Y Graph menu.

The Show List Display icon displays/hides the List Display area. This is the same as the View > List Display menu.

The Show Parameters icon displays/hides the Parameters area. This is the same as the View > Parameters menu.

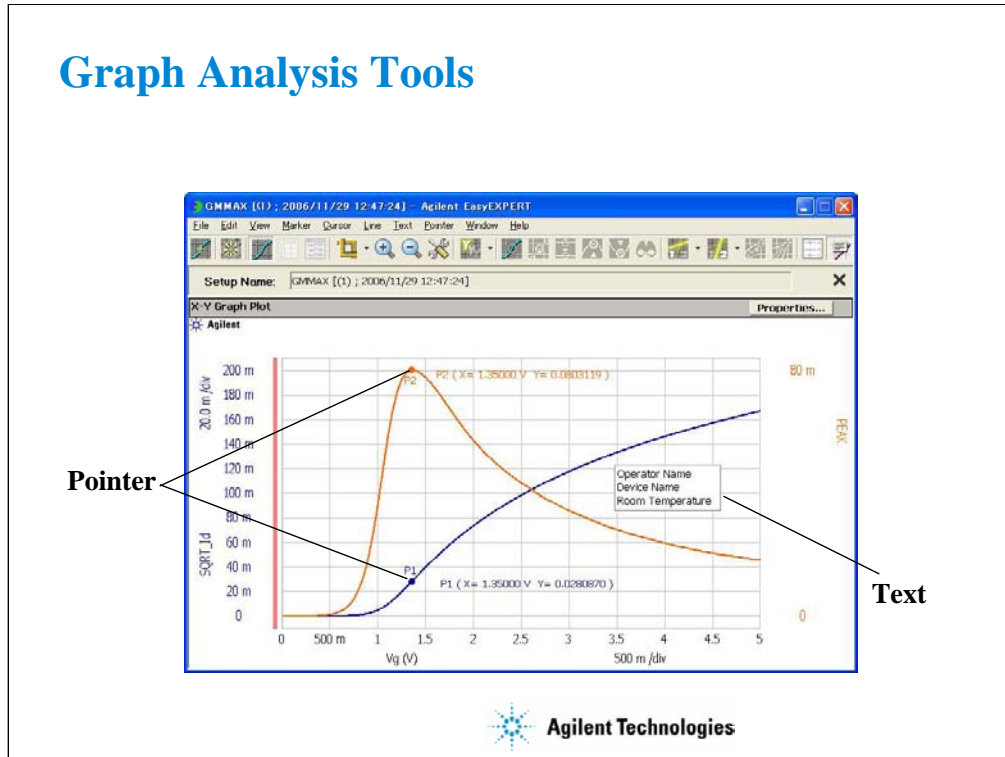
Graph Analysis Tools



The Data Display window provides marker, cursors, and lines for analyzing test result data. Marker is used to read measurement data and draw a tangent line. Cursors are used to read the cursor position and draw a normal line, gradient line, or regression line. The cursor/marker position data is displayed top of the graph plot area.

Clicking Y axis can select the Y axis effective for the analysis tools. On the graph, left axis is always Y1 axis. And the right axis is selectable from Y2 to Y8 axes.

Graph Analysis Tools

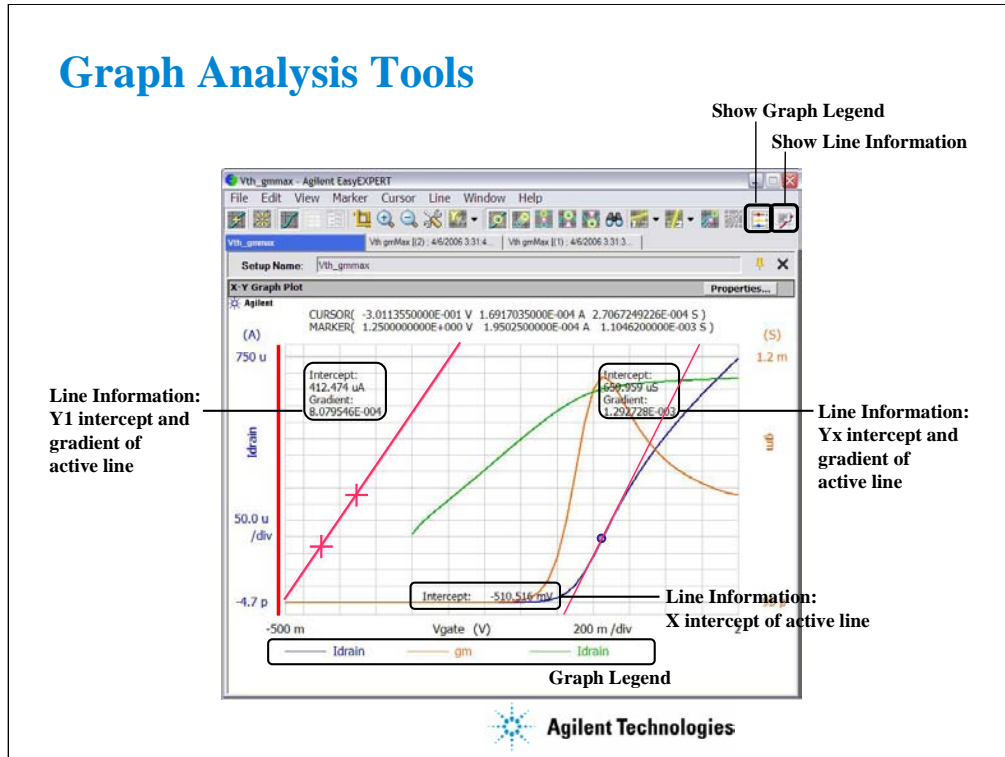


Text and pointer are the tools to decorate the X-Y Graph.

The text is used to leave notes on the graph. The notes will be measurement conditions, device information, operator name, and so on. Up to 20 texts can be added to a graph.

The pointer is used to indicate the remarkable measurement point and show the X and Y coordinates like the marker. The new pointer can be displayed on the marker point at first and can be moved on the measurement data curve by using the rotary knob or the mouse wheel. Up to 30 pointers can be added to a graph.

Graph Analysis Tools

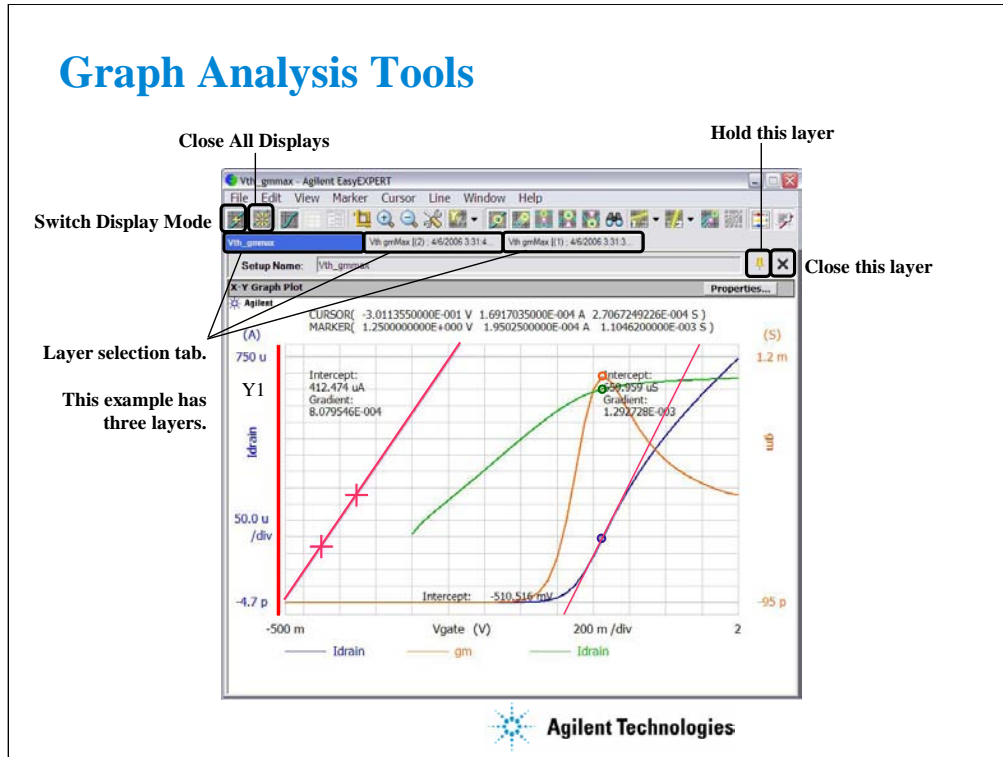


When a line is displayed, the line information can be displayed in the graph plot area.

The Show Line Information icon displays/hides the line information. This is the same as the View > Line Information ON/OFF menu.

The Show Graph Legend icon displays/hides the graph legend. This is the same as the View > Graph Legend ON/OFF menu.

Graph Analysis Tools



If the append measurement is performed, the data display layer is added to the Data Display window. In this example, the Data Display window has three layers.

Use the icons shown above to organize the data display layers.

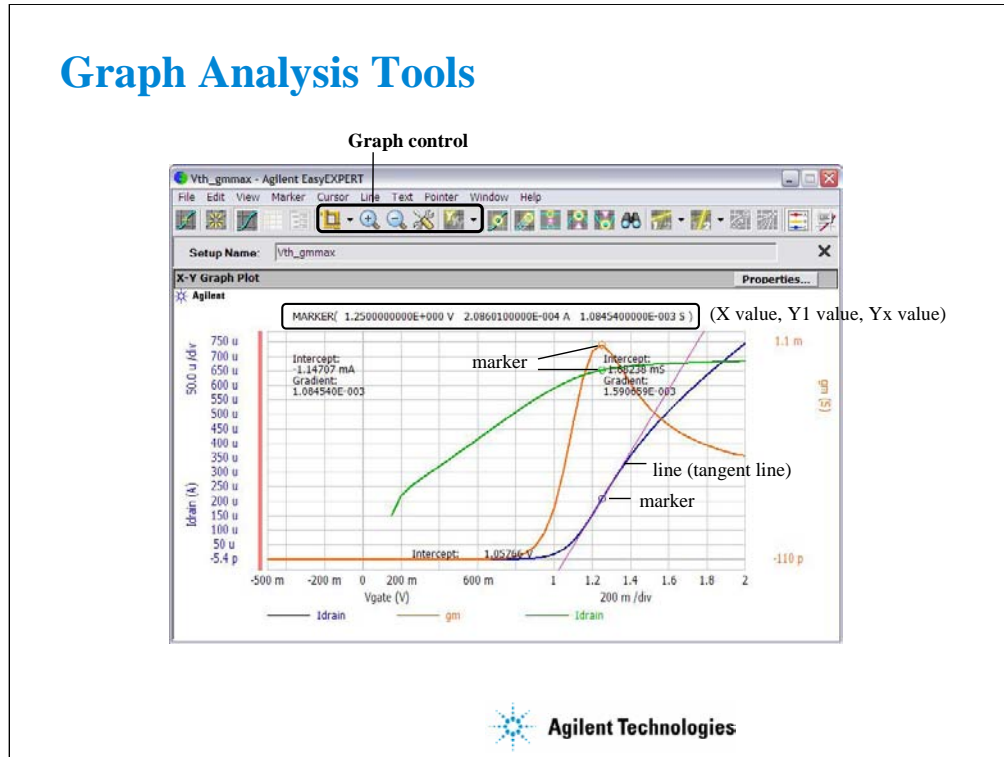
Switch Display Mode icon switches the mode, overwrite or append.

In the overwrite mode, the data is displayed in a new Data Display window.

In the append mode, the data is displayed on a new display layer in the present Data Display window.

The Data Display window can hold up to 10 display layers. And the earliest layer over 10 will be automatically deleted. The Hold this layer icon is available when the window holds at least two layers. If this icon shows the standing pin, the layer will be held. If this icon shows the laid pin, the layer can be deleted. Double clicking the tab gives the same result as this icon.

Graph Analysis Tools



Graph control:

Auto Scale icon will change the graph scale automatically to fit the trace in the graph. The right arrow button opens the menu for enabling or disabling the run time auto scaling. This function is set independently for the X and Y axes. If this function is enabled, the graph scale will be changed automatically to fit the trace in the graph during the measurement.

Zoom In icon zooms the data graph in. This enlarges the trace in the graph. Then the center of zooming will be the cursor position.

Zoom Out icon zooms the data graph out. This reduces the trace in the graph.

Graph Setup icon opens the Graph Setup dialog box used to change the graph axis setup.

Choose Active Y axis icon selects the Y axis that is effective for the analysis tools (marker control and auto scaling).

If multiple layers are opened on the Data Display window, the scale change is applied to the layers. This means that the X-Y graph scale will be shared by all display layers. The auto scaling is performed as follows.

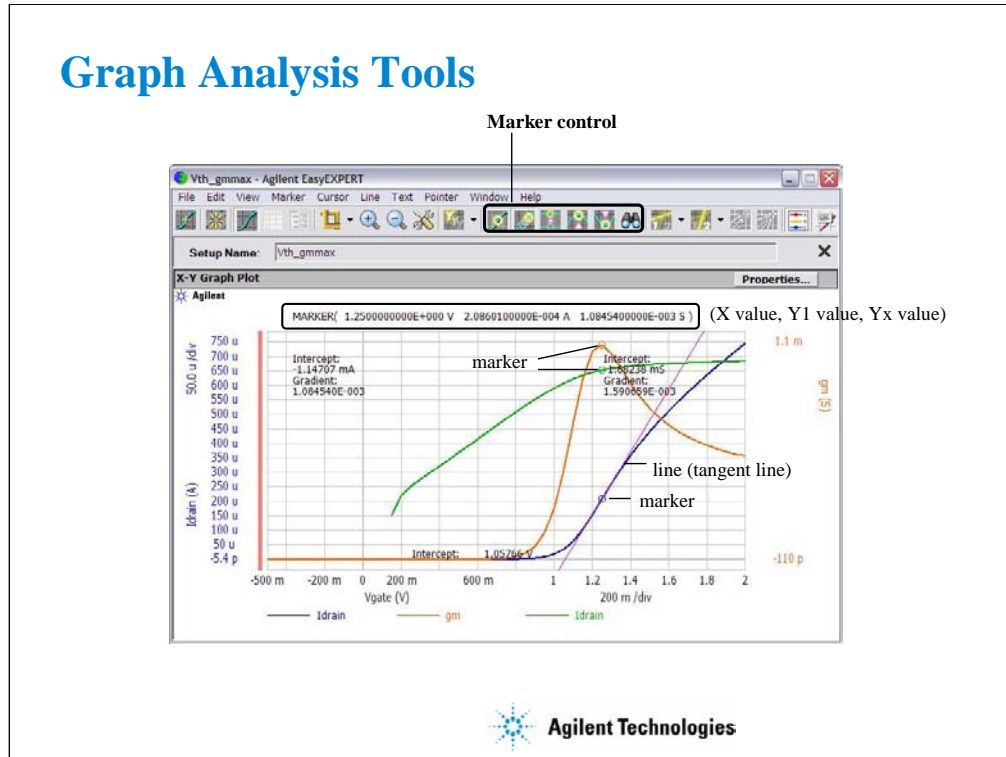
1. Graph scale is optimized for the data on the selected layer (top layer).
2. The graph scale is applied to the graph in the all layers.

Note that auto scaling is performed independently for the left and right Y axes.

There is also a function for resetting the graph scale. Click View > Cancel Scaling > This Display or All Displays.

This Display will reset the selected layer only. All Displays will reset all display layers.

Graph Analysis Tools



Marker control:

Marker ON/OFF icon enables or disables the marker.

Interpolation ON/OFF icon enables or disables the interpolation function of measurement data. You can read the interpolation data between two actual measurement points.

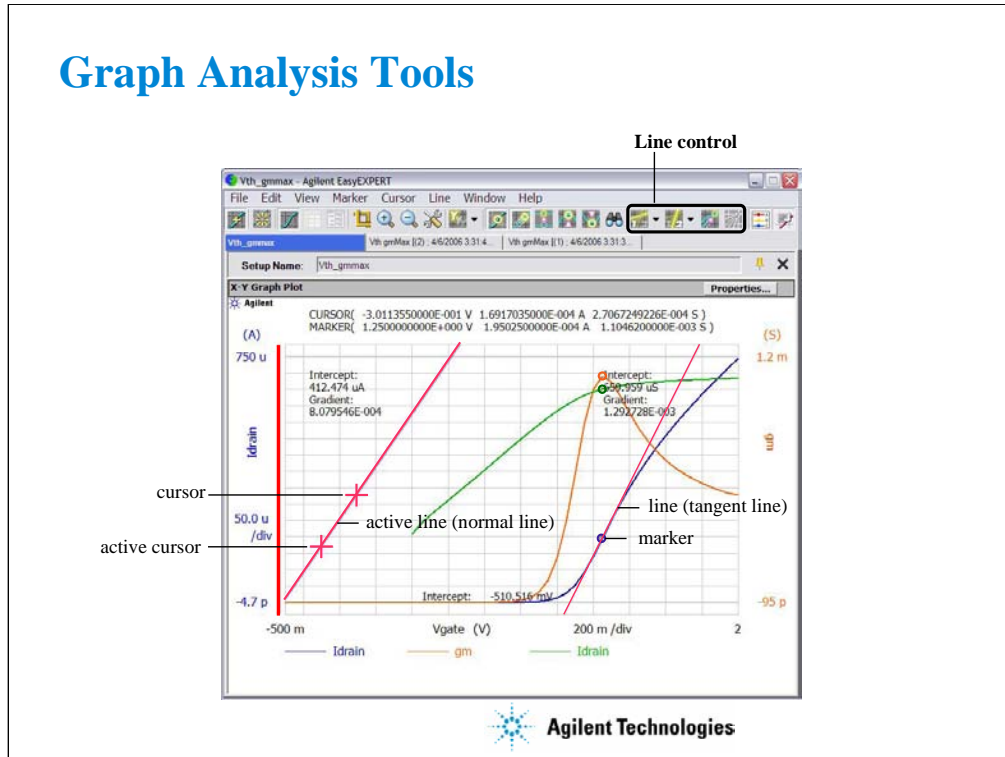
Marker Skip icon moves the marker to the next measurement curve that is added by the VAR2 variable.

Marker Maximum icon moves the marker to the maximum measurement point.

Marker Minimum icon moves the marker to the minimum measurement point.

Marker Search icon opens the Direct Marker/Cursor dialog box used to specify the coordinate values to move the marker.

Graph Analysis Tools



Line control:

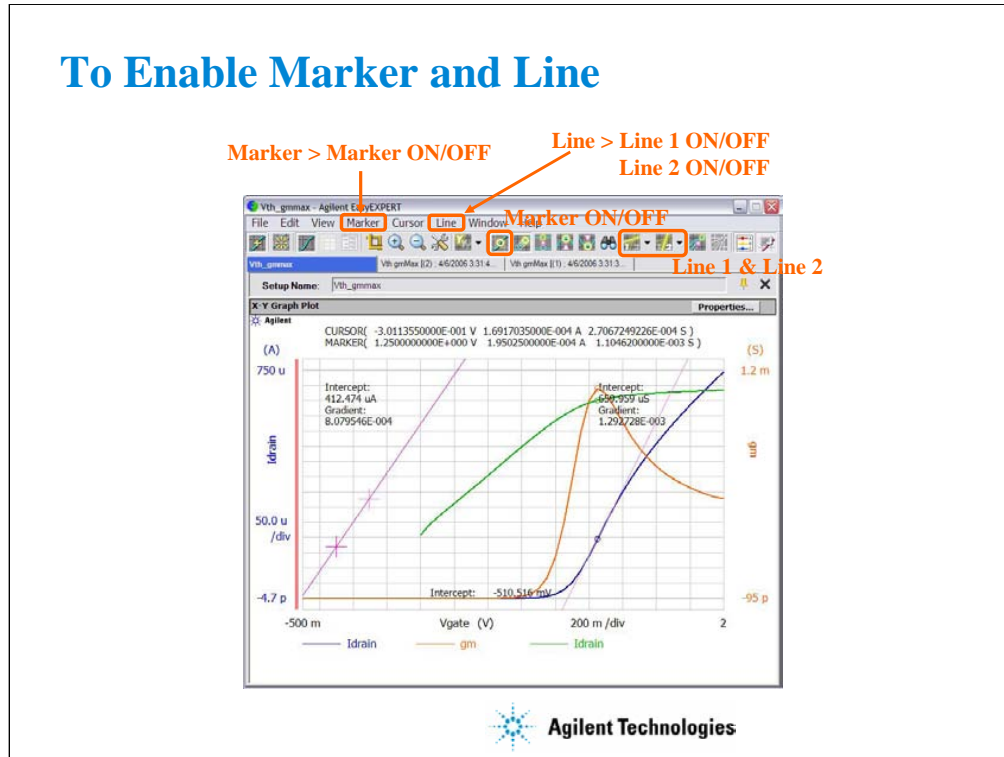
Line 1 State icon enables or disables line 1 and its function: normal, gradient, tangent, or regression.

Line 2 State icon enables or disables line 2 and its function: normal, gradient, tangent, or regression.

Cursor to Marker icon moves the cursor to the marker position.

Adjust Gradient icon is available when a gradient line is active. Clicking this icon enables the rotary knob and the mouse wheel to increase/decrease the gradient of the line. Clicking this icon again, clicking the rotary knob, or clicking the mouse wheel disables this function.

To Enable Marker and Line



To enable maker, click the Marker ON/OFF icon, or select the Marker > Marker ON/OFF menu.

To enable the Line 1, click Line 1 icon and select one of the line mode. Or select the Line > Line 1 ON/OFF menu and select one of the line mode.

To enable the Line 2, click Line 2 icon and select one of the line mode. Or select the Line > Line 2 ON/OFF menu and select one of the line mode.

If you enable the Normal line, two cursors are available. The cursors specify the points that the line passes through.

If you enable the Gradient line, a cursor is available. The cursor specifies the point that the line passes through.

If you enable the Regression line, two cursors are available. The cursor specify the measured data used to draw the regression line.

To Draw Normal Line

The screenshot shows the Agilent EasyExpert interface with a graph titled 'X-Y Graph Plot'. The graph displays several curves: a purple line labeled 'Idrain', a green curve labeled 'gm', and a blue curve labeled 'Idrain'. A normal line (orange) is drawn through two cursors (crosshair markers). Annotations with orange arrows point to the 'Line N > Normal' icon in the toolbar and the 'Cursor To Marker' icon. A separate diagram shows a blue line passing through two crosshair markers, with a box labeled '2 cursors' and an arrow pointing to the line.

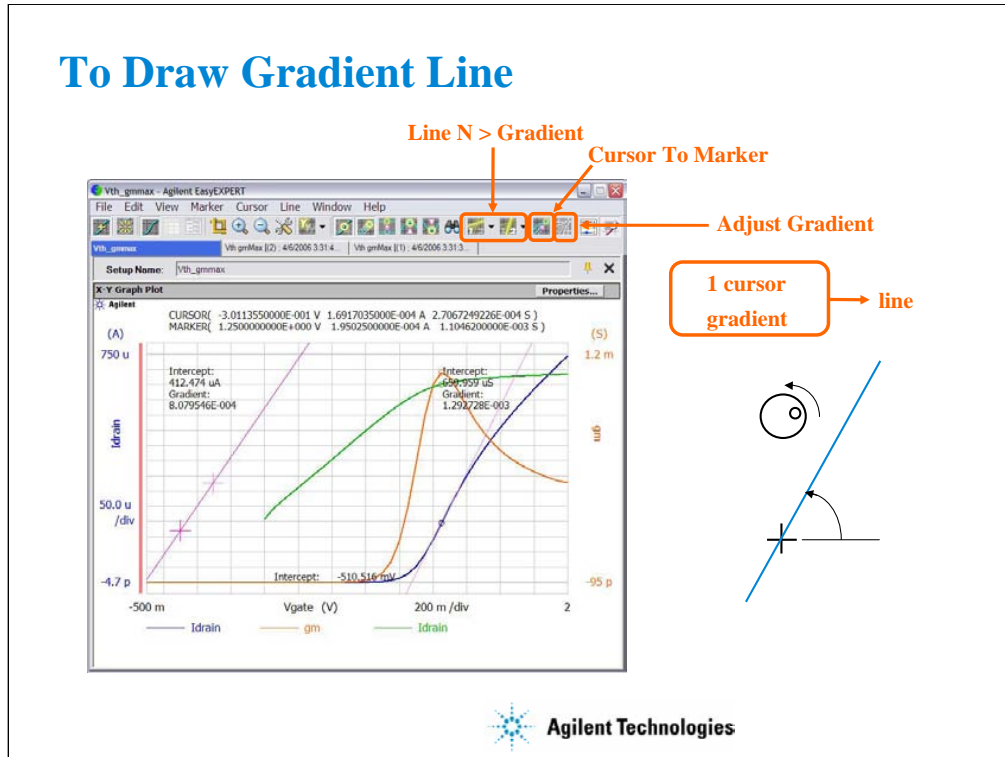
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Enable the Normal line by clicking the Line 1 (or Line 2) icon and Normal.

Move cursors to draw the line. The line passes through the cursor points.

To move the cursor, you can use the Cursor To Marker icon. The cursor will move to the marker point.

To Draw Gradient Line



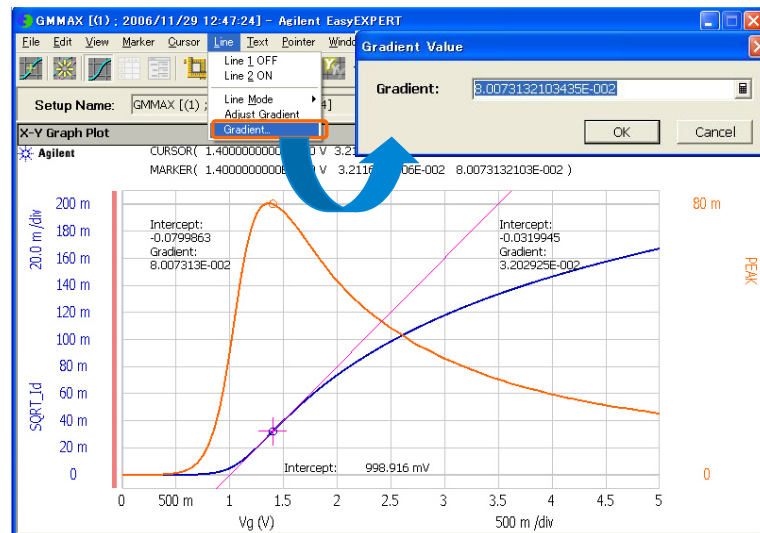
Enable the Gradient line by clicking the Line 1 (or Line 2) icon and Gradient.

Move the cursor to specify the point that the line passes through. And click the Adjust Gradient icon.

Use the rotary knob or the mouse scroll button to adjust the gradient of the line.

To move the cursor, you can use the Cursor To Marker icon. The cursor will move to the marker point.

To Set Gradient Value

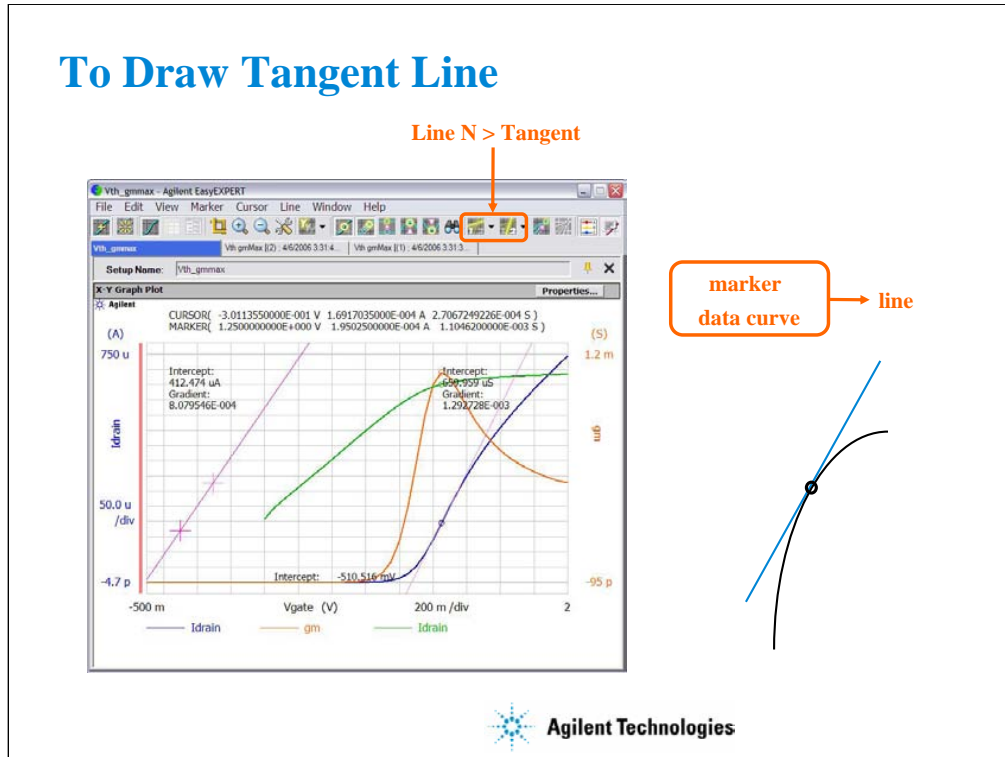


This is another way to draw the gradient line.

Set the line 1 or 2 ON and select the gradient line mode. Then click Line > Gradient... to open the Gradient Value dialog box.

On the dialog box, enter the desired gradient value, and click OK to draw the gradient line.

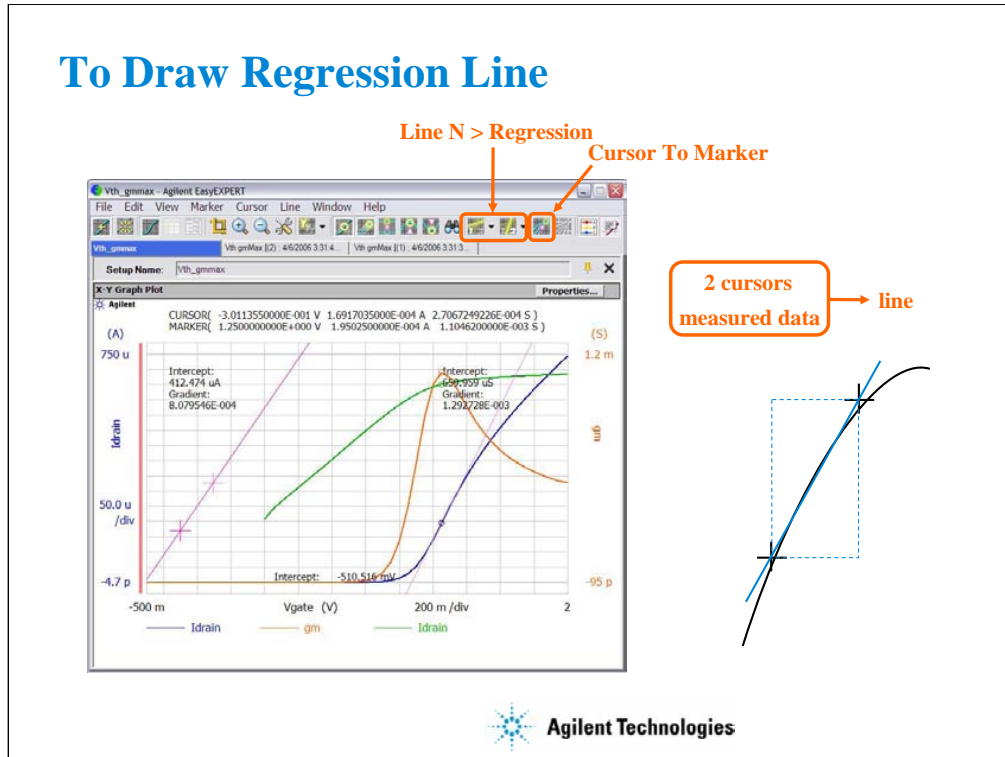
To Draw Tangent Line



Enable the Tangent line by clicking the Line 1 (or Line 2) icon and Tangent.

Move marker to draw the line. The tangent line will pass through the marker point.

To Draw Regression Line

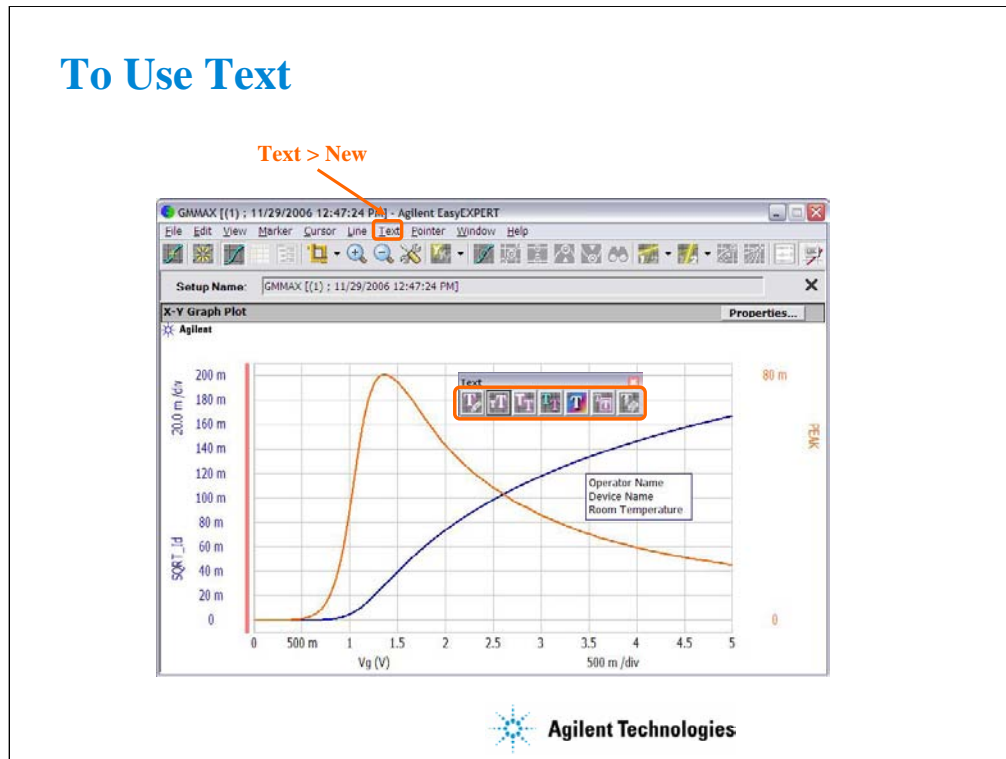


Enable the Regression line by clicking the Line 1 (or Line 2) icon and Regression.

Move cursors to specify the region of the measurement data used for the regression calculation.

To move the cursor, you can use the Cursor To Marker icon. The cursor will move to the marker point.

To Use Text



To add a text, click Text > New. A text editor appears. Then enter the text you desire.

The following functions are available for the selected text(s) via the Text menu, the Text icons, or the right-click menu.

Clicking on a text will select the text. To select the multiple texts, click the text while holding down the Shift key on the keyboard.

Edit Mode: Edits the selected text.

Size: Sets the font size of the selected text(s). The available setting values are Largest, Large, Medium, Small, Smallest, and Fixed Point (6, 7, 8, 9, 10, 11, 12, 14, 16, 18, or 20). For settings other than Fixed Point, an appropriate size will automatically be applied. For Fixed Point, the specified font size will always be applied.

Font: Sets the font of the selected text(s).

Text Color: Sets the text color of the selected text(s). Click Customize to open the color palette.

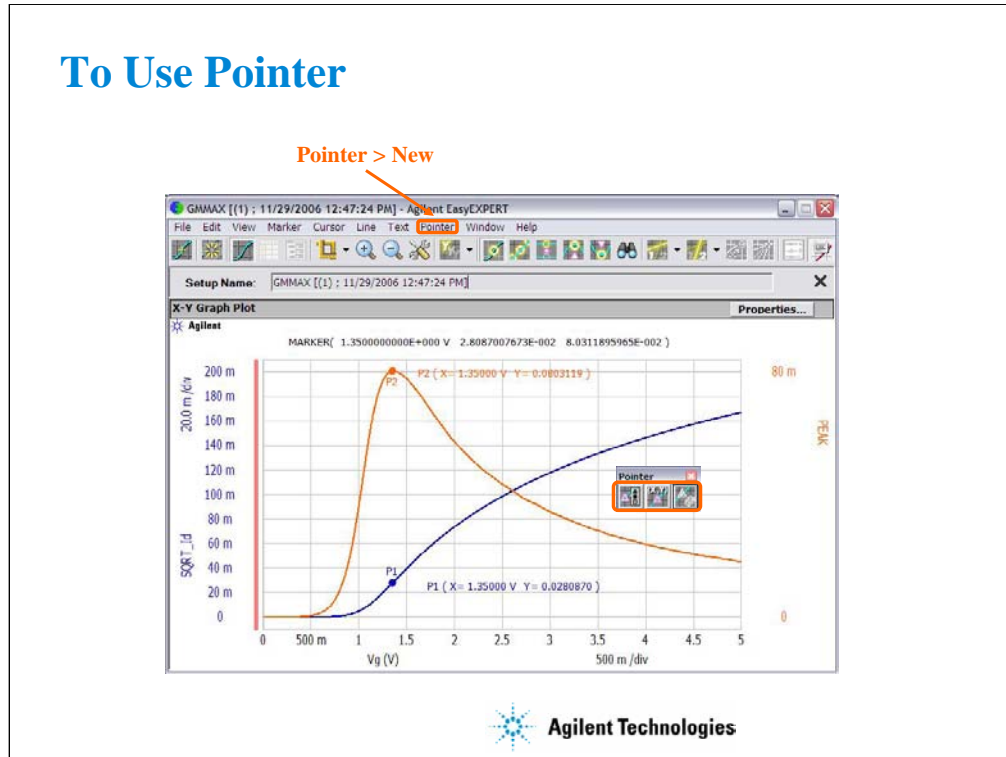
Background Color: Sets the background color of the selected text(s). Click Customize to open the color palette.

Hide Frame/Show Frame: Hides or shows the frame for the selected text(s).

Delete: Deletes the selected text(s).

Dragging a text moves this text.

To Use Pointer



To add a pointer, set Marker ON, click Pointer > New. A pointer and description (pointer ID and X-Y coordinate values) appear. Then move the pointer you desire by using the rotary knob or the mouse wheel.

The following functions are available for the selected pointer(s) or description(s) via the Pointer menu, the Pointer icons, or the right-click menu.

Clicking on a pointer will select the pointer. To select the multiple pointers, click the pointer while holding down the Shift key on the keyboard.

Clicking on a description will select the description of a pointer. To select the multiple descriptions, click the description while holding down the Shift key on the keyboard.

Shape: Sets the shape of the selected pointer(s).

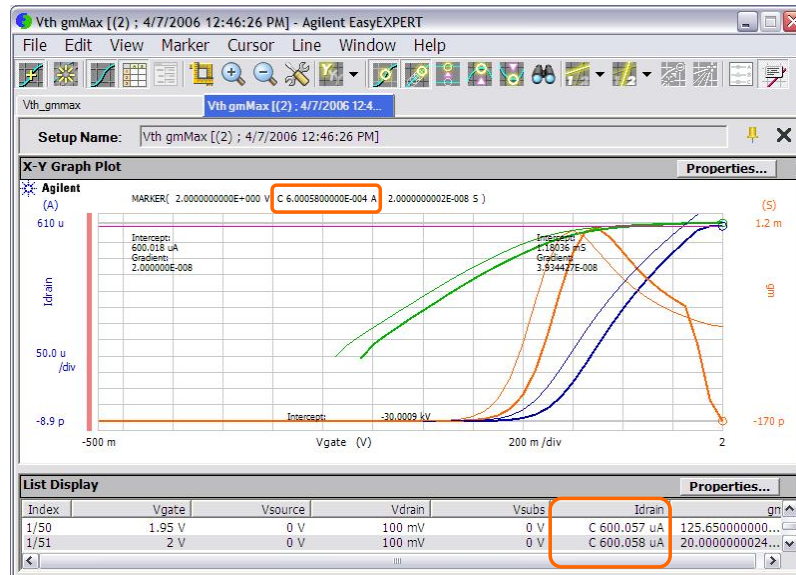
Hide Description/Show Description: Hides or shows the description of the selected pointer(s).

Delete: Deletes the selected pointer(s).

The rotary knob or the mouse wheel can be used to move the selected pointer in the VAR1 direction. The pointer can not be moved in the VAR2 direction.

Dragging a description of pointer moves this description of pointer.

Data Status



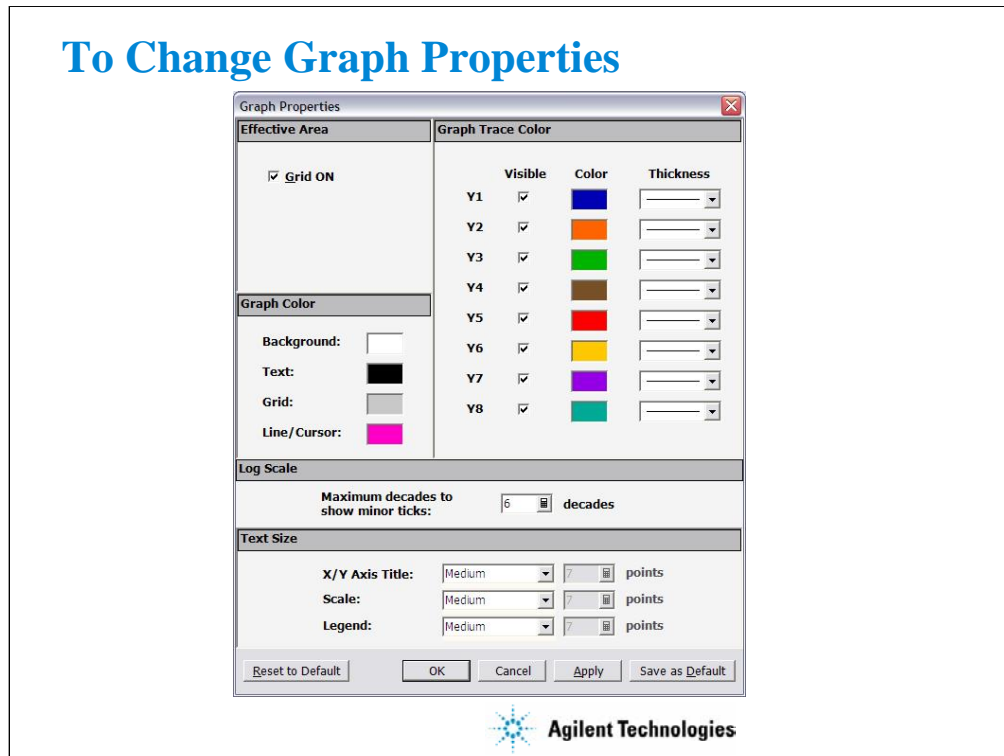
If measurement unit detects any status while measurement, the status code is recorded with the measurement data. In this example, a SMU detected the compliance condition in the drain channel, so the status code C is put just before the Idrain value.

SMU status code:

- C: Compliance
- T: Other channel compliance
- X: Oscillation
- V: Overflow

MFCMU status code:

- U: Unbalance
- D: I/V amp saturation
- V: Overflow



The Graph Properties dialog box is used to set the following setting of the selected Data Display window. This dialog box is opened by clicking the Properties... button in the X-Y Graph Plot area or by selecting the Edit > Graph Properties... menu of the Data Display window.

The Grid ON check box in the Effective Area is used to display the grid in the X-Y Graph.

The Graph Color area is used to set the color map for the Data Display window. You can change the color of the background, text, graph grid, and line/cursor. The color palette is opened by clicking the pattern of the item.

The Graph Trace Color area is used to set visibility, color, and thickness of the data traces Y1 to Y8 plotted on the graph.

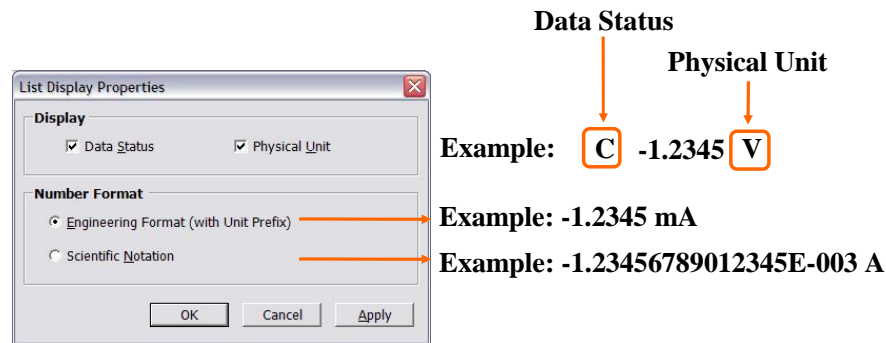
The Log Scale area is used to set the maximum number of decades to show the minor ticks for the log axis. If the number of graph decades is less than or equal to the entered value, the minor ticks are displayed. If it is greater than the entered value, the minor ticks are not displayed.

The Text Size area is used to set the font size for the graph. The available settings are Largest, Large, Medium, Small, Smallest, and Fixed. For settings other than Fixed, the appropriate size is automatically selected. For Fixed, a font size entry field is provided, and the specified font size is always applied.

- X/Y Axis Title: Font size for the axis title
- Scale: Font size for the X and Y coordinate values
- Legend: Font size for the graph legend

To Change List Display Properties

Edit > List Display Properties...



This dialog box is used to set the data display format in the List Display area. This dialog box is opened by clicking the Properties... button in the List Display area or by selecting Edit > List Display Properties... menu of the Data Display window.

Display:

Check the following check box to add the data status or the physical unit to data. Unchecking the box removes it.

- Data Status: Adds or removes the status code before data.
- Physical Unit: Adds or removes the physical unit after data.

Number Format:

Selects the data display format from the following formats.

- Engineering Format (with Unit Prefix):

Data display with arithmetic point, SI prefix, and unit.

Example: -1.2345 mA

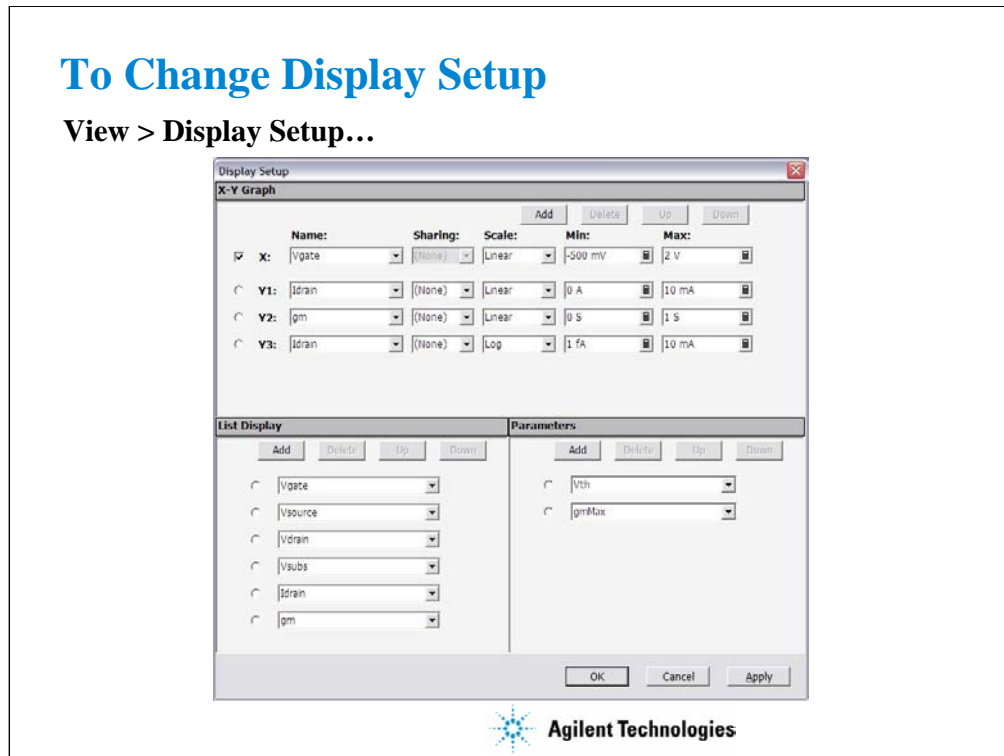
- Scientific Notation:

Data display with arithmetic point, exponential part (E, +/- sign, and three-digit number), and unit.

Example: -1.23456789012345E-003 A

To Change Display Setup

View > Display Setup...



This dialog box is used to change the graph scale and data to be displayed in the Data Display window.

The X-Y Graph area sets the X and Y1 to Y8 axes of the X-Y Graph Plot area.

Name: Specifies the parameter for the axis

- Sharing: Specifies the group for sharing the Y axis scale. Select from Group 1, Group 2, Group 3, Group 4, or None (no grouping). The Scale, Min, and Max values are shared by the Y axes in the same group. The scale set by Run Time Auto Scale, Auto Scale, Zoom in, and/or Zoom out are also shared. If another layer on the Data Display window contains an X-Y trace which has the same name for both its grouped Y parameter and its X parameter, the scaling will also be shared by this X-Y trace.

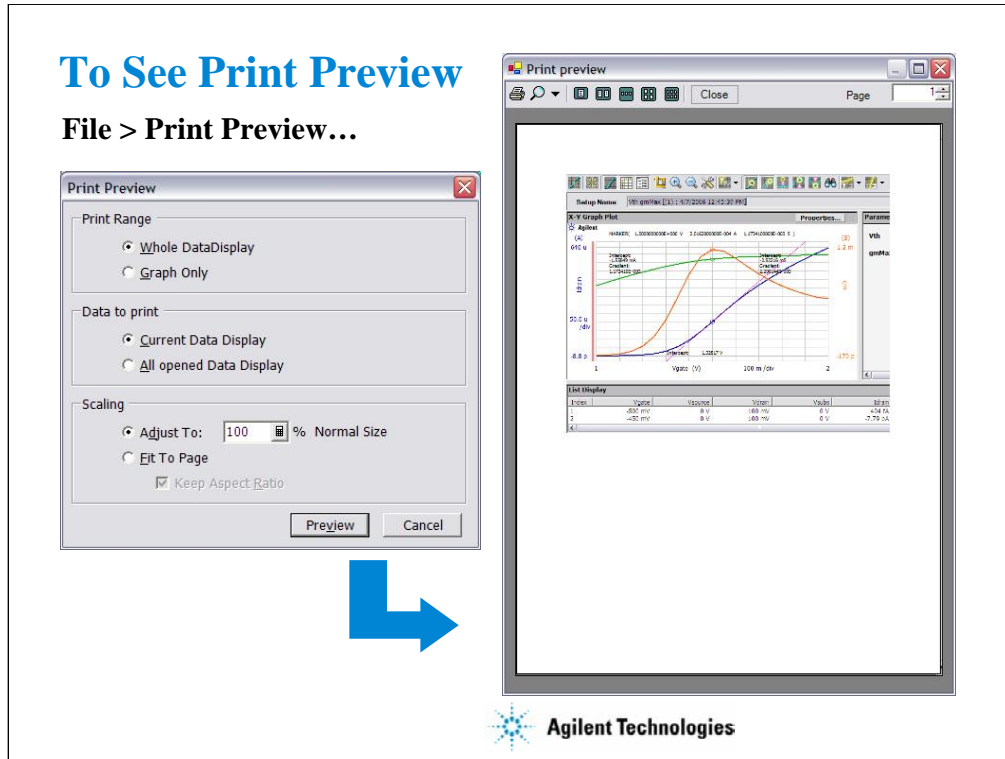
- Scale: Scale of the axis, Linear or Log

- Min: Minimum value of the axis

- Max: Maximum value of the axis

The List Display area selects the variables to be listed in the List Display area. Up to 20 variables can be set.

The Parameters area selects the variables to be listed in the Parameters area. Up to 20 parameters can be set.

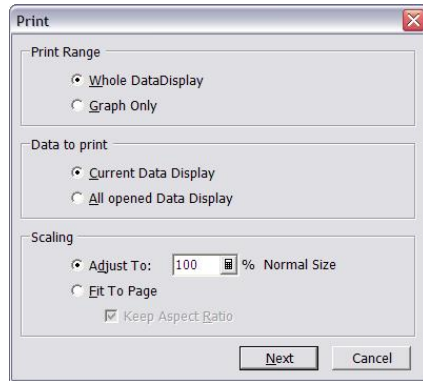


The Data Display window provides the File > Print Preview... function to show the print preview. This is an example of the print preview.

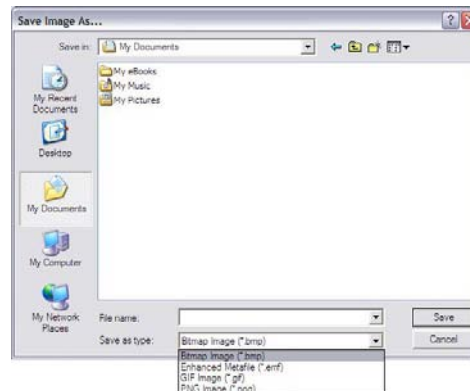
- Select the File > Print Preview menu to open the Print Preview dialog box.
- Set the Print Range, Data to print, and Scaling.
- Click Preview button. The Print preview window is displayed.

To Print Display Data

File > Print



File > Save Image As...



bmp, emf, gif, or png format



The Data Display window provides the display image output capability to a printer or a file.

Before printing, connect a printer to the B1500A via the parallel interface or the LAN, and set up it by using the Add Printer Wizard of Windows. After that, do following.

- Select the File > Print menu to open the Print dialog box.
- Set the Print Range, Data to print, and Scaling.
- Click Next button.
- Select the printer, and set the Properties.
- Click OK button.

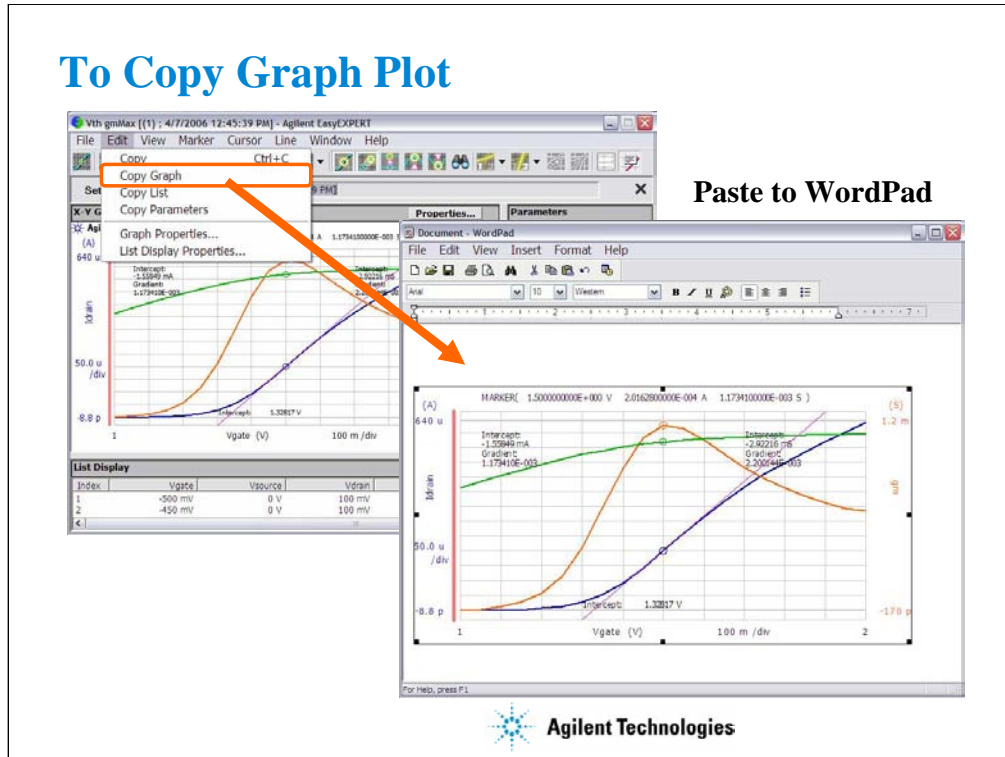
You can export the display image to a file as shown below.

- Select the File > Save Image As... menu to open the Save Image As... dialog box.
- Select the format (file type) from Save As Type menu.
- Enter the file name.
- Click Save button.

The file can be imported by the graphics software that supports the exported file type. The EasyEXPERT supports the following types.

- bmp: Bitmap image
- emf: Enhanced metafile
- gif: GIF image
- png: PNG image

To Copy Graph Plot



You can copy graph image to the clipboard, and paste it to a word processing software. In the above example, the graph image is pasted to the WordPad.

This is an example of the copy and paste operation.

- Select the Edit > Copy Graph menu on the Data Display window.
- Select the Edit > Paste menu on the WordPad.

To Copy List Data

The screenshot illustrates the process of copying data from a graph to external applications. It shows three windows: the main data display window with the 'Copy List' menu option highlighted, a Notepad window containing the copied data, and a Microsoft Excel spreadsheet view of the same data. Arrows indicate the flow of data from the graph to Notepad and then to Excel.

Paste to Notepad

Open by a spreadsheet software

Index	vgate	vsource	vdrain	vsubs	idrain	gm
1	-500 mv	0 v	100 mv	0 v	404 fA	-163.88 pS
2	-450 mv	0 v	100 mv	0 v	-7.79 pA	-81.58 pS
3	-400 mv	0 v	100 mv	0 v	-7.74 pA	2.7599999999999999 pS
4	-350 mv	0 v	100 mv	0 v	-7.51 pA	-860.00000000000007 fS
5	-300 mv	0 v	100 mv	0 v	-7.82 pA	-3.0699999999999998 pS
6	-250 mv	0 v	100 mv	0 v	-7.824 pA	-810.0000000000002 fS
7	-200 mv	0 v	100 mv	0 v	-7.901 pA	-850.0000000000006 fS
8	-150 mv	0 v	100 mv	0 v	-8.299 pA	-1.7399999999999998 pS
9	-100 mv	0 v	100 mv	0 v	-8.075 pA	2.5 pS
10	-50 mv	0 v	100 mv	0 v	-7.657 pA	32.02 pS
11	0 v	0 v	100 mv	0 v	-4.873 pA	-6.280000000000001 pS
12	50 mv	0 v	100 mv	0 v	-8.295 pA	-34.72 pS
13	100 mv	0 v	100 mv	0 v	-8.345 pA	3.030000000000001 pS
14	150 mv	0 v	100 mv	0 v	-7.992 pA	-2.43 pS

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You can copy the data list to the clipboard, and paste it to a word processing software. In the above example, the data list is pasted to the Notepad.

This is an example of the copy and paste operation.

- Select the Edit > Copy List menu on the Data Display window.
- Select the Edit > Paste menu on the Notepad.

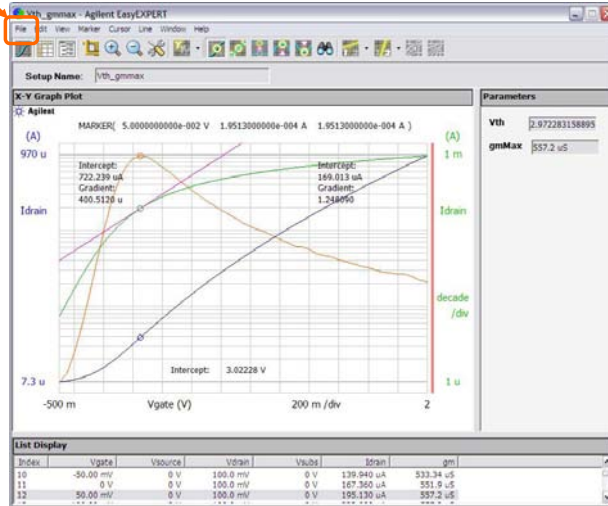
You can save the data as a text file, and read it by using a spreadsheet software. Data elements are separated by a tab.

Note:

As same as the Copy List function, the Copy Parameter function is used to copy the data in the Parameter area.

To Save Analysis Result

- Select File > Update Test Result → Saves graph information to data record.
- Select File > Save Image As... → Saves graph image as a file.



To leave the graph modification information such as scaling, marker, cursor, and line on the graph, select the File > Update Test Result menu.

You can see the all information when you open the graph again. Note that the modification information will be destroyed if you did not do it.

To save the graph image as a file, select the File > Save Image As... menu.

You can save the image as a bmp, emf, gif, or png file.

Class Exercise

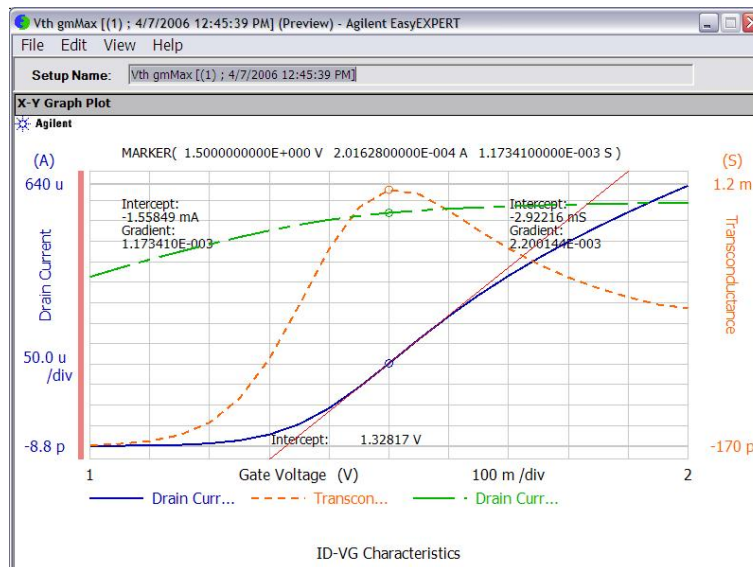
Use the analysis tools.

1. Use your test setup (for example, GMMAX in the Demo preset group) and perform measurement .
2. Enable marker and draw line. Try it for all line types.
3. Copy/paste/save data list, and open it by using a spreadsheet software (optional, if you can).
4. Save analysis condition. Re-open the test record.
5. Export your test record. And import it.



Note:

To Use Preview Window



This example is result of the changes shown in the previous page.
Line style was changed as shown above. The titles are set as follows.
Graph title: ID-VG Characteristics
X axis title: Gate Voltage
Y1 axis title: Drain Current
Y2 axis title: Transconductance
Y3 axis title: Drain Current
Also color of line1 was changed to red, and thickness of trace was changed.

To change the setup again, open the Preview Settings dialog box by selecting the View > Preview Settings... menu.

Class Exercise

Use the Preview window.

1. **Use your test record used in the previous exercise.**
2. **Change the graph image as you want.**
 - Add graph title and change axis title.
 - Change line style
 - Change color and thickness
3. **Print the graph image if a printer is available.**



Note:





4

Classic Test Environment



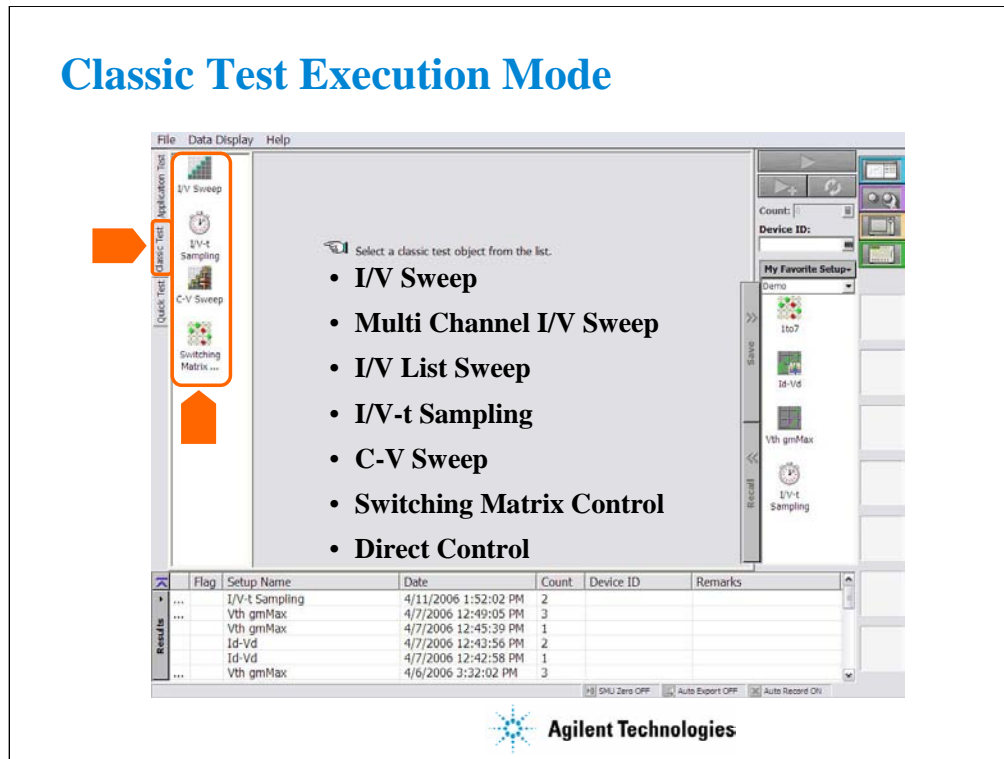
In This Module

- **Classic Test Execution Mode**
- **I/V Sweep Measurement**
- **Multi Channel I/V Sweep Measurement**
- **I/V List Sweep Measurement**
- **I/V-t Sampling Measurement**
- **C-V Sweep Measurement**
- **Switching Matrix Control**
- **Direct Control**



Note:

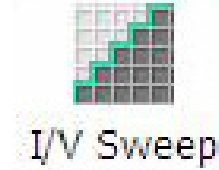
Classic Test Execution Mode



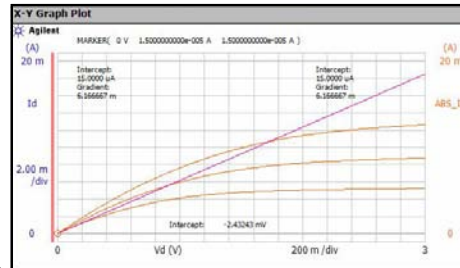
To use the classic test mode, click the Classic Test tab. And select the execution mode. The following modes are available.

- I/V Sweep: For X-Y characteristics measurement of I or V.
- Multi Channel I/V Sweep: For simultaneous multi channel (up to 10) sweep measurement of I or V.
- I/V List Sweep: For multi channel (up to 10) I/V sweep measurement using list data.
- I/V-t Sampling: For time-Y characteristics measurement of I or V.
- C-V Sweep: For DC bias-impedance characteristics measurement.
- Switching Matrix Control: For B2200 switching matrix control.
- Direct Control: For various measurements (e.g. C-f measurement, Quasi-Static C-V measurement) using Agilent FLEX commands.

I/V Sweep Measurement



- To Define Source/Measurement Channels
- To Read Time Stamp Data and Data Index
- To Set Source Outputs (VAR1, VAR2, VAR1', Pulse, CONST)
- To Set Timing Parameters
- To Set Sweep Abort Function
- Range, ADC/Integ, Advanced
- To Set User Functions
- To Set Analysis Functions
- To Set Auto Analysis Function
- To Set Display Parameters (X-Y Graph, Data List, Parameter)



This section explains how to perform I/V sweep measurement. You will perform the above tasks to execute the I/V sweep measurement.

To Define Source/Measurement Channels

I/V Sweep

Channel Setup

Setup Name

Channel Definition

- SMU
- V name/I name
- I/V/IPULSE/VPULSE/Common
- VAR1/VAR2/VAR1'/CONST

Unit	V Name	I Name	Mode	Function
SMU1:HP	Vg	Id	VPULSE	VAR1
SMU2:HR	Vg	Id	V	VAR2
SMU3:HR	Vs	Is	V	CONST
SMU4:HR	Vsub	Isub	V	VAR1'

Miscellaneous Variables

Time Stamp Name: Time Index Name: Index

Flag	Setup Name	Date	Count	Device ID	Remarks
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:29 PM	2		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:03:17 PM	2		
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:03 PM	1		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:02:51 PM	1		
<input type="checkbox"/>	Trng vth2	8/15/2005 3:01:14 PM	1		

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Click the I/V Sweep icon and open the setup editor. Then click the Channel Definition tab to display the channel definition screen.

- Enter the Setup Name for the test setup to be defined on the setup editor.
- List SMUs used for source output or measurement, and set the following parameters.
 - Unit: SMU name or number
 - V Name: Variable name for the voltage measurement or source data
 - I Name: Variable name for the current measurement or source data
 - Mode: Source output mode, V (voltage), I (current), VPULSE (voltage pulse), IPULSE (current pulse), or COMMON (ground)
 - Function: Source output function, VAR1 (primary sweep), VAR2 (secondary sweep), VAR1' (synchronous sweep), CONST (constant)

V Name and I Name are used to specify the parameters displayed on the Data Display window. The display parameters are selected on the Display Setup tab screen.

To Read Time Stamp Data and Index

Channel Setup

The screenshot shows the 'Channel Setup' window for a 'Trng Id-Vd' setup. The 'Channel Definition' table is as follows:

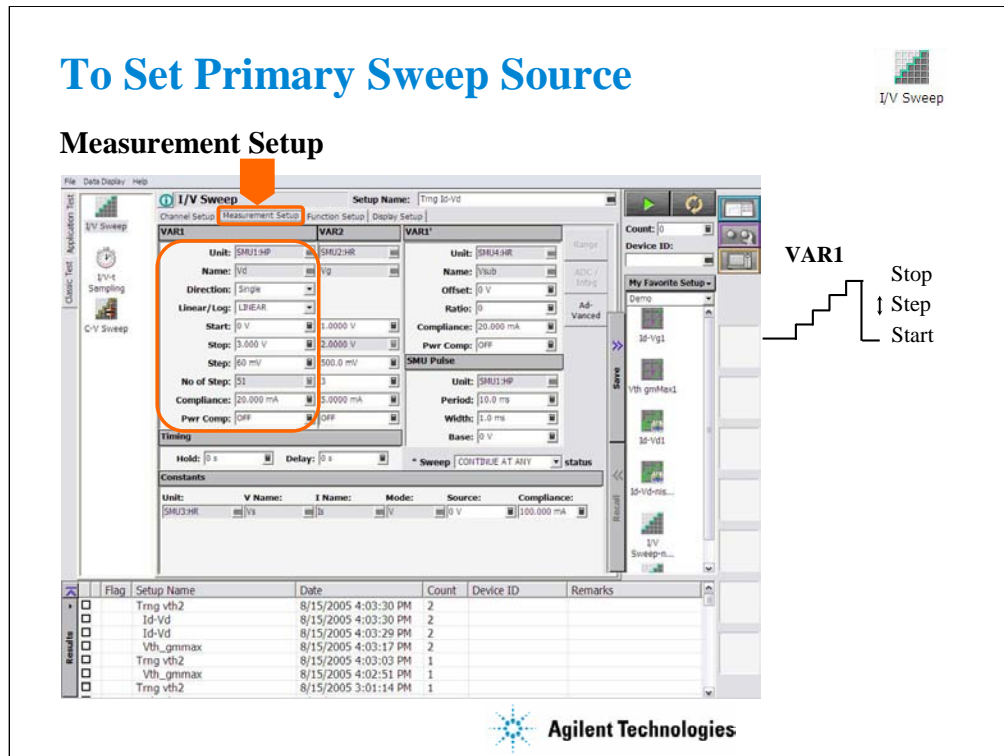
Unit	V Name	I Name	Mode	Function
SRU1:HP	Vg	Id	VPULSE	VARI
SRU2:HR	Vg	Id	V	VARI2
SRU3:HR	Vs	Is	V	CONST
SRU4:HR	Vsub	Isub	V	VARI1

In the 'Miscellaneous Variables' section, the 'Time Stamp Name' is 'Time' and the 'Index Name' is 'Index'. The 'Results' table at the bottom contains the following data:

Flag	Setup Name	Date	Count	Device ID	Remarks
	Trng vth2	8/15/2005 4:03:30 PM	2		
	Id-Vd	8/15/2005 4:03:30 PM	2		
	Id-Vd	8/15/2005 4:03:29 PM	2		
	Vth_gmmax	8/15/2005 4:03:17 PM	2		
	Trng vth2	8/15/2005 4:03:03 PM	1		
	Vth_gmmax	8/15/2005 4:02:51 PM	1		
	Trng vth2	8/15/2005 3:01:14 PM	1		

You can read measurement data by using the Data Display window. Parameters displayed on the window are selected on the Display Setup tab screen. If you enter the variable name in the V Name, I Name, Time Stamp Name, and/or Index Name entry fields, you can choose the variables as the display parameters.

- The time stamp is the time the measurement is started for each measurement point.
- The index is the index number for each measurement data.



The Measurement Setup tab screen is used to set the source output value and timing parameters.

At the VAR1 area, you set the primary sweep source output.

- Unit: SMU name or number
- Name: Variable name of source output
- Direction: Single (start to stop) or Double (start to stop to start)
- Linear/Log: Linear sweep or Log sweep
- Start: Source output start value
- Stop: Source output stop value
- Step: Source output incremental step value
- No of Step: Number of sweep steps
- Compliance: SMU compliance value
- Pwr Comp: SMU power compliance value

To Set Secondary Sweep Source

Measurement Setup

The screenshot shows the 'I/V Sweep' Measurement Setup window. The 'Measurement Setup' tab is selected, and an orange box highlights the configuration fields for VAR2. The fields include Unit (SMU2:HR), Name (V2), Direction (Single), Linear/Log (LINEAR), Start (0 V), Stop (2.0000 V), Step (50 mV), No of Step (3), Compliance (20.000 mA), and Pwr Comp (OFF). To the right, two waveforms are displayed: VAR1 is a staircase waveform, and VAR2 is a single step function. The Agilent Technologies logo is at the bottom center.

Flag	Setup Name	Date	Count	Device ID	Remarks
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:29 PM	2		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:03:17 PM	2		
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:03 PM	1		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:02:51 PM	1		
<input type="checkbox"/>	Trng vth2	8/15/2005 3:01:14 PM	1		

At the VAR2 area, you set the secondary sweep source output.

- Unit: SMU name or number
- Name: Variable name of source output
- Start: Source output start value
- Stop: Source output stop value
- Step: Source output incremental step value
- No of Step: Number of sweep steps
- Compliance: SMU compliance value
- Pwr Comp: SMU power compliance value

To Set Synchronous Sweep Source

I/V Sweep

Measurement Setup

Flag	Setup Name	Date	Count	Device ID	Remarks
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:29 PM	2		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:03:17 PM	2		
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:03 PM	1		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:02:51 PM	1		
<input type="checkbox"/>	Trng vth2	8/15/2005 3:01:14 PM	1		

At the VAR1' area, you set the synchronous sweep source output.

- Unit: SMU name or number
- Name: Variable name of source output
- Offset: B value of the above formula.
- Ratio: A value of the above formula.
- Compliance: SMU compliance value
- Pwr Comp: SMU power compliance value

The VAR1' output is expressed by the following formula.

$$\text{VAR1' output} = A \times (\text{VAR1 output}) + B$$

To Set Pulse Output

Measurement Setup

The screenshot shows the 'I/V Sweep' Measurement Setup window. The 'SMU Pulse' section is highlighted with a red box, showing the following parameters:

- Unit: SMU1:HP
- Period: 10.0 ms
- Width: 1.0 ms
- Base: 0 V

To the right of the screenshot, a pulse waveform diagram is shown with the following labels:

- Trigger: A blue arrow pointing to the start of the pulse.
- Width: Two horizontal double-headed arrows indicating the pulse width.
- Period: A horizontal double-headed arrow indicating the time between the start of two pulses.
- Hold time: A horizontal double-headed arrow indicating the time between the end of one pulse and the start of the next.
- Base: A horizontal line at the bottom of the pulse, representing the pulse base value.

Below the diagram, a note states: "Delay time cannot be set."

At the bottom of the screenshot, the Agilent Technologies logo is visible.

At the SMU Pulse area, you set the SMU pulse timing parameter and the pulse base value.

- Unit: SMU name or number
- Period: Pulse period
- Width: Pulse width
- Base: Pulse base value

Only a SMU can be set to the pulse source.

To Set Constant Output

Measurement Setup

The screenshot shows the 'I/V Sweep' Measurement Setup dialog box. The 'Constants' section is highlighted with an orange box. The fields in this section are:

Unit:	V Name:	I Name:	Mode:	Source:	Compliance:
SMU3:HR	v1a	i1a	V	0 V	100.000 mA

Other visible settings include:

- Channel Setup:** VAR1, VAR2, VAR3
- Timing:** Hold: 0 s, Delay: 0 s
- SMU Pulse:** Unit: SMU1:HP, Period: 10.0 ms, Width: 1.0 ms, Base: 0 V

Icons on the right side of the interface include I/V Sweep, I/V-t Sampling, and C-V Sweep.

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At the Constants area, you set the SMU constant output.

- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Mode: Source output mode, V (voltage), I (current), VPULSE (voltage pulse), IPULSE (current pulse), or COMMON (ground)
- Source: SMU output value
- Compliance: SMU compliance value

To Set Timing Parameters

Measurement Setup

The screenshot shows the 'I/V Sweep' Measurement Setup window. The 'Timing' section is highlighted with a red box, showing 'Hold: 0 s' and 'Delay: 0 s'. To the right, a timing diagram shows a pulse with a blue hold period, a red delay period, and a blue measurement period. Labels 'Trigger', 'Measurement time', 'Delay time', and 'Hold time' point to these respective parts of the waveform.

Flag	Setup Name	Date	Count	Device ID	Remarks
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:29 PM	2		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:03:17 PM	2		
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:03 PM	1		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:02:51 PM	1		
<input type="checkbox"/>	Trng vth2	8/15/2005 3:01:14 PM	1		

At the Timing area, you set the source output and measurement timing.

- Hold: Source output hold time. Time after the measurement trigger until starting delay time.
- Delay: Measurement start delay time. Time after the hold time until starting measurement.

When a SMU forces pulse, the delay time is ignored. Source output and measurement timing will be controlled by the pulse width and pulse period.

To Set Sweep Abort Function

Measurement Setup

I/V Sweep

C-V Sweep

CONTINUE AT ANY
STOP AT ANY ABNORMAL
-Range overflow
-SMU compliance
-SMU oscillation

Flag	Setup Name	Date	Count	Device ID	Remarks
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:30 PM	2		
<input type="checkbox"/>	Id-Vd	8/15/2005 4:03:29 PM	2		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:03:17 PM	2		
<input type="checkbox"/>	Trng vth2	8/15/2005 4:03:03 PM	1		
<input type="checkbox"/>	Vth_gmmax	8/15/2005 4:02:51 PM	1		
<input type="checkbox"/>	Trng vth2	8/15/2005 3:01:14 PM	1		

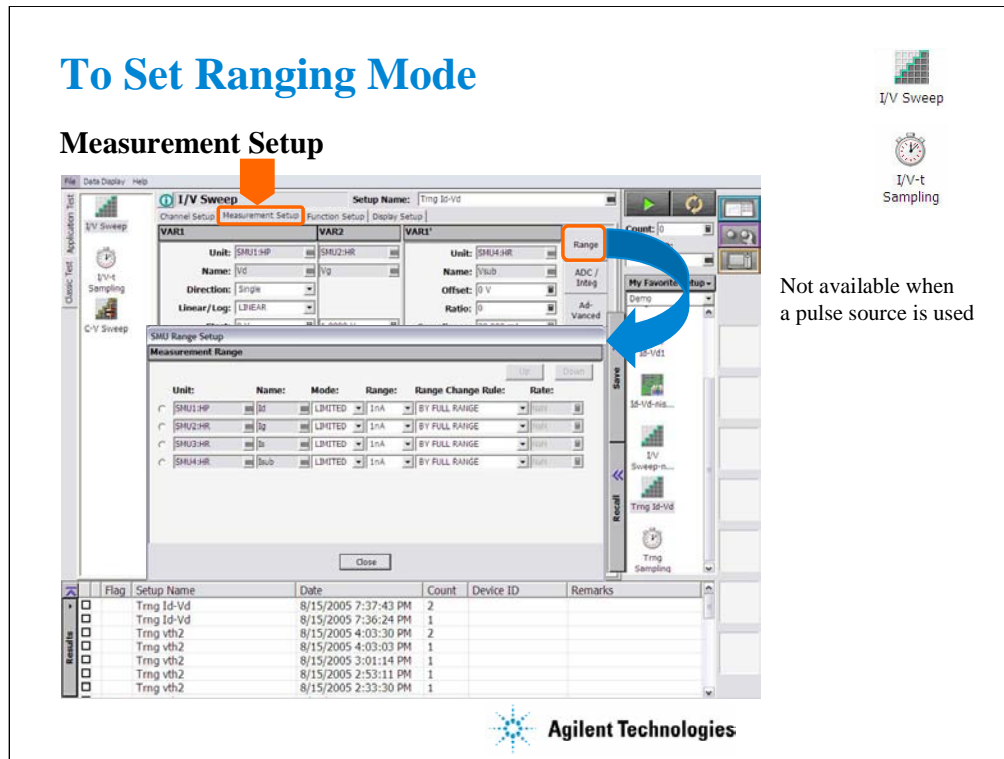
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This field sets the sweep abort function.

When this field is CONTINUE AT ANY, the sweep measurement is not aborted.

When this field is STOP AT ANY ABNORMAL, the sweep measurement will be aborted when one of the following conditions is detected.

- Measurement range overflow
- SMU compliance
- SMU oscillation



The Range button opens the SMU Range Setup dialog box. The dialog box is used to set the measurement ranging mode. This button is not available when a pulse source is used.

- Unit: SMU name or number
- Name: Variable name for the measurement data
- Mode: Ranging mode, AUTO, LIMITED, or FIXED
- Range: Range value
- Range Change Rule: BY FULL RANGE, GO UP AHEAD, or UP AND DOWN AHEAD
- Rate: Value used for range changing. See the following formula.

For the AUTO or LIMITED, SMU automatically selects the minimum range that covers the measurement value, and performs the measurement by using the range. For the limited auto ranging, the instrument does not use the range lower than the specified range value. For example, if you select the 100 nA limited auto ranging, the instrument never uses the 10 nA range and below.

BY FULL RANGE performs normal auto ranging operation.

For the GO UP AHEAD and UP AND DOWN AHEAD rules, specify the *Rate* value, 11 to 100, which fixes the boundary of the ranging. The ranging occurs when the measurement data goes across the *boundary* values shown below.

$$\text{go up boundary} = \text{present measurement range} \times \text{Rate} / 100$$

$$\text{go down boundary} = \text{present measurement range} \times \text{Rate} / 1000$$

The *go down boundary* is available only for the UP AND DOWN AHEAD rule.

To Set ADC/Integration Time

Measurement Setup

The screenshot shows the 'I/V Sweep' Measurement Setup dialog box. The 'ADC/Integ' button is highlighted with a blue arrow. A text box to the right of the dialog box states 'Not available when a pulse source is used'. The dialog box contains the following sections:

- Channel Setup:** VAR1, VAR2, VAR3. Each channel has fields for Unit, Name, Direction, Linear/Log, Start, Stop, and Step.
- A/D Converter & Integration Time Setup:**
 - A/D Converter:** A table with columns for Unit, Name, and ADC. The ADC column has dropdown menus for HR ADC and HS ADC.
 - Integration Time:** Fields for Mode (AUTO, MANUAL, PLC), Factor, and Auto Zero (ON/OFF).

At the bottom of the dialog box, there is a table with columns for Flag, Setup Name, Date, Time, and Count.

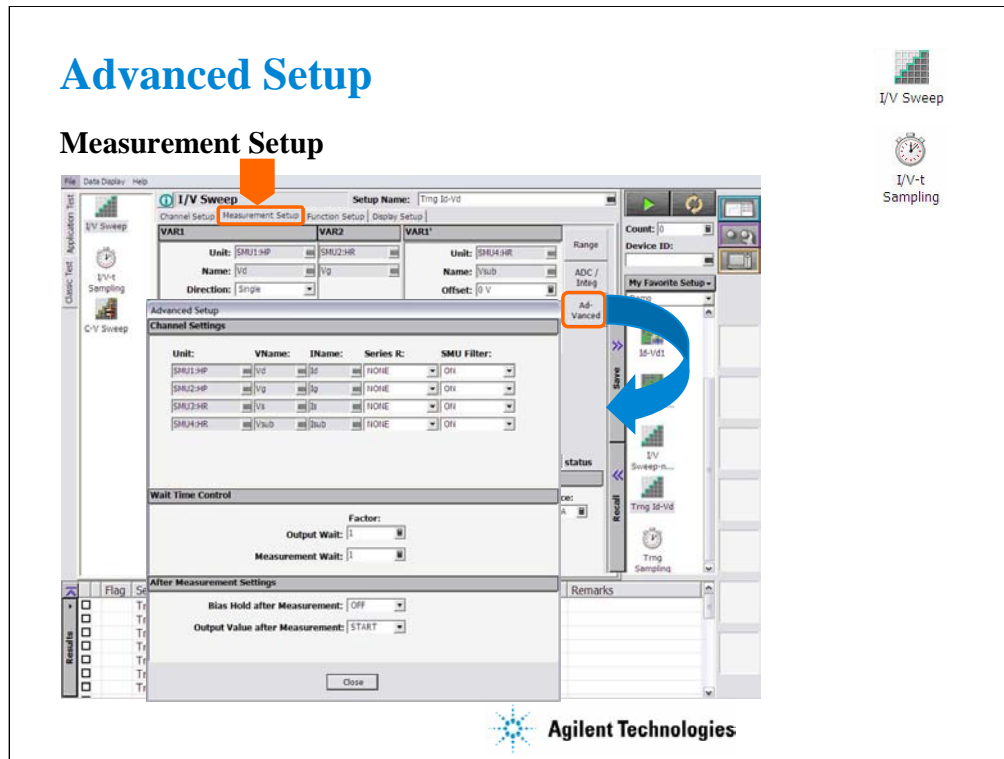
The ADC/Integ button opens the A/D Converter & Integration Time Setup dialog box. The dialog box is used to select the ADC for each SMU and set the integration time for each ADC (high resolution or high speed). This button is not available when a pulse source is used.

A/D Converter:

- Unit: SMU name or number
- Name: Variable name of the measurement data
- ADC: ADC type, HR ADC (high resolution) or HS ADC (high speed)

Integration Time:

- Mode: AUTO, MANUAL, or PLC. Rule to decide the integration time. For details, see online help or User's Guide.
- Factor: Coefficient for the reference value of the integration time.
- Auto Zero: Auto Zero function ON or OFF. For HR ADC.



The Advanced button opens the Advanced Setup dialog box. The dialog box is used to set the SMU filter and SMU series resistor settings, and set the wait time.

Channel Settings:

- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Series R: SMU series resistor NONE or 1MOHM (1000000 ohm)
- SMU Filter: SMU filter ON or OFF

Wait Time Control:

- Factor: Coefficient for the reference value of the wait time. For details, see online help or User's Guide.

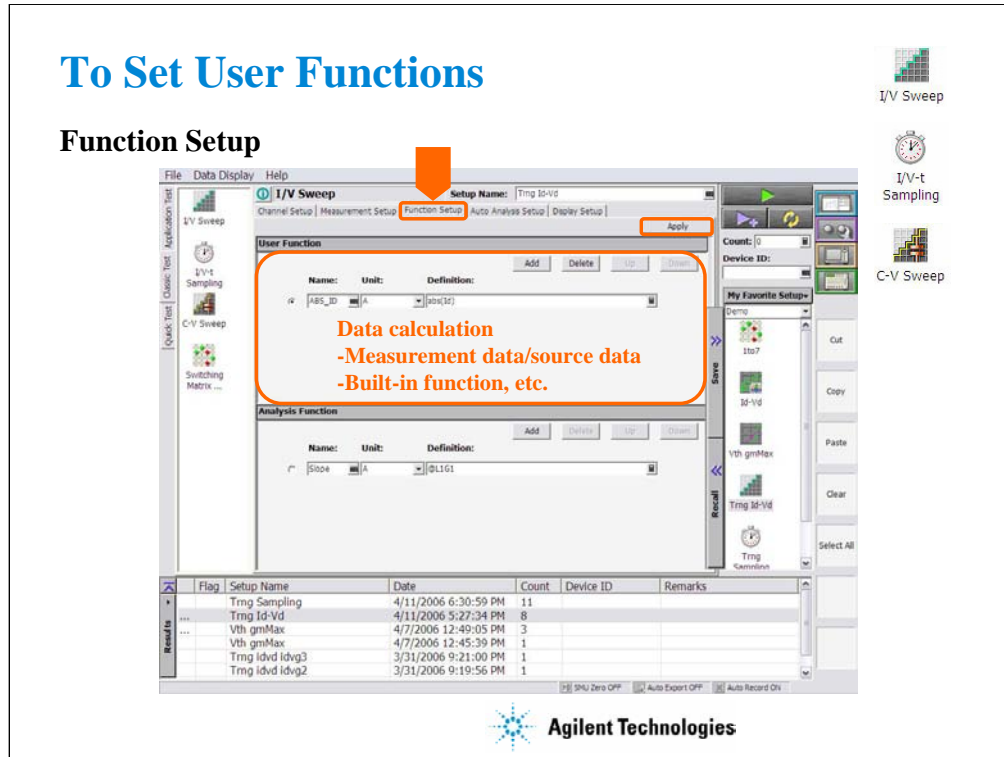
After Measurement Settings:

- Bias Hold after Measurement: Bias hold function ON or OFF.
- Output Value after Measurement: Source output value after measurement. START (sweep start value), STOP (sweep stop value), SOURCE (sampling output source value), or BASE (sampling output base value)

Note: Pulse channel output after measurement is always Base value.

To Set User Functions

Function Setup



Click the Function Setup tab to display the User Function/Analysis Function setup screen. The user functions can be displayed on the X-Y Graph Plot, List Display, and Parameters area of the Data Display window. Up to 20 functions can be set.

Name: Function name

Unit: Unit of the function

Definition: Definition of the function. The following identifiers can be used.

- Variables for the measurement/output data used in this test
- Functions defined in the above lines
- Local variables passed from the application test that calls this test as a component
- Built-in functions and global variables

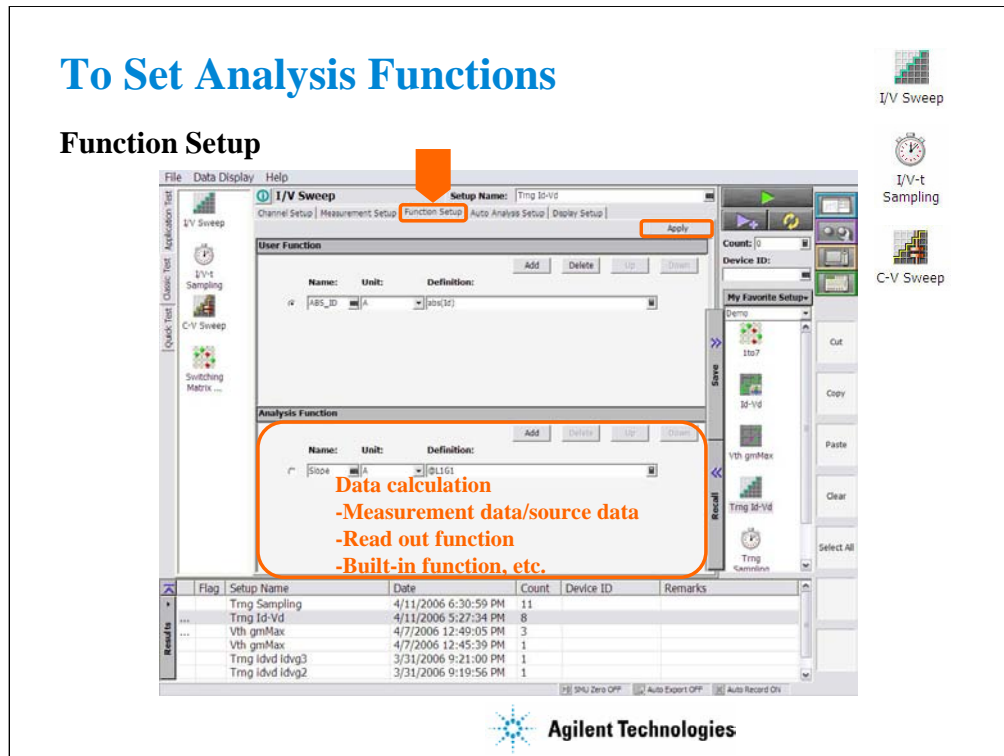
For details, see online help or User's Guide.

Note:

The Apply button performs calculation of the definition in this screen. If this button is clicked when the Data Display window associated with this test has been opened, the display is also updated. The associated Data Display window will be the Data Display window that displays the last measurement data or that is recalled at last.

To Set Analysis Functions

Function Setup



The analysis functions can be displayed on the Parameters area of the Data Display window. Up to 20 functions can be set.

Name: Function name

Unit: Unit of the function

Definition: Definition of the function. The following identifiers can be used.

- Variables for the measurement/output data used in this test
- Functions defined in the above lines
- Local variables passed from the application test that calls this test as a component
- Built-in functions and global variables
- Read out functions

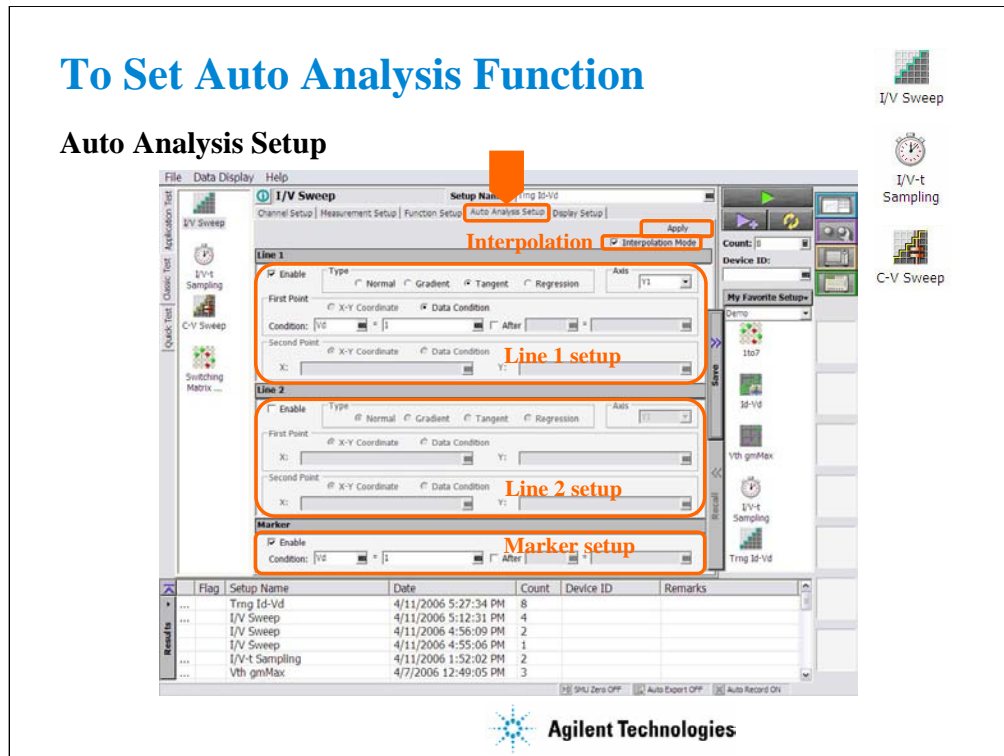
For details, see online help or User's Guide.

Note:

The Apply button performs calculation of the definition in this screen. If this button is clicked when the Data Display window associated with this test has been opened, the display is also updated. The associated Data Display window will be the Data Display window that displays the last measurement data or that is recalled at last.

To Set Auto Analysis Function

Auto Analysis Setup



Click the Auto Analysis Setup tab to display the auto analysis setup screen. The auto analysis capability allows you to display/move the marker/line on the data graph automatically after measurement. The above example displays marker at $V_d=1$ V point and draw a tangent line for this point.

Interpolation Mode: Check this box to enable the interpolation mode. You can position marker between measurement points.

Line 1, Line 2: This area sets the line 1 or line 2 automatically displayed and moved to the specified position after the measurement. Check Enable box to enable the line.

For Type, select a line type, Normal, Gradient, Tangent, or Regression.

For Axis, select the axis effective for the line.

In First Point and Second Point, specify the cursor points used to draw line.

In Gradient, specify the slope of the Gradient line.

Marker: This area sets the marker automatically displayed and moved to the specified position after the measurement. Check Enable box to enable the marker.

For Condition, enter a variable name and a condition expression to specify where you want the marker to display.

For After, check this box to enable the additional condition. And enter a second variable and condition expression. This sets up a search start condition for finding specified point.

For example, you can specify the following expressions to search for a measurement point that satisfies the first condition after the second condition is satisfied.

Condition: $[DGM] = [MAX(DGM)*0.01]$ [x] After $[DGM] = [MAX(DGM)]$

Note:

The Apply button performs calculation of the definition in this screen. If this button is clicked when the Data Display window associated with this test has been opened, the display is also updated. The associated Data Display window will be the Data Display window that displays the last measurement data or that is recalled at last.

To Set X-Y Graph Display

Display Setup

The screenshot shows the 'I/V Sweep' window in the Agilent Classic Test Environment. The 'Display Setup' tab is active, and the 'X-Y Graph' section is highlighted with an orange box. The text 'Specify X axis and Y axis' is displayed in the center of this section. The window includes a menu bar (File, Data Display, Help), a toolbar, and a data table at the bottom. The data table has columns for Flag, Setup Name, Date, Count, Device ID, and Remarks.

Flag	Setup Name	Date	Count	Device ID	Remarks
...	Trng Id-Vd	4/11/2006 5:27:34 PM	8		
...	I/V Sweep	4/11/2006 5:12:31 PM	4		
...	I/V Sweep	4/11/2006 4:56:09 PM	2		
...	I/V Sweep	4/11/2006 4:55:06 PM	1		
...	I/V-t Sampling	4/11/2006 1:52:02 PM	2		
...	Vth gmMax	4/7/2006 12:49:05 PM	3		

Click the Display Setup tab to display the display setup screen. The X-Y Graph area is used to set the X axis and Y axis of the X-Y Graph Plot area in the Data Display window.

- Name: Name of variable to plot on the X axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

To Set Data List Display

Display Setup

The screenshot shows the 'I/V Sweep' setup window. The 'List Display' section is highlighted with an orange box, and an orange arrow points to it with the text 'Select variables to list'. The 'X-Y Graph' section shows variables like Vd, Id, and ABS_ID. The 'Parameters' section shows 'Slope'. The bottom of the window shows a table with columns: Flag, Setup Name, Date, Count, Device ID, and Remarks.

Flag	Setup Name	Date	Count	Device ID	Remarks
...	Trng Id-Vd	4/11/2006 5:27:34 PM	8		
...	I/V Sweep	4/11/2006 5:12:31 PM	4		
...	I/V Sweep	4/11/2006 4:56:09 PM	2		
...	I/V Sweep	4/11/2006 4:55:06 PM	1		
...	I/V-t Sampling	4/11/2006 1:52:02 PM	2		
...	Vth gmMax	4/7/2006 12:49:05 PM	3		

The List Display area selects the variables to be listed in the List Display area of the Data Display window. Up to 20 variables can be set.

To Set Parameters Display

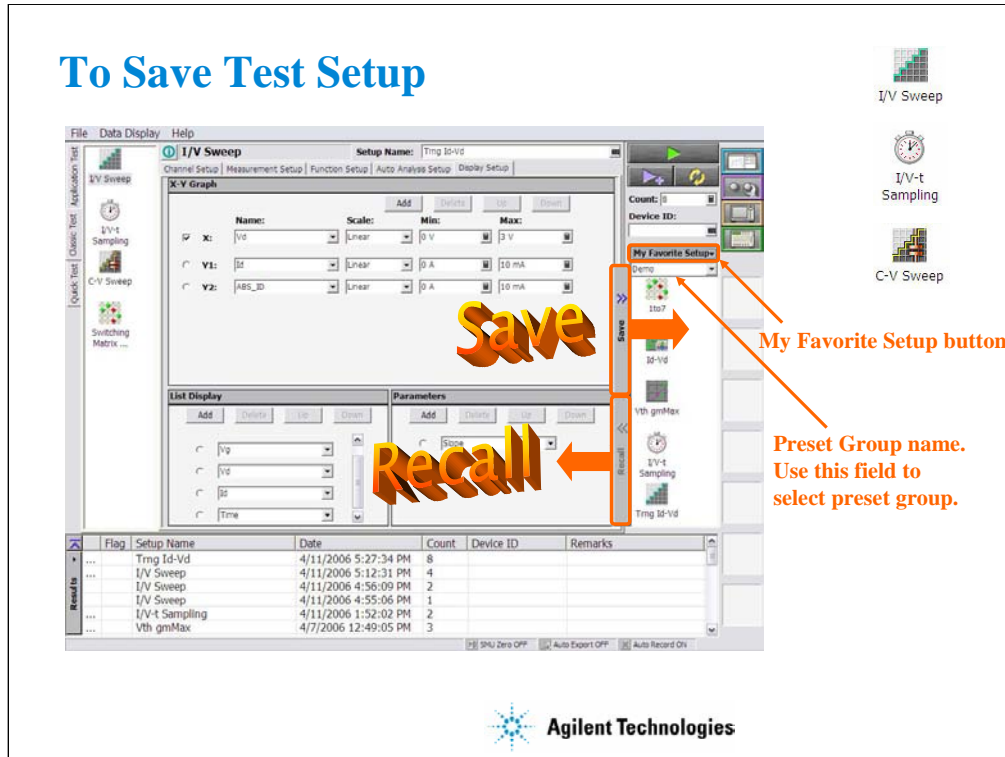
Display Setup

Select parameters to display

Flag	Setup Name	Date	Count	Device ID	Remarks
...	Trng Id-Vd	4/11/2006 5:27:34 PM	8		
...	I/V Sweep	4/11/2006 5:12:31 PM	4		
...	I/V Sweep	4/11/2006 4:56:09 PM	2		
...	I/V Sweep	4/11/2006 4:55:06 PM	1		
...	I/V-t Sampling	4/11/2006 1:52:02 PM	2		
...	Vth gmMax	4/7/2006 12:49:05 PM	3		

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The Parameters area selects the variables to be listed in the Parameters area of the Data Display window. Up to 20 parameters can be set.



The test setups you create **MUST** be saved to the internal hard disk drive as “My Favorite Setup”.

To save the setup, click the Save button.

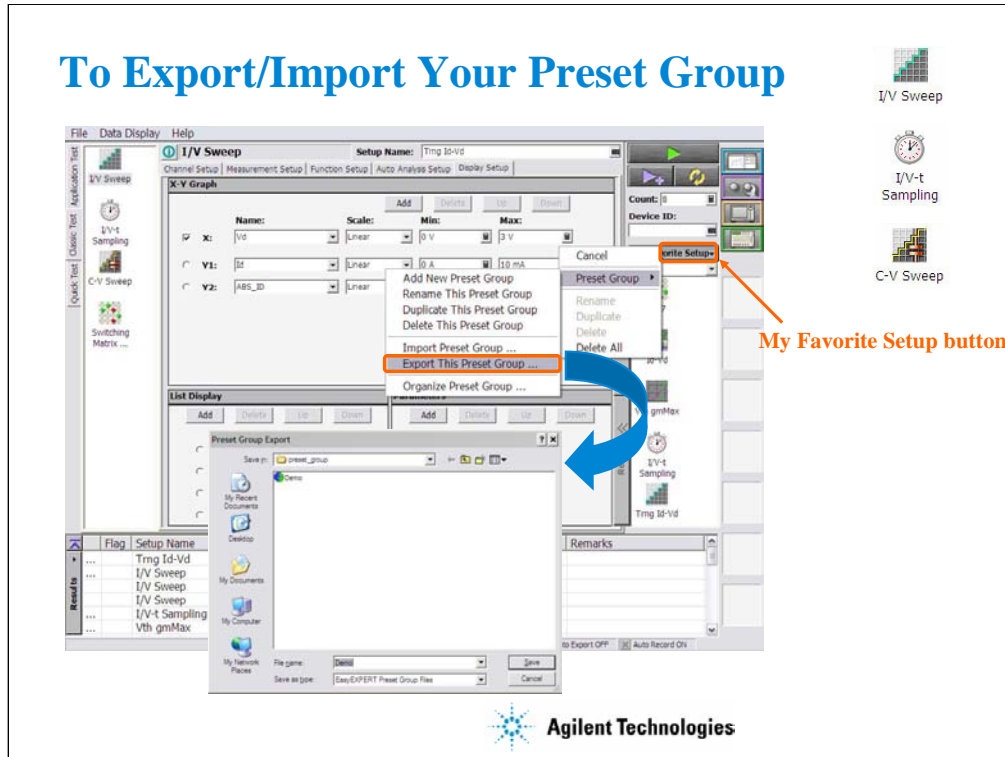
To recall the setup, click the Recall button.

You can organize the setups by using Preset Group. In the above example, the Demo group is selected and listed in the “My Favorite Setup”.

To create a new preset group, click the My Favorite Setup button to display the function menu, and select Add New Preset Group.

To select the available preset group, use the field below the My Favorite Setup button.

To Export/Import Your Preset Group



You can export/import your preset group.

To export the present preset group, click the My Favorite Setup button, select Export, and specify the folder and the name of the preset group to export.

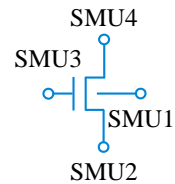
To import the preset group, click the My Favorite Setup button, select Import, and specify the preset group to import.

Class Exercise



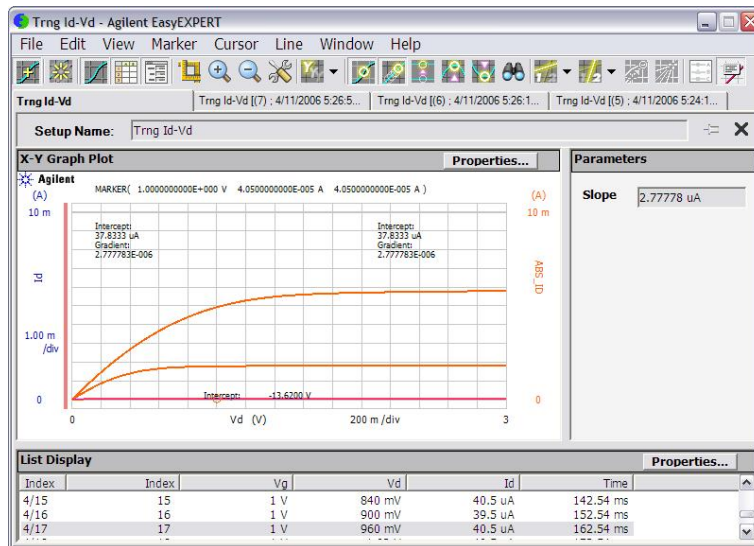
Define test setup and perform test.

1. Click I/V Sweep icon and open setup editor.
2. Define test setup as shown in the previous pages.
3. Save it as Trng Id-Vd.
4. Connect device, and perform test.
5. Export preset group, and import it.



Note:

Measurement Result Example



This is a test result example displayed on the Data Display window.

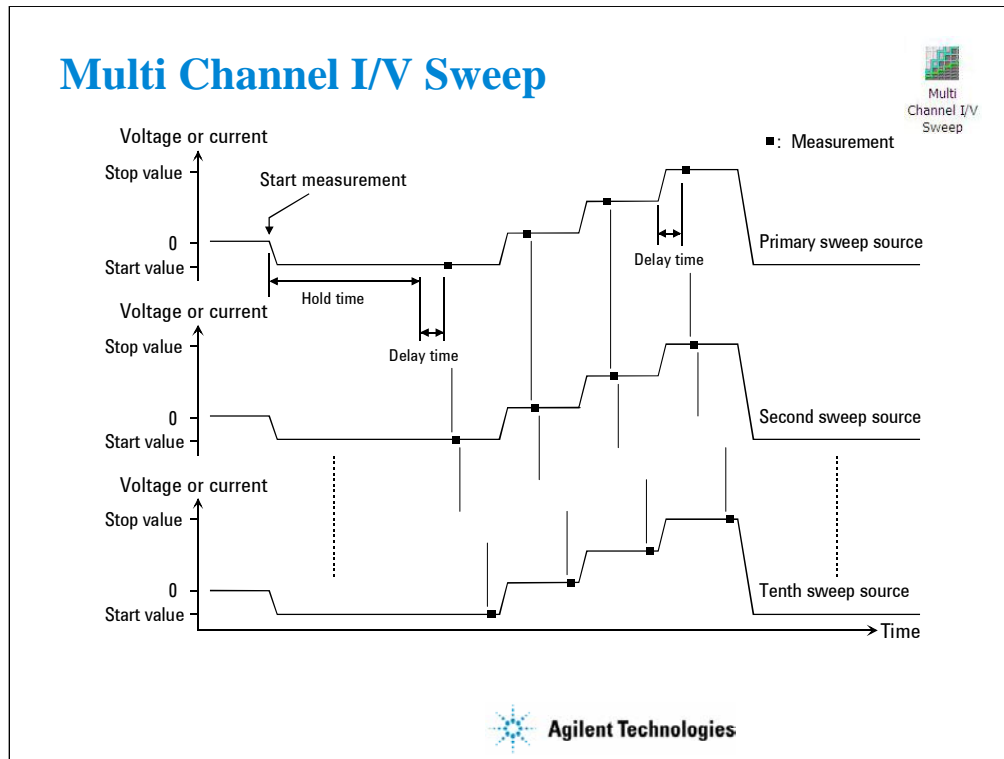
Multi Channel I/V Sweep



- **To Define Source/Masurement Channels**
- **To Set Var1 Sweep Sources**
- **To Set Constant Output**
- **To Set Ranging Mode**
- **To Set ADC/Integration Time**
- **Advanced Setup**
- **To Set User Functions**
- **To Set Data Display**



This section explains how to perform the Multi Channel I/V sweep measurement. You will perform the above tasks to execute the Multi Channel I/V sweep measurement.

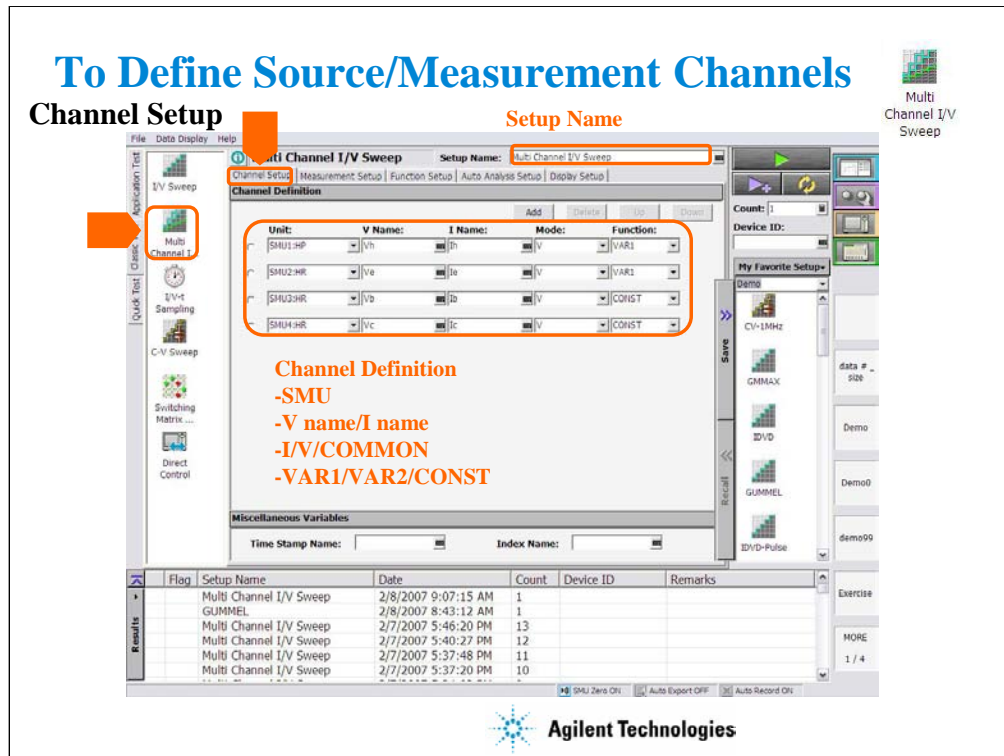


Multi Channel I/V Sweep measurement is similar to I/V Sweep measurement.

Changes from I/V Sweep are listed below.

- All SMU can be set to the VAR1 sweep source (up to 10 channels)
- Both voltage mode and current mode are available for the VAR1 sweep output
- VAR1' sweep output is not available
- SMU pulse output is not available

The output channels start to output in the order in which they are listed on the Channel Setup screen. If multiple measurement channel are used, the channels perform the measurements in order.



Click the Multi Channel I/V Sweep icon and open the setup editor. Then click the Channel Setup tab to display the channel definition screen.

- Enter the Setup Name for the test setup to be defined on the setup editor.
- List SMUs used for source output or measurement, and set the following parameters.
 - Unit: SMU name or number
 - V Name: Variable name for the voltage measurement or source data
 - I Name: Variable name for the current measurement or source data
 - Mode: Source output mode, V (voltage), I (current), or COMMON (ground)
 - Function: Source output function, VAR1 (primary sweep), VAR2 (secondary sweep), CONST (constant)

Note: Up to 10 sources can be set to VAR1.

V Name and I Name are used to specify the parameters displayed on the Data Display window. The display parameters are selected on the Display Setup tab screen.

To Set VAR1 Sweep Sources

Measurement Setup

Multi Channel I/V Sweep

SMU1 Stop
Start

SMU2 Stop
Start

Flag	Setup Name	Date	Count	Device ID	Remarks
	Multi Channel I/V Sweep	2/8/2007 9:07:15 AM	1		
	GUMMEL	2/8/2007 8:43:12 AM	1		
	Multi Channel I/V Sweep	2/7/2007 5:46:20 PM	13		
	Multi Channel I/V Sweep	2/7/2007 5:40:27 PM	12		
	Multi Channel I/V Sweep	2/7/2007 5:37:48 PM	11		
	Multi Channel I/V Sweep	2/7/2007 5:37:20 PM	10		

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The Measurement Setup tab screen is used to set the source output value and timing parameters.

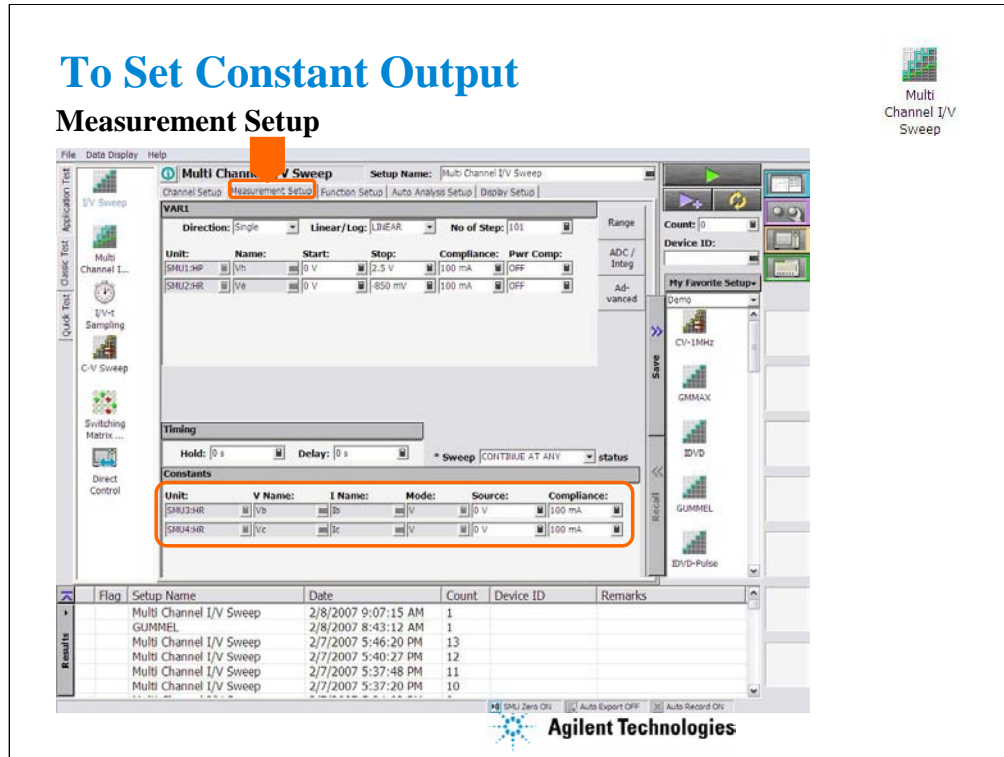
At the VAR1 area, you set VAR1 sweep sources.

Follows are common parameters for all VAR1 sweep sources.

- Direction: Single (start to stop) or Double (start to stop to start)
- Linear/Log: Linear sweep or Log sweep
- No of Step: Number of sweep steps

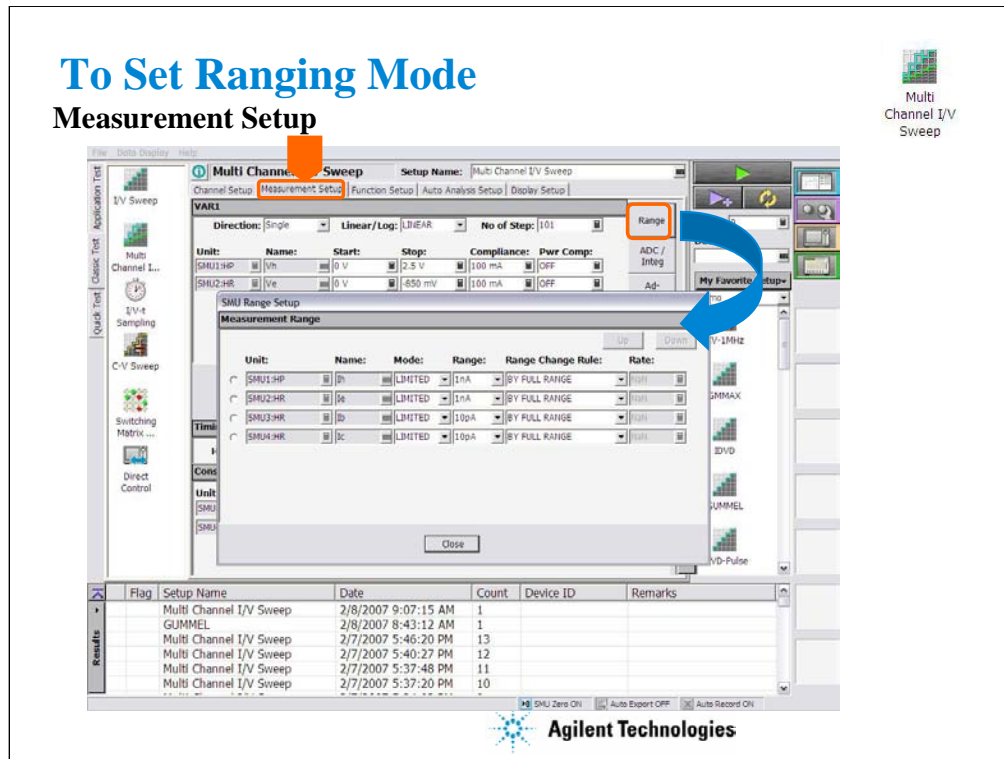
Following parameters can be set for each VAR1 sweep sources.

- Unit: SMU name or number
- Name: Variable name of source output
- Start: Source output start value
- Stop: Source output stop value
- Compliance: SMU compliance value
- Pwr Comp: SMU power compliance value



At the Constants area, you set the SMU constant output.

- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Mode: Source output mode, V (voltage), I (current), or COMMON (ground)
- Source: SMU output value
- Compliance: SMU compliance value



The Range button opens the SMU Range Setup dialog box. The dialog box is used to set the measurement ranging mode.

- Unit: SMU name or number
- Name: Variable name for the measurement data
- Mode: Ranging mode, AUTO, LIMITED, or FIXED
- Range: Range value
- Range Change Rule: BY FULL RANGE, GO UP AHEAD, or UP AND DOWN AHEAD
- Rate: Value used for range changing. See the following formula.

For the AUTO or LIMITED, SMU automatically selects the minimum range that covers the measurement value, and performs the measurement by using the range. For the limited auto ranging, the instrument does not use the range lower than the specified range value. For example, if you select the 100 nA limited auto ranging, the instrument never uses the 10 nA range and below.

BY FULL RANGE performs normal auto ranging operation.

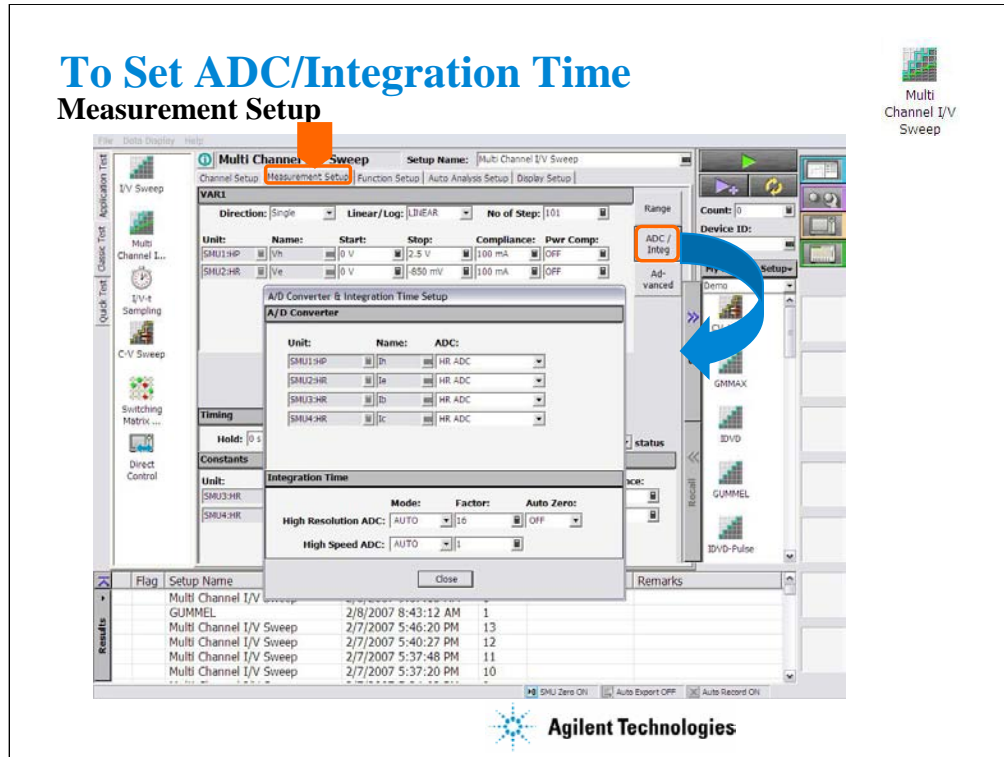
For the GO UP AHEAD and UP AND DOWN AHEAD rules, specify the *Rate* value, 11 to 100, which fixes the boundary of the ranging. The ranging occurs when the measurement data goes across the *boundary* values shown below.

$$go\ up\ boundary = present\ measurement\ range \times Rate / 100$$

$$go\ down\ boundary = present\ measurement\ range \times Rate / 1000$$

The *go down boundary* is available only for the UP AND DOWN AHEAD rule.

To Set ADC/Integration Time Measurement Setup



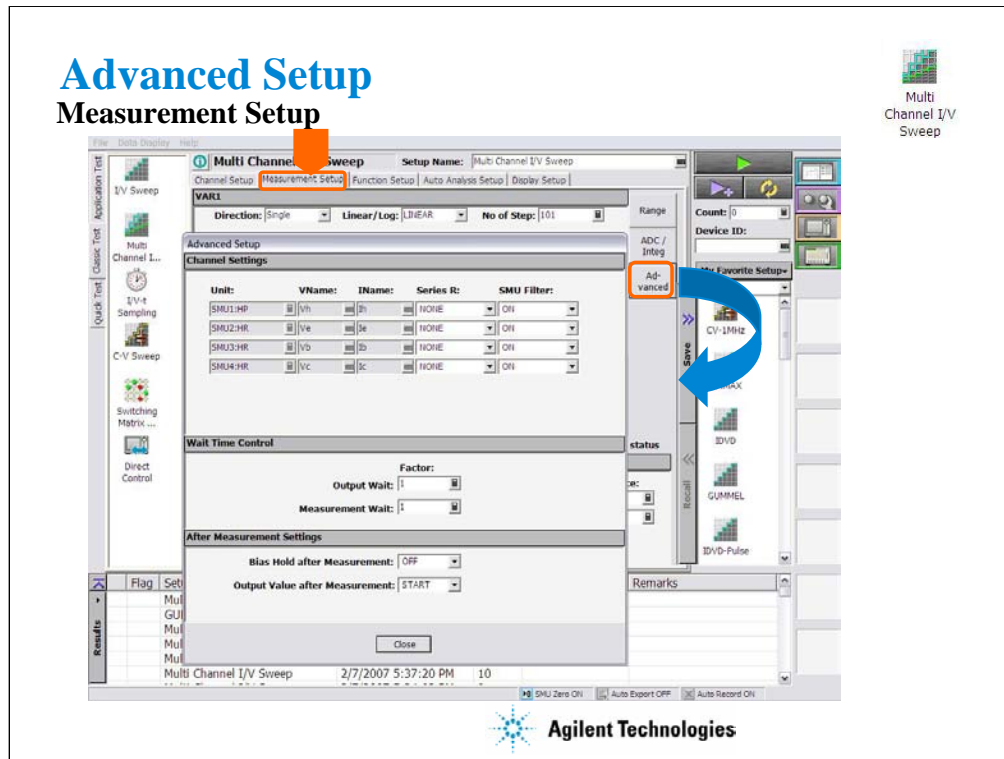
The ADC/Integ button opens the A/D Converter & Integration Time Setup dialog box. The dialog box is used to select the ADC for each SMU and set the integration time for each ADC (high resolution or high speed). This button is not available when a pulse source is used.

A/D Converter:

- Unit: SMU name or number
- Name: Variable name of the measurement data
- ADC: ADC type, HR ADC (high resolution) or HS ADC (high speed)

Integration Time:

- Mode: AUTO, MANUAL, or PLC. Rule to decide the integration time. For details, see online help or User's Guide.
- Factor: Coefficient for the reference value of the integration time.
- Auto Zero: Auto Zero function ON or OFF. For HR ADC.



The Advanced button opens the Advanced Setup dialog box. The dialog box is used to set the SMU filter and SMU series resistor settings, and set the wait time.

Channel Settings:

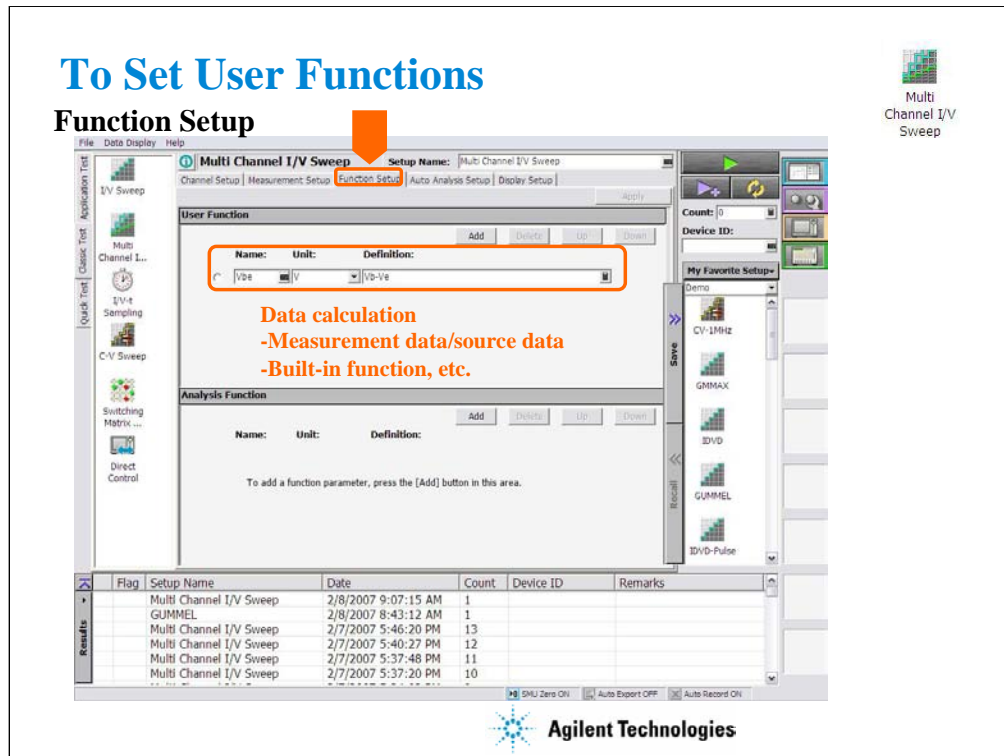
- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Series R: SMU series resistor NONE or 1MOHM (1000000 ohm)
- SMU Filter: SMU filter ON or OFF

Wait Time Control:

- Factor: Coefficient for the reference value of the wait time. For details, see online help or User's Guide.

After Measurement Settings:

- Bias Hold after Measurement: Bias hold function ON or OFF.
- Output Value after Measurement: Source output value after measurement. START (sweep start value), STOP (sweep stop value).



Click the Function Setup tab to display the User Function/Analysis Function setup screen. The user functions can be displayed on the X-Y Graph Plot, List Display, and Parameters area of the Data Display window. Up to 20 functions can be set.

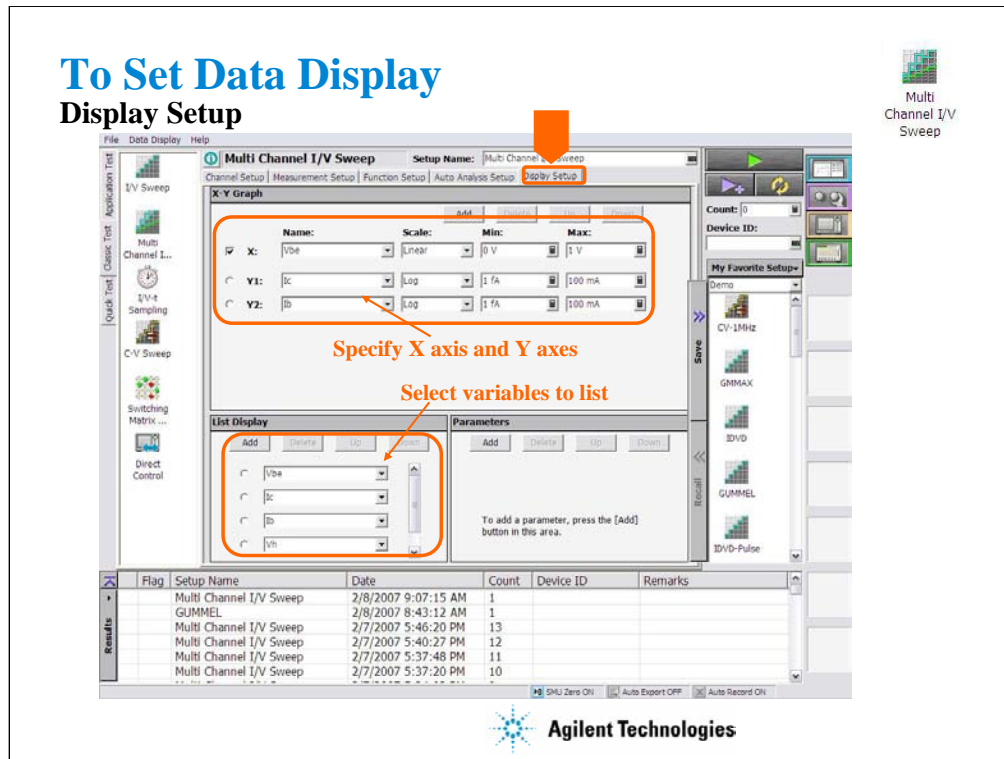
Name: Function name

Unit: Unit of the function

Definition: Definition of the function. The following identifiers can be used.

- Variables for the measurement/output data used in this test
- Functions defined in the above lines
- Local variables passed from the application test that calls this test as a component
- Built-in functions and global variables

For details, see online help or User's Guide.



Click the Display Setup tab to display the display setup screen.

The X-Y Graph area is used to set the X axis and Y axes of the X-Y Graph Plot area in the Data Display window.

- Name: Name of variable to plot on the X axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

The List Display area selects the variables to be listed in the List Display area of the Data Display window. Up to 20 variables can be set.

For example, following variables are set for the Class Exercise.

Vbe, Ic, Ib, Vh, Ih

Class Exercise

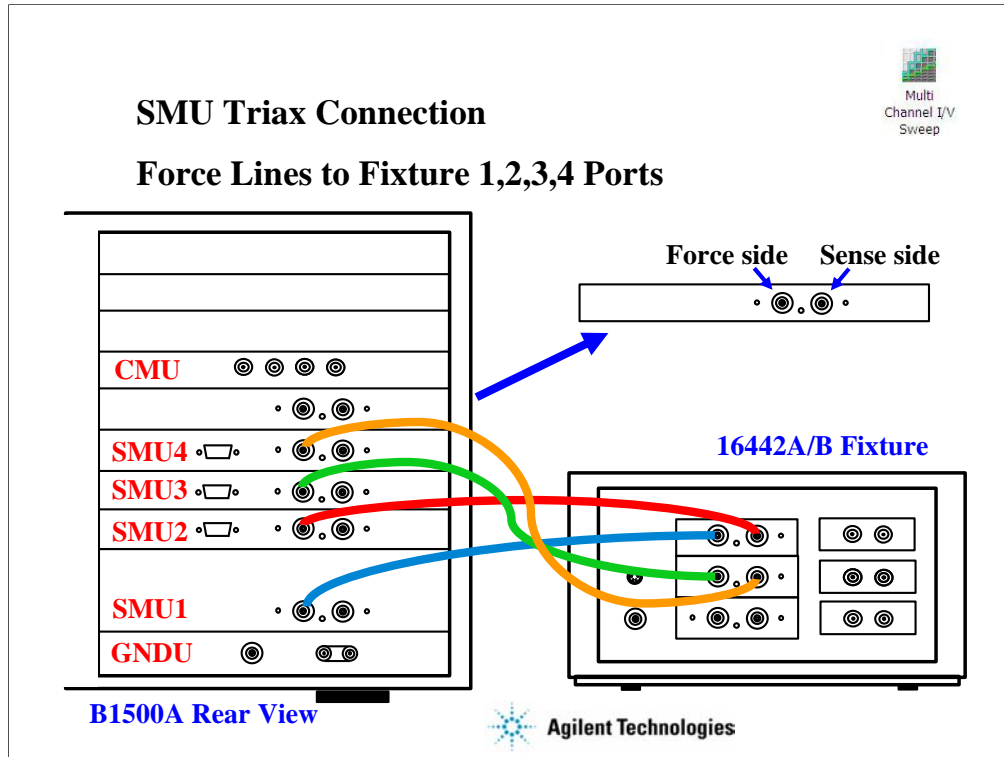


Define test setup and perform test.

1. **Click Multi Channel I/V Sweep icon and open setup editor.**
2. **Define test setup as shown in the previous pages.**
3. **Save it as Trng Multi.**
4. **Connect devices (NPN Bipolar Transistor and Red Miniature LED) as shown in next several pages, and perform test.**
5. **Export preset group, and import it.**



Note:

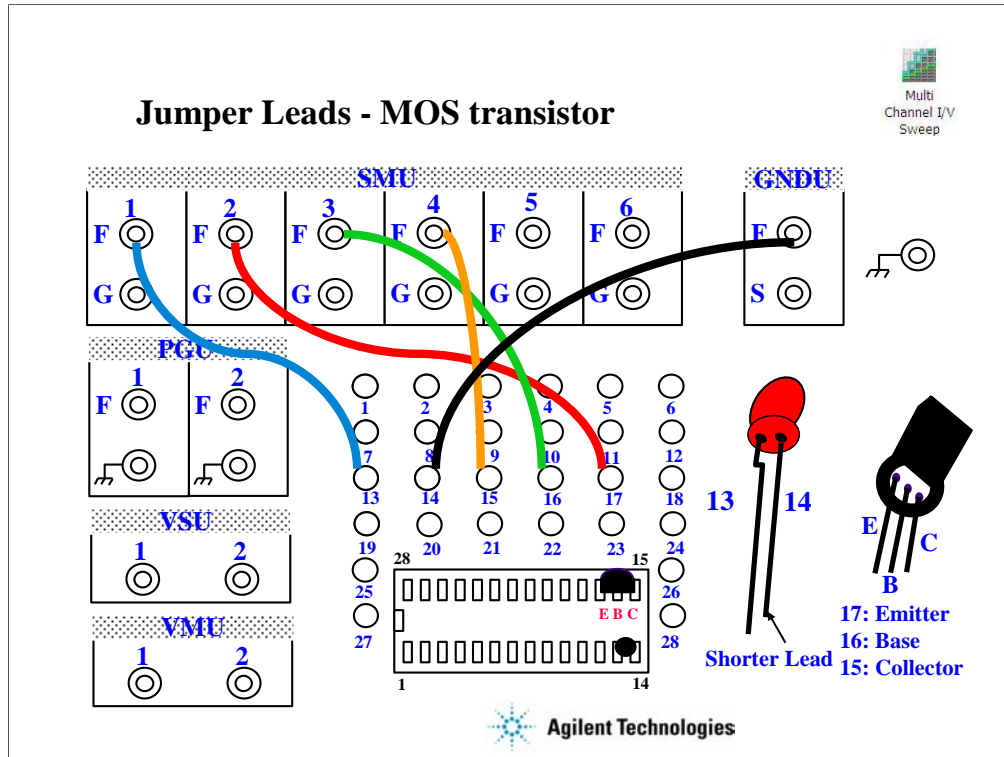


For the non-Kelvin connections, connect only the Force lines, leaving the Sense lines open.

Connect corresponding numbers. On the 16442A/B fixture use the numbers labeled 1 - 6, not 1 - 3.

Your B1500A may not match the SMU configuration shown in this figure. Note that SMU1 is the module top of the GNDU (ground unit). The SMU number become large from bottom to top as shown.

This is the SMU cable setup that will be used in the remainder of the class exercises.



For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme.

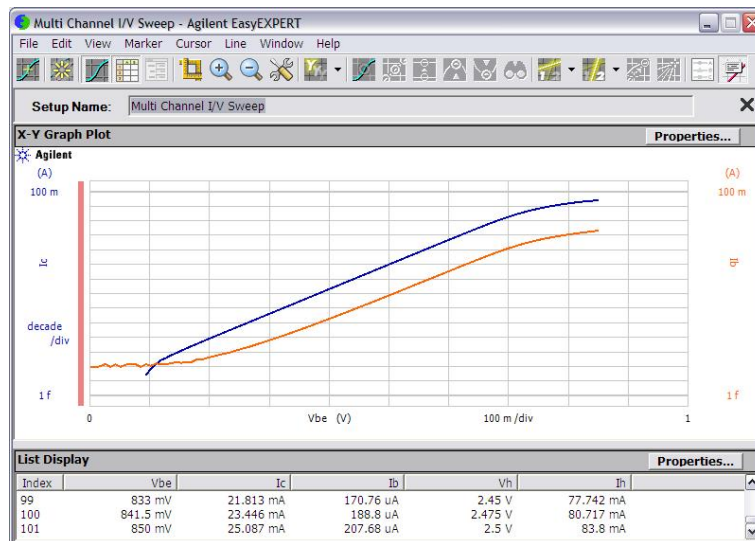
Connect jumper leads as follows.

- Terminal 13 : SMU1 F terminal
- Terminal 14 : GNDU F terminal
- Terminal 15 : SMU4 F terminal
- Terminal 16 : SMU3 F terminal
- Terminal 17 : SMU2 F terminal

Locate the bipolar transistor in the corner of the 28-pin dual in line socket as shown, with the flat side of the device facing toward you. Unlike the MOS device, the bipolar transistor is not static sensitive. You may touch the leads without using a ground strap.

Locate the LED between terminals 13 and 14 of the 28-pin dual in line socket.

Measurement Result Example



This is a test result example displayed on the Data Display window.

At the start of measurement, LED lights off. Beyond the threshold voltage, the LED lights on.

I/V List Sweep



- **To Define Source/Measurement Channels**
- **To Set Var1 Sweep Sources**
- **To Set Constant Output**
- **To Set Ranging Mode**
- **To Set ADC/Integration Time**
- **Advanced Setup**
- **To Set User/Analysis Functions**
- **Auto Analysis Setup**
- **To Set Data Display**



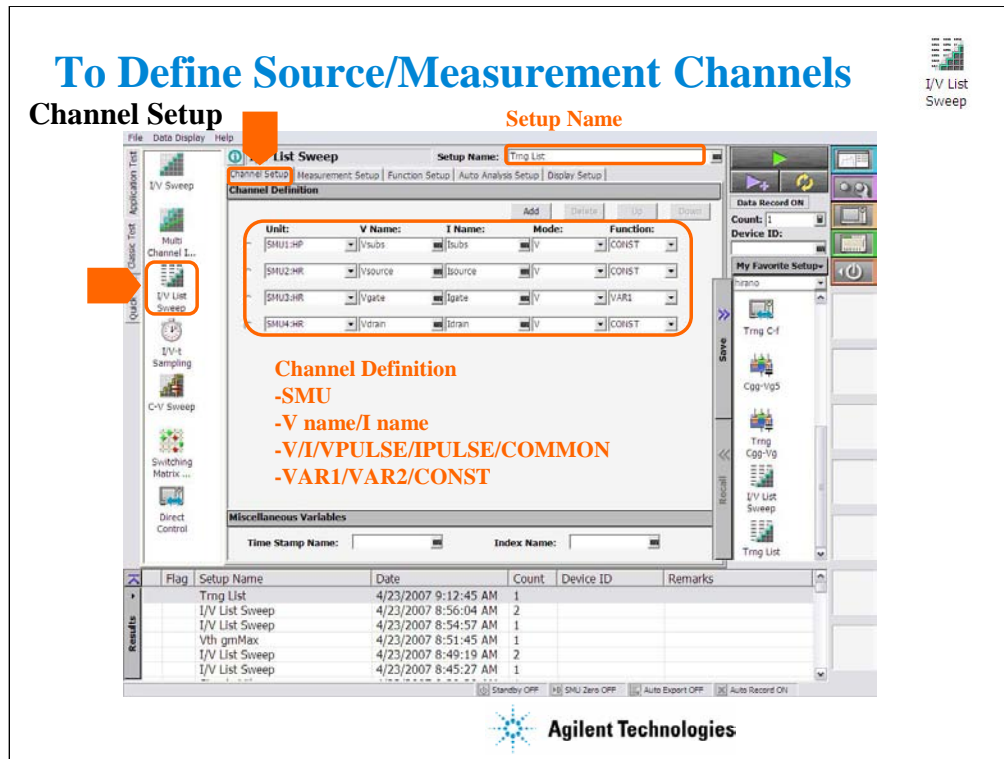
This section explains how to perform I/V List sweep measurement. You will perform the above tasks to execute the I/V List sweep measurement.

I/V List Sweep measurement is similar to I/V Sweep measurement.

Changes from the I/V Sweep are listed below.

- VAR1/VAR2 step output values are set by using a vector data. Vector data from a spreadsheet software, either tab separated or comma separated can be copied to the Define vector data dialog box via the Windows clipboard.
- All SMU installed in the B1500A can be set to VAR1.
- VAR1' is not supported.

For more information, see online help or User's Guide.



Click the I/V List Sweep icon and open the setup editor. Then click the Channel Setup tab to display the channel definition screen.

- Enter the Setup Name for the test setup to be defined on the setup editor.
- List SMUs used for source output or measurement, and set the following parameters.

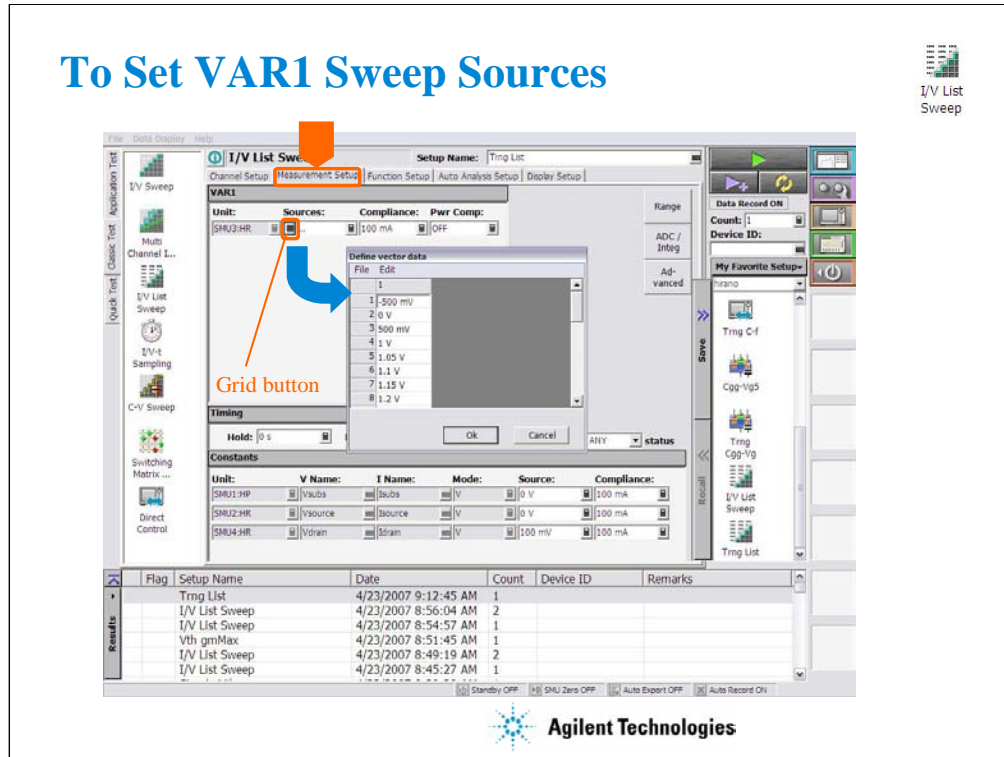
- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Mode: Source output mode, V (voltage), I (current), VPULSE (voltage pulse), IPULSE (current pulse), or COMMON (ground)
- Function: Source output function, VAR1 (primary sweep), VAR2 (secondary sweep), or CONST (constant)

Note: Up to 10 sources can be set to VAR1.

V Name and I Name are used to specify the parameters displayed on the Data Display window. The display parameters are selected on the Display Setup tab screen.

To Set VAR1 Sweep Sources

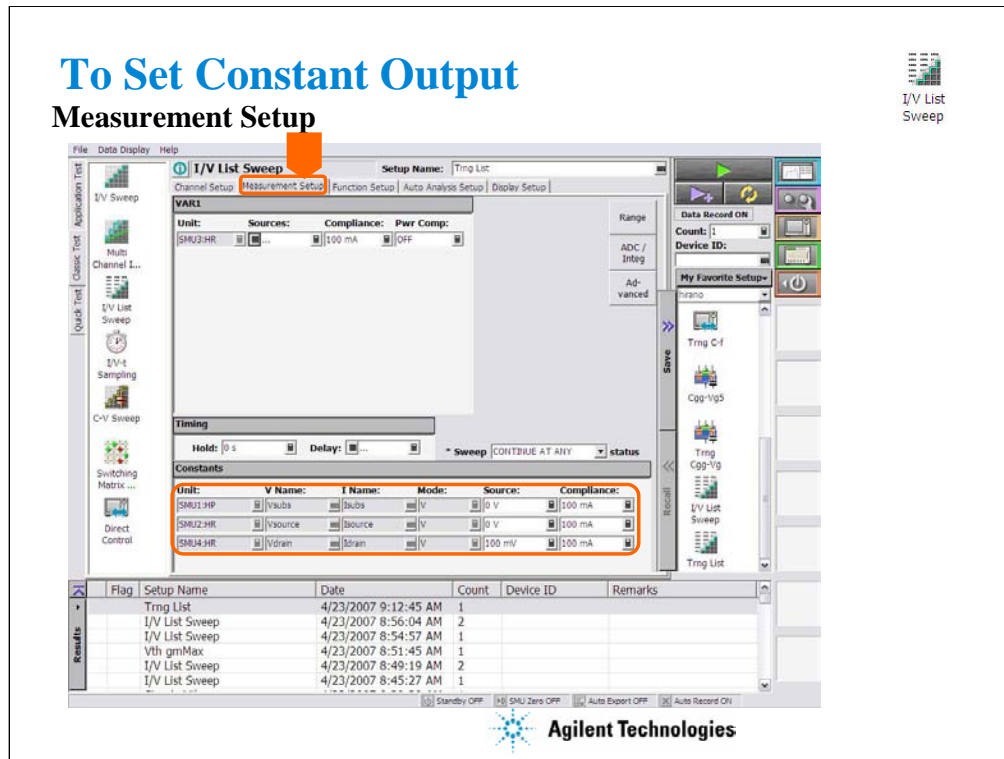
I/V List Sweep



The Measurement Setup tab screen is used to set the source output value and timing parameters.

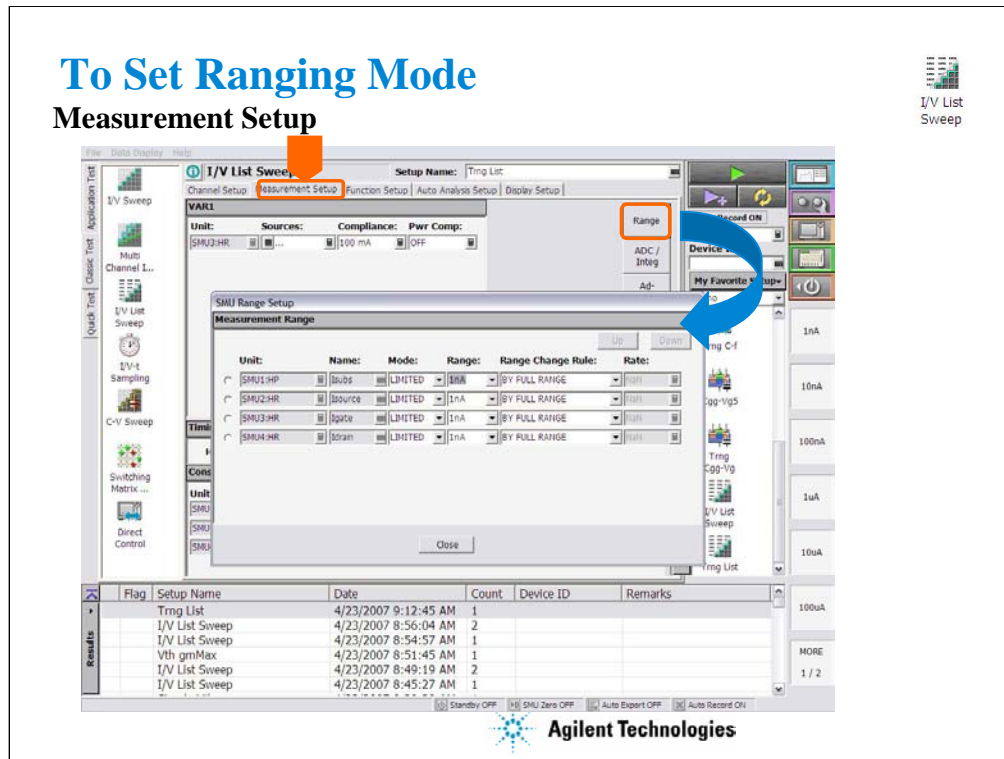
At the VAR1 area, you set VAR1 sweep sources.

- Unit: SMU name or number
- Source: Click the grid button to open the Define vector data dialog box. Enter the vector data of VAR1. For example, -500 m, 0, 500 m, 1, 1.05, 1.1, 1.15, 1.2, 1.25, 1.3, 1.35, 1.4, 1.45, 1.5, 1.55, 1.6, 1.65, 1.7, 1.75, 1.8, 1.85, 1.9, 1.95, 2, 2.5, and 3 V are set for the Vth-gmMax. Step voltages near the gmMax are set to 50 mV and others are set to 500 mV.
- Compliance: SMU compliance value
- Pwr Comp: SMU power compliance value



At the Constants area, you set the SMU constant output.

- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Mode: Source output mode, V (voltage), I (current), VPULSE (voltage pulse), IPULSE (current pulse), or COMMON (ground)
- Source: SMU output value. For example, Vdrain is set to 100 mV for the Vth-gmMax.
- Compliance: SMU compliance value



The Range button opens the SMU Range Setup dialog box. The dialog box is used to set the measurement ranging mode.

- Unit: SMU name or number
- Name: Variable name for the measurement data
- Mode: Ranging mode, AUTO, LIMITED, or FIXED
- Range: Range value
- Range Change Rule: BY FULL RANGE, GO UP AHEAD, or UP AND DOWN AHEAD
- Rate: Value used for range changing. See the following formula.

For the AUTO or LIMITED, SMU automatically selects the minimum range that covers the measurement value, and performs the measurement by using the range. For the limited auto ranging, the instrument does not use the range lower than the specified range value. For example, if you select the 100 nA limited auto ranging, the instrument never uses the 10 nA range and below.

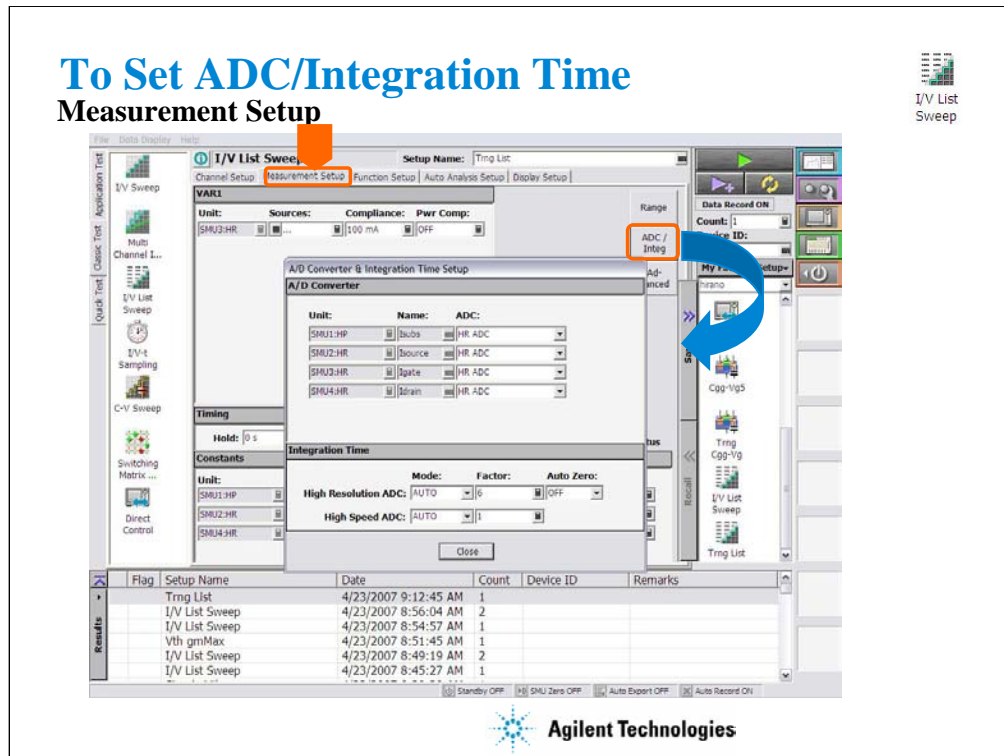
BY FULL RANGE performs normal auto ranging operation.

For the GO UP AHEAD and UP AND DOWN AHEAD rules, specify the *Rate* value, 11 to 100, which fixes the boundary of the ranging. The ranging occurs when the measurement data goes across the *boundary* values shown below.

$$go\ up\ boundary = present\ measurement\ range \times Rate / 100$$

$$go\ down\ boundary = present\ measurement\ range \times Rate / 1000$$

The *go down boundary* is available only for the UP AND DOWN AHEAD rule.



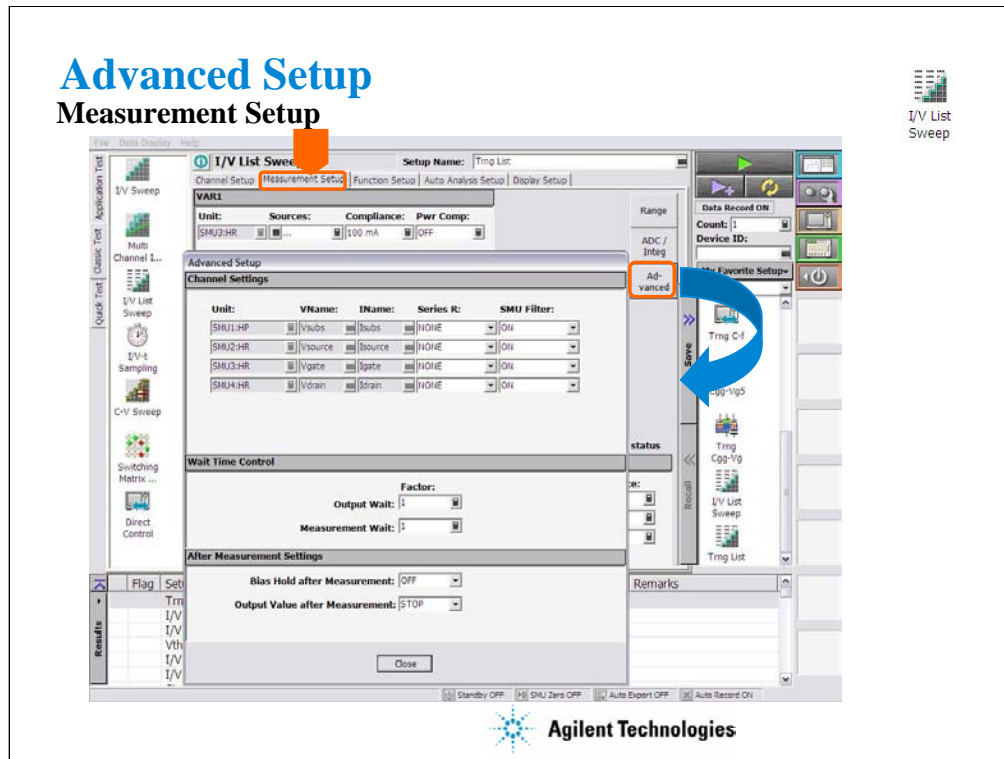
The ADC/Integ button opens the A/D Converter & Integration Time Setup dialog box. The dialog box is used to select the ADC for each SMU and set the integration time for each ADC (high resolution or high speed). This button is not available when a pulse source is used.

A/D Converter:

- Unit: SMU name or number
- Name: Variable name of the measurement data
- ADC: ADC type, HR ADC (high resolution) or HS ADC (high speed)

Integration Time:

- Mode: AUTO, MANUAL, or PLC. Rule to decide the integration time. For details, see online help or User's Guide.
- Factor: Coefficient for the reference value of the integration time.
- Auto Zero: Auto Zero function ON or OFF. For HR ADC.



The Advanced button opens the Advanced Setup dialog box. The dialog box is used to set the SMU filter and SMU series resistor settings, and set the wait time.

Channel Settings:

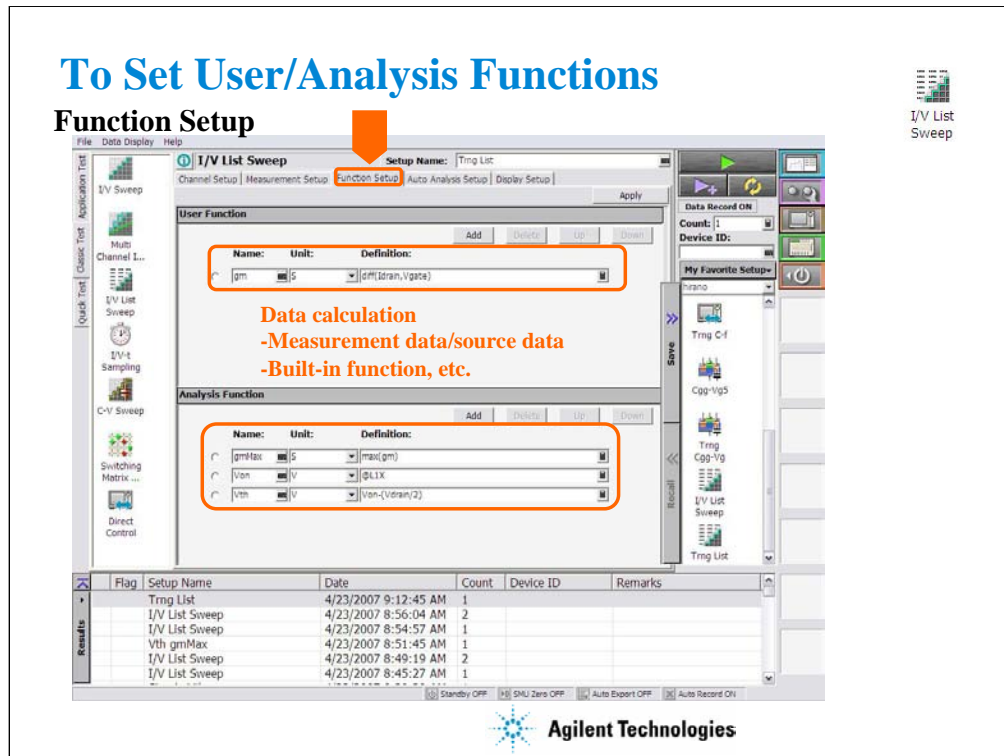
- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Series R: SMU series resistor NONE or 1MOHM (1000000 ohm)
- SMU Filter: SMU filter ON or OFF

Wait Time Control:

- Factor: Coefficient for the reference value of the wait time. For details, see online help or User's Guide.

After Measurement Settings:

- Bias Hold after Measurement: Bias hold function ON or OFF.
- Output Value after Measurement: Source output value after measurement. START (sweep start value), STOP (sweep stop value).



Click the Function Setup tab to display the User Function/Analysis Function setup screen. The user/analysis functions can be displayed on the X-Y Graph Plot, List Display, and Parameters area of the Data Display window. Up to 20 functions can be set.

Name: Function name

Unit: Unit of the function

Definition: Definition of the function. The following identifiers can be used.

- Variables for the measurement/output data used in this test
- Functions defined in the above lines
- Local variables passed from the application test that calls this test as a component
- Built-in functions and global variables

For details, see online help or User's Guide.

For example, following user/analysis functions are set for the Vth-gmMax.

<Name> <Unit> <Definition>

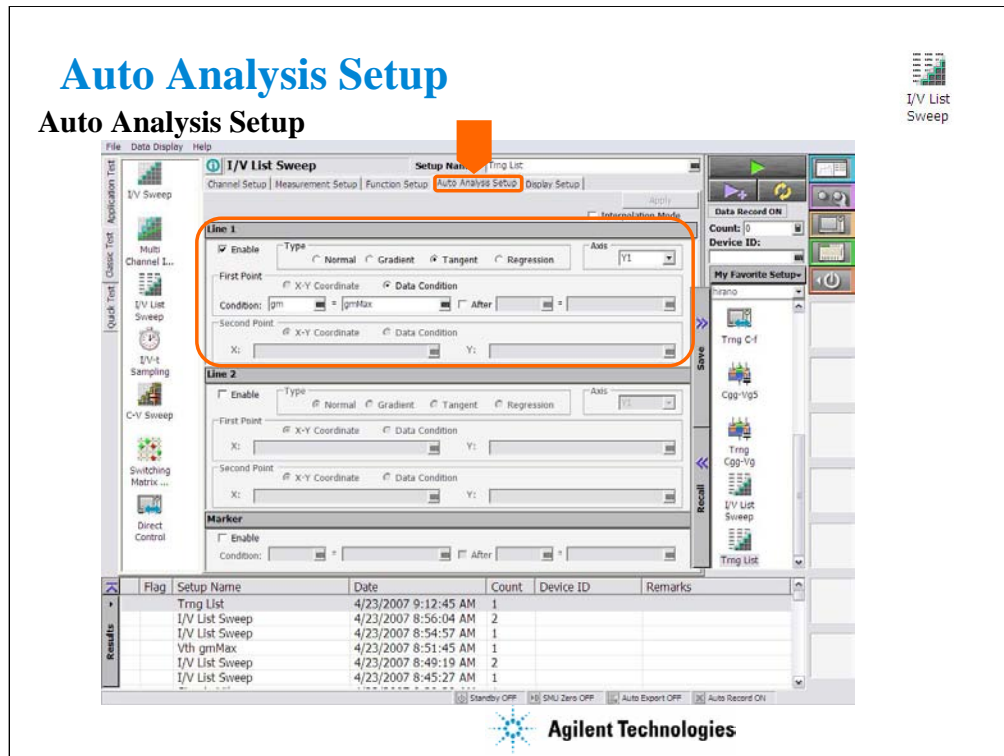
Gm S diff(Idrain,Vgate)

gmMax S max(gm)

Von V @L1X

Vth V Von-(Vdrain/2)

For built-in functions, see online help or User's Guide.



Click the Auto Analysis Setup tab to display the Auto Analysis setup screen. This screen is used to set the automatic analysis function. When a measurement finishes, the function automatically draws lines, a marker, or both on the X-Y Graph of the Data Display window.

You can set up two lines and one marker for the automatic analysis function.

In the Line 1 and Line 2 areas, you can set up the lines to be drawn.

In the Marker area, you can set up the marker.

For details, see online help or User's Guide.

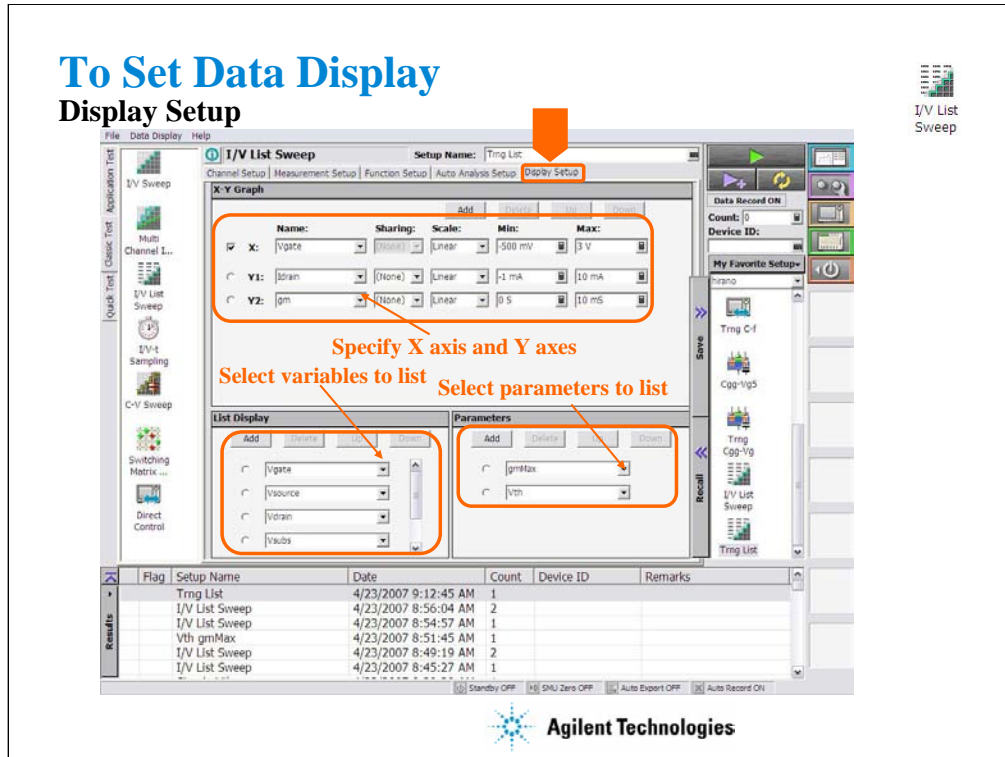
For example, the Line 1 is set for the Vth-gmMax .

Type: Tangent

Axis: Y1

First Point: Data Condition

Condition: gm = gmMax



Click the Display Setup tab to display the display setup screen.

The X-Y Graph area is used to set the X axis and Y axes of the X-Y Graph Plot area in the Data Display window.

- Name: Name of variable to plot on the X axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

For example, following axes are set for the Vth-gmMax.

<Name>	<Sharing>	<Scale>	<Min>	<Max>
X Vgate		Linear	-500 mV	3 V
Y1 Idrain	(None)	Linear	-1 mA	10 mA
Y2 gm	(None)	Linear	0 S	10 mS

The List Display area selects the variables to be listed in the List Display area of the Data Display window. Up to 20 variables can be set.

For example, following variables are set for the Vth-gmMax.

Vgate, Vsource, Vdrain, Vsubs, Idrain, gm

The Parameters area selects the variables to be listed in the Parameters area of the Data Display window. Up to 20 parameters can be set.

For example, following parameters are set for the Vth-gmMax.

gmMax, Vth

Class Exercise

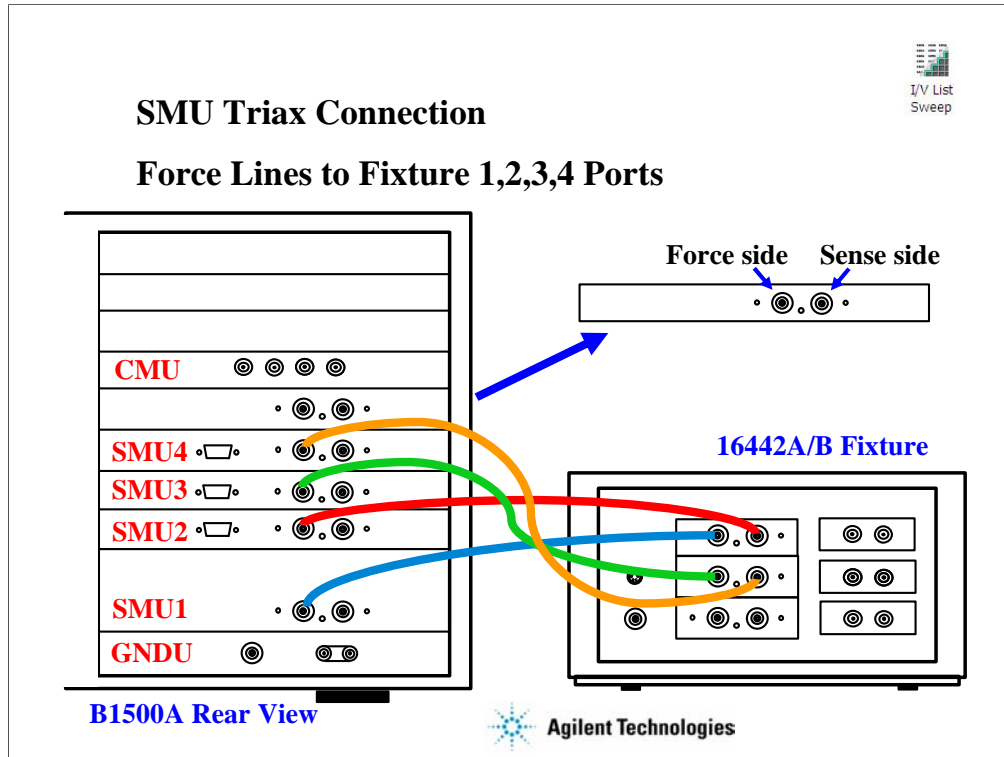


Define test setup and perform test.

1. **Click I/V List Sweep icon and open setup editor.**
2. **Define test setup as shown in the previous pages.**
3. **Save it as Trng List.**
4. **Connect an N-ch MOSFET as shown in next several pages, and perform test.**
5. **Export preset group, and import it.**



Note:

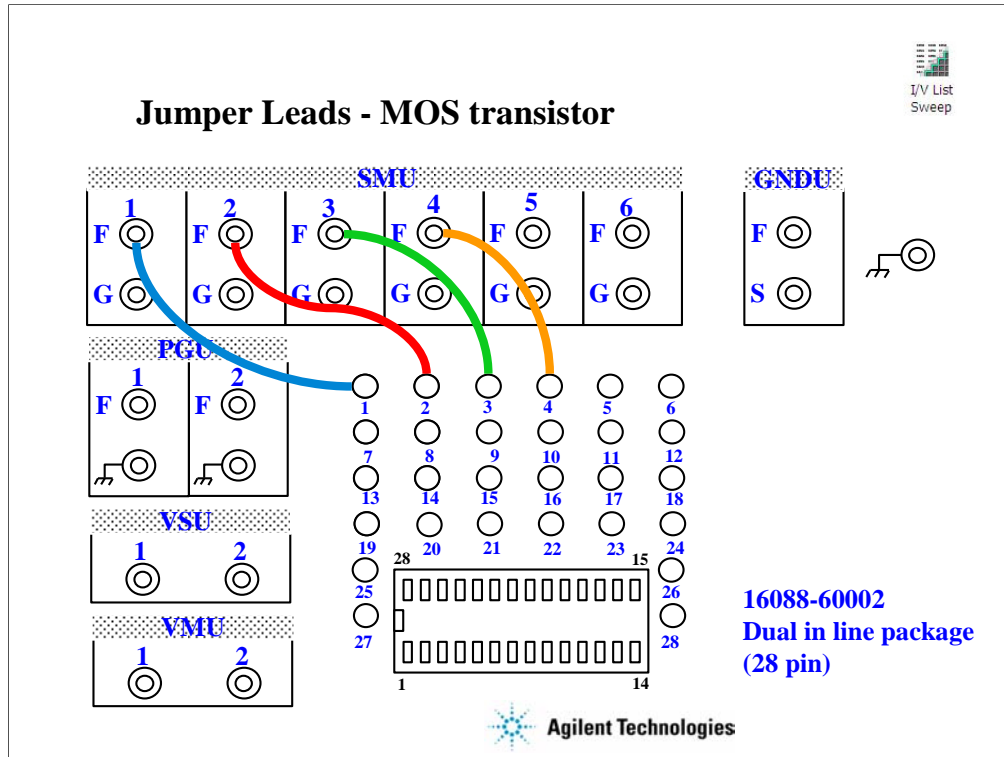


For the non-Kelvin connections, connect only the Force lines, leaving the Sense lines open.

Connect corresponding numbers. On the 16442A/B fixture use the numbers labeled 1 - 6, not 1 - 3.

Your B1500A may not match the SMU configuration shown in this figure. Note that SMU1 is the module top of the GNDU (ground unit). The SMU number become large from bottom to top as shown.


This is the SMU cable setup that will be used in the remainder of the class exercises.




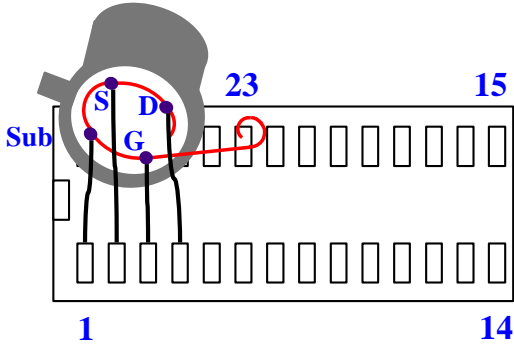
For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme. On older fixtures, this scheme is shown in light blue lettering. In newer fixtures, this scheme is shown in white reverse background lettering.

Device Orientation and Insertion








Insert the transistor last, AFTER connecting the cables and leads. Remove the shorting wire after insertion in the socket.

- 1: Substrate
- 2: Source
- 3: Gate
- 4: Drain



The MOS FET leads must be re-arranged into a straight line as shown.

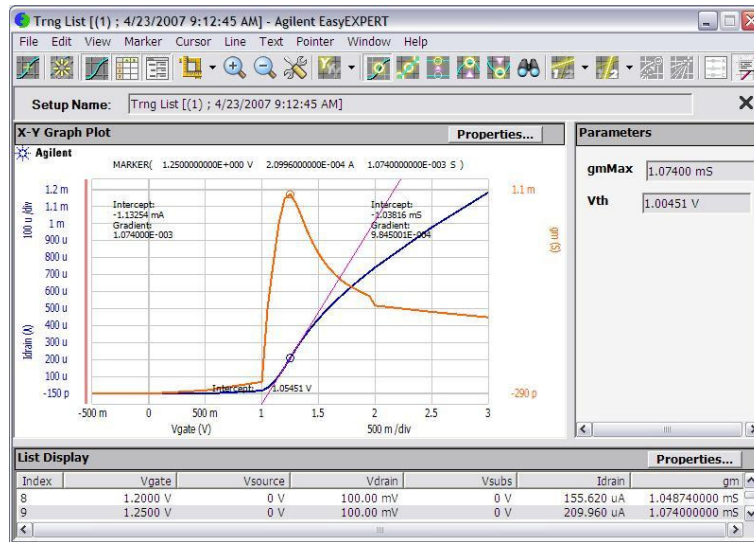
IMPORTANT:

The MOS FET is highly sensitive to electrostatic damage. Touching the bare leads can definitely destroy the device. The device comes with a special shorting wire attached. Bend the leads the way you want, insert the device in the socket, and then remove the shorting wire. The wire has a tab. Just grab the tab and pull straight out. The wire will spiral out as you pull.

Once the shorting wire is removed, you must use a wrist strap when handling the device.

Measurement Result Example

I/V List
Sweep



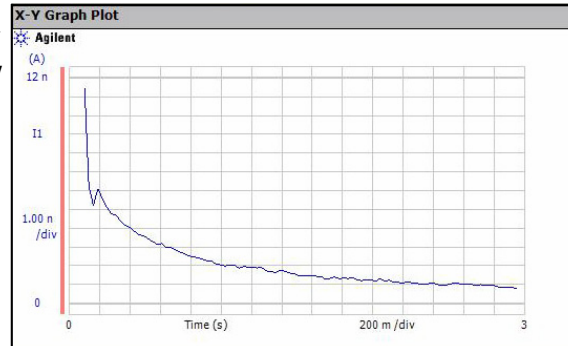
This is a test result example displayed on the Data Display window.

I/V-t Sampling Measurement

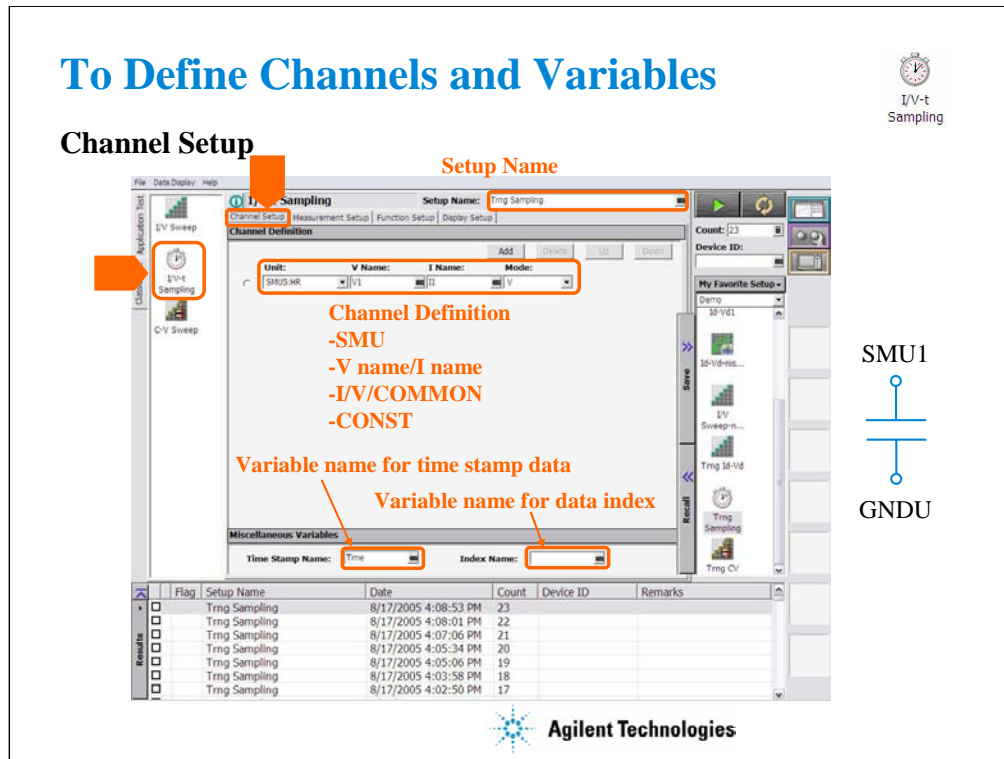


I/V-t
Sampling

- To Define Channels and Variables
- To Set Sampling Parameters
- To Set SMU Outputs (CONST)
- Range/ADC/Advanced
- To Set User Functions/
Analysis Functions
- To Set Data Display



This section explains how to perform I/V-t sampling measurement. You will perform the above tasks to execute the I/V-t sampling measurement.



Click the I/V-t Sampling icon and open the setup editor. Then click the Channel Definition tab to display the channel definition screen.

- Enter the Setup Name for the test setup to be defined on the setup editor.
- List SMUs used for source output or measurement, and set the following parameters.
 - Unit: SMU name or number
 - V Name: Variable name for the voltage measurement or source data
 - I Name: Variable name for the current measurement or source data
 - Mode: Source output mode, V (voltage), I (current), or COMMON (ground)
 - Time Stamp Name: Variable name for the time stamp data
 - Index Name: Variable name for the data index

You can read measurement data by using the Data Display window. Parameters displayed on the window are selected on the Display Setup tab screen. If you enter the variable name in the V Name, I Name, Time Stamp Name, and/or Index Name entry fields, you can choose the variables as the display parameters.

- The time stamp is the time the measurement is started for each measurement point.
- The index is the index number for each measurement data.

To Set Sampling Parameters

Measurement Setup

I/V-t
Sampling

Sampling parameter

Trigger

Measurement time

Sampling interval

Hold time

Flag	Setup Name	Date	Count	Device ID	Remarks
	Trng Sampling	4/11/2006 6:30:59 PM	11		
	Trng Sampling	4/11/2006 6:30:15 PM	10		
	Trng Sampling	4/11/2006 6:29:11 PM	9		
	Trng Sampling	4/11/2006 6:28:26 PM	8		
	Trng Sampling	4/11/2006 6:24:45 PM	7		
	Trng Sampling	4/11/2006 6:24:03 PM	6		

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Click the Measurement Setup tab to display the setup screen for the sampling timing parameters and the SMU source output parameters. At the Sampling Parameter area, you set the following sampling timing parameters.

Linear/Log:

Sampling mode. LINEAR for linear sampling. LOG10, LOG25, LOG50, LOG100, LOG250, or LOG500 for logarithmic sampling. For the logarithmic sampling, the number after LOG indicates the number of measurement data in a decade. For example, LOG10 mode is used to get 10 data/decade.

For the log sampling, the B1500A holds only the data that can be plotted on the log scale in the same distance as close as possible. Only the held data is counted in the number of measurement result data.

For the linear sampling with Interval < 2 ms, if the total measurement time runs over the specified time Interval × No of Samples, the sampling measurement will be stopped even if the number of measurement result data is less than the specified No of Samples.

Interval:

Interval of the sampling, in seconds. 0.002 to 65.535 s, 0.001 s resolution.

Interval < 0.002 s in 0.00001 s resolution is also available for the linear sampling. It must satisfy the following formula. For details, see online help or User's Guide.

Interval ≥ 0.0001 + 0.00002 × (number of measurement channels-1)

To Set Sampling Parameters

Measurement Setup

Flag	Setup Name	Date	Count	Device ID	Remarks
	Trng Sampling	4/11/2006 6:30:59 PM	11		
	Trng Sampling	4/11/2006 6:30:15 PM	10		
	Trng Sampling	4/11/2006 6:29:11 PM	9		
	Trng Sampling	4/11/2006 6:28:26 PM	8		
	Trng Sampling	4/11/2006 6:24:45 PM	7		
	Trng Sampling	4/11/2006 6:24:03 PM	6		

No of Samples:

Number of samples. Integer. 1 to the following value.

For linear: $100001 / (\text{number of measurement channels})$

For logarithmic: $1 + (\text{number of data for 11 decades})$

Total Sampling Time:

This field just displays the total sampling time that is the time from the measurement start time for the first point to the end of sampling measurement. It does not include the hold time.

Total Sampling Time = Interval \times No of Samples

Output Sequence:

Source output sequence. SIMULTANEOUS or SEQUENTIAL.

Hold Time:

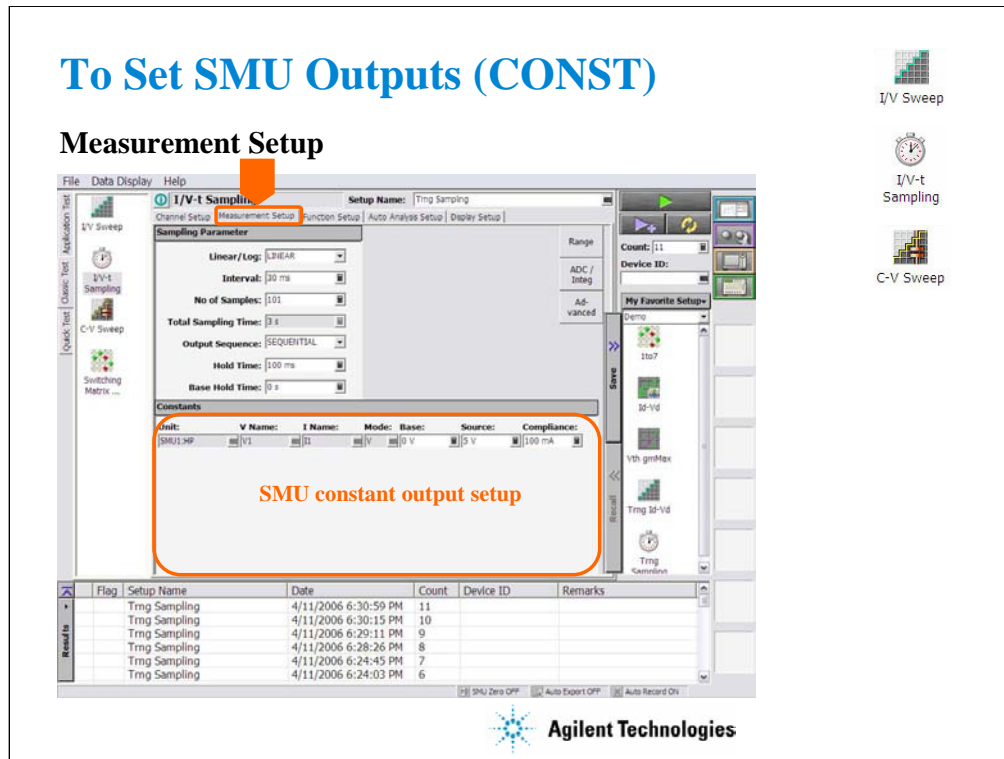
Time since the Source value output until the first sampling point, in seconds. 0 to 655.35 s, resolution 0.01 s.

The following values are also available for Interval < 0.002 s. |Hold Time| will be the time since the sampling start until the Source value output.

-0.09 to -0.0001 s, resolution 0.0001 s.

Base Hold Time:

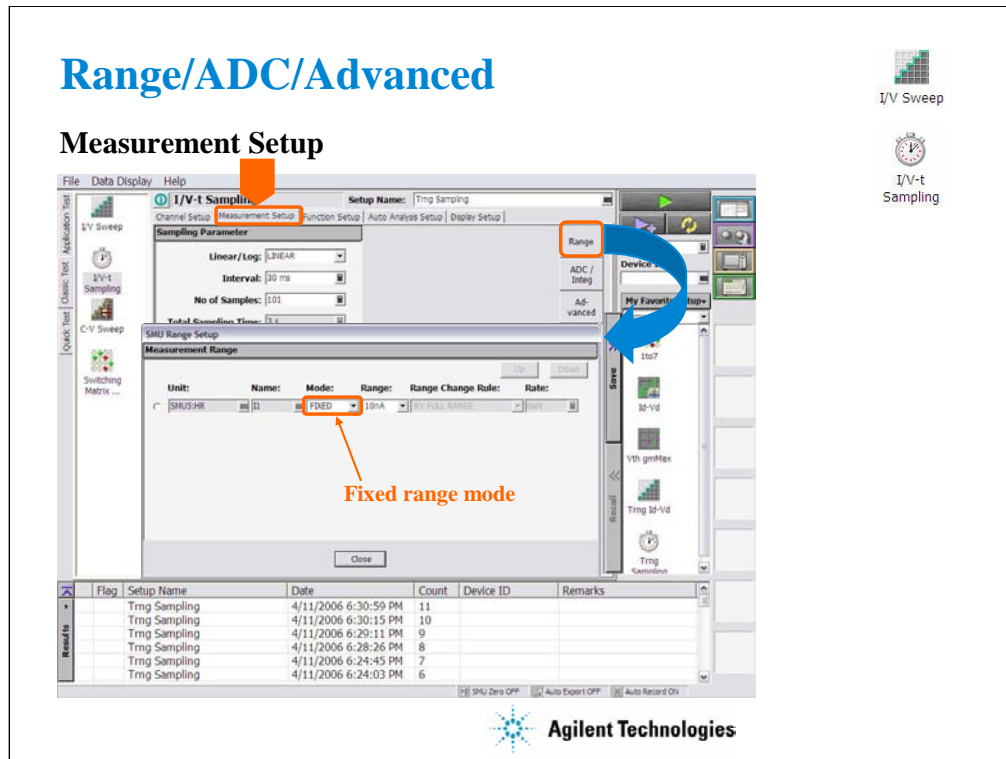
Hold time of the Base value output until the Source value output, in seconds. 0 to 655.35 s, resolution 0.01 s.



At the Constants area, you set the SMU constant output.

- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Mode: Source output mode, V (voltage), I (current), or COMMON (ground)
- Base and Source: SMU output value
- Compliance: SMU compliance value

Base value is available for all output channels for the SIMULTANEOUS mode and the last source channel for the SEQUENTIAL mode.



The Range button opens the SMU Range Setup dialog box.

The ADC/Integ button opens the A/D Converter & Integration Time Setup dialog box.

The Advanced button opens the Advanced Setup dialog box.

For the dialog boxes, see the following pages respectively in the I/V Sweep section of this module.

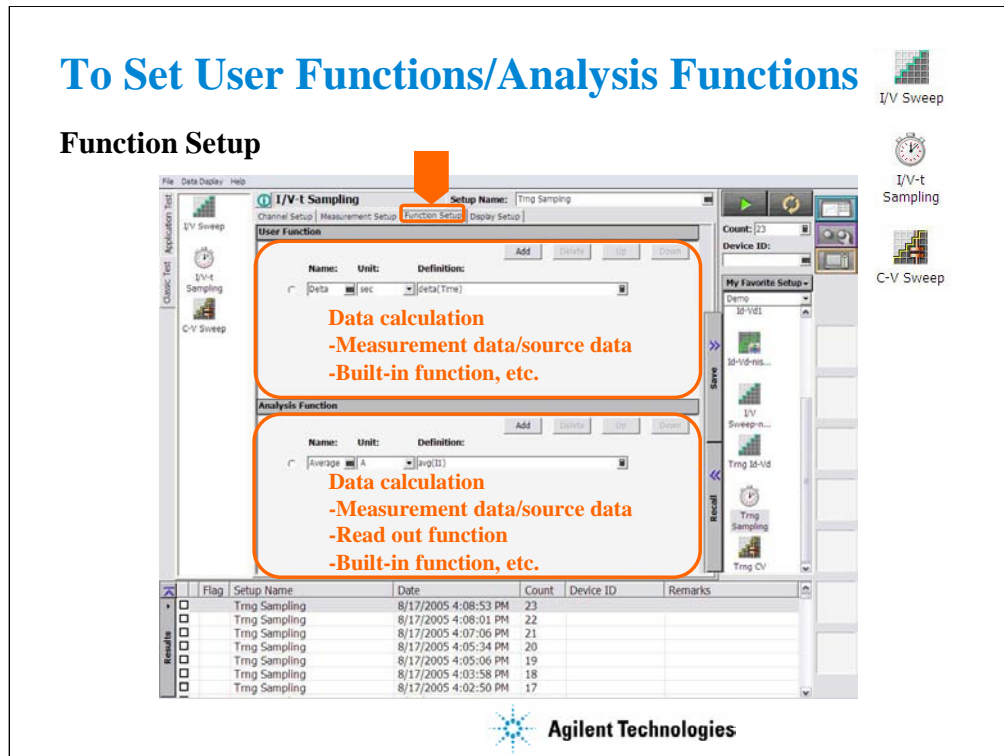
To Set Ranging Mode

To Set ADC/Integration Time

Advanced Setup

Note:

If the range changing occurs during measurement, the SMU may not complete measurement within the sampling interval. So use FIXED range if the sampling interval is top priority and the resolution/sensitivity is second priority.



Click the Function Setup tab to display the User Function/Analysis Function setup screen.

The user functions can be displayed on the X-Y Graph Plot, List Display, and Parameters area of the Data Display window. Up to 20 functions can be set.

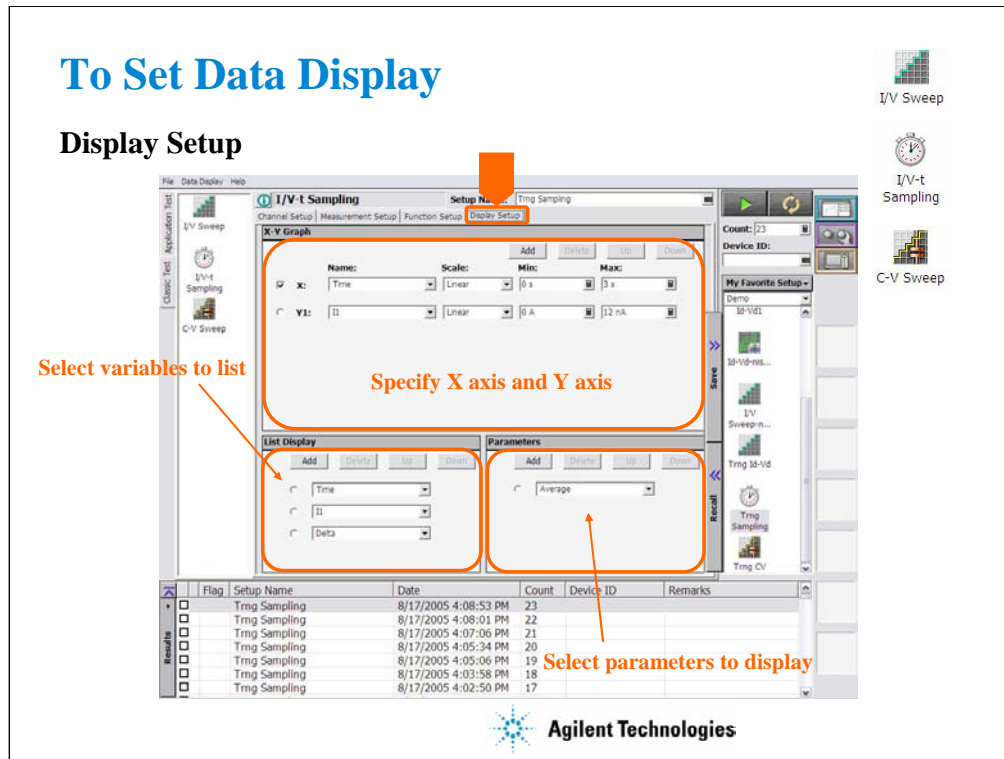
- Name: Function name
- Unit: Unit of the function
- Definition: Definition of the function. The following identifiers can be used.
 - Variables for the measurement/output data used in this test
 - Functions defined in the above lines
 - Local variables passed from the application test that calls this test as a component
 - Built-in functions and global variables

For details, see online help or User's Guide.

The analysis functions can be displayed on the Parameters area of the Data Display window. Up to 20 functions can be set.

- Name: Function name
- Unit: Unit of the function
- Definition: Definition of the function. The following identifiers can be used.
 - Variables for the measurement/output data used in this test
 - Functions defined in the above lines
 - Local variables passed from the application test that calls this test as a component
 - Built-in functions and global variables
 - Read out functions

For details, see online help or User's Guide.



Click the Display Setup tab to display the display setup screen. The X-Y Graph area is used to set the X axis and Y axis of the X-Y Graph Plot area in the Data Display window.

- Name: Name of variable to plot on the X axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

The List Display area selects the variables to be listed in the List Display area of the Data Display window. Up to 20 variables can be set.

The Parameters area selects the variables to be listed in the Parameters area of the Data Display window. Up to 20 parameters can be set.

Class Exercise



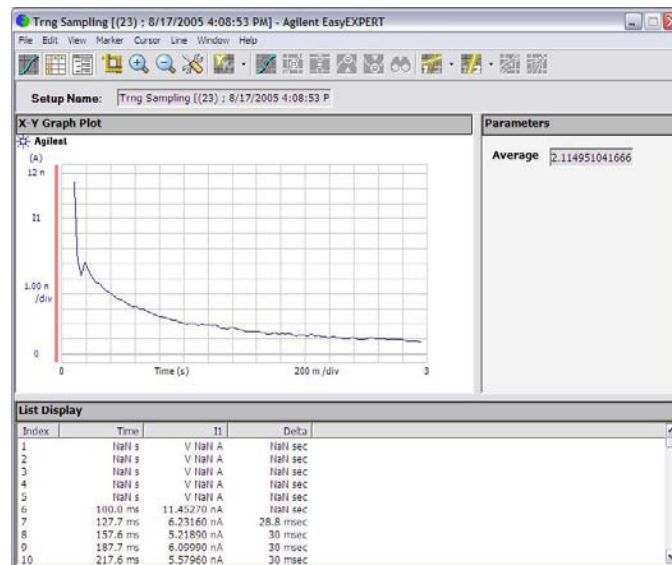
Define test setup and perform test.

1. Click I/V-t Sampling icon and open setup editor.
2. Define test setup as shown in the previous pages.
3. Save it as Trng Sampling.
4. Connect device (capacitance), and perform test.
5. Export preset group, and import it.



Note:

Measurement Result Example



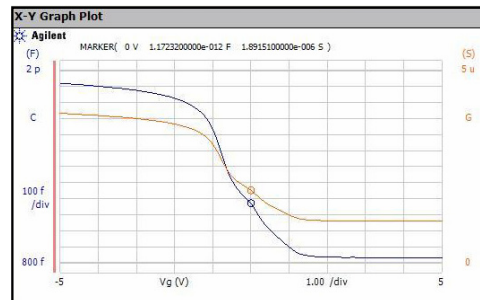
This is a test result example displayed on the Data Display window.

C-V Sweep Measurement



C-V Sweep

- To Define Channels and Variables
- To Set Sweep Source
- To Set Signal Source
- To Set Measurement Timing and Abort Function
- To Set SMU Outputs (CONST)
- Range/Advanced
- To Set User Functions/
Analysis Functions
- To Set Data Display
- To Perform Compensation
and Correction



 Agilent Technologies

This section explains how to perform C-V sweep measurement. You will perform the above tasks to execute the C-V sweep measurement.

To Define Channels and Variables

Channel Setup

Setup Name

Channel Definition

- CMU/SMU
- V name/I name
- I/V/COMMON

Miscellaneous Variables

Time Stamp Name: Time Index Name: Index

Flag	Setup Name	Date	Count	Device ID	Remarks
	Tmg CV	8/17/2005 12:43:32 PM	20		
	Tmg CV	8/17/2005 12:42:53 PM	19		
	Tmg CV	8/17/2005 12:41:58 PM	18		
	Tmg CV	8/17/2005 12:40:35 PM	17		
	Tmg CV	8/17/2005 12:39:33 PM	16		
	Tmg CV	8/17/2005 12:39:02 PM	15		
	Tmg CV	8/17/2005 12:37:36 PM	14		

Variable name for time stamp data

Variable name for data index

Click the C-V Sweep icon and open the setup editor. Then click the Channel Definition tab to display the channel definition screen.

- Enter the Setup Name for the test setup to be defined on the setup editor.
- List units used for source output or measurement, and set the following parameters.
 - Unit: MFCMU/SMU name or number
 - V Name: Variable name for the voltage measurement or source data
 - I Name: Variable name for the current measurement or source data
 - Mode: Source output mode, V (voltage), I (current), or COMMON (ground)
 - Time Stamp Name: Variable name for the time stamp data
 - Index Name: Variable name for the data index

You can read measurement data by using the Data Display window. Parameters displayed on the window are selected on the Display Setup tab screen. If you enter the variable name in the V Name, I Name, Time Stamp Name, and/or Index Name entry fields, you can choose the variables as the display parameters.

- The time stamp is the time the measurement is started for each measurement point.
- The index is the index number for each measurement data.

To Set Sweep Source

Measurement Setup

CV sweep

Stop
↓ Step
Start

Agilent Technologies

The Measurement Setup tab screen is used to set the source output and timing parameters.

At the C-V area, you set the DC bias output of the MFCMU.

- V Name: Variable name of the MFCMU output
- Model: MFCMU measurement mode. Primary and secondary measurement parameters. Select one from the following four models.
 - Cp-G: Parallel capacitance (F) and Conductance (S)
 - Cp-D: Parallel capacitance (F) and Dissipation factor
 - Cs-Rs: Series capacitance (F) and Series resistance (ohm)
 - Z-Th: Impedance (ohm) and Phase (degree)
- C/Z Name: Variable name of the primary measurement parameter, C or Z
- G/D/R/Th Name: Variable name of the secondary measurement parameter, G, D, R, or Th
- Direction: Sweep direction, single (start to stop) or double (start to stop to start)
- Start: Source output start value
- Stop: Source output stop value
- Step: Source output incremental step value
- No of Step: Number of sweep steps

To Set Signal Source

C-V Sweep

Measurement Setup

The screenshot shows the 'C-V Sweep' measurement setup interface. The 'Measurement Setup' tab is active. The 'Signal Source' section is highlighted with an orange box. It contains the following parameters:

- Frequency List:** 1 MHz
- F Name:** Freq
- AC Level:** 30 mV
- Integration Time:** Mode: PLC, Factor: 2
- Timing:** Hold: 0 s, Delay: 0 s, * Sweep: CONTINUE AT ANY status
- Constants:** (Empty table)

Agilent Technologies

At the Signal Source area, you set the MFCMU output frequency and oscillator level.

- Frequency List: MFCMU output frequency
- F Name: Variable name of MFCMU output frequency
- AC Level: MFCMU oscillator level, 10 mV to 250 mV, 1 mV resolution

To Set Meas. Timing and Abort Function

Measurement Setup

Integration time (AUTO or PLC)

Sweep abort function

CONTINUE AT ANY
STOP AT ANY ABNORMAL

- Range overflow
- MFCMU error
- SMU compliance
- SMU oscillation

Trigger

Measurement time

Delay time

Hold time

Timing parameters

There is no item to display in this area.

Agilent Technologies

At the Integration Time area, you set the integration time of the impedance measurement by the MFCMU.

- Mode: AUTO or PLC. Rule to decide the integration time. For details, see online help or User's Guide.
- Factor: Coefficient for the reference value of the integration time.

At the Timing area, you set the source output and measurement timing.

- Hold: Source output hold time. Time after the measurement trigger until starting delay time.
- Delay: Measurement start delay time. Time after the hold time until starting measurement.

The Sweep [] status field sets the sweep abort function.

When this field is CONTINUE AT ANY, the sweep measurement is not aborted.

When this field is STOP AT ANY ABNORMAL, the sweep measurement will be aborted when one of the following conditions is detected.

- Measurement range overflow
- MFCMU error
- SMU compliance
- SMU oscillation

To Set SMU Outputs (CONST)

Measurement Setup

The screenshot shows the 'Measurement Setup' window for a 'C-V Sweep'. The 'Measurement Setup' tab is highlighted with an orange box. The 'C-V' section contains the following parameters:

- V Name: Vg
- Model: Cp-G
- C Name: C
- G Name: G
- Direction: Single
- Start: -5 V
- Stop: 5 V
- Step: 100 mV
- No of Step: 101

The 'Signal Source' section contains the following parameters:

- Frequency List: 1 MHz
- F Name: Freq
- AC Level: 30 mV

The 'Integration Time' section contains the following parameters:

- Mode: PLC
- Factor: 2

The 'Timing' section contains the following parameters:

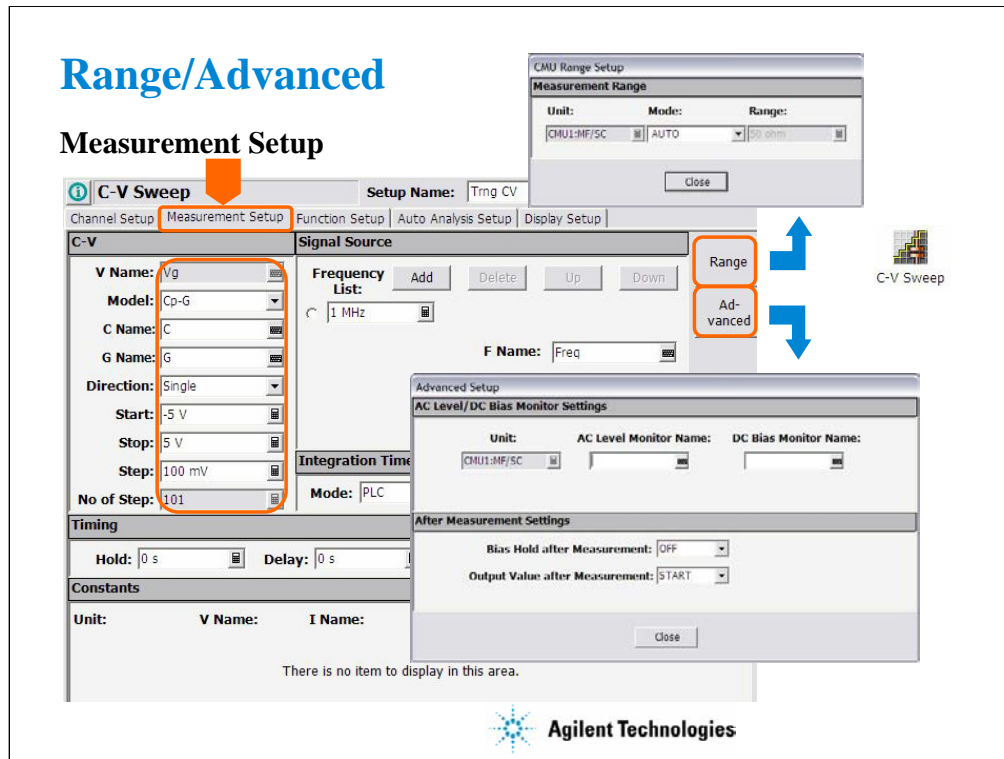
- Hold: 0 s
- Delay: 0 s
- * Sweep: CONTINUE AT ANY status

The 'Constants' section is highlighted with an orange box and contains the text 'SMU output setup' and 'There is no item to display in this area.'

Agilent Technologies

At the Constants area, you set the SMU constant output.

- Unit: SMU name or number
- V Name: Variable name for the voltage measurement or source data
- I Name: Variable name for the current measurement or source data
- Mode: Source output mode, V (voltage), I (current), or COMMON (ground)
- Source: SMU output value
- Compliance: SMU compliance value



The Range button opens the CMU Range Setup dialog box. The dialog box is used to set the measurement ranging operation.

- Unit: CMU name or number
- Mode: Ranging mode, AUTO or FIXED
- Range: Measurement range. This field is effective when Mode=FIXED. Available values are 50 ohm, 100 ohm to 300 kohm ($=<200$ kHz), 100 ohm to 30 kohm ($=<2$ MHz), and 100 ohm to 3 kohm ($=<5$ MHz) in 1, 3 step

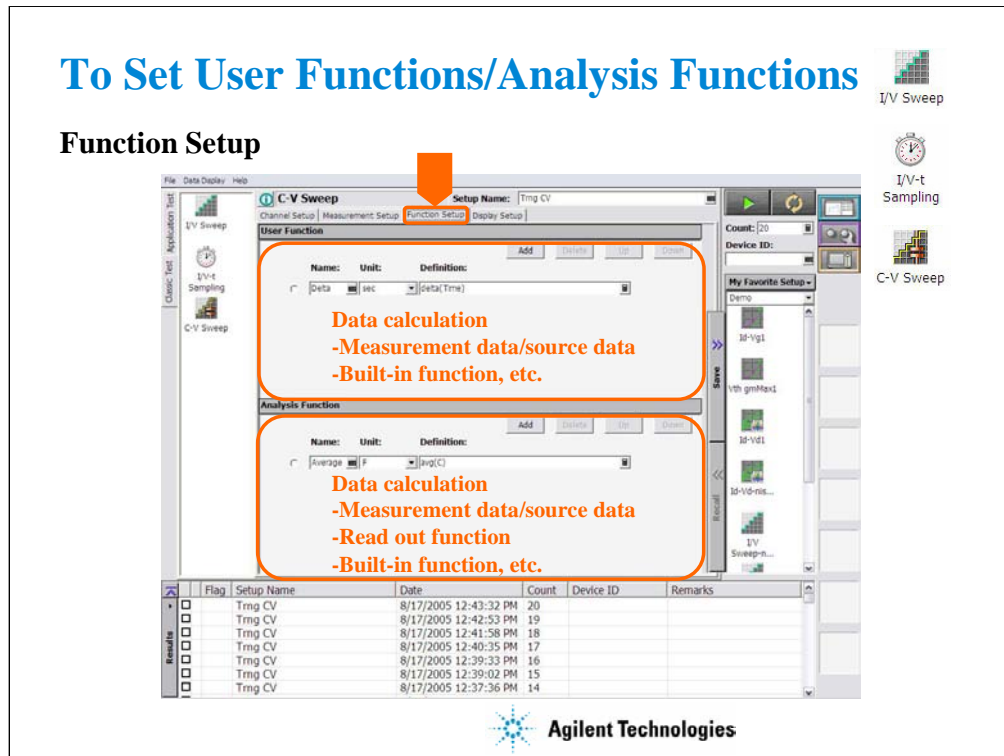
The Advanced button opens the Advanced Setup dialog box used to set the following functions.

AC Level/DC Bias Monitor Settings:

Defines the variables for the AC level data and the DC bias data monitored by the MFCMU while the capacitance measurement is performed.

After Measurement Settings:

- Bias Hold after Measurement: Bias hold function ON or OFF.
- Output Value after Measurement: Source output value after measurement. START (sweep start value) or STOP (sweep stop value)



Click the Function Setup tab to display the User Function/Analysis Function setup screen.

The user functions can be displayed on the X-Y Graph Plot, List Display, and Parameters area of the Data Display window. Up to 20 functions can be set.

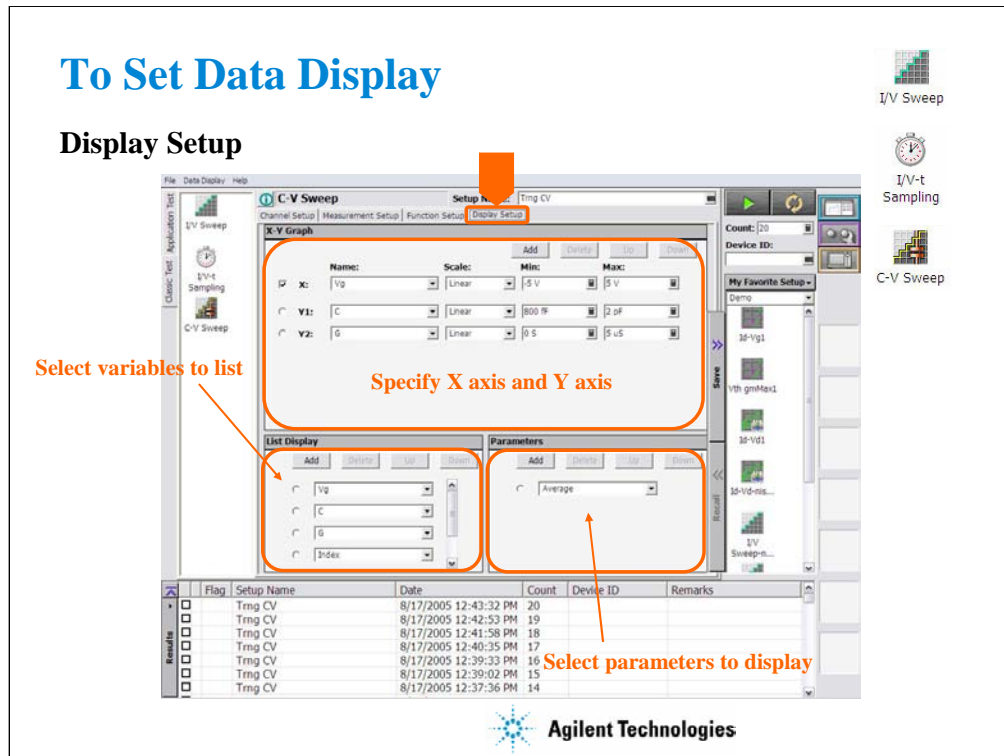
- Name: Function name
- Unit: Unit of the function
- Definition: Definition of the function. The following identifiers can be used.
 - Variables for the measurement/output data used in this test
 - Functions defined in the above lines
 - Local variables passed from the application test that calls this test as a component
 - Built-in functions and global variables

For details, see online help or User's Guide.

The analysis functions can be displayed on the Parameters area of the Data Display window. Up to 20 functions can be set.

- Name: Function name
- Unit: Unit of the function
- Definition: Definition of the function. The following identifiers can be used.
 - Variables for the measurement/output data used in this test
 - Functions defined in the above lines
 - Local variables passed from the application test that calls this test as a component
 - Built-in functions and global variables
 - Read out functions

For details, see online help or User's Guide.

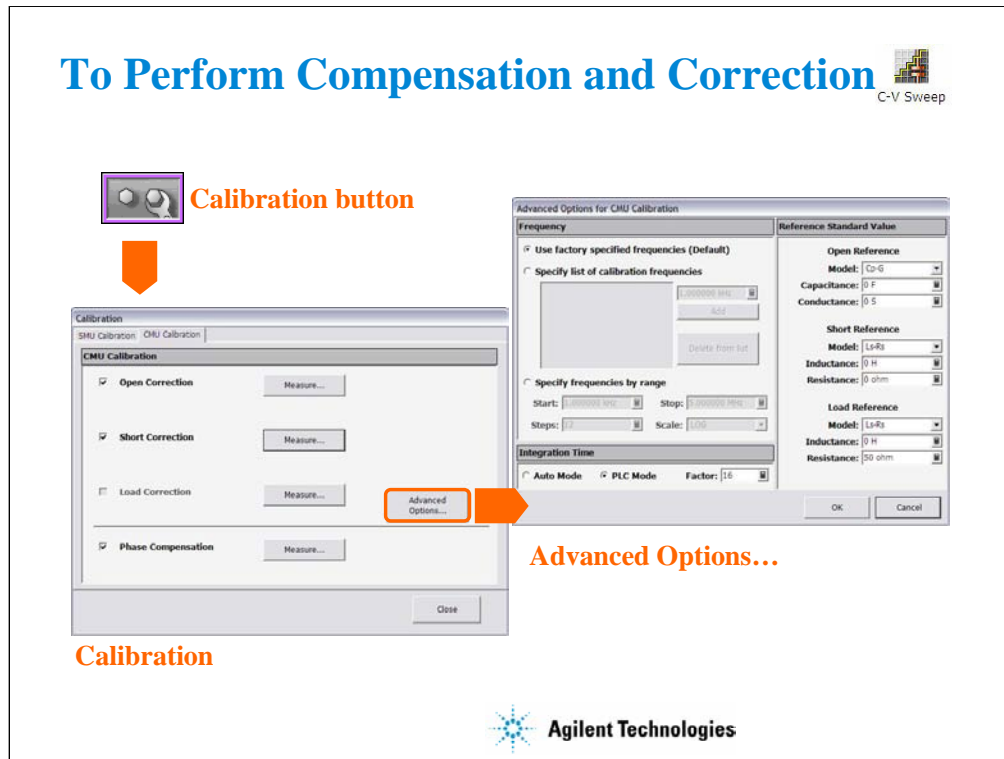


Click the Display Setup tab to display the display setup screen. The X-Y Graph area is used to set the X axis and Y axis of the X-Y Graph Plot area in the Data Display window.

- Name: Name of variable to plot on the X axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

The List Display area selects the variables to be listed in the List Display area of the Data Display window. Up to 20 variables can be set.

The Parameters area selects the variables to be listed in the Parameters area of the Data Display window. Up to 20 parameters can be set.



The 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.

- Phase compensation: Corrects phase error caused by extending measurement cables.
- Open correction: Corrects for stray admittance. Effective for high impedance measurements.
- Short correction: Corrects for residual impedance. Effective for low impedance measurements.
- Load correction: Corrects any error by using the working standard (load standard).

Click the Calibration button to open the Calibration window. And click the CMU calibration tab on the window to perform the compensation and correction data measurement.

- To measure the phase compensation data, open the measurement terminals at the end of the device side and click the Measure... button.
- To measure the open correction data, open the measurement terminals at the end of the device side and click the Measure... button.
- To measure the short correction data, connect the measurement terminals together at the end of the device side and click the Measure... button.
- To measure the load correction data, connect the load standard that has the reference value or calibration value. Then, click the Measure... button.

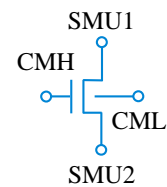
For details of the error correction (CMU calibration) and the Advanced Options, see online help or User's Guide. The Advanced Options window is used for the compensation/correction data measurement setup.

Class Exercise



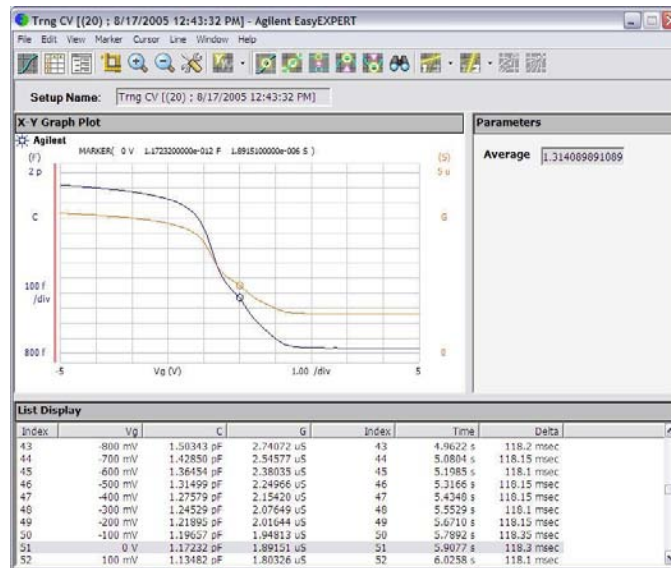
Define test setup and perform test.

1. Click C-V Sweep icon and open setup editor.
2. Define test setup as shown in previous pages. And save it as Trng CV.
3. Open measurement terminals, and perform phase compensation and open correction.
4. Connect device, and perform test.
5. Export preset group, and import it.



Note:

Measurement Result Example



This is a test result example displayed on the Data Display window.

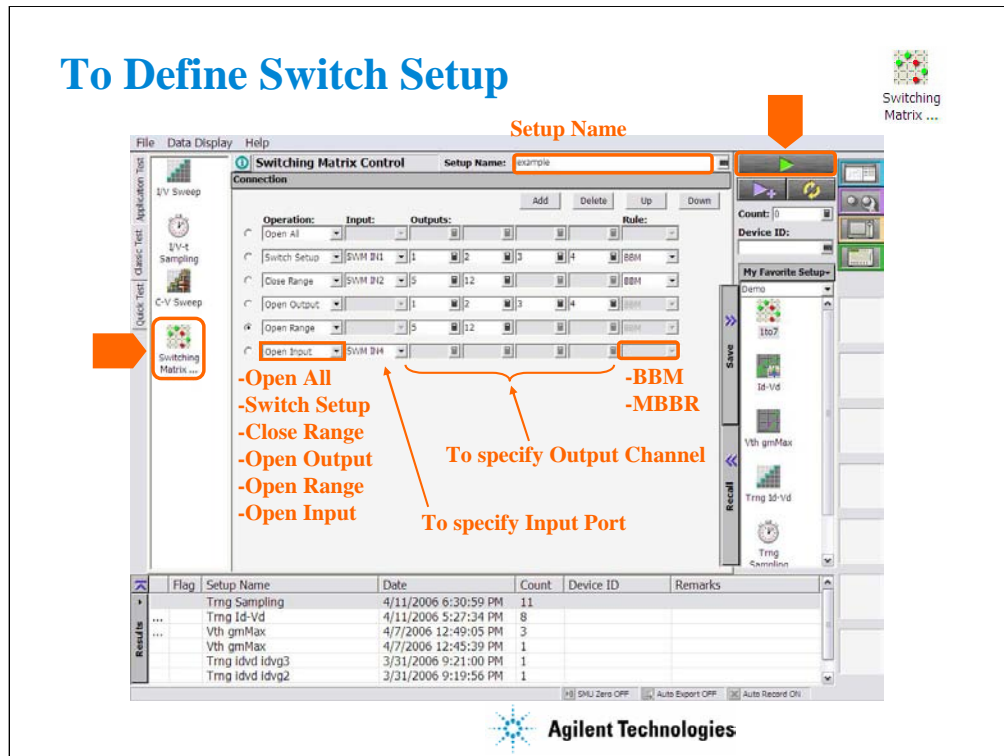
Switching Matrix Control



- To Define Switch Setup



This section explains how to define the switch setup for B2200 Switching Matrix.



This setup screen is used to create the relay control setup (switch setup) for Agilent B2200A/B2201A Switching Matrix.

To send the switch setup to B2200, click the Single button. Before doing this, you have to establish the GPIB connection to B2200 by using the Switching Matrix tab screen of the Configuration window and B1500A is set to system controller. See Module 12.

This screen provides the following GUI.

Add: Adds a setup row for relay connection.

Delete: Deletes the setup row. To select the setup row, use the left radio button.

Up: Moves the selected setup row upward.

Down: Moves the selected setup row downward. The setup row provides the following entry fields.

Operation: Relay control operation. Open All, Switch Setup, Close Range, Open Output, Open Range, or Open Input. See the next page.

Input: B2200 input port number or label. Available for the Switch Setup, Close Range, and Open Input operations.

Outputs: B2200 output channel number or label. Four entry fields are available for the Switch Setup and Open Output operations to specify the output channels. Two entry fields are available for the Close Range and Open Range operations to specify the range of output channels.

Rule: Relay connection rule. BBM or MBBR.

- BBM: Breaks the previous connection and then makes the new connection for the specified outputs.
- MBBR: Makes the new connection and then breaks the previous connection for the specified outputs.

Operation and number of Outputs



Operation	Description	Number of Outputs
Open All	Opens all relays.	0
Switch Setup	Makes the connection from the specified input port to the specified output channels. Up to four output channels can be specified at once.	4
Close Range	Makes the connection from the specified input port to the specified output channels. They are between two channels given by the Outputs fields.	2
Open Output	Opens the relays connected to the specified output channels. Up to four output channels can be specified at once.	4
Open Range	Opens the relays connected to the specified output channels. They are between two channels given by the Outputs fields.	2
Open Input	Opens the relays connected to the specified input port.	0



Note:

Class Exercise



Define switch setup and send it to B2200.

1. **Click Switching Matrix Control icon and open setup editor.**
2. **Define switch setup as you want. And save it as Trng Switch.**
3. **If B2200 is available, establish the GPIB connection between B1500 (must be set to system controller) and B2200, and apply your switch setup.**



Note:

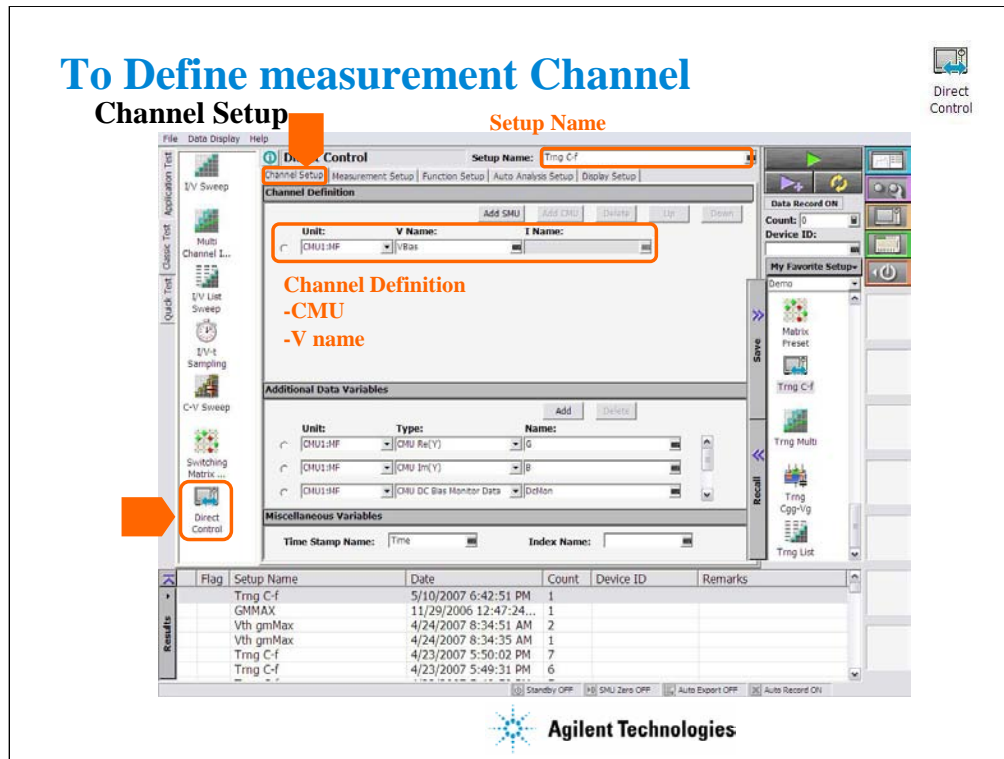
Direct Control



- **To define measurement channel.**
- **To set Measurement Data Variables and Miscellaneous Variables.**
- **To set Agilent FLEX commands.**
- **To set User Functions.**
- **To set Data Display.**



This section explains how to use Direct Control to perform various measurements (e.g. C-f measurement, Quasi-Static C-V measurement) using Agilent FLEX commands. You will perform the above tasks to use Direct Control (C-f measurement for example).



Click the Direct Control icon and open the setup editor. Then click the Channel Setup tab to display the channel definition screen.

- Enter the Setup Name for the test setup to be defined on the setup editor.
- Add CMU used for measurement.

To Set Measurement Data and Miscellaneous Variables

Channel Setup

Types and Names for Measurement Data Variables

Unit	Type	Name
CMU1:MF	CMU Re(Y)	G
CMU1:MF	CMU Im(Y)	B
CMU1:MF	CMU DC Bias Monitor Data	DcMon

Time Stamp Name: Time

Flag	Setup Name	Date	Count	Device ID	Remarks
	Trng C-f	5/10/2007 6:42:51 PM	1		
	GMMAX	11/29/2006 12:47:24...	1		
	Vth gmMax	4/24/2007 8:34:51 AM	2		
	Vth gmMax	4/24/2007 8:34:35 AM	1		
	Trng C-f	4/23/2007 5:50:02 PM	7		
	Trng C-f	4/23/2007 5:49:31 PM	6		

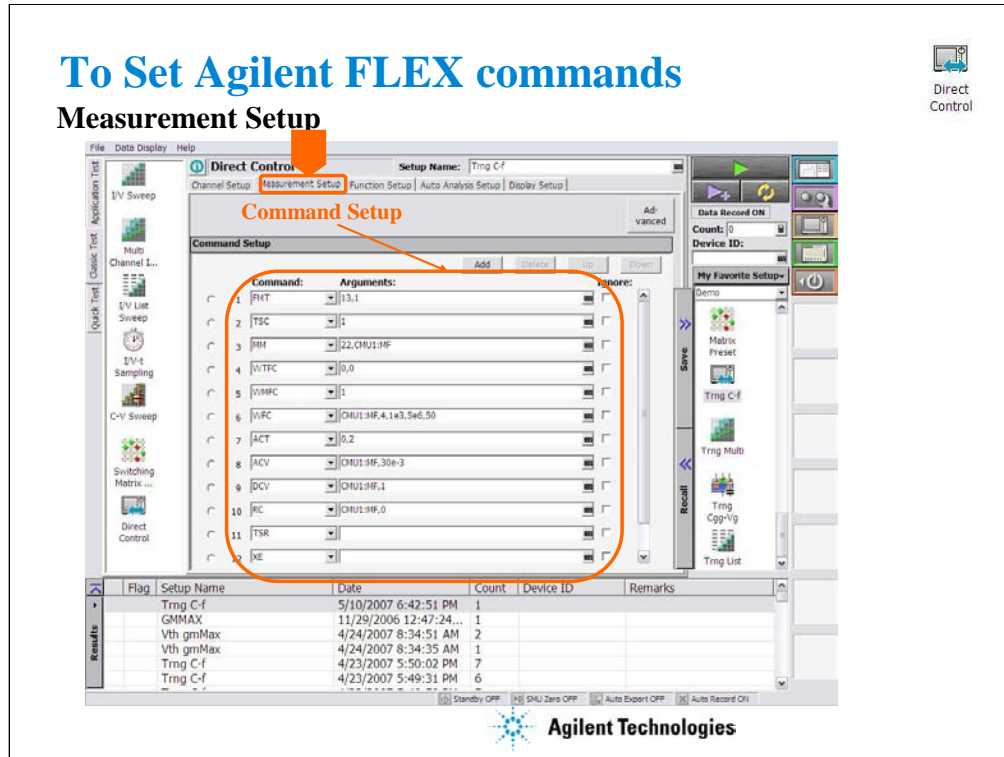
Variable name for time stamp data

Agilent Technologies

You can read measurement data by using the Data Display window. Parameters displayed on the window are selected on the Display Setup tab screen. If you enter the variable name in entry fields, you can choose the variables as the display parameters.

For example, following Measurement Data Variables are set for the C-f Sweep Measurement.

<Unit>	<Type>	<Name>
CMU1:MF	CMU Re(Y)	G
CMU1:MF	CMU Im(Y)	B
CMU1:MF	CMU DC Bias Monitor Data	DcMon
CMU1:MF	CMU AC Level Monitor Data	AcMon
CMU1:MF	CMU Frequency	Freq

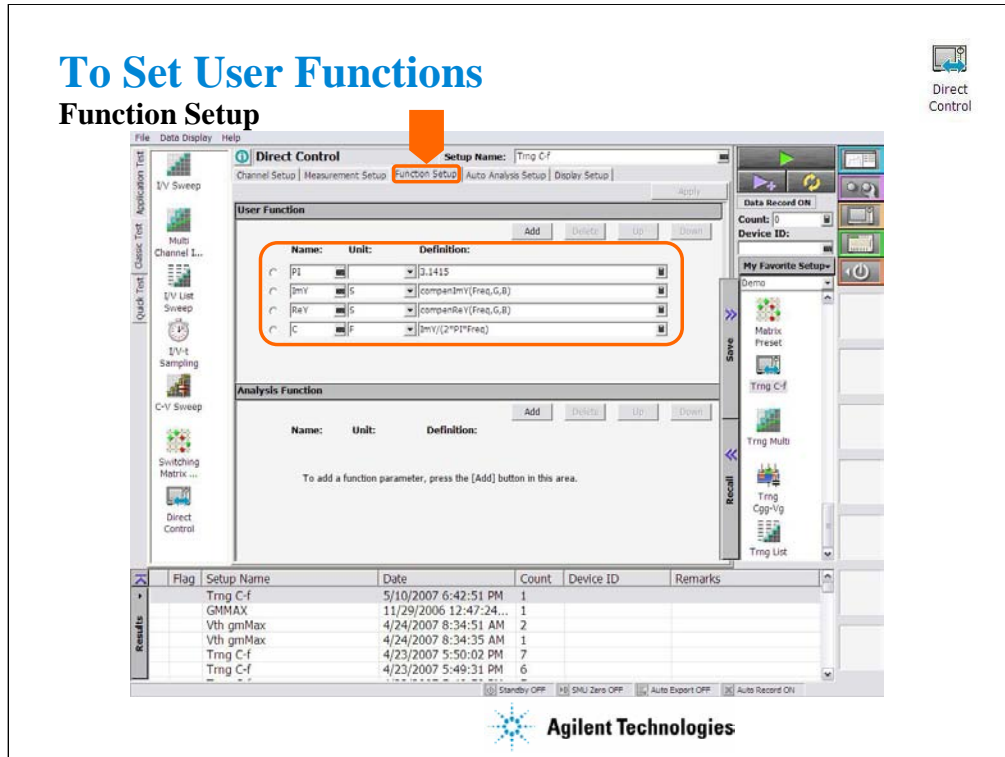


The Measurement Setup tab screen is used to set Agilent FLEX commands for measurement. For example, following FLEX commands are set for the C-f Sweep Measurement.

<Command>	<Arguments>
1 FMT	13,1
2 TSC	1
3 MM	22,CMU1:MF
4 WTFC	0,0
5 WMFC	1
6 WFC	CMU1:MF,4,1e3,5e6,50
7 ACT	0,2
8 ACV	CMU1:MF,30e-3
9 DCV	CMU1:MF,1
10 RC	CMU1:MF,0
11 TSR	
12 XE	
13 ReadDataBuffer	

See B1500A Programming Guide for more details about FLEX commands.

To Set User Functions Function Setup



Click the Function Setup tab to display the User Function/Analysis Function setup screen. The user functions can be displayed on the X-Y Graph Plot, List Display, and Parameters area of the Data Display window. Up to 20 functions can be set.

Name: Function name

Unit: Unit of the function

Definition: Definition of the function. The following identifiers can be used.

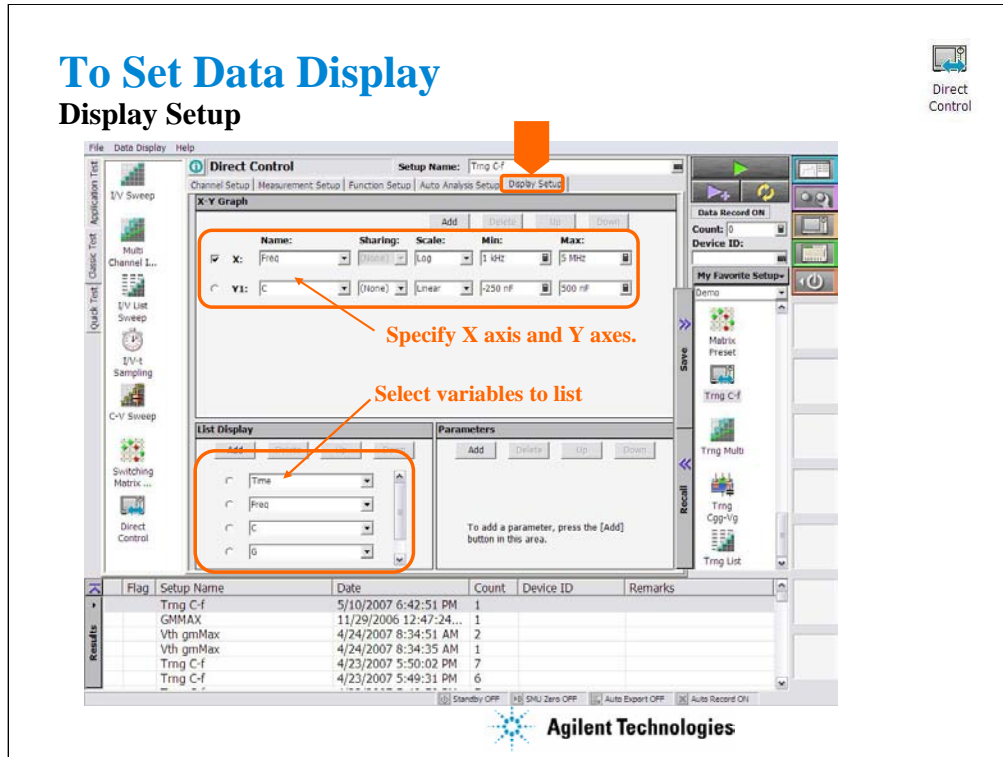
- Variables for the measurement/output data used in this test
- Functions defined in the above lines
- Local variables passed from the application test that calls this test as a component
- Built-in functions and global variables

For details, see online help or User's Guide.

For example, following user functions are set for C-f Sweep Measurement.

<Name> <Unit> <Definition>

PI		3.1415
ImY	S	compenImY(Freq,G,B)
ReY	S	compenReY(Freq,G,B)
C	F	ImY/(2*PI*Freq)



Click the Display Setup tab to display the display setup screen. The X-Y Graph area is used to set the X axis and Y axes of the X-Y Graph Plot area in the Data Display window.

- Name: Name of variable to plot on the axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

For example, following axes are set for the C-f Sweep Measurement.

	<Name>	<Scale>	<Min>	<Max>
X	Freq	Linear	1 kHz	5 MHz
Y1	C	Linear	-250 nF	500 nF

The List Display area selects the variables to be listed in the List Display area of the Data Display window. Up to 20 variables can be set.

For example, following variables are set for the C-f Sweep Measurement.

Time, Freq, C, G, B

Class Exercise

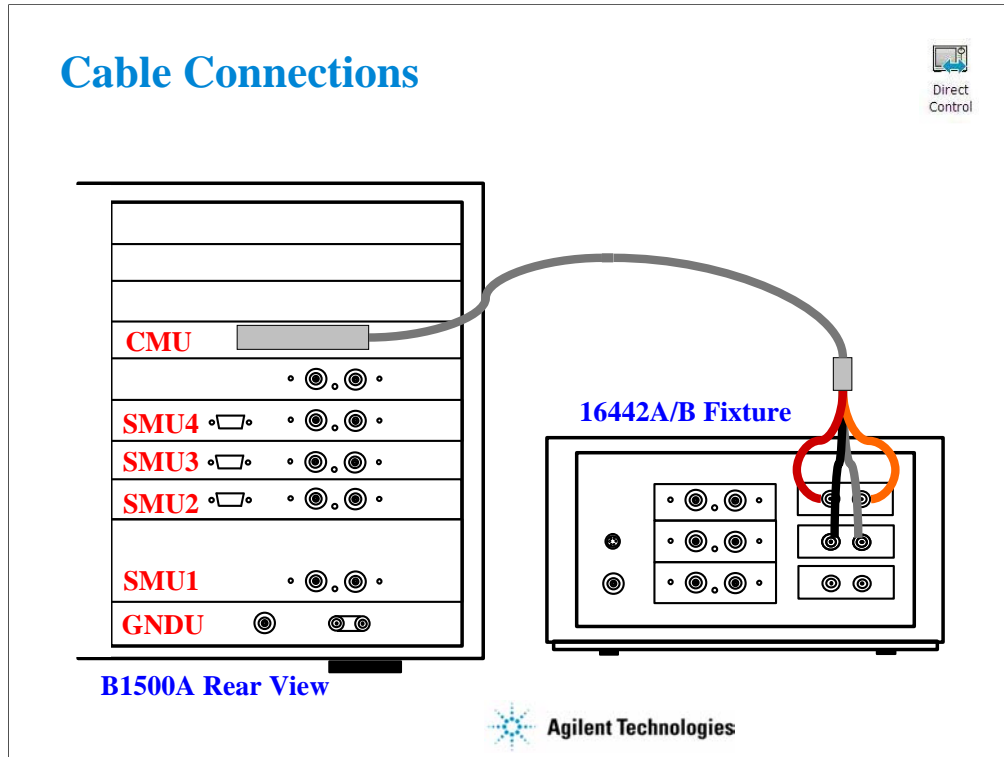


Define test setup and perform test.

1. **Click Direct Control icon and open setup editor.**
2. **Define test setup as shown in the previous pages.**
3. **Save it as Trng C-f.**
4. **Connect a device (capacitance) as shown in next several pages, and perform test.**
5. **Export preset group, and import it.**



Note:



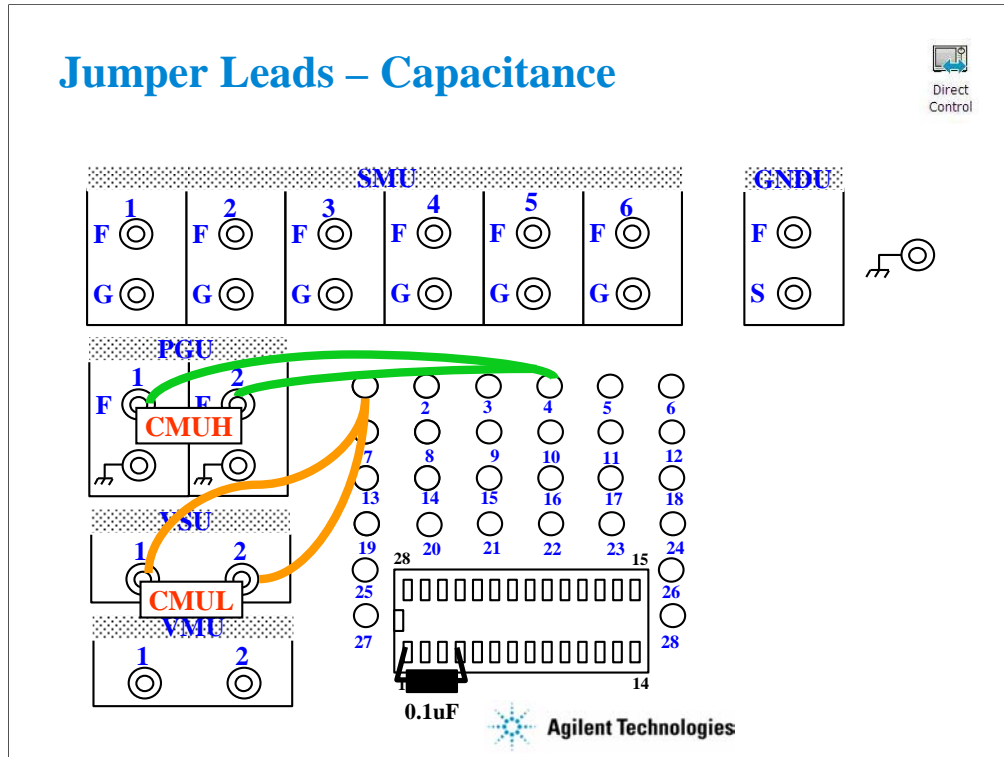
The following cables are required to perform this class exercise.

CMU cable (Agilent N1300A-001/002), 1 ea.

One side of the CMU cable forms the attachment used to join and fix it to the CMU. And the other side provides four BNC connectors used to connect the fixture as shown.

Connect the cables between the B1500A and the test fixture as follows.

- Hcur : PGU1 (red)
- Hpot : PGU2 (orange)
- Lcur : VSU1 (black)
- Lpot : VSU2 (gray)

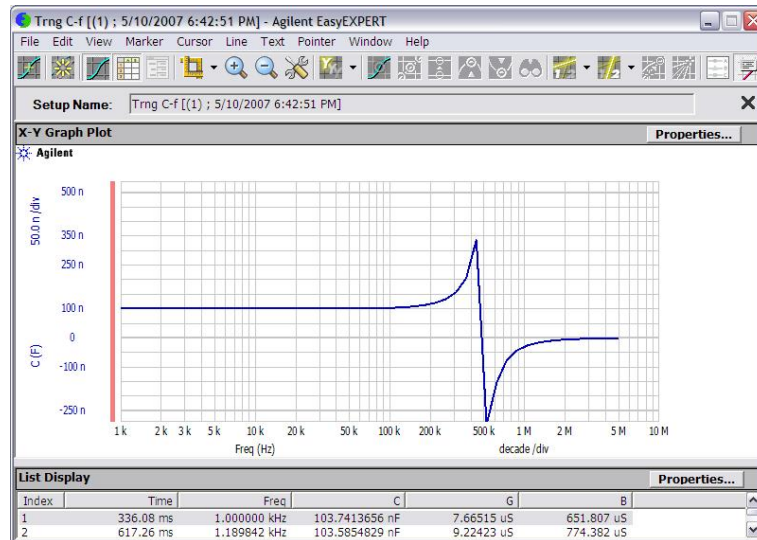


For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

This class exercise requires four jumper leads to connect the DUT. Connect the jumper leads between the following terminals.

- PGU1 : terminal 1
- PGU2 : terminal 1
- VSU1 : terminal 4
- VSU2 : terminal 4

Measurement Result Example



This is a test example displayed on the Data Display window.





5 Basic Measurement

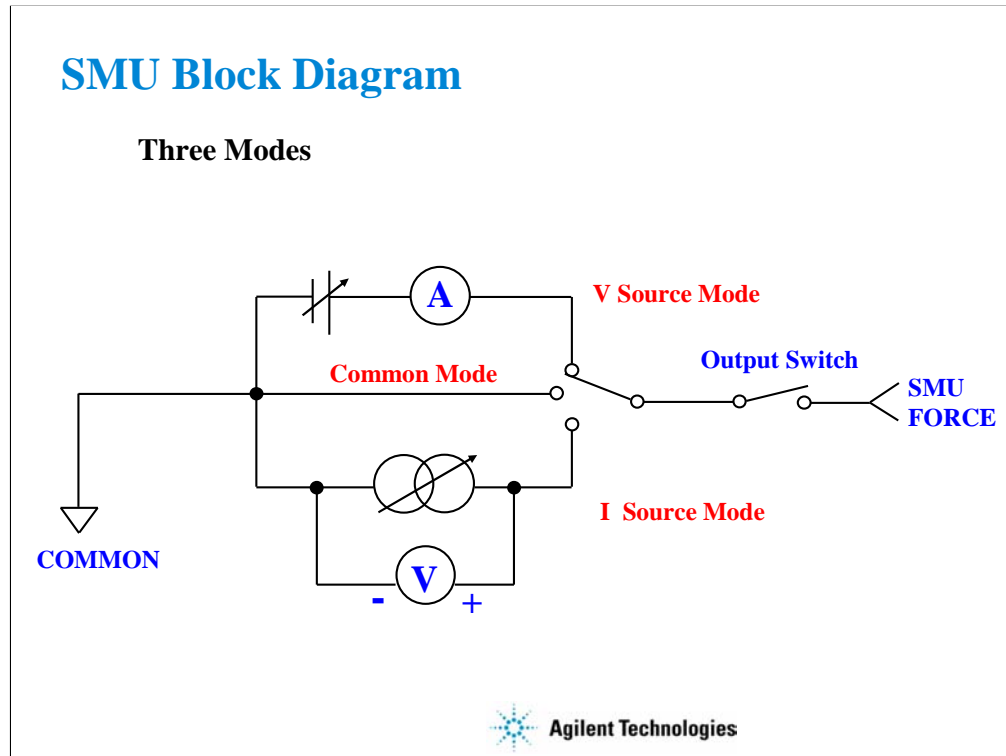


In This Module

- SMU Fundamentals
- Classic Test Environment
- SMUs Connected in Series or Parallel
- Cabling and Fixture Issues
- Kelvin and Driven Guard
- Probes and Prober Connections
- Triax and Coax Adapters
- Safety Interlock Issues



Note:



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

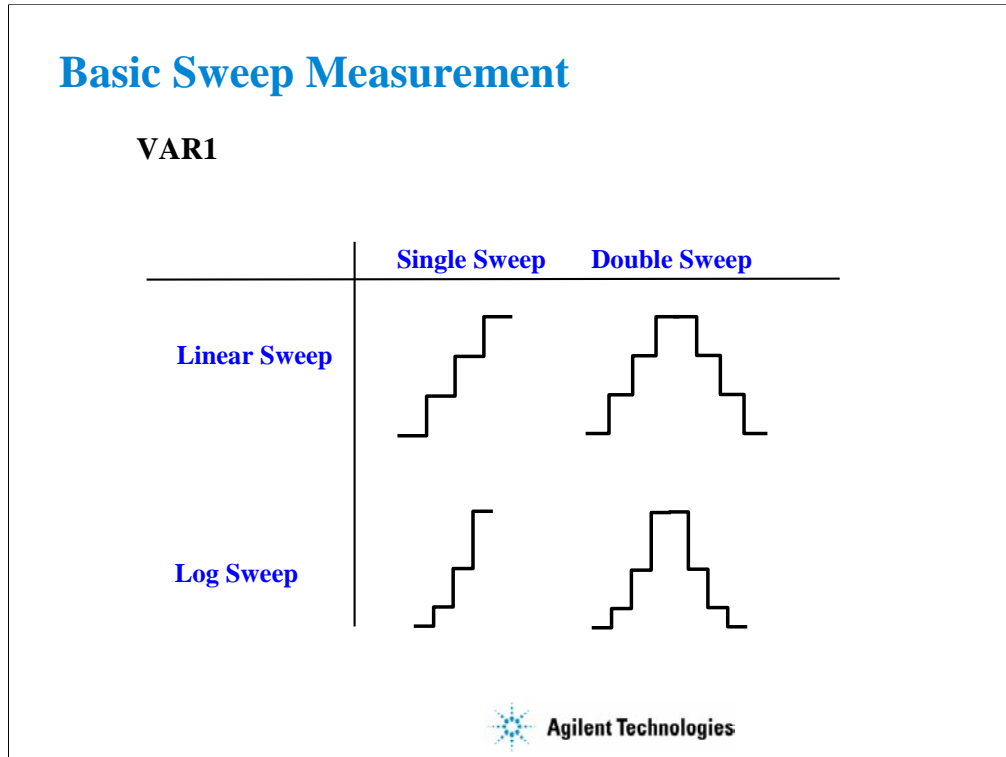
- Voltage source while monitoring current
- Current source while monitoring voltage
- Source common with no monitor

The SMUs on the B1500A 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).



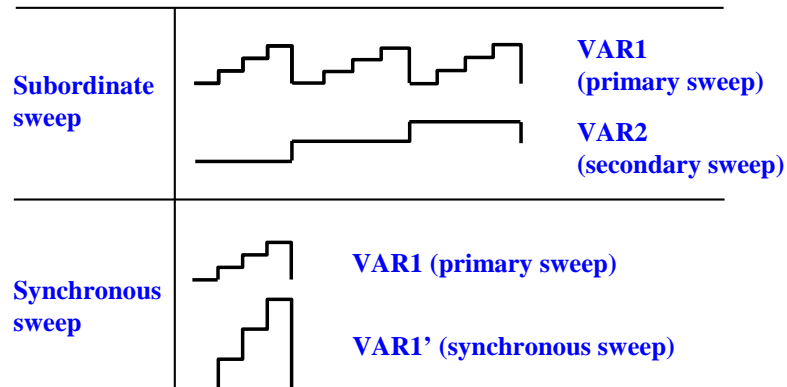
The SMUs can now sweep up to a value and then back down (double sweep). This feature is useful when the device must be tested without abruptly removing the forcing condition.

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

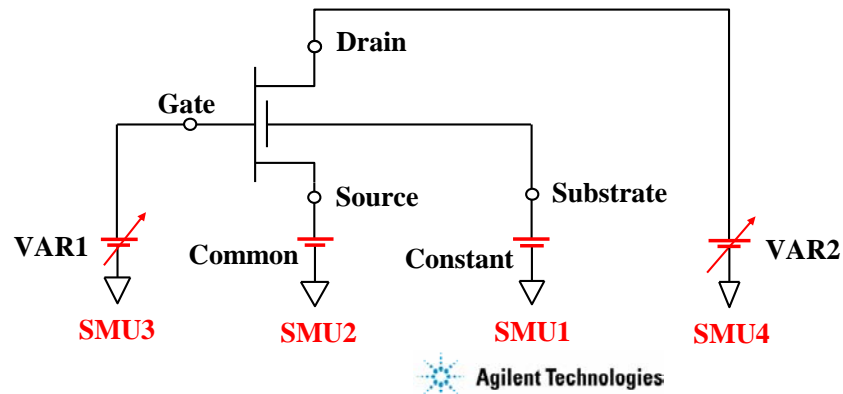


A subordinate sweep variable (VAR2) may be combined with the basic sweep variable (VAR1). This corresponds to the step knob and sweep knob of a curve tracer. This produces a family of curves. VAR2 may be called the secondary sweep.

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.

Why Four SMUs?


- Four terminal MOS device
- Only one configuration required
- Speed up testing



The basic semiconductor device is the 4-terminal MOS transistor. By assigning an SMU to each terminal, you have complete flexibility to make any measurement without having to change the device hookup. No relays are required to switch any connection; this is all done by changing the mode of the SMU from the front panel.

Class Exercise

MOS Id vs Vd Basic Measurement

- You will connect the SMU cables and jumper leads
- You will then "properly" insert the MOS transistor
- You will learn how to load a setup data
- Observe Classic Test setup screen
- Click  button to make a new measurement
- Observe Application Test setup screen

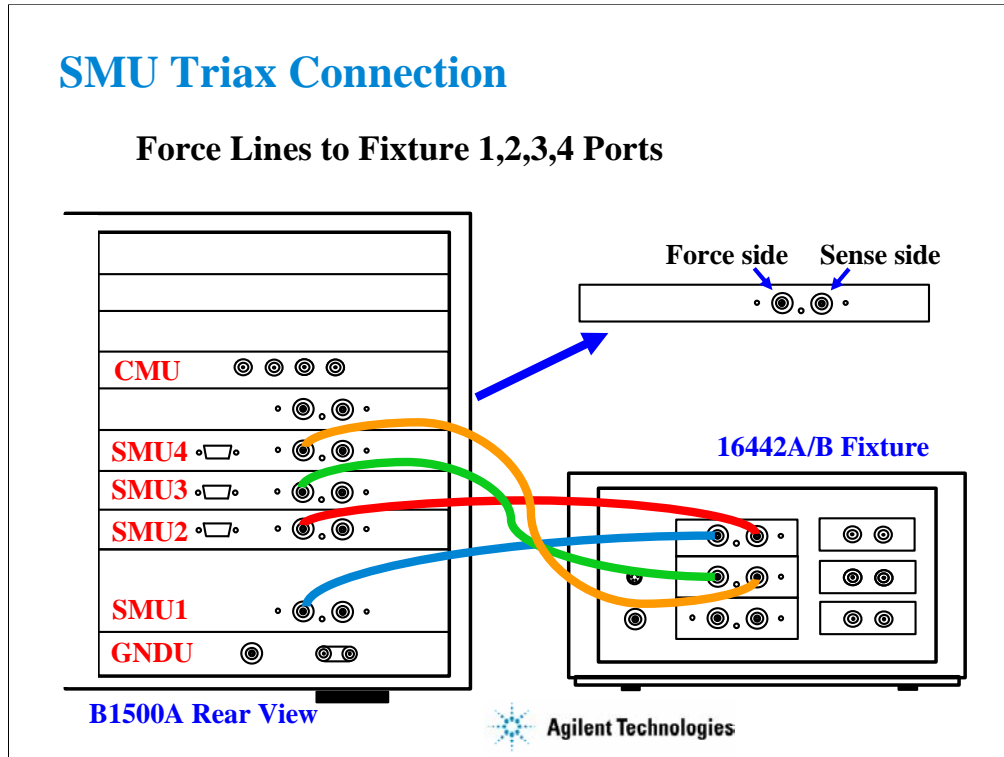
To Get Started:

- Use the next several pages as you guide
- Verify that four triax cables are connected as shown
- Connect four jumper leads to the 28 pin socket as shown
- Insert the MOS transistor using the "anti-static" procedure



The purpose of this class exercise is to familiarize yourself with how to connect a MOS FET device, and make a basic IDVD family of curves measurement. You will observe the Application Test setup screen and the Classic Test setup screen (interrelationship between the Channel Setup, Measurement Setup, Display Setup screen).

The next several pages show how to connect the 4-terminal MOS FET used in this course. The device for this exercise includes a separate substrate pin. This corresponds to the back gate connection. We can observe all characteristics of the device as if we were probing it at the wafer level.



For the non-Kelvin connections, connect only the Force lines, leaving the Sense lines open.

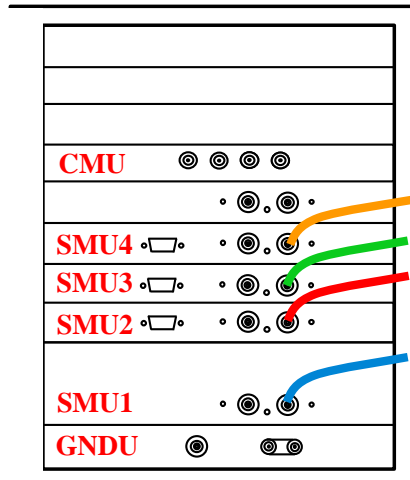
Connect corresponding numbers. On the 16442A/B fixture use the numbers labeled 1 - 6, not 1 - 3.

Your B1500A may not match the SMU configuration shown in this figure. Note that SMU1 is the module top of the GNDU (ground unit). The SMU number become large from bottom to top as shown.

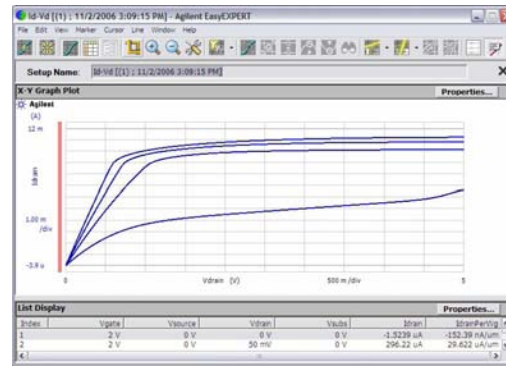
This is the SMU cable setup that will be used in the remainder of the class exercises.

Wrong Triaxial Hookup

If you use the Sense lines ...



B1500A Rear View



Curves clamped at 10 mA level



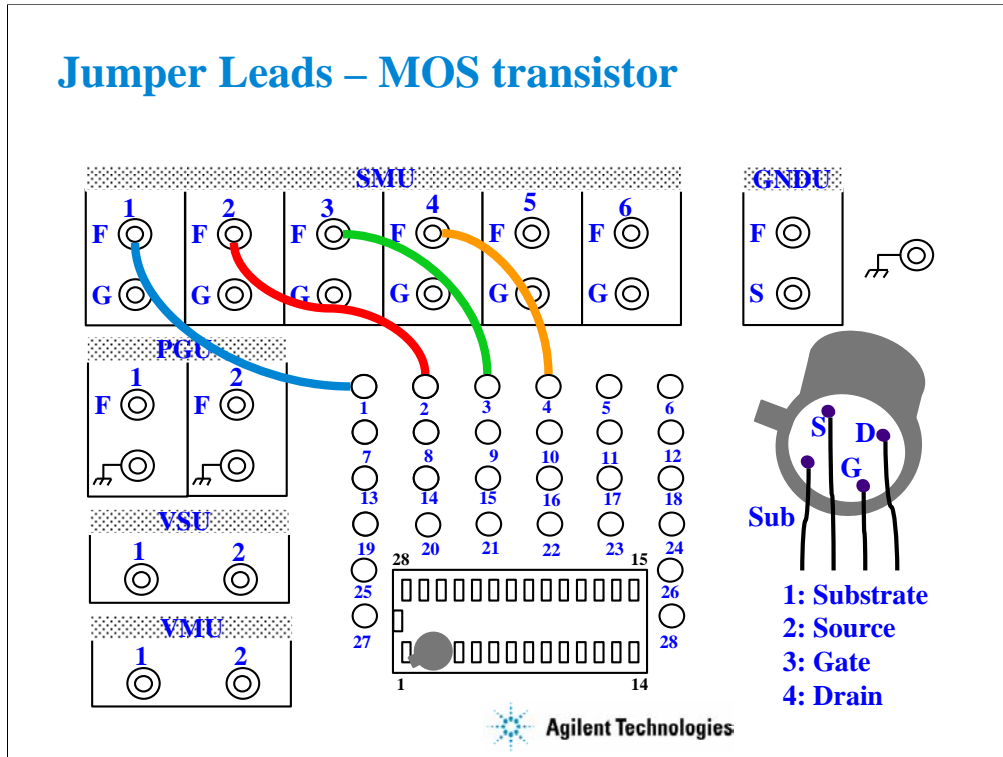
This picture shows the triax cables connected to the right set of connectors which is wrong. The 4 triax cables must be connected to the left set of connectors (FORCE).

You will likely see this type of erroneous response with clamping at 10 mA (no trace above 10 mA even though compliance is set much higher). Also you may see the response with notches at 10 mA level.

The effect is magnified when the SMU measurement ranging is set to AUTO.

This curve was produced using your training class MOS device and the IDVD setup.

No error was seen until the ranging was changed from FIXED 100 mA to AUTO. Then it was evident that the cables were hooked up improperly.

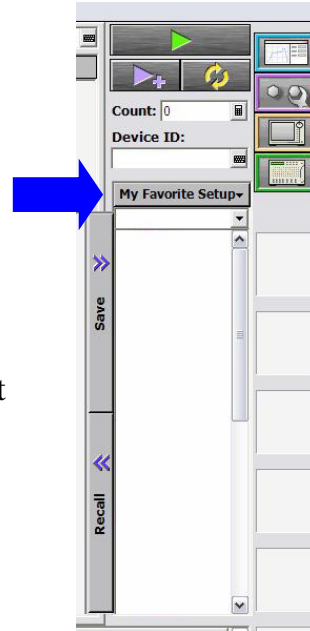


For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme. On older fixtures, this scheme is shown in light blue lettering. In newer fixtures, this scheme is shown in white reverse background lettering.

To Import Demo Data

1. Prepare the Agilent B1500A Manual CD-ROM Edition 4 or later
2. Insert the CD-ROM into the B1500A built-in CD-ROM drive
3. Click My Favorite Setup button
4. Click Preset Group > Import Preset Group ...
5. Import "data\Demo.xpg" on the Manual CD-ROM



The Agilent B1500A Manual CD-ROM stores demo data used for performing this class exercise. Insert the CD-ROM and import the demo data to the EasyEXPERT database. The demo.xpg file contains the test setup data used in this class exercise.

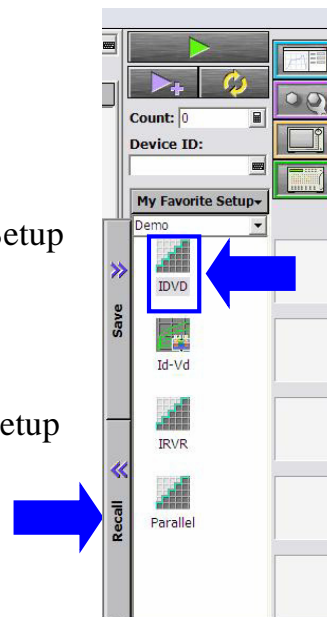
To Get Setup Data

To Get Classic Test Setup:

1. Highlight IDVD in My Favorite Setup
2. Click Recall button

To Get Application Test Setup:

1. Highlight Id-Vd in My Favorite Setup
2. Click Recall button



You can get the test setup data as shown.

IDVD is a sample setup data for Classic Test.

Id-Vd is a sample setup data for Application Test.

Classic Test – Channel Setup

	Unit:	V Name:	I Name:	Mode:	Function:
<input type="checkbox"/>	SMU1:HP	Vsub	Isub	V	CONST
<input type="checkbox"/>	SMU2:HP	Vs	Is	COMMON	CONST
<input type="checkbox"/>	SMU3:HR	Vg	Ig	V	VAR2
<input type="checkbox"/>	SMU4:HR	Vd	Id	V	VAR1



After you get the IDVD setup data, you will see the Classic Test setup screen as shown.

The Channel Setup screen allows the user to assign a meaningful name to the force/meas functions of each SMU. These names may be used in the Function Setup screen to define algebraic expressions.

The Mode column is used to determine whether a particular SMU is to be used to 1) force current and measure voltage (I mode), or 2) force voltage and measure current (V mode). The entry COMMON implies the node is used as "ground."

The Function column defines which SMUs are to be used as swept sources or constant sources. VAR1 is the primary swept source. VAR2 is known as the subordinate swept source, meaning VAR1 will sweep through its range, then VAR2 will step and VAR1 will sweep again. CONST is self-explanatory.

Classic Test – Measurement Setup

The screenshot displays the Measurement Setup interface for a classic test. It is divided into several sections:

- VAR1 and VAR2:** Parameters for two sweep variables. VAR1 (SMU4:HR) has Name: Vd, Direction: Single, Linear/Log: LINEAR, Start: 0 V, Stop: 5 V, Step: 50 mV, No of Step: 101, Compliance: 100 mA, and Pwr Comp: OFF. VAR2 (SMU3:HR) has Name: Vg, Start: 2 V, Stop: 5 V, Step: 1 V, No of Step: 4, Compliance: 10 mA, and Pwr Comp: OFF.
- Timing:** Hold: 0 s, Delay: 0 s.
- Sweep:** * Sweep CONTINUE AT ANY status. A blue arrow points to this dropdown menu with the text "Do not abort on compliance, oscillation, etc." circled in blue.
- Constants:** A table for defining non-swept voltage/current sources.

Unit:	V Name:	I Name:	Mode:	Source:	Compliance:
SMU1:HP	Vsub	Isub	V	0 V	100 mA

Agilent Technologies logo is visible at the bottom center.

The Measurement Setup screen is shown here. The variables VAR1 and VAR2 define the sweep parameters. In a case where two sweep parameters are defined, the second parameter (VAR2) is called the subordinate (secondary) sweep parameter. This means that the primary parameter will be swept once for each discrete value of the subordinate parameter.

The “Constants” area is used to define non-swept voltage/current sources. This area is used to define ground references (forcing zero volts) as well as constant biases.

Classic Test – Display Setup

The screenshot shows two panels from a software interface. The top panel, titled "X-Y Graph", contains controls for defining the graph axes. It has buttons for "Add", "Delete", "Up", and "Down". Below these are fields for "Name:", "Sharing:", "Scale:", "Min:", and "Max:". The "X:" axis is set to "Vd" with a "Linear" scale, ranging from "0 V" to "5 V". The "Y1:" axis is set to "Id" with a "Linear" scale, ranging from "0 A" to "40 mA". The bottom panel is split into two sections: "List Display" and "Parameters". The "List Display" section has buttons for "Add", "Delete", "Up", and "Down", and three radio buttons with dropdown menus for "Vg", "Vd", and "Id". The "Parameters" section has buttons for "Add", "Delete", "Up", and "Down", and one radio button with a dropdown menu for "Idrain".



The Display Setup screen allows you to set the X-Y graph axes. The display setup is divorced from the measurement setup to allow the user to tailor the view to a particular region of interest.

This screen also allows you to set data variable names to be displayed in the List Display and Parameters areas on the Data Display window which is opened when the measurement is started.

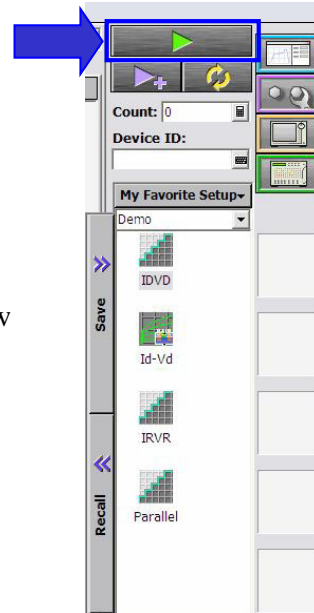
To Start Measurement

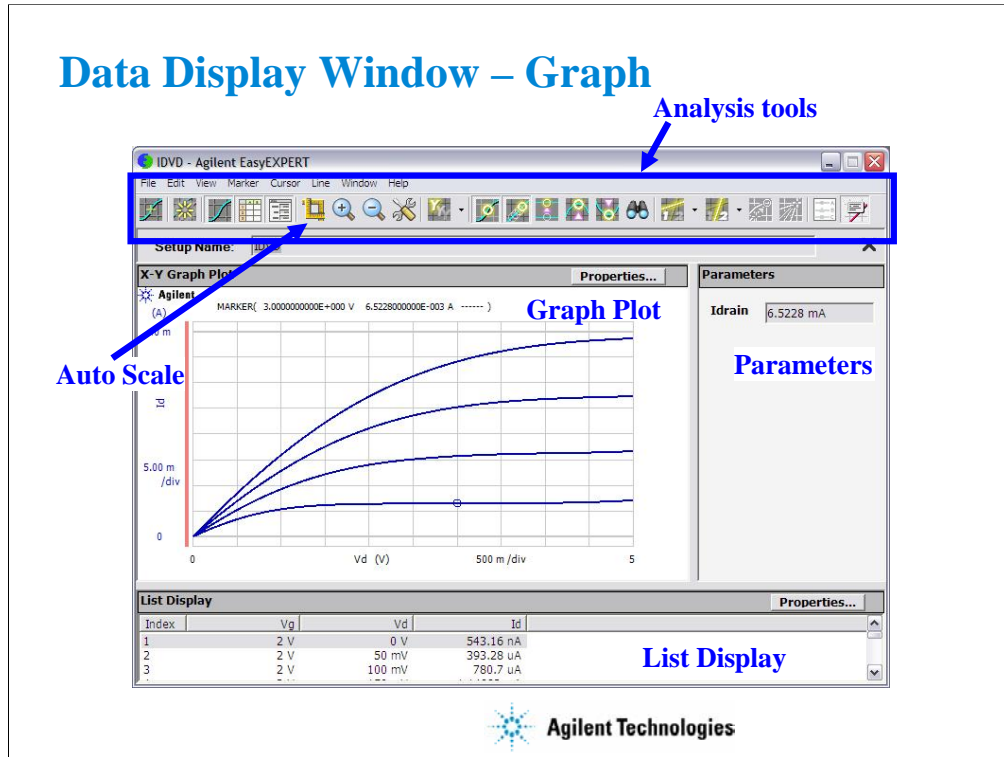
1. Click Single button



This opens the Data Display window and starts measurement.

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





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

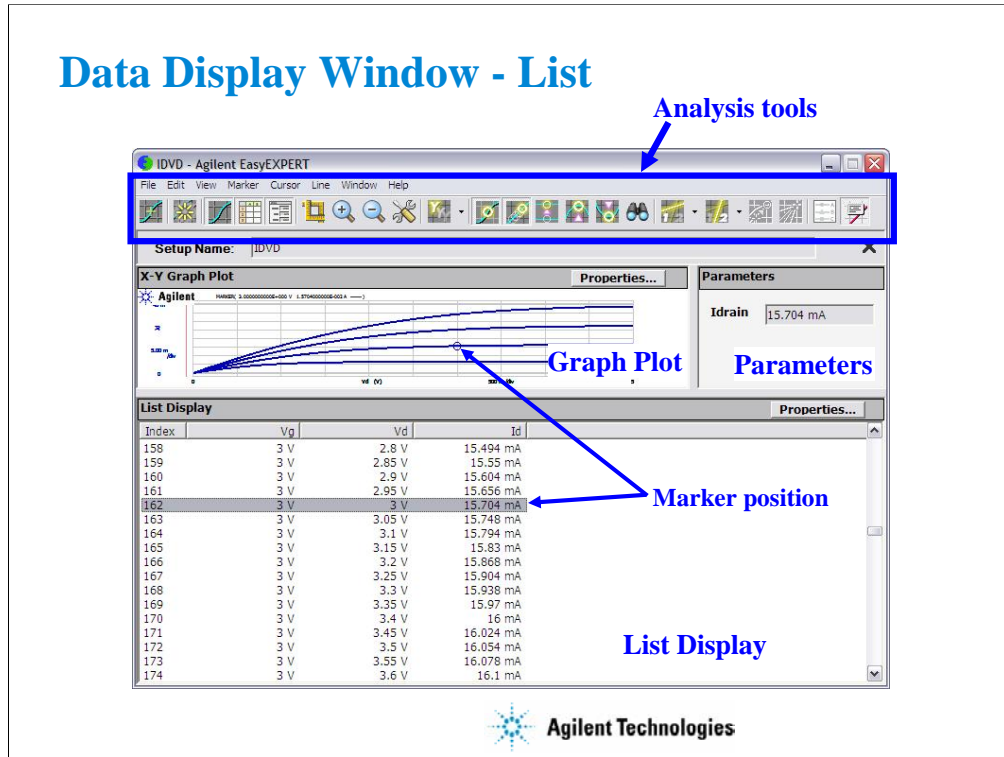
Markers are used to traverse the actual measurement data. Markers cannot be placed anywhere on the screen except on an actual measurement trace. They are denoted with a small circle. One moves the markers with the front panel rotary pulse generator (RPG) knob, mouse, or touch screen.

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.

The details of the analysis tools function are discussed in [Module3](#).

To Copy List Data

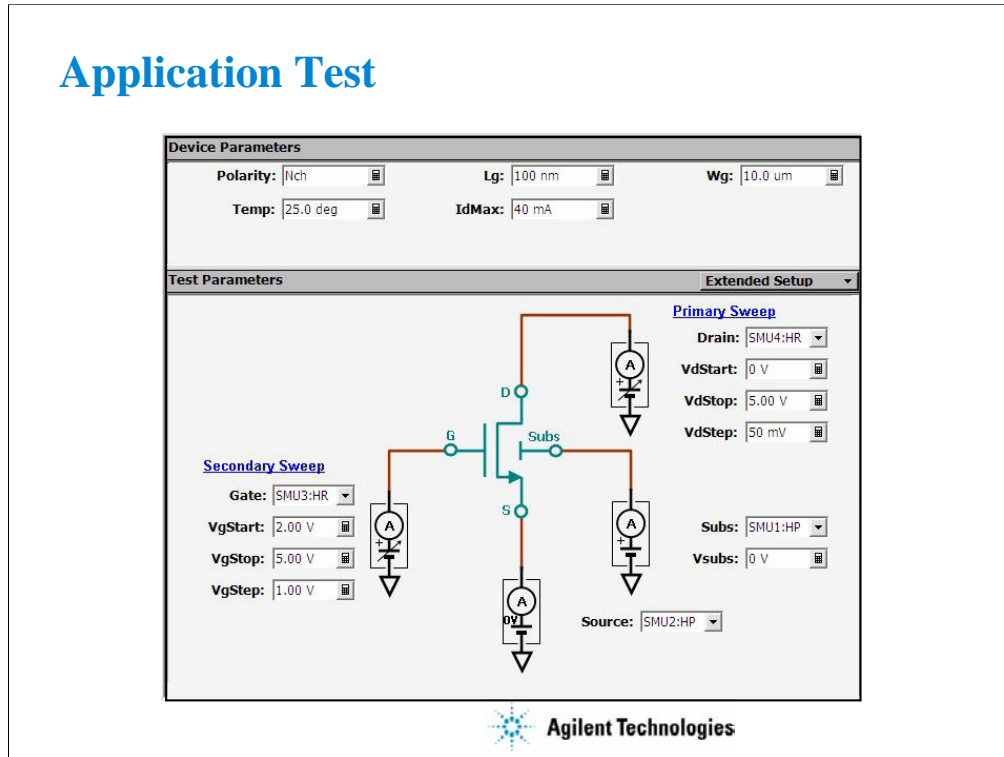
The screenshot shows the 'IDVD - Agilent EasyEXPERT' interface. The 'Copy List' menu option is highlighted with a blue box. A blue arrow points from this menu to a Notepad window titled 'idvd.txt - Notepad'. The Notepad window contains the following data:

Index	Vg	Vd	Id
1	2 V	0 V	543.16 uA
2	2 V	50 mV	393.28 uA
3	2 V	100 mV	780.7 uA
4	2 V	150 mV	1.14982 mA
5	2 V	200 mV	1.509 mA
6	2 V	250 mV	1.8512 mA
7	2 V	300 mV	2.185 mA
8	2 V	350 mV	2.4990 mA
9	2 V	400 mV	2.8050 mA
10	2 V	450 mV	3.0924 mA
11	2 V	500 mV	3.3698 mA
12	2 V	550 mV	3.6266 mA
13	2 V	600 mV	3.8744 mA
14	2 V	650 mV	4.104 mA
15	2 V	700 mV	4.3234 mA
16	2 V	750 mV	4.5244 mA
17	2 V	800 mV	4.7122 mA
18	2 V	850 mV	4.8888 mA
19	2 V	900 mV	5.0482 mA
20	2 V	950 mV	5.1936 mA
21	2 V	1 V	5.3298 mA
22	2 V	1.05 V	5.4566 mA
23	2 V	1.1 V	5.5702 mA
24	2 V	1.15 V	5.6742 mA
25	2 V	1.2 V	5.7668 mA

A second blue arrow points from the Notepad window to a spreadsheet window. The spreadsheet window shows the data pasted into it, with columns labeled 'Index', 'Vg', 'Vd', and 'Id'. The data in the spreadsheet matches the data in the Notepad window.



Application Test



Recall Id-Vd application test setup data.

After you get the Id-Vd setup data, you will see the Application Test setup screen as shown.

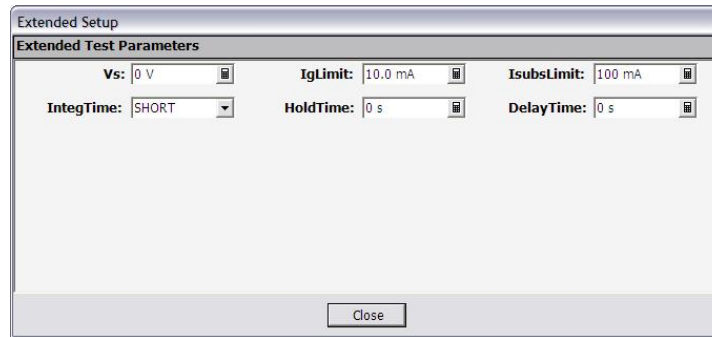
Test Parameters area shows the device connection information and allows the user to set the SMU outputs.

Device Parameters area allows the user to set device parameters. In the Id-Vd setup, the device parameters are polarity, gate length, gate width, temperature, and maximum drain current.

Extended Setup button opens the Extended Setup dialog box shown in the next page.

Application Test – Extended Setup

Clicking the Extended Setup button opens ...



The Extended Setup dialog box allows the user to set the additional test setup parameters. In the Id-Vd setup, the additional parameters are source voltage, maximum gate current, maximum substrate current, integration time, hold time, and delay time.

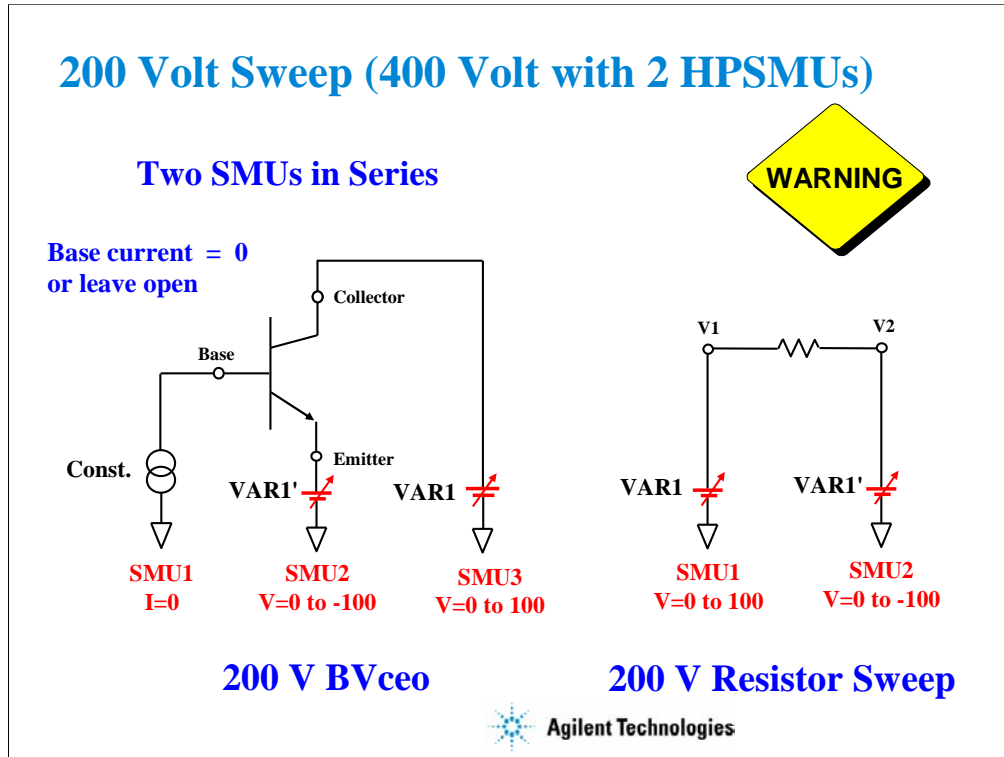
SMUs May Be Connected

In Series or Parallel

- To Double the Output Voltage
 - from 100 V to 200 V for HRSMU and MPSMU
 - from 200 V to 400 V for HPSMU
- To Double the Output Current
 - from 100 mA to 200 mA for HRSMU and MPSMU
 - from 1 A to 2 A for HPSMU
- Use the VAR1' mode to synchronize two SMUs



You can double the voltage or current output by combining SMUs.
The VAR1' mode allows a second SMU to be swept in tandem with the first.



Higher voltages are necessary to observe breakdown conditions, such as BV_{ceo} . In the case of BV_{ceo} the base must be open (no SMU) or the SMU must be set as a current source with $I=0$.

One SMU must sweep in a positive direction while the other sweeps in a negative direction. The result is a floating measurement with double the differential voltage. A resistor is used in the next few slides to demonstrate a 200 V sweep.

Note: Using two HPSMUs, it is possible to sweep a total of 400 Volts.

Channel and User Function Pages

Two SMUs in Series

The image shows two overlapping screenshots of the Agilent software interface. The top screenshot is the 'Channel Definition' page for an 'I/V Sweep' setup named 'IRVR'. It shows two channels: Channel 1 (SMU3:HR) with V Name 'V1', I Name 'I1', Mode 'V', and Function 'VAR1'; and Channel 2 (SMU4:HR) with V Name 'V2', I Name 'I2', Mode 'V', and Function 'VAR1'. The bottom screenshot is the 'User Function' page for the same setup. It shows two user functions: 'VR' with Unit 'V' and Definition 'V1-V2', and 'IR' with Unit 'A' and Definition '-I2'. A blue arrow points from the text 'Voltage across resistor VR = V1-V2' to the 'V1-V2' definition in the 'VR' user function row.

Unit:	V Name:	I Name:	Mode:	Function:
SMU3:HR	V1	I1	V	VAR1
SMU4:HR	V2	I2	V	VAR1

Name:	Unit:	Definition:
VR	V	V1-V2
IR	A	-I2

Voltage across resistor
 $VR = V1 - V2$



The voltage across the resistor (VR) is the difference between V1 and V2. A simple user function can be used to plot VR.

Measurement and Display Pages

Two SMUs in Series

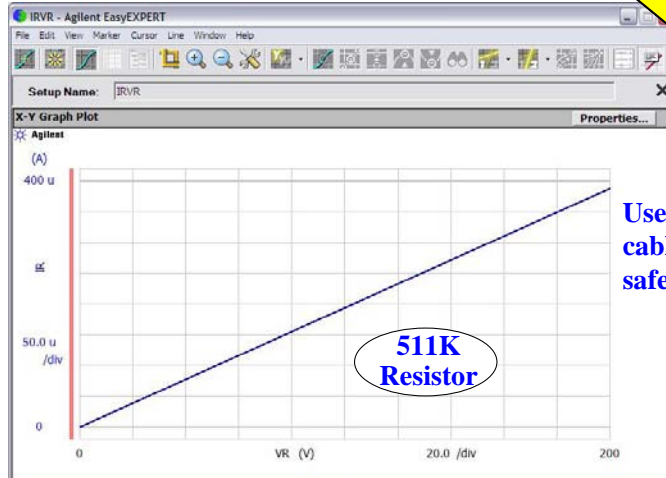
VARI' Ratio = -1

The screenshot displays the 'I/V Sweep' Measurement Setup page for a setup named 'IRVR'. The 'Measurement Setup' tab is active, showing two channels: VAR1 and VAR1'. VAR1 is configured with Unit: SMU3:HR, Name: V1, Direction: Single, Linear/Log: LINEAR, Start: 0 V, Stop: 100 V, Step: 1 V, No of Step: 101, Compliance: 1 mA, and Pwr Comp: OFF. VAR1' is configured with Unit: SMU4:HR, Name: V2, Offset: 0 V, Ratio: -1, and Compliance: 1 mA. A blue arrow points from the text 'VARI' Ratio = -1' to the 'Ratio: -1' field. The 'Display Setup' tab is also visible, showing an 'X-Y Graph' with two traces: X: VR (Linear scale, Min: 0 V, Max: 200 V) and Y1: IR (Linear scale, Min: 0 A, Max: 400 uA). The Agilent Technologies logo is at the bottom.

The VAR1' mode is used to synchronously sweep two SMUs. Setting Ratio = -1 forces one SMU to sweep in the opposite direction of the other.

Graphics Page 0 to 200 V

Two SMUs in Series



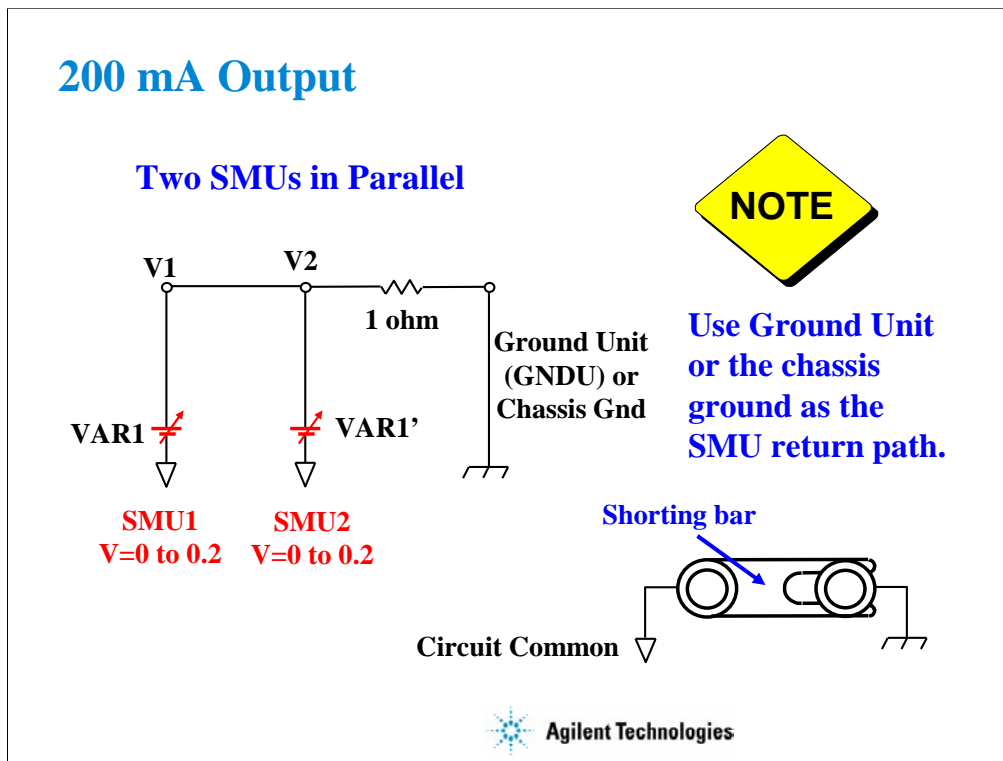
Use the interlock cable and observe safety precautions.



The result is a clean 200 V sweep.

Remember that there is a serious shocking hazard.

The interlock cable is necessary for any voltage sweep greater than 42 V.



Two SMUs can be operated in parallel.

The trick is to not use any SMU as COMMON.

HRSMU and MPSMU can only sink 100 mA.

Use GNDU (ground unit) or the chassis to sink the 200 mA of current. Chassis noise level will not affect the measurement. There is a shorting bar in the back of the instrument which connects SMU common to the chassis. The shorting bar must be connected as shown above. Use the connector on the shorting bar to make an easy chassis connection to your circuit. The chassis connection is also provided if you use a packaged part test fixture, such as the 16058A or 16442A/B.

Note

The only time you would ever want to remove the shorting bar, is the case of floating the instrument circuit common when using other instruments. An example might be a connection to a RF Network Analyzer. You may want to remove chassis ground loops by connecting the circuit common directly to the NWA chassis.

Note

Never use the chassis ground for low current measurements. It is noisy. Use the GNDU or an SMU set to 0 volts or COMMON mode.

Note

If the GNDU is used, connect the 16493L GNDU cable between the GNDU and the test fixture. Do not connect the triaxial cable. The GNDU is rated for up to 4.2 A, while the maximum current rating of the triaxial cable is 1 A.

Channel and User Function Pages

Two SMUs in Parallel

The screenshot displays the 'I/V Sweep' configuration window for a 'Parallel' setup. It is divided into two main sections: 'Channel Definition' and 'User Function'.

Channel Definition: This section contains a table with columns for Unit, V Name, I Name, Mode, and Function. Two channels are defined:

Unit	V Name	I Name	Mode	Function
SMU3:HR	V1	I1	V	VAR1
SMU4:HR	V2	I2	V	VAR1'

User Function: This section contains a table with columns for Name, Unit, and Definition. A user function is defined:

Name	Unit	Definition
Itotal	A	I1+I2

A blue arrow points from the text 'Current in resistor Itotal = I1+I2' to the 'Definition' field of the user function table.



A user function totals the current in both SMUs.

Measurement and Display Pages

Two SMUs in Parallel

VAR1' Ratio = 1

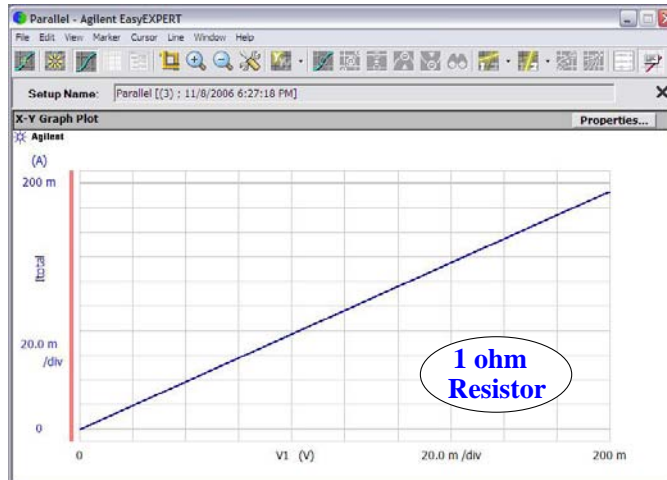
The screenshot shows the 'I/V Sweep' measurement setup and display configuration. The 'Measurement Setup' page is active, showing two channels: VAR1 and VAR1'. VAR1 is configured with Unit: SMU3:HR, Name: V1, Direction: Single, Linear/Log: LINEAR, Start: 0 V, Stop: 200 mV, Step: 2 mV, No of Step: 101, Compliance: 100 mA, and Pwr Comp: OFF. VAR1' is configured with Unit: SMU4:HR, Name: V2, Offset: 0 V, Ratio: 1, and Compliance: 100 mA. A blue arrow points from the text 'VAR1' Ratio = 1' to the 'Ratio: 1' field. The 'Display Setup' page is also visible, showing an 'X-Y Graph' with X-axis labeled 'V1' and Y-axis labeled 'Itotal', both with Linear scales and ranges from 0 to 200 mV and 0 to 200 mA respectively.



The VAR1' mode with Ratio = 1 forces two SMUs to sweep the same voltage.

Graphics Page 0 to 200 mA

Two SMUs in Parallel



The result is a clean sweep to 200 mV. It shows the current measurement data near 200 mA.

Cabling and Fixturing Issues

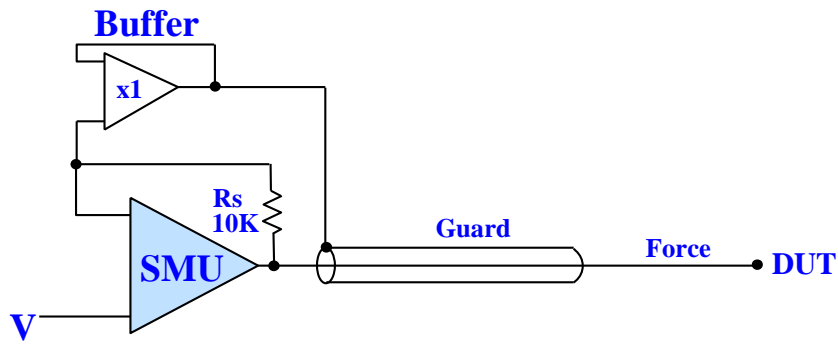
- Guard connection
- Kelvin connection
- Prober interface
- Triaxial Probes
- RF Fixturing interface
- Feedthru and triax to coax adapters
- 16442A/B fixture interlock
- 16058A fixture compatibility



The B1500A 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.

Guard Connection for Non-Kelvin Connection

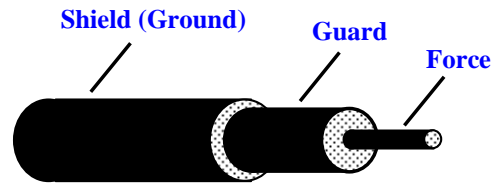
Simplified Diagram



The guard connection is needed for 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.

Triaxial Cable for Non-Kelvin connection

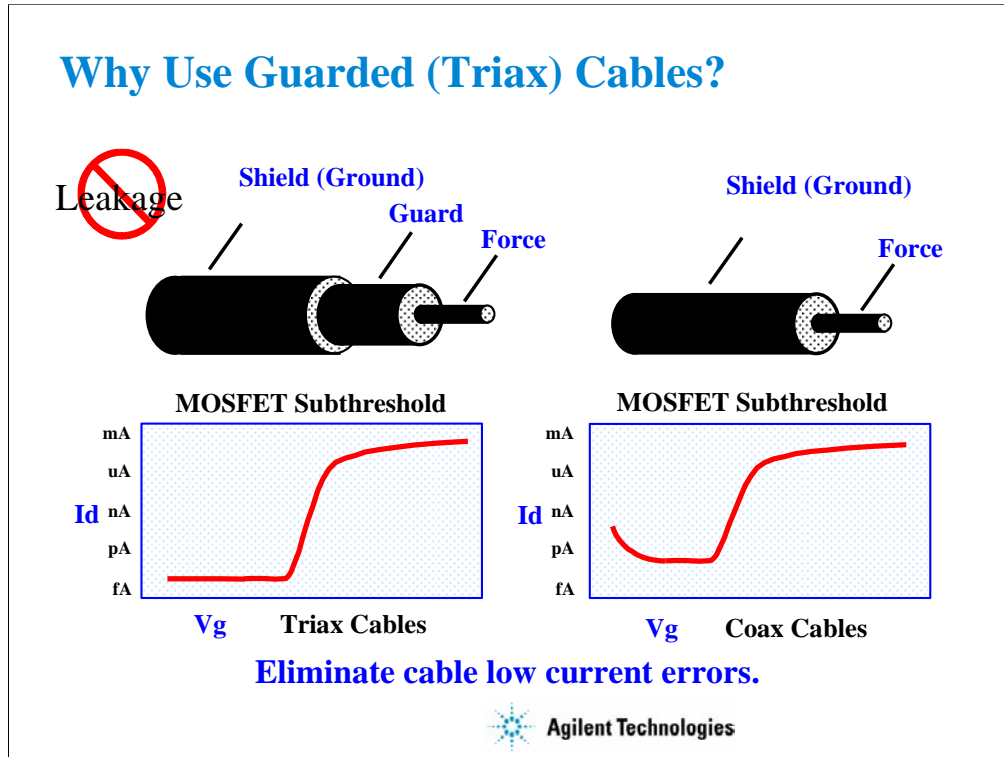


	16494A-001 (1.5 m)	16494A-002 (3.0 m)
Shield Capacitance	900 pF	1800 pF
Guard Capacitance	130 pF	240 pF
Force Resistance	160m ohm	320m ohm



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.

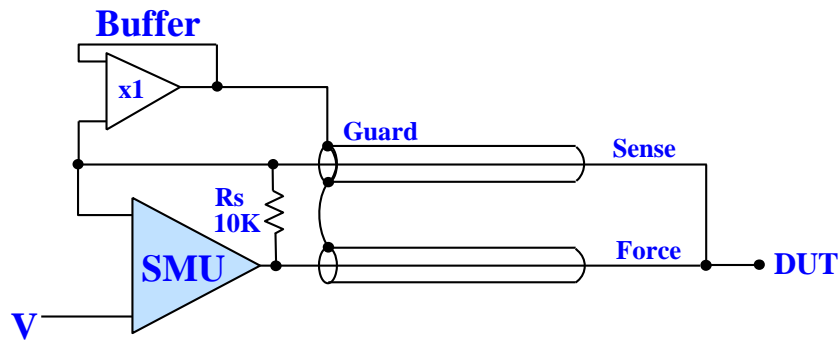
RULES:

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

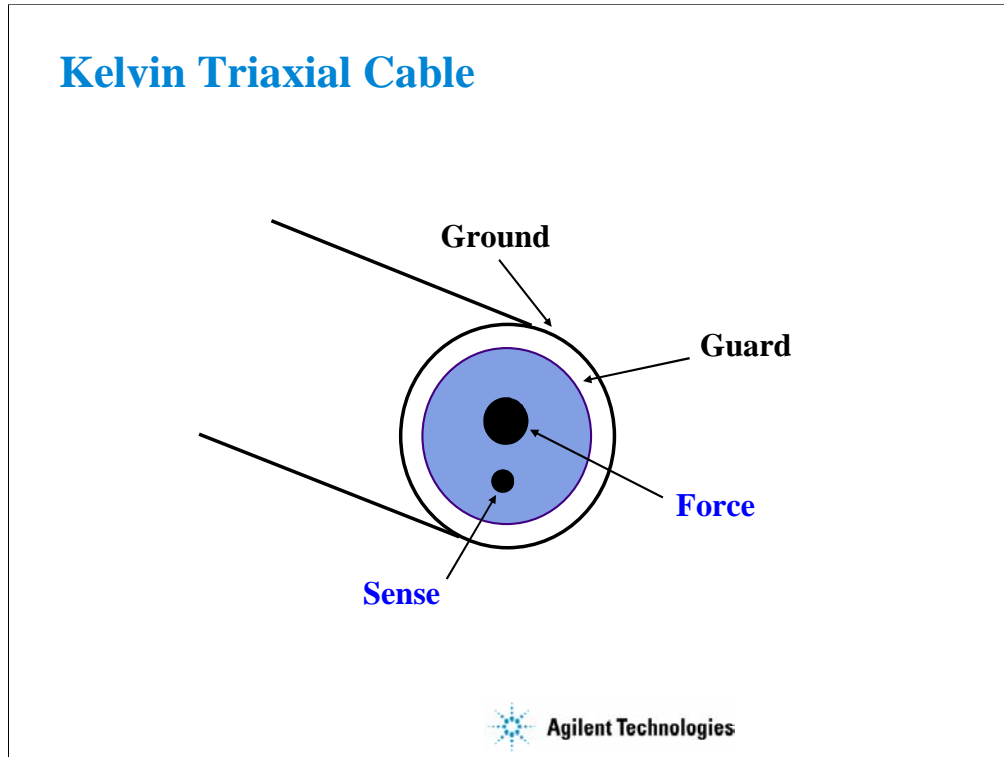
Simplified Diagram



 Agilent Technologies

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 B1500A 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.

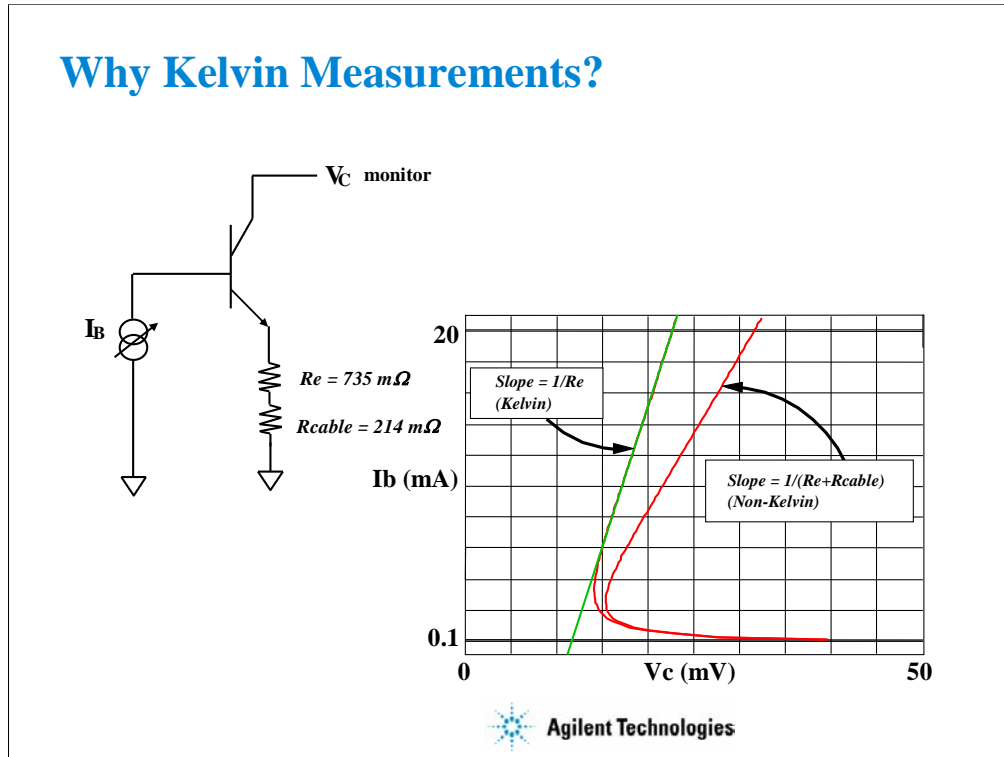


The triaxial cables are good for low current measurements. However, two cables are necessary for low resistance Kelvin measurements.

Agilent 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 Teflon cable. Friction is reduced and the cable is less sensitive to noise caused by moving the cable.

Kelvin triaxial cable assemblies are available with two connector options:

16494B	B1500/4156 compatible on one end; 4142 compatible on the other end
16493K	B1500/4156 compatible on both ends (standard option)



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 0.214 ohm path through the cable and fixture. From the graph we can see the emitter resistance is 0.735 ohm when compensated using the Kelvin connection. Non-Kelvin resistance is 0.949 ohm, due to the extra 0.214 ohm cable and fixture resistance error.

Class Exercise

Bipolar Re Using A Kelvin SMU

- You will connect a Kelvin triax cable to the B1500A
- You will then connect jumper leads and the bipolar device
- You will get the REKELV setup
- You will observe R_e using Kelvin and Non-Kelvin connections.
Why is the Non-Kelvin error so large?

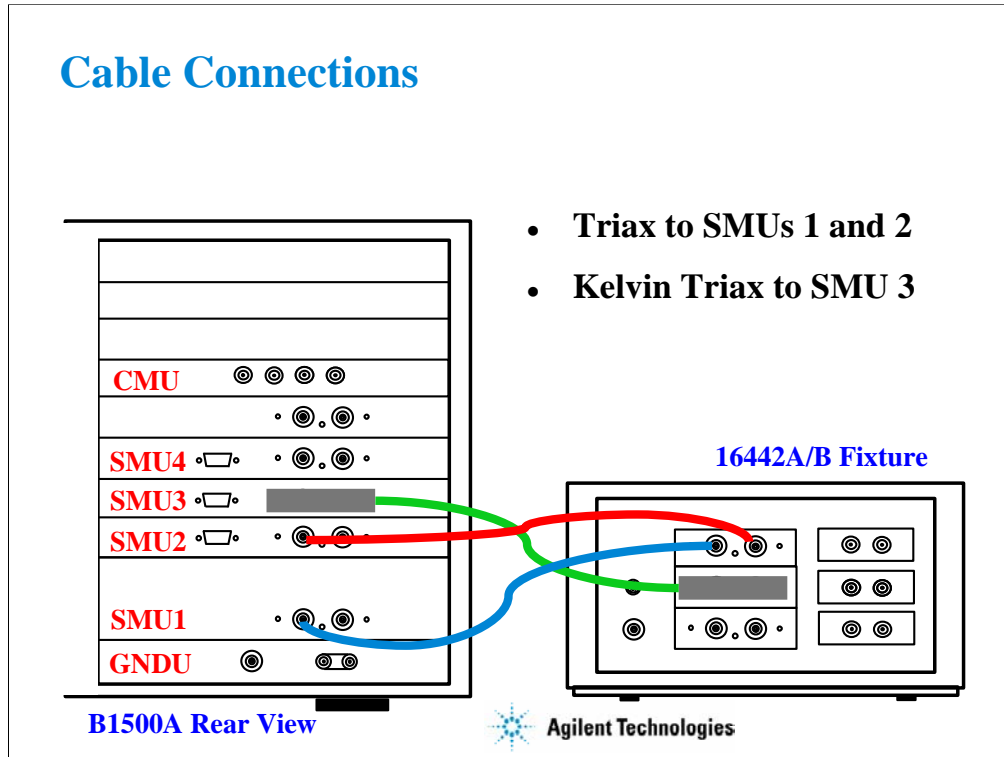
To Get Started:

- Use the next several pages as you guide
- Verify that all triax cables are connected properly
- Connect four jumper leads to the 28 pin socket as shown
- Insert the bipolar transistor (not static sensitive)



The purpose of this class exercise is to familiarize yourself with making a Kelvin measurement. Low resistance measurements such as R_e , R_c (bipolar) or R_s , R_d (MOS) are excellent examples because the resistances are of the same approximate magnitude as cable resistances. Kelvin techniques must be used, or your error can be as much as 100 %.

The next several pages lead you through the steps of connecting a Kelvin cable, making the correct Force/Sense jumper lead connections, orienting the device properly in the socket, and getting the REKELV algorithm. The measurement will be R_e (emitter resistance) of a bipolar transistor. You will be able to remove the Sense jumper lead on the Emitter terminal of the device to see the gross measurement degradation when the connection is non-Kelvin (no sense connection near the device).



This class example requires a Kelvin triaxial cable. If the Kelvin cable is not available, substitute two standard triax cables.

SMUs 1,2,3 can all be connected with Kelvin triaxial cables, but only SMU3 requires the Kelvin connection.

Note

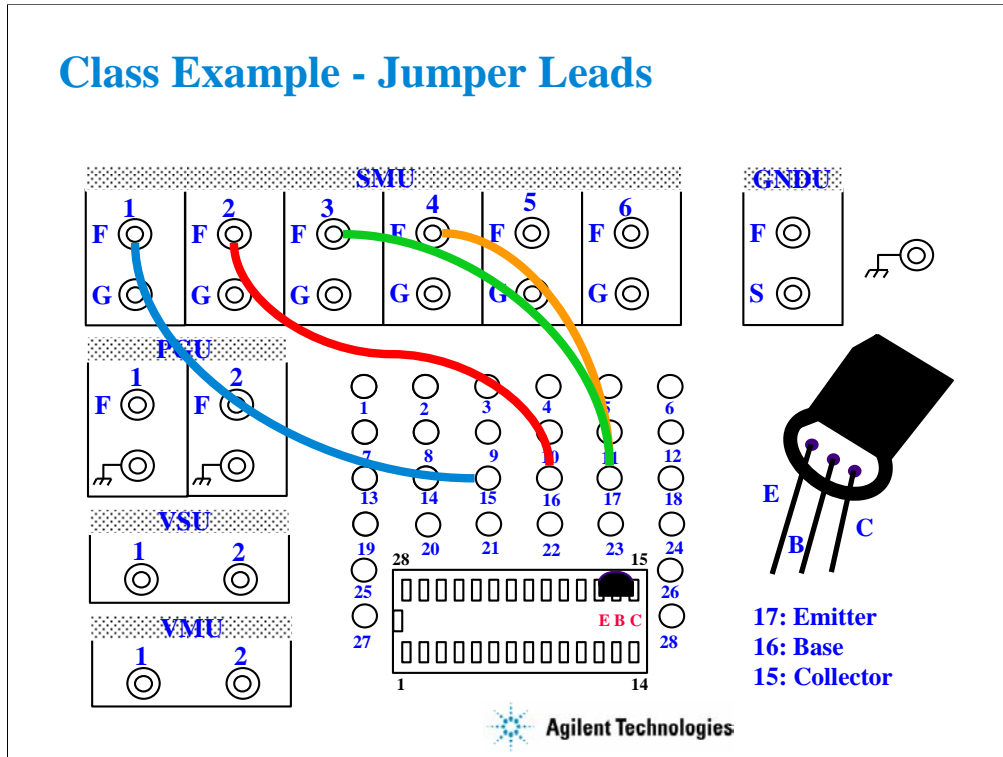
If you use the 16058A fixture instead of the 16442A/B, connect the triaxial cables as shown below.

SMU1 Force ---> 16058A SMU1

SMU2 Force ---> 16058A SMU2

SMU3 Force ---> 16058A SMU3

SMU3 Sense ---> 16058A SMU4



Connect jumper leads as shown. Where, the SMU4 F terminal is connected to the B1500A's SMU3 Sense connector. So the couple of the SMU3 F and SMU4 F terminals makes a Kelvin terminal.

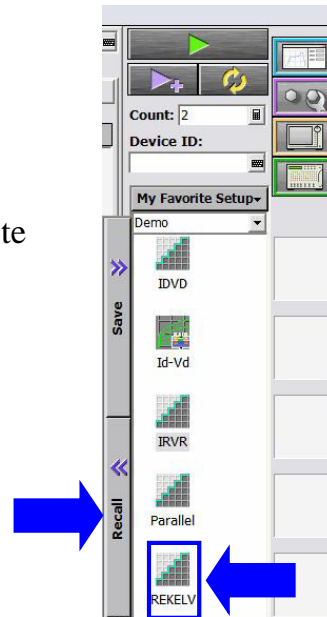
Locate the bipolar transistor in the corner of the socket as shown, with the flat side of the device facing toward you.

Unlike the MOS device, the bipolar transistor is not static sensitive. You may touch the leads without using a ground strap.


To Get Setup Data

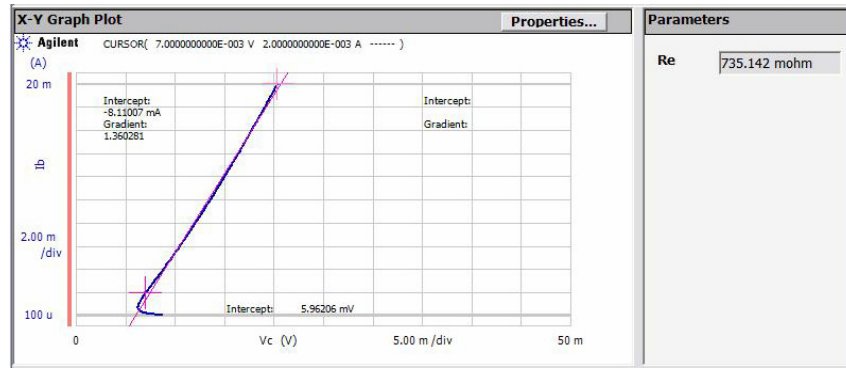
To Get REKELV Test Setup:

1. Highlight REKELV in My Favorite Setup
2. Click Recall button



Single Kelvin Measurement

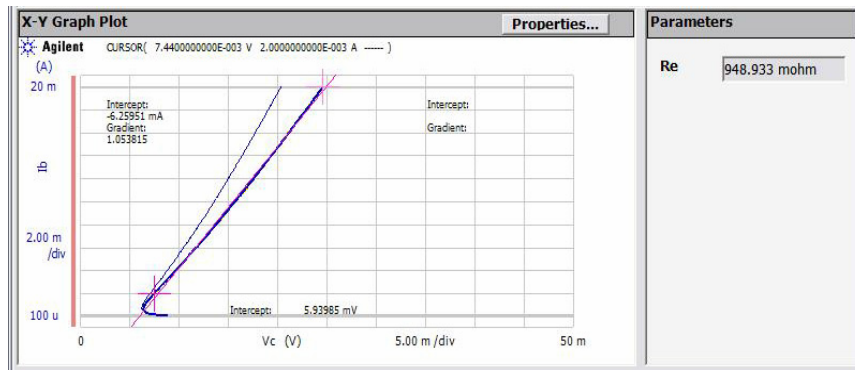
Click  button to start measurement



Click the Single button to make a new measurement. You should see a response similar to this, with the analysis line correctly overlaying the curve.

Non-Kelvin Measurement

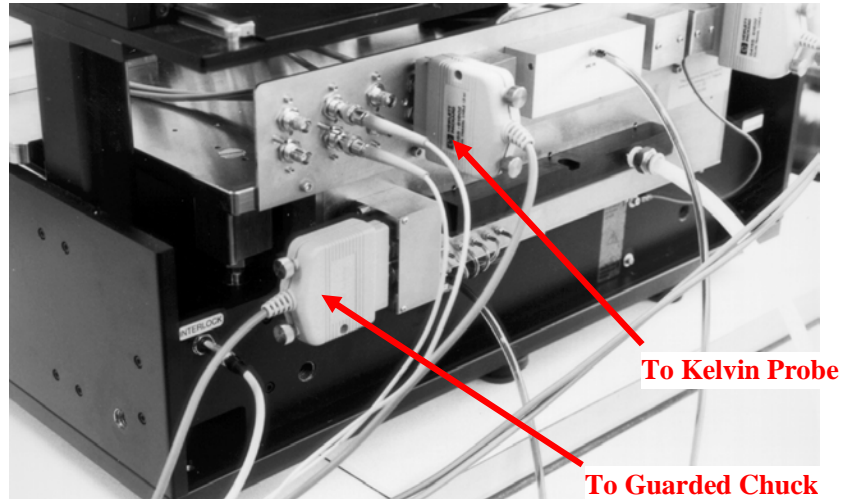
Click  button to start append measurement



Remove the jumper lead connected between the terminal 17 and the SMU4 F terminal. And click the Append button to add another measurement to the graph.

Now you see the very large difference between Kelvin and non-Kelvin measurements when the resistance is low. You can see that Re jumps from about 0.735 ohm in this example, to about 0.949 ohm. The extra resistance is due to cable loss and fixture loss. This resistance is compensated out when you use the Kelvin connection.

Prober Kelvin Cable Connection

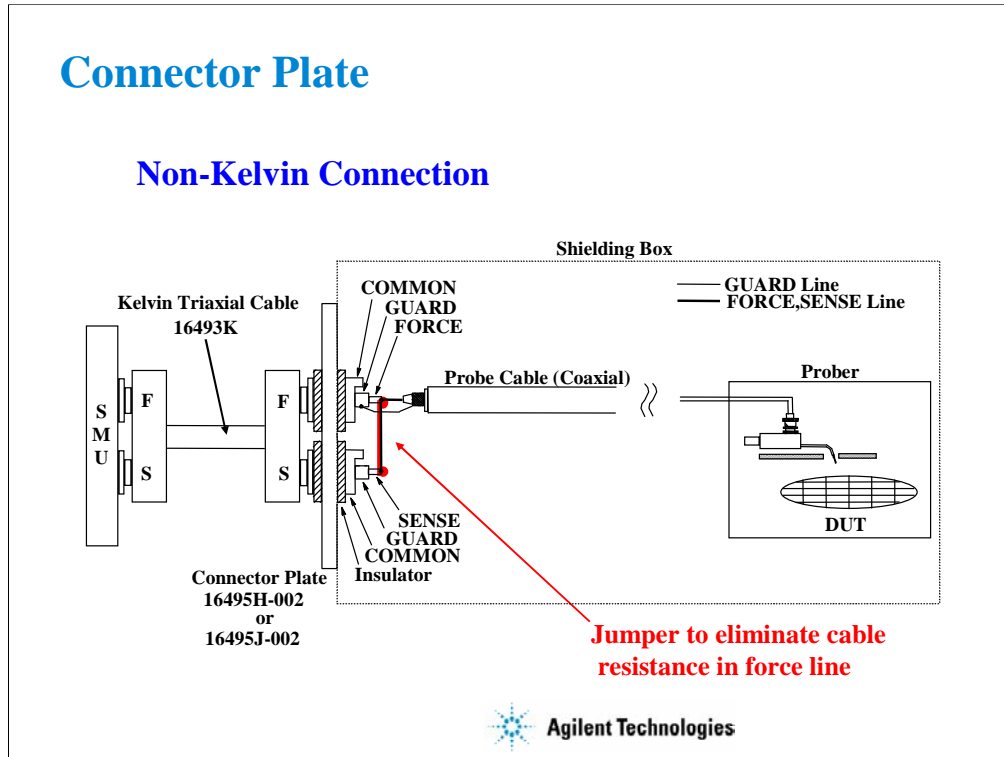


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Photo of SMU cable connection to a Cascade Microtech Summit probe station.
The Kelvin triaxial cables mate directly to the probe station.

Connector Plate

Non-Kelvin Connection



This is a "hybrid" Kelvin connection. Cable resistance from SMU is eliminated by shorting FORCE and SENSE lines inside the prober. A short line to the probe makes the non-Kelvin connection, simplifying hookup.

Simplifying the Prober Connection

- **Use single triax for basic MOS FET measurements**
- **One triax on each Force line**
- **Leave the Sense lines open...no cable connected**
- **Use triax bulkhead feedthru adapters on the prober**
- **Use a probe holder with a triaxial connector**
- **Use a probe holder than accommodates replaceable probe tips (inexpensive repair)**



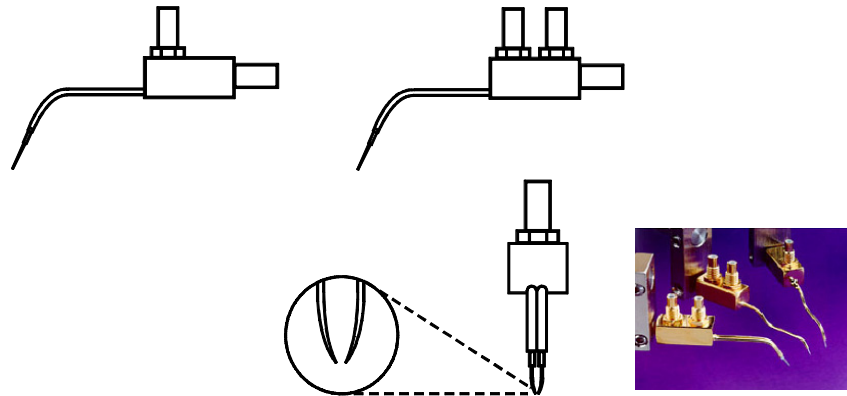
The next section sheds light on the confusing topic of connection to the device under test. Without proper considerations, noise, capacitance, sense resistance, or inductance will result in unacceptable measurement error.

Triaxial Probes

Guarded to within 2mm of tip

Single Triax

Kelvin Triax

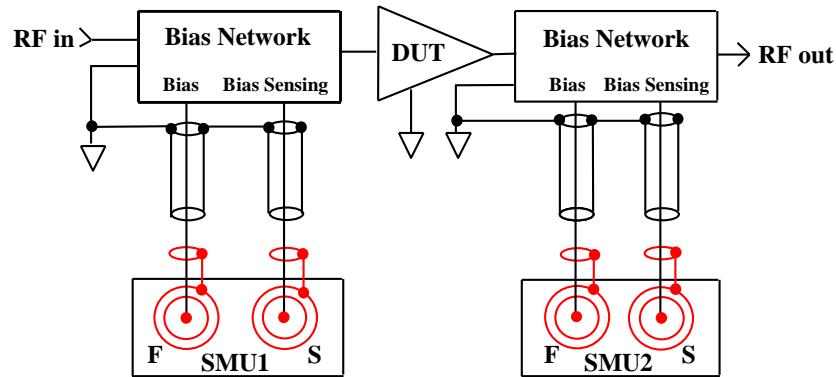


 Agilent Technologies

These probes are guarded within 2mm of the probe tip, ideal for low current applications. The Kelvin triax probe is the ideal mate for the Kelvin triax cable. A third variation of these probes is a Kelvin triax probe with only one probe. The Kelvin connection is made inside the probe holder. This compromise eliminates most cable loss while making a single point contact.

Simplifying RF Connections

- Triax is not necessary...bias currents are > 1 nA.
Use triax to coax adapters with floating guard.



Above 1 nA guarding is of little use. Cable capacitance has a negligible effect on the bias port. Use the floating guard triax(m) to BNC(f) adapter at the B1500A rear panel. Then use standard coax BNC cables. Use sense to minimize series resistance error. 100 mV errors can occur in bias voltages if remote sensing is not used.

Some recent bias tees from Agilent Technologies are specially designed to mate easily to triax SMU ports.

Interlock Connection

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



To prevent shock hazard, the B1500A 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 16442A/B 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 connect to the BNC type interlock connector on the 16088B, your fixture or prober, use the 16435A Interlock Cable Adapter. The 16435A provides a BNC cable and a small adapter box which is used to join the BNC cable and the interlock cable furnished with the B1500A.

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

1252-1419 Female 6-pin plug connector

1252-1418 Male 6-pin cable connector

16442A/B Fixture



16493J-001 **1.5 m cable**
16493J-002 **3.0 m cable**



The 16493J interlock cable is designed to be connected directly between the B1500A's interlock connector and the 16442A/B. If the fixture lid is closed, internal switch is closed, and then the B1500A can perform measurement up to 100 volts; 200 V with the HPSMU.

16058A Fixture Compatibility

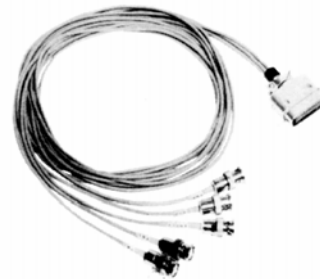
Use the 16058A with the B1500A

- 4 non-Kelvin SMU inputs
- 3 general purpose coaxial inputs

Add the 16493A Adapter Cable

- Interlock connection
- 4 additional coaxial inputs

Add the 16435A Adapter



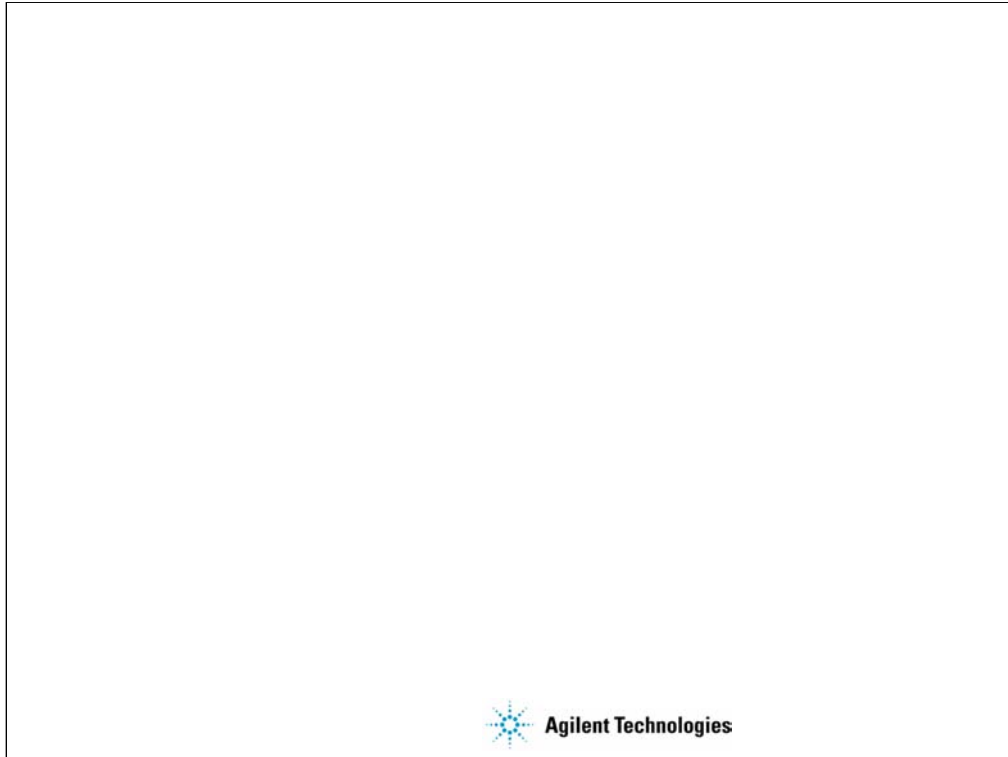
The 16058A has 4 non-Kelvin SMU inputs and 3 coaxial inputs for the other instrument connection.

By adding the 16493A Adapter Cable, you get access to 5 more coaxial connections. The adapter was designed to bring out the fixture interlock connection and 4 additional connections, such as the 4142/4155/4156's VSU/VMU.

The 16493A cable converts the 16058A fixture interlock connection to a single coaxial connector. This mates directly with the 16435A Interlock Cable Adapter mentioned on the previous page.

Note

You will notice that the socket modules for Agilent Technologies entire DC parametric product line are interchangeable. So socket modules that came with the 4142, 4145, 4155, or 4156 will work with the 16058A, 16088A/B, and 16442A/B fixtures.



In This Module

- Low-Current Measurement Challenges
- Calibration and Zero Cancel
- Effect of Cable Movement
- ASU for Ultra Low-Current Measurement
- Low-Current Subthreshold
- Trade-Off Speed Vs Accuracy
- Low-Current Gummel Plot
- Low-Current Gate Oxide Leakage



This module is primarily written for the B1500A installed with the HRSMU (high resolution SMU) and covers sub pA measurement techniques. Course exercises are included which fully explore speed vs. accuracy issues to the fA level.

Low Current Measurement What is possible?

- Measurements below 10 fA at the wafer level
- Repeatability within a few fA
- Speeds less than 1 minute for subthreshold sweep



Making wafer level measurements to fA levels is easy and routine using proper measurement procedures on a low noise probe station. This module explains how.

Low Current Measurement Challenges

- NOISE FROM PROBER
 - Faraday enclosure required
 - Eliminate all electrical interference
- STRAY CAPACITANCE
 - Full guarding, including the probe
 - Guarded chuck to measure substrate current
- MEASUREMENT SETUP
 - Hold time, integration, auto ranging
- CALIBRATION & ZERO CANCEL



Measurement below 1pA is not possible without special attention to the prober and cabling. The wafer must be in total darkness and in an electrically isolated metal box. Motors must be turned off or completely shielded.

Stray capacitance kills any hope of making good low current measurements. High cable capacitance which is unguarded can produce pA level currents during voltage steps. The probes themselves must be guarded.

The B1500A defaults at bootup to setup conditions which are not optimized for ultra low current. This is desirable because there is a large trade-off between speed and ultra-low current accuracy. The typical use is moderate current levels where settings can be optimize for speed, not accuracy.

There are some features such as zero cancel, which can eliminate the last 10 or 20 fA of error from your measurement. Before zeroing, you should check that SMU CALIBRATION has been performed. SMU Calibration removes most error and makes the final zero cancel easier.

Clean Probing Environment What is Required?

- ✓ Low loss triaxial connection (no matrix card)
- ✓ Guard to tip of probe (no bare needle or probe cards)
- ✓ No air flowing near probe tip (including dry nitrogen)
- ✓ No hot chuck
- ✓ Chuck isolated from ground (10^{13} ohms)
- ✓ Chuck guarded for substrate measurements
- ✓ Shielded probe station
- ✓ No vibration; cables stationary
- ✓ Microscope light, motors, etc. off



This check list covers most sources of noise or stray capacitance. In a "clean" probing environment the B1500A can be used with short integration time and no delay time between steps.

Debugging A Noisy Probe System Where to Start?

- Sweep 0 to 1 volt with no cables attached to SMU
 - Check that there is a +/- 3 fA base line
- Add prober cables but no prober
 - Wait several minutes
 - Still +/- 3 fA base line?
- Add shielded prober but no probes
- Add probes



This is a systematic strategy for focusing in on the sources of noise and error. You can be very surprised. Some prober cable is not low loss. You may see popping noise due to relaxing of Teflon fiber in the cables, high current level due to poor dielectric loss, etc. You may find improper triax adapters, high levels of stray capacitance, etc., as you add prober and probe connections.

Low Current Calibration & Zero Cancel

- WAIT 30 MINUTES AFTER TURN ON
 - Instrument must stabilize
- CAL & ZERO WITH PROBES UP
 - Prevent device damage
- ZERO EVERY 30 MINUTES
 - To get repeatable fA level measurements



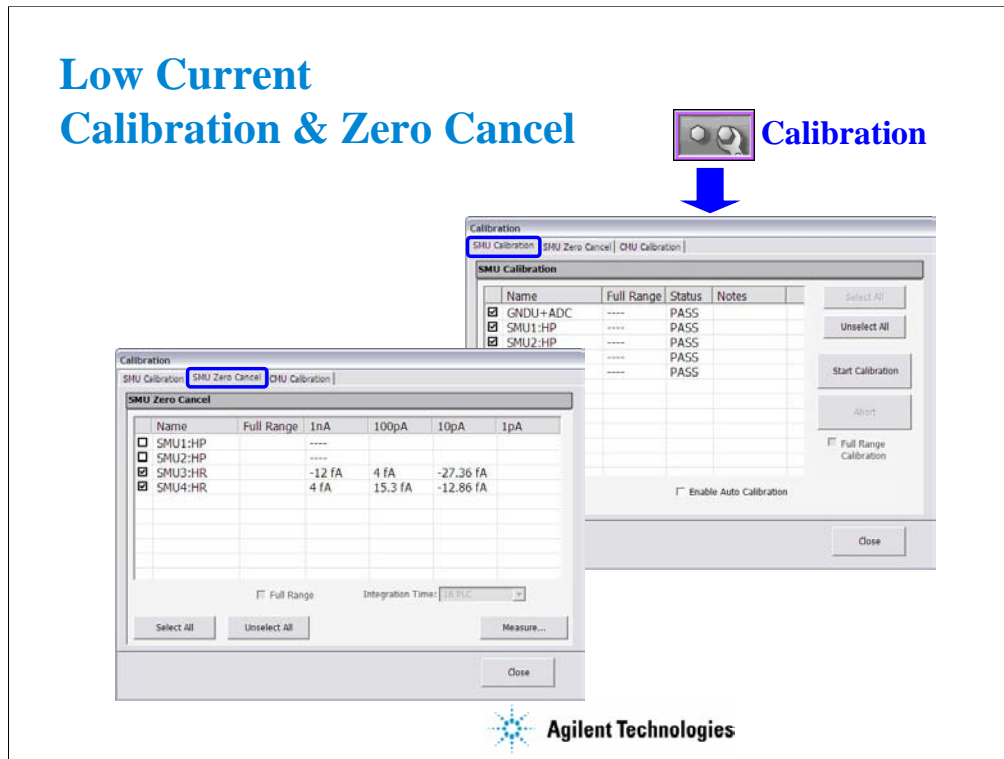
The SMU can be thought of as a sophisticated OP AMP. With any OP AMP there is an associated input offset error. This error is small and varies with ambient temperature shifts and other factors. It can be reduced to a negligible amount with a zero cancel function.

Zeroing is performed with the probes up. If there is a very large error to correct, you may get a warning message. This usually means that SMU CALIBRATION has not been recently performed. SMU calibration eliminates gross. ZEROing only has an effect on the 1 nA range or less.

Use the Calibration window to perform the SMU calibration and zero cancel. See the next page.

NOTE:

The B1500A provides the auto calibration function which automatically starts calibration for all modules every 30 minutes if the output switches of all modules are off for 30 minutes. You can enable or disable this function on the Calibration window. If auto-calibration is enabled, move probes up (open measurement terminals) after measurement to prevent device damage and to perform calibration correctly.



Click Calibration button to open the Calibration window.

SMU calibration is performed on the SMU Calibration tab screen. Specify the modules for calibration by checking the left check box and click Start Calibration button to start calibration. If ASU (atto sense/switch unit) is connected and 1 pA range is used for measurement, check Full Range Calibration check box before clicking Start Calibration button.

SMU zero cancel is performed on the SMU Zero Cancel tab screen. Specify the modules for zero by checking the left check box and click Measure... button to start SMU zero. If ASU is connected and 1 pA range is used for measurement, check Full Range check box before clicking Measure... button.

To enable the auto calibration function, check the Enable Auto Calibration check box on the SMU Calibration tab screen.

Class Exercise

Measurements Near Zero fA

You will be able to answer the following questions:

- What does a sweep into an open SMU port look like?
- What is the time per meas using PLC integration?
- Add a 1.5 m cable during a sweep...how long to settle?
- Move and bend the cable...how much current flows?

To Get Started:

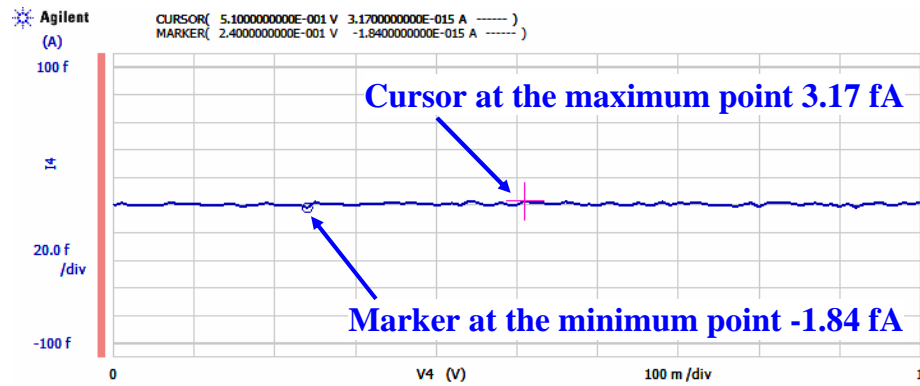
- Use the next several pages as your guide
- Remove any cable attached to SMU4
- Measure SMU4 noise level using the setup shown



The following pages lead you step-by-step through the "ZERO CHECK" class exercise. This is the logical place to start if you are debugging a "noisy" test environment.

You will create an algorithm to look at the low level measurement capability of a SMU. On the next page you will see the expected curve when looking into an open at the rear panel.

ZERO CHECK - No cable Using Default SMU Setup

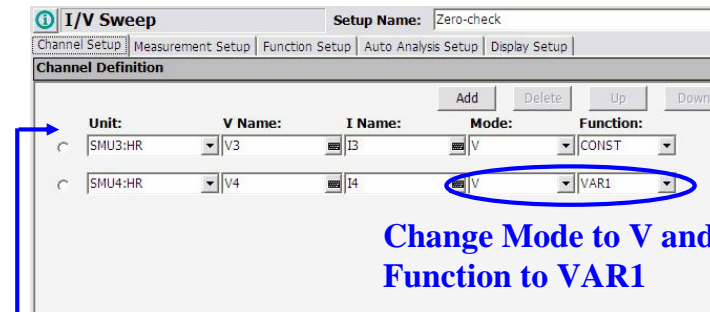


+/- 3 fA variation typical, using 16 PLC integration time



With slight modification of the default SMU settings of Classic Test I/V Sweep, you can check the conditions of your measurement system. This is a typical plot when no cable is attached to the SMU port. You would typically expect no more than a few fAs of deviation from zero using 16 PLC integration time.

ZERO CHECK Channel Setup



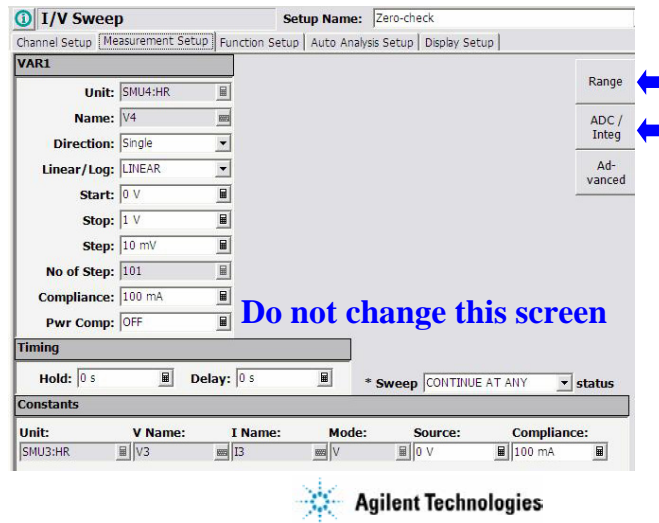
Delete SMU1 and SMU2



- Click the Classic Test tab, I/V Sweep, and Select to display the Channel Setup screen.
- On this display, delete the rows of SMU1 and SMU2.
- Change the Mode of SMU4 to V.
- Change the Function of SMU4 to VAR1.

This setup will be used for checking the zero measurement on SMU4.

ZERO CHECK Measurement Setup



This default sweep setup is enough for the Zero Check measurement.

The sweep steps are small (10 mV) and that is ideal for checking current at fA levels.

Also the sweep starts at 0, so no big discontinuities on the first step of the sweep.

There is no need to change anything on the Measurement Setup screen. But the ranging mode and the integration time settings must be changed. See the next page.

Click Range button to change the ranging mode.

Click ADC/Integ button to change the integration time setting.

ZERO CHECK Range and Integration Time

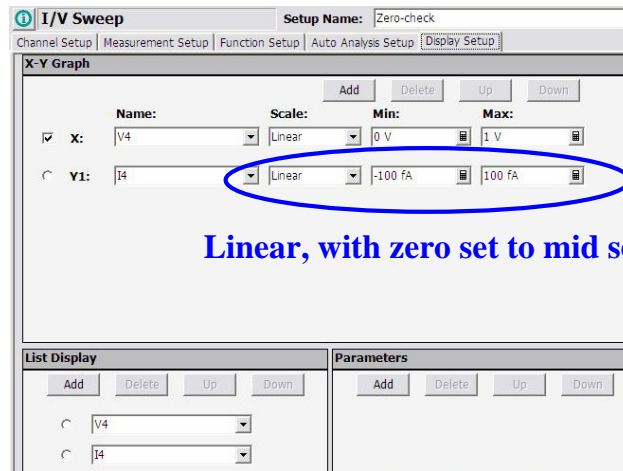
**Change SMU Range to
AUTO or LIMITED 10 pA**

**Change Integration Time to
16 PLC**

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You must change the range setting from the default of LIMITED 1 nA to LIMITED 10 pA or to AUTO. Otherwise you will have 100 fA resolution instead of the best 1 fA resolution possible. Also change the High Resolution ADC Mode to PLC and Factor to 16. You will see +/- 3 fA variation measurement result as shown in the previous slide.

ZERO CHECK Display Setup



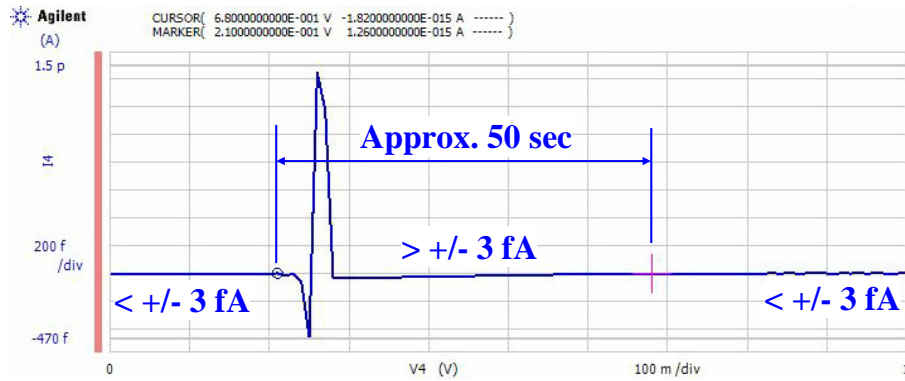
Linear, with zero set to mid scale



The best check is done with a LINEAR scale which brackets either side of ZERO by 100 fA or less.

A log scale is particularly unacceptable, Log plots of zero are not possible, and all readings of a log plot must be either all positive or all negative.

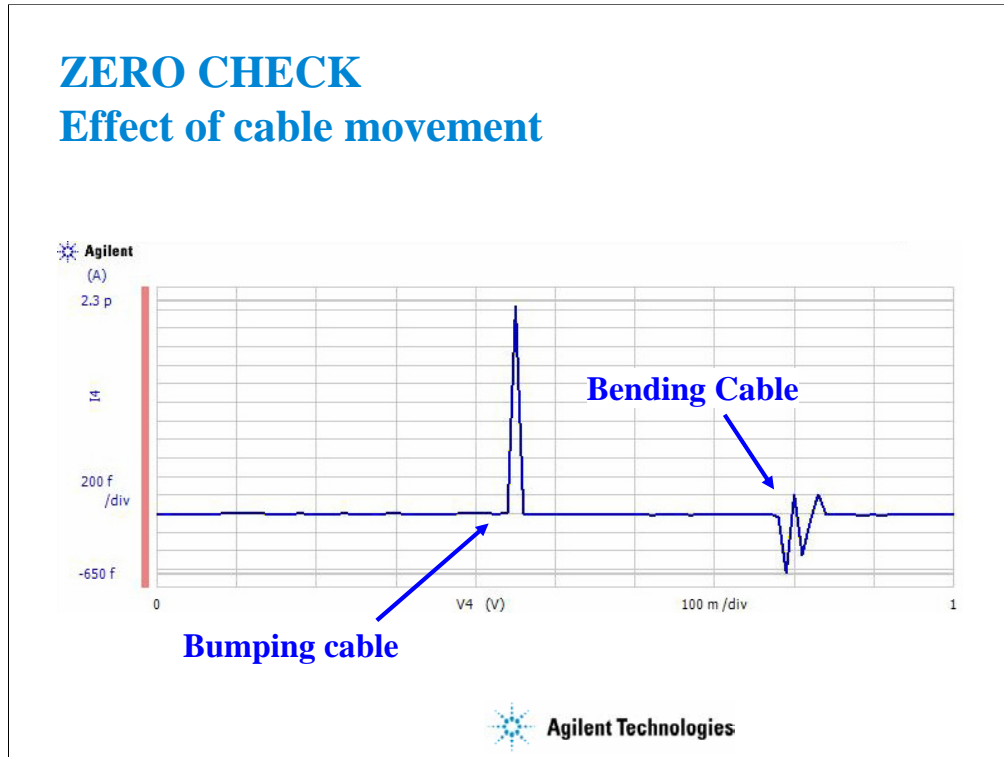
ZERO CHECK Effect of connecting a triaxial cable



Agilent Technologies

If you change anything in your fixturing or cabling, wait at least 1 minute before making a measurement at low currents.

Here we see the effect of connecting a cable to the open SMU port of the B1500A. The discontinuity lasted for 50 seconds of a 2 minute sweep from 0 to 1 volt in 10 mV steps.



As you can see, your fixturing must be free from vibration. Bending cables during a test is another NO NO. The above measurements were made on a single triax cable for classic parameter analyzers. The Kelvin triax cable is less sensitive to movement (triboelectric effects). However, either cable works fine to fA level if the cables are reasonably still...i.e. not swinging, coiled up and moved, etc.

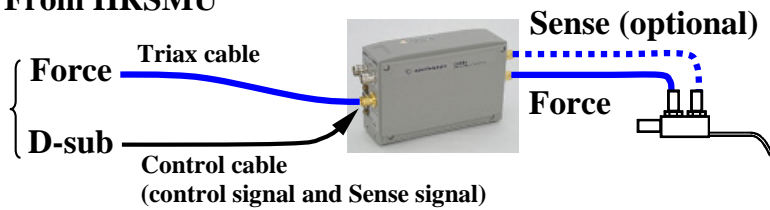
(End Of This Class Exercise)

ZERO CHECK Appendix: Using ASU



For Ultra Low Current Measurement

From HRSMU

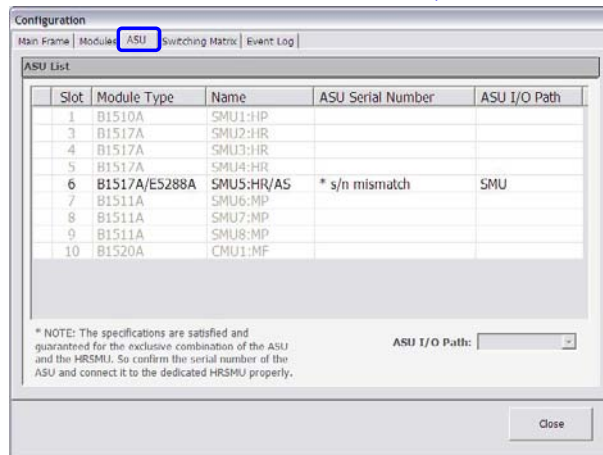


For ultra low current measurement, use ASU (atto sense/switch unit).
The HRSMU has an innate 1 fA measurement resolution. And the ASU extends it to 0.1 fA.

Note that the ASU must be connected to the HRSMU before turning on the B1500A.

ZERO CHECK Appendix: Using ASU

 Configuration



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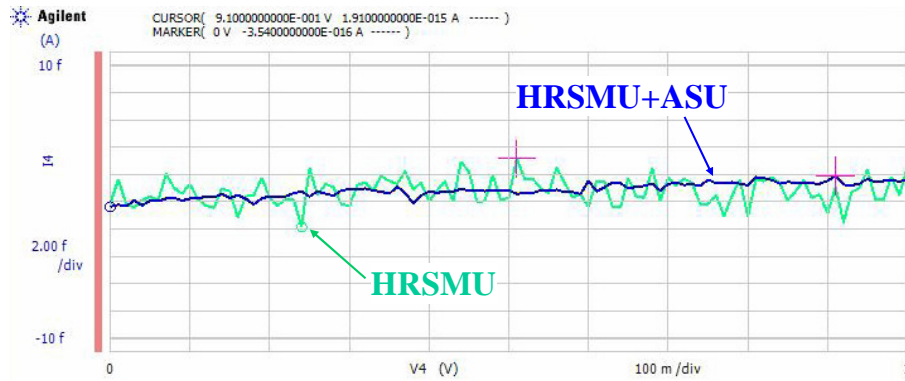
You can check whether the ASU connection is correct or wrong. Open the Configuration window and look at the ASU tab screen.

If the ASU Serial Number field shows its serial number, the HRSMU-ASU combination is correct.

If the ASU Serial Number field shows *s/n mismatch, the combination is wrong.

The B1500A can work with this wrong combination however it cannot satisfy its specifications. The specifications are guaranteed for the correct combination of HRSMU and ASU.

ZERO CHECK Appendix: Using ASU



This slide shows the open measurement results with ASU and without ASU.

The ASU provides the 1 pA measurement range and the stable measurement results as shown.

The 1 pA range is disabled with the default setting. To enable the 1 pA range, set the ranging mode to LIMITED 1 pA (1 pA limited auto ranging) or FIXED 1 pA (1 pA fixed range).

Class Exercise

Low Current Subthreshold

You will:

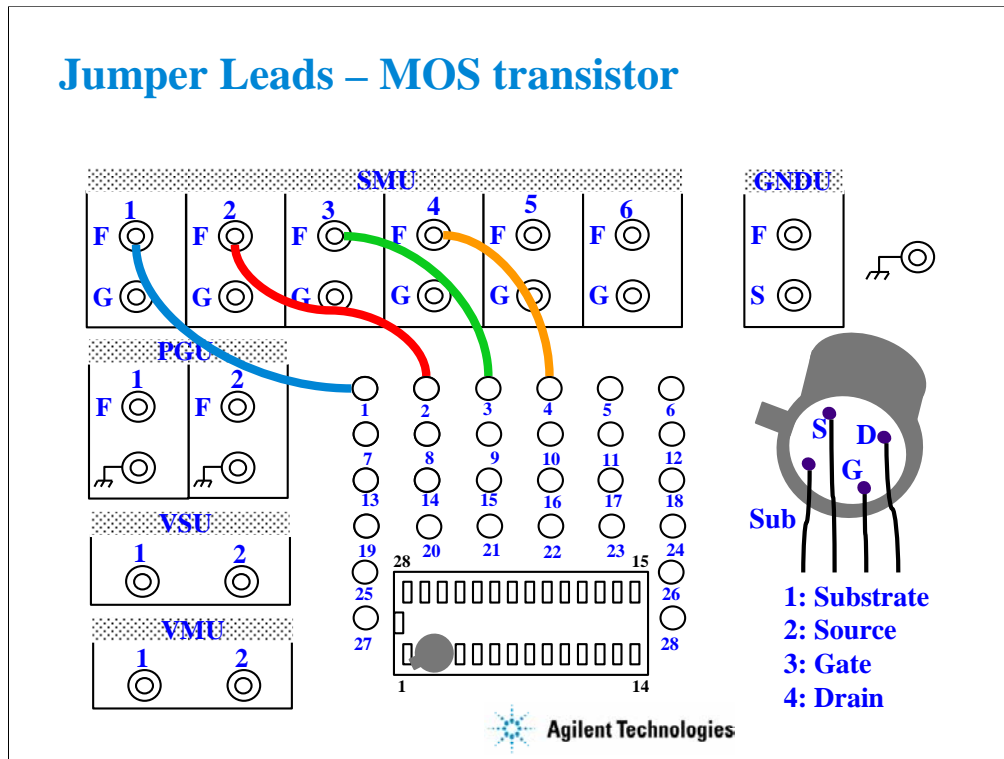
- Check low level accuracy with fixture lid open/closed
- Observe trade off between resolution and speed
- Change resolution from LIMITED 1 nA to LIMITED 10 pA
- Observe trade off between averaging and speed
- Change integration from AUTO to PLC to MANUAL

To Get Started:

- Use the next pages to setup the MOS FET correctly
- Get the IDVG setup in the Demo preset group



The following pages show a typical plot of the subthreshold curves for this class exercise, device connections, and setup changes with comments.



For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme. On older fixtures, this scheme is shown in light blue lettering. In newer fixtures, this scheme is shown in white reverse background lettering.

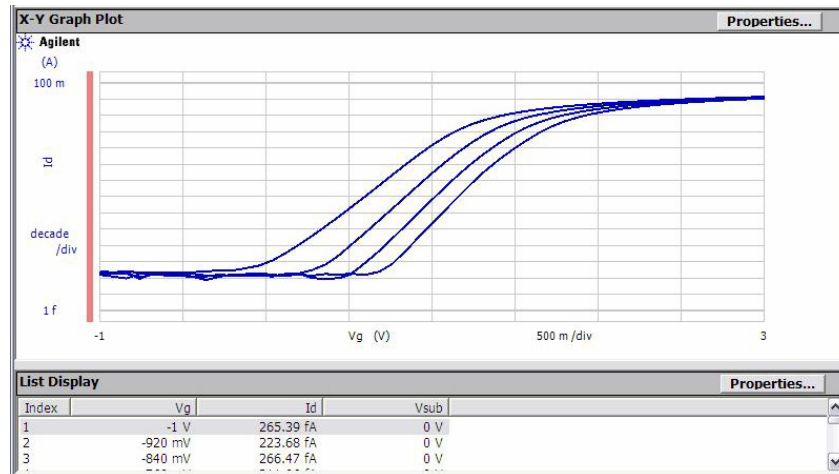
Connect the cables between the B1500A and test fixture as follows.

- SMU1 : SMU1
- SMU2 : SMU2
- SMU3 : SMU3
- SMU4 : SMU4

Connect jumper leads as follows.

- Terminal 1 : SMU1 F terminal
- Terminal 2 : SMU2 F terminal
- Terminal 3 : SMU3 F terminal
- Terminal 4 : SMU4 F terminal

Class Exercise SD214DE MOS Subthreshold



With lid closed, you should see this typical response using the IDVG setup data. If the subthreshold region is much higher, at the pA or nA level, the MOS device may be statically damaged. Replace the device using the handling procedure detailed on the previous page.

Class Exercise Trade Off Speed vs Accuracy

SMU Range Setup

Unit:	Name:	Mode:	Range:	Range Change Rule:	Rate:
SMU1:HP	[Sub]	LIMITED	1nA	BY FULL RANGE	[Full]
SMU2:HP	[5]	LIMITED	1nA	BY FULL RANGE	[Full]
SMU3:HR	[p]	LIMITED	10pA	BY FULL RANGE	[Full]
SMU4:HR	[d]	LIMITED	100nA	BY FULL RANGE	[Full]

Change LIMITED range from 10 pA to 100 nA.

Integration Time

Mode:	Factor:	Auto Zero:
High Resolution ADC: PLC	16	[Off]
High Speed ADC: AUTO	1	[Off]

**Change Factor from 16 to 1.
Change Mode from PLC to NORMAL.**



You can trade off speed vs accuracy by varying the LIMITED range setting or the integration time setting.

The 100 nA range will speed up the test but you will lose low-end resolution. Try setting LIMITED to 10 pA range or 100 pA range. Accuracy increases but speed slows considerably.

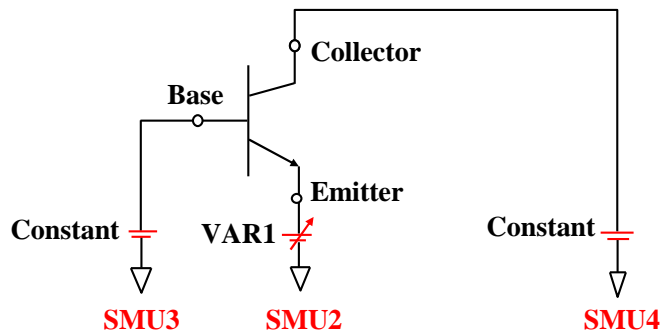
For the integration time, small factor value will speed up but accuracy decreases.

Also measurement speed will be changed by the Mode setting. Set the mode which provides applicable measurement results.

Gummel Plot

What is measured?

- V_e is swept while V_b and V_c are held at 0 V
- I_b and I_c are plotted on log scale



The "Gummel Plot" is an excellent low current measurement to make on a bipolar transistor. It plots log base current and log collector current against the same bias voltage. A good bipolar device has constant gain over a wide bias range (both curves are linear and parallel). Low level base and collector currents can be measured to the fA level on small signal devices.

Above, we see the simplest channel definition for making a Gummel plot. The emitter is swept from ground to a negative value on a NPN device. Another method would be to hold V_e at 0 V while synchronously sweeping V_b and V_c in a positive direction. In the later case, V_b could be the primary sweep VAR1, and V_c could be the synchronous sweep VAR1'.

Class Exercise

Low Current Gummel Plot

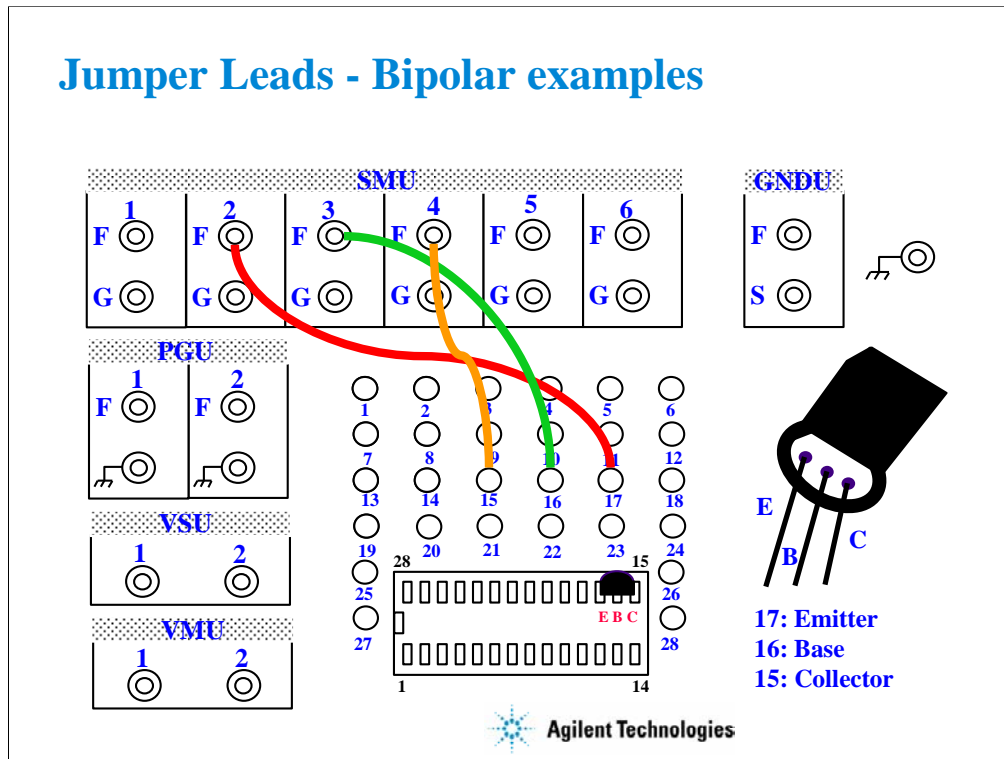
- You will notice that sub 10 fA measurements are possible

To Get Started:

- Set the jumper leads for the bipolar transistor
- Insert the device and perform a zero cancel offset
- Get the GUMMEL setup in the Demo preset group



The following pages will lead you through the setup and measurement procedure for a low current Gummel measurement. Single triaxial cable connections to the force lines of SMUs 2, 3, and 4 are fine for this test. Kelvin triaxial cables are not necessary.



For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme.

Connect the cables between the B1500A and test fixture as follows.

- SMU1 : SMU1
- SMU2 : SMU2
- SMU3 : SMU3
- SMU4 : SMU4

Connect jumper leads as follows.

- Terminal 15 : SMU4 F terminal
- Terminal 16 : SMU3 F terminal
- Terminal 17 : SMU2 F terminal

Locate the bipolar transistor in the corner of the socket as shown, with the flat side of the device facing toward you.

Unlike the MOS device, the bipolar transistor is not static sensitive. You may touch the leads without using a ground strap.

Gummel Plot Measurement Setup

VARI

Unit: SMU2:HP
Name: Ve
Direction: Single
Linear/Log: LINEAR
Start: 0 V
Stop: -850 mV
Step: -10 mV
No of Step: 86
Compliance: 100 mA
Pwr Comp: OFF

Range
ADC / Integ
Advanced

Timing
Hold: 0 s Delay: 0 s * Sweep CONTINUE AT ANY status

Constants

Unit:	V Name:	I Name:	Mode:	Source:	Compliance:
SMU3:HR	Vb	Ib	V	0 V	100 mA
SMU4:HR	Vc	Ic	V	0 V	100 mA



V_e is swept below ground level to keep positive bias on the NPN device.

Gummel Plot Range and Integration Time

The image shows two dialog boxes from an Agilent instrument. The top dialog is 'SMU Range Setup' with a 'Measurement Range' table. The bottom dialog is 'A/D Converter & Integration Time Setup' with an 'Integration Time' section. Blue circles and arrows highlight specific settings.

Unit	Name	Mode	Range	Range Change Rule	Rate
SMU2:HP	Ie	LIMITED	1nA	BY FULL RANGE	Full
SMU3:HR	Ib	LIMITED	10pA	BY FULL RANGE	Full
SMU4:HR	Ic	LIMITED	10pA	BY FULL RANGE	Full

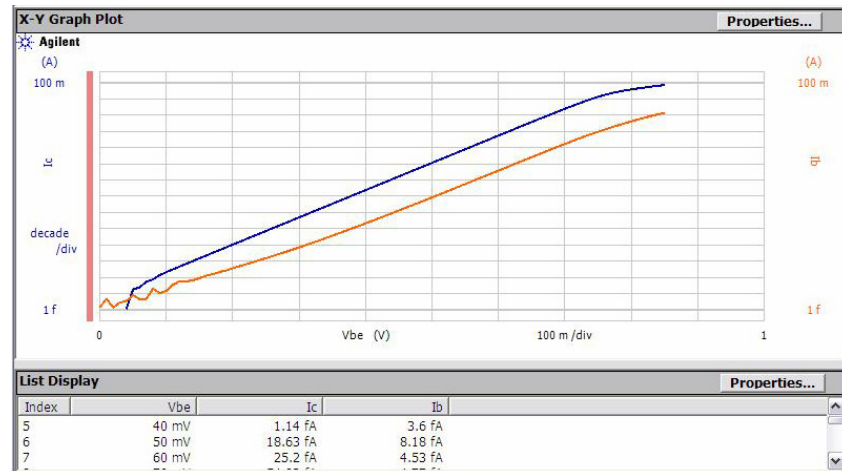
Integration Time settings:
High Resolution AD: Mode: PLC, Factor: 16, Auto Zero: OFF
High Speed ADC: Mode: AUTO, Factor: 1

Annotations:
- A blue circle around '16' in the High Resolution AD Factor field is labeled '16 PLC'.
- A blue circle around the 'LIMITED' mode and '10pA' range for SMU3:HR and SMU4:HR is labeled 'Maximum resolution'.

Medium integration smoothes the plot at the ultra low levels. Make sure the range is set to AUTO or LIMITED to lowest current range:

- HRSMU: 10 pA
- MPSMU: 1 nA
- HPSMU: 1 nA

LOW CURRENT MEASUREMENT Gummel Plot

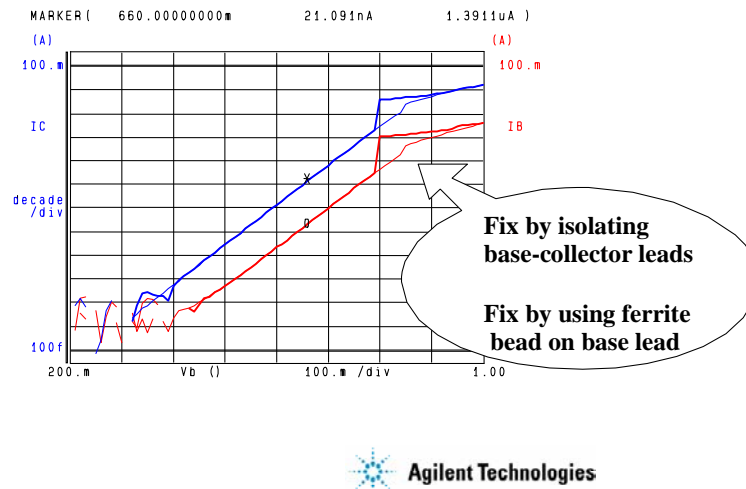


This curve shows a normal gummel characteristic of the bipolar transistor. The collector current is linear when plotted on log scale from 10 mA down to fA levels.

Keep the fixture lid closed and do not bump any part of the setup during the measurement.

(End of This Class Exercise)

Gummel Plot With Base-Collector Self Oscillation

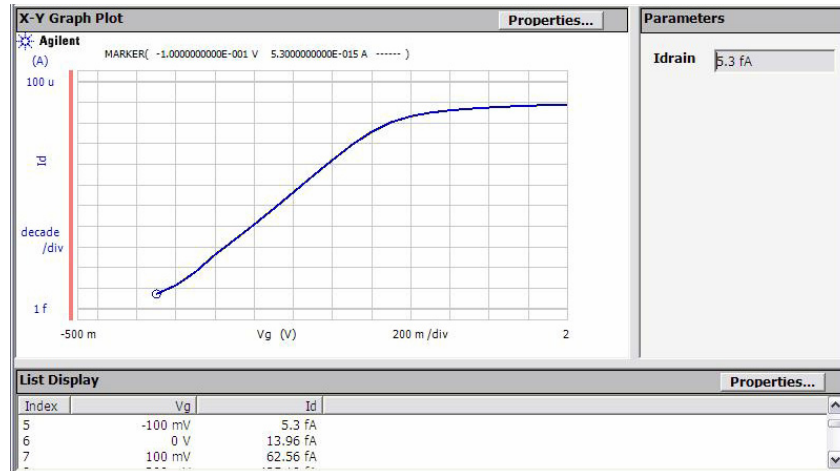


This is a common occurrence when high frequency bipolar transistors are tested with jumper lead connections. When RF couples in the air to the base lead, there can be enough DC rectification to increase the base current bias. This causes positive feedback. At some point along the curve, there will be enough feedback to abruptly turn on the transistor (steep increase in base and collector current).

Separating the leads can help marginally. Threading one or two ferrite beads onto the base jumper lead usually solves the problem. Use ferrite beads with any type of 4145, 4155, 4156 jumper lead. Using the beads on a jumper lead involves prying open one end of the plastic connector. The connector is temporarily unsoldered from the lead to slip on several beads.

For severe oscillation, the RF transistor must be tested in an RF fixture designed to maintain RF isolation between input (base) and output (collector) ports.

ULTRA LOW CURRENT Subthreshold Curve



This curve shows the high quality measurement that you would typically expect with the B1500A and a well guarded probe station. The MARKER is sitting at 5.3 fA near the subthreshold region.

To get best ultra low current accuracy, zero the SMU offset error just prior to taking the measurement by using the Calibration window. See beginning of this module, before page 10 in this module. Do the ZEROing procedure with the probes up.

ULTRA LOW CURRENT Measurement Setup

Small STEP: 100 mV

Large HOLD TIME: 3 sec

Hold: 3 s

Step: 100 mV

Start: -500 mV

Stop: 2 V

No of Step: 26

Compliance: 1 mA

Pwr Comp: OFF

Timing

Hold: 3 s **Delay: 0 s** * Sweep CONTINUE AT ANY status

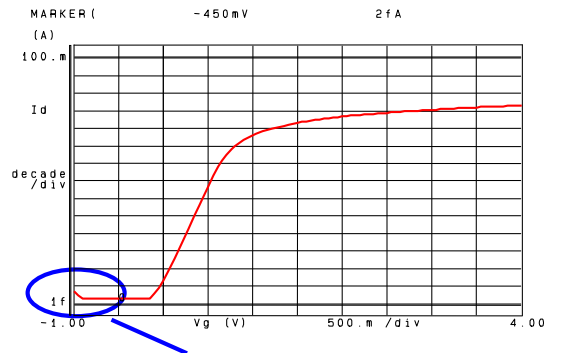
Unit:	V Name:	I Name:	Mode:	Source:	Compliance:
SMU1:HP	Vsub	Isub	V	0 V	100 mA
SMU2:HP	Vs	Is	V	0 V	100 mA
SMU4:HR	Vd	Id	V	1 mV	1 mA

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To prevent charging current due to residual cable or probe capacitance, you should limit the STEP size to 100 mV. The B1500A has a built-in delay time on the low current ranges, and you do not need to add extra time.

If the STEP is large, like the -500 mV for the first point in this sweep, simply add an initial hold time. 3 to 5 seconds should work fine. This has the effect of holding off measurement for a specified amount of time, at the beginning point only.

ULTRA LOW CURRENT Effect of Cable Charging Current



Not part of the subthreshold characteristic



You can see an initial high current that drops off after a few measurements. This is the effect when delay time is set to zero. Any residual capacitance due to un-guarded probes is the cause. This effect is minimal in this case due to the use of fully guarded probes to within 2 mm of the probe tip. With unguarded probes this initial charging current can be orders of magnitude larger, and dominate the low end portion of the subthreshold curve.

The solution is to improve the guarding as much as practical. Then get the last bit of charging out of the curve by using a delay time of at least 3 seconds in the Measurement Setup. This gives the cable time to discharge prior to making the first measurement.

ULTRA LOW CURRENT Range and Integration Time

SMU Range Setup

Unit:	Name:	Mode:	Range:	Range Change Rule:	Rate:
SMU4:HR	Id	LIMITED	10pA	BY FULL RANGE	High
SMU3:HR	Iq	LIMITED	1nA	BY FULL RANGE	High
SMU2:HP	Is	LIMITED	1nA	BY FULL RANGE	High
SMU1:HP	Isub	LIMITED	1nA	BY FULL RANGE	High

Lowest resolution: Auto or Limited 10 pA

A/D Converter & Integration Time Setup

Unit:	Name:	ADC:
SMU4:HR	Id	HR ADC
SMU3:HR	Iq	HR ADC
SMU2:HP	Is	HR ADC
SMU1:HP	Isub	HR ADC

Integration Time

High Resolution ADC:	Mode:	Factor:	Auto Zero:
PLC	PLC	50	OFF
High Speed ADC:	AUTO	1	

Set long integration time

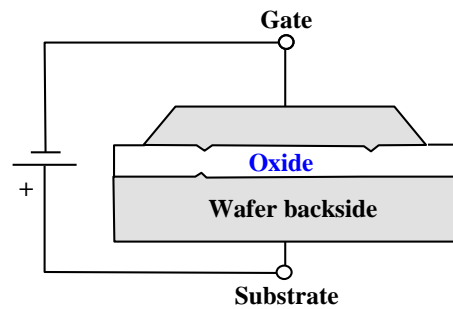


In this example we are measuring Id very accurately. The B1500A autoranges every decade of current down to 1 nA as a factory default. Change this to AUTO or LIMITED 10 pA to get two more ranges of low end resolution (1 fA resolution). The factory default of LIMITED 1 nA gives 100 fA resolution and is adequate for most measurements. Since the B1500A can trade off speed for resolution, you get better speed performance by limiting current ranging.

If your prober environment is not ultra low noise, you can remove some random noise by setting long integration time.

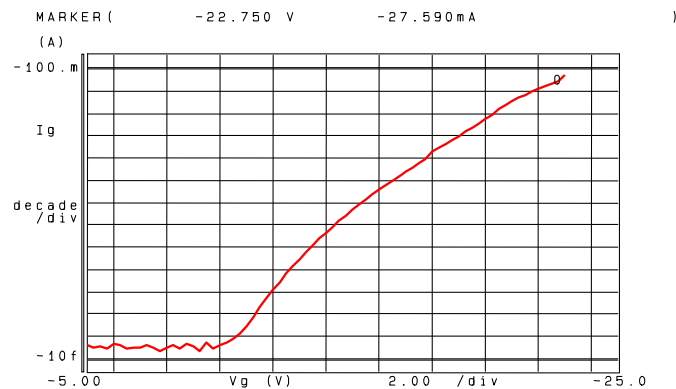
Low Current Leakage Gate Oxide

- Leakage to fA levels
- Electrical connection to wafer backside
- Chuck must be guarded



Gate oxide leakage tests are complicated by the fact that there is an electrical connection to the back of the wafer. The chuck must be insulated and guarded to get meaningful low current results. The huge capacitance of the chuck surface would cause charging currents which would swamp out the low level currents you are trying to measure through the oxide.

Low Current Gate Oxide Measurement Fowler-Nordheim (FN) Plot



The Fowler-Nordheim (FN) plot is a log plot of oxide leakage in accumulation mode breakdown. The plot shows a characteristic "arc" leading up to the rupture current.

This plot is a measurement result example of a MOS capacitor on a wafer. You cannot get this kind of plot by measuring the class exercise MOS FET.

The MARKER is set to -27.590 mA. This is the point at which rupture of the gate oxide occurred. The B1500A has the sweep abort function which automatically aborts sweep measurement when any abnormal occurs.

FOWLER-NORDHEIM PLOT Measurement Page

Unit: SMU3:HR
Name: Vg
Direction: Single
Linear/Log: LINEAR
Start: -5 V
Stop: -25 V
Step: -250 mV
No of Step: 81
Compliance: 50 mA
Pwr Comp: OFF

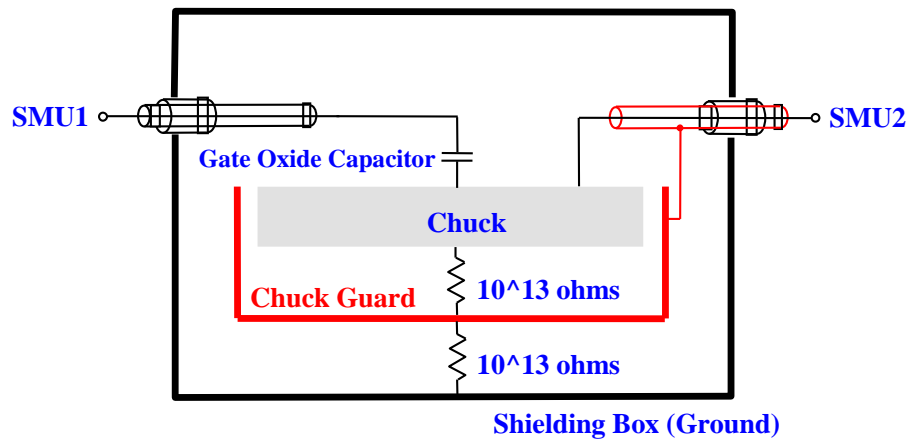
Timing
Hold: 3 s
Delay: 0 s
Sweep: STOP AT ANY ABNORMAL status

Constants
Unit: SMU1:HP
V Name: Vsub
I Name: Isub
Mode: V
Source: 0 V
Compliance: 100 mA



A 3 second delay at the beginning of the measurement will be required. The SMU must initially step from 0 to -5 V, a very large step. Fully guarded probes to within 2 mm of probe tip and fully guarded chuck eliminated the need for delays at every measurement point. The only wait will be the initial 3 second hold time.

Low Current Gate Oxide Meas. Using Guarded Chuck



This is a simplified block diagram of the prober requirements for a guarded chuck connection. When implemented properly, very fast low level sweeps are possible due to the elimination of stray capacitance at the probes (wafer top side) as well as in the chuck (wafer bottom side).



7

Measurement Functions



In This Module

- SMU Pulsed Sweep Measurement
- I/V-t Sampling Measurement
- Negative Hold Time for High Speed Sampling
- Auto Analysis
- Bias Hold Function
- SMU Filter
- SMU Series Resistor
- Standby Function



There are too many measurement functions to conveniently cover in one module. Ultra low current measurement and capacitance measurement are covered in separate modules.

This module covers the key features listed above.

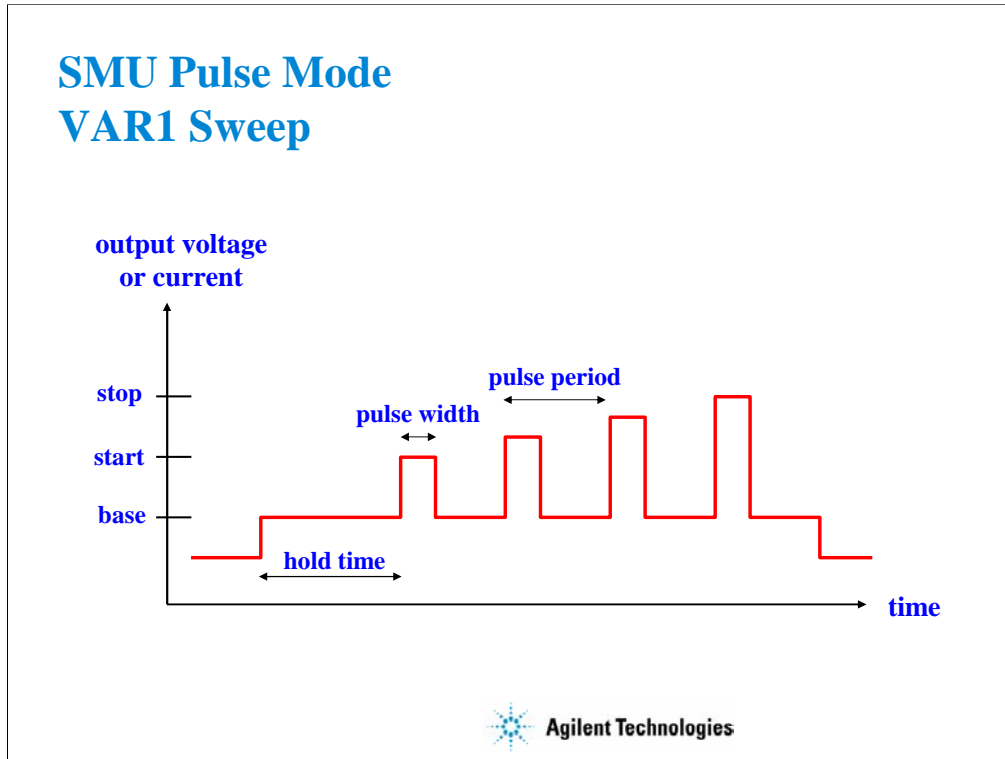
SMU Pulsed Sweep Measurement

- Use PULSE mode for precise force/measure timing
 - Pulse down to 500 μ s width
 - Use current ranges from 1 nA to 1 A (HPSMU)
 - Use voltage ranges from 2 V to 200 V (HPSMU)
- Use PULSE mode for repeatable 1 A measurements
 - Eliminate heating during IV sweeps
 - Avoid device damage
- Only one pulsed source is available
- Only one measurement channel is available
- Set the expected maximum measurement value to Compliance
- Measurement integration time cannot be changed



SMUs can be pulsed for precise force/measure timing, or to reduce heating of the device when forcing high currents.

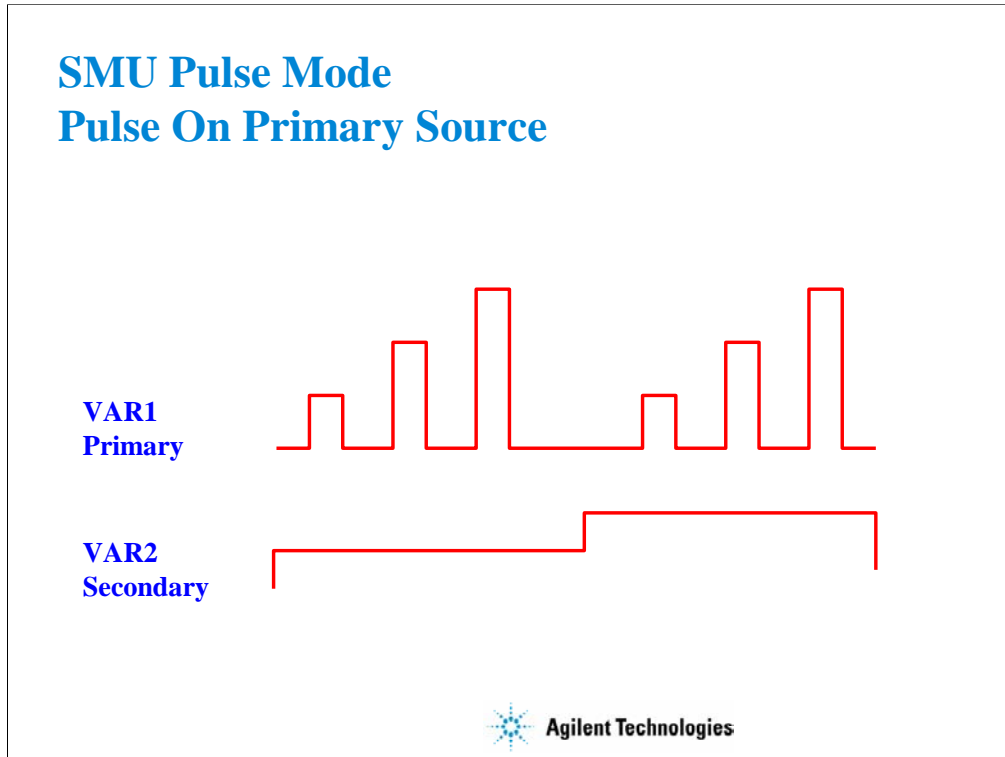
The measurement unit performs measurement by using the compliance range. It is the minimum range which covers the Compliance value. The Compliance value should be the expected maximum measurement value or greater.



When you select VPULSE or IPULSE on the Channel Setup screen, the SMU Pulse area will appear on the Measurement Setup screen.

Pulse period may be adjusted from 5 ms to 5 s in 100 us steps. Pulse period is measured from the base value to peak value transition, between two consecutive pulses.

Pulse width may be adjusted from 0.5 ms to 2 s in 100 us steps. Pulse width is measured between the transition from base value to peak value and the transition from peak value to base value.

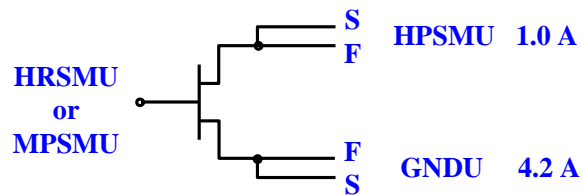


One SMU can pulse while another follows. Either VAR1 or VAR2 may be pulsed, but not both.

The settings above could be used to pulse a drain while stepping the gate.

Hints on Pulsing the HPSMU

- Use the HPSMU or GNDU as the current return path
- Use Kelvin connections (must use on GNDU)
- Use 16493L GNDU cable for the GNDU connection



The 1 A SMU (HPSMU) cannot use another MPSMU or HRSMU as the current return. It must be used with the other HPSMU or the GNDU that can sink enough current. The GNDU is the unit that you can use without defining in the Channel Setup.

The GNDU can sink up to 4.2 A, and it is designed for the Kelvin connection. The force and sense lines must be shorted near the DUT.

For the connection of the GNDU, do not use the normal triaxial cable. The GNDU is rated for up to 4.2 A, while the maximum current rating of the triaxial cable is 1 A.

SMU Pulse Mode Limitations

- Minimum pulse width is 500 us
- Only one pulsed source is available
- Only one measurement channel is available
- Measurement range is always compliance range
- Integration time cannot be changed



Class Exercise

SMU Pulse Mode

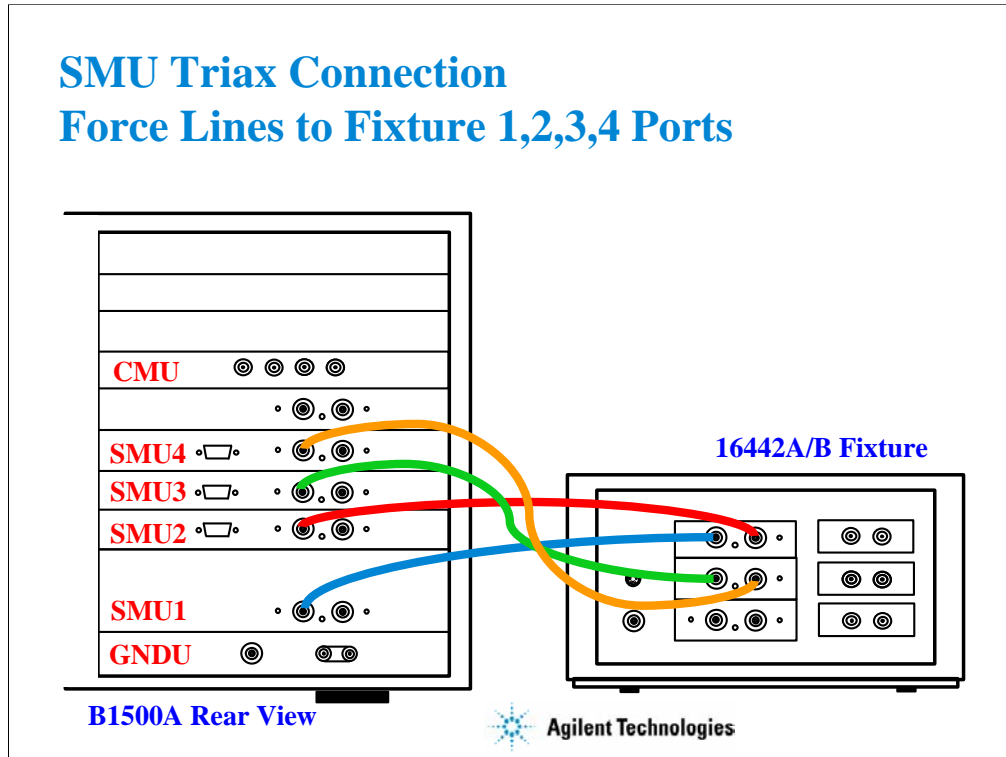
- You will observe a MOS FET family of curves
- You will edit VAR1 from V mode to VPULSE mode
- You will learn how to properly define a "pulsed" algorithm

To Get Started:

- Use the next several pages as you guide
- Get the IDVD setup
- Follow the instructions on the following pages



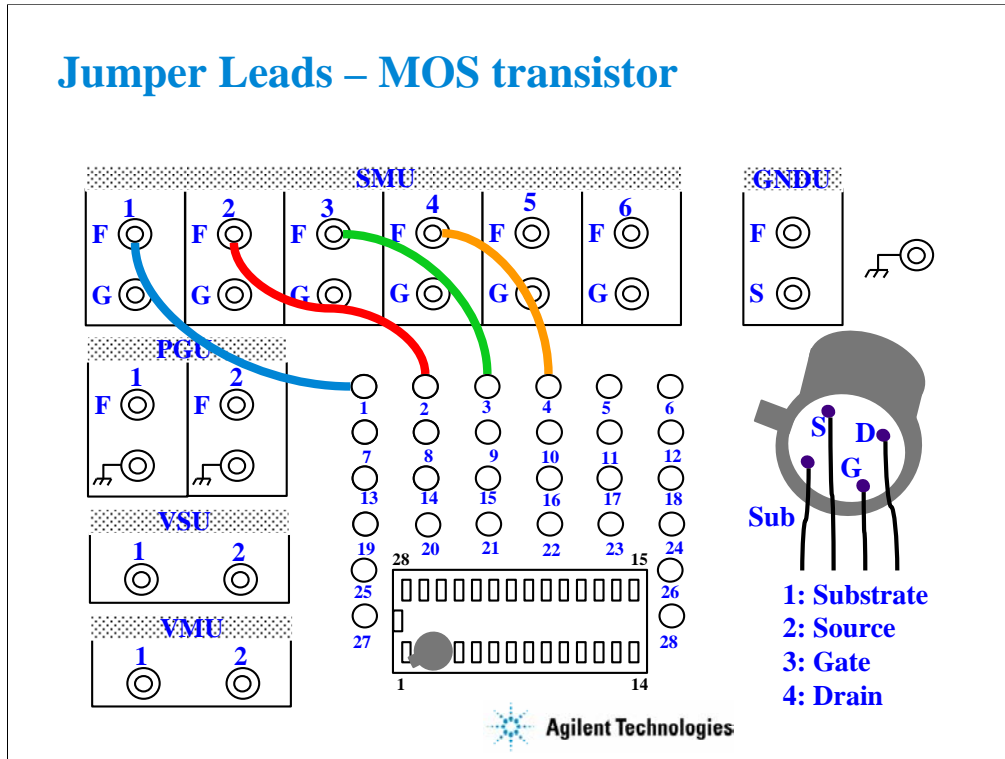
You will setup a basic MOS family of curves without VPULSE. Then change VAR1 to VPULSE.



This is the SMU cable setup that will be used in the remainder of the class exercises.

Connect the cables between the B1500A and test fixture as follows.

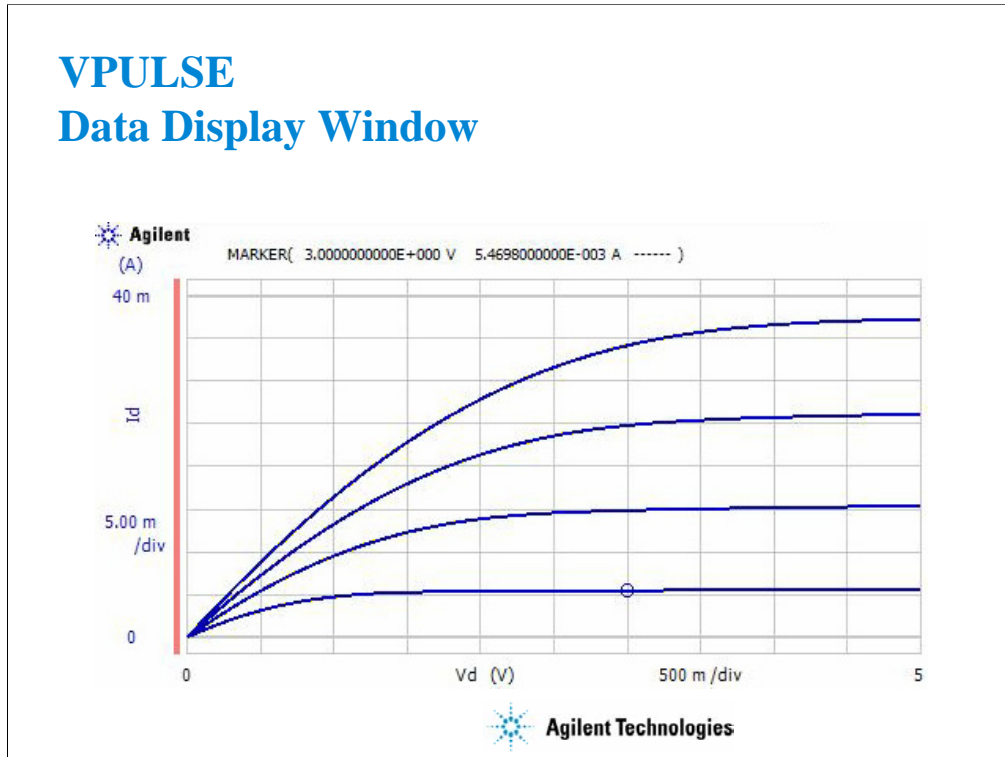
- SMU1 : SMU1
- SMU2 : SMU2
- SMU3 : SMU3
- SMU4 : SMU4



For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme. On older fixtures, this scheme is shown in light blue lettering. In newer fixtures, this scheme is shown in white reverse background lettering.

VPULSE Data Display Window



Make a measurement to verify the setup is correct. You should see the above family of curves. The algorithm is defaulted to standard staircase sweep on VAR1 (no pulsed SMU).

VPULSE Channel Setup

Enter new name before save

Channel Setup | Measurement Setup | Function Setup | Auto Analysis Setup | Display Setup

Channel Definition

Add Delete Up Down

Unit:	V Name:	I Name:	Mode:	Function:
SMU1:HP	Vsub	Isub	V	CONST
SMU2:HP	Vs	Is	COMMON	CONST
SMU3:HR	Vg	Ig	V	VAR2
SMU4:HR	Vd	Id	VPULSE	VAR1

Drain pulse



Switch VAR1 from V mode to VPULSE mode. A new panel will pop up on the Measurement Setup.

Before saving this new setup, enter new name into the Setup Name field, then click the Save button.

VPULSE Measurement Setup

The screenshot shows the measurement setup for VPULSE. The interface is divided into several sections:

- VAR1 and VAR2:** Unit: SMU4:HR, SMU3:HR; Name: Vd, Vg; Direction: Single; Linear/Log: LINEAR; Start: 0 V, 2 V; Stop: 5 V, 5 V; Step: 50 mV, 1 V; No of Step: 101, 4; Compliance: 100 mA, 10 mA; Pwr Comp: FF, OFF.
- Timing:** Hold: 0 s, Delay: 0.5 s; * Sweep: CONTINUE AT ANY; status.
- Constants:** Unit: SMU1:HP; V Name: Vsub; I Name: Isub; Mode: V; Source: 0 V; Compliance: 100 mA.
- SMU Pulse:** Unit: SMU4:HR; Period: 10 ms; Width: 1 ms; Base: 0 V.
- Buttons:** Range, ADC/Integ, Advanced.

Annotations in blue text and arrows:

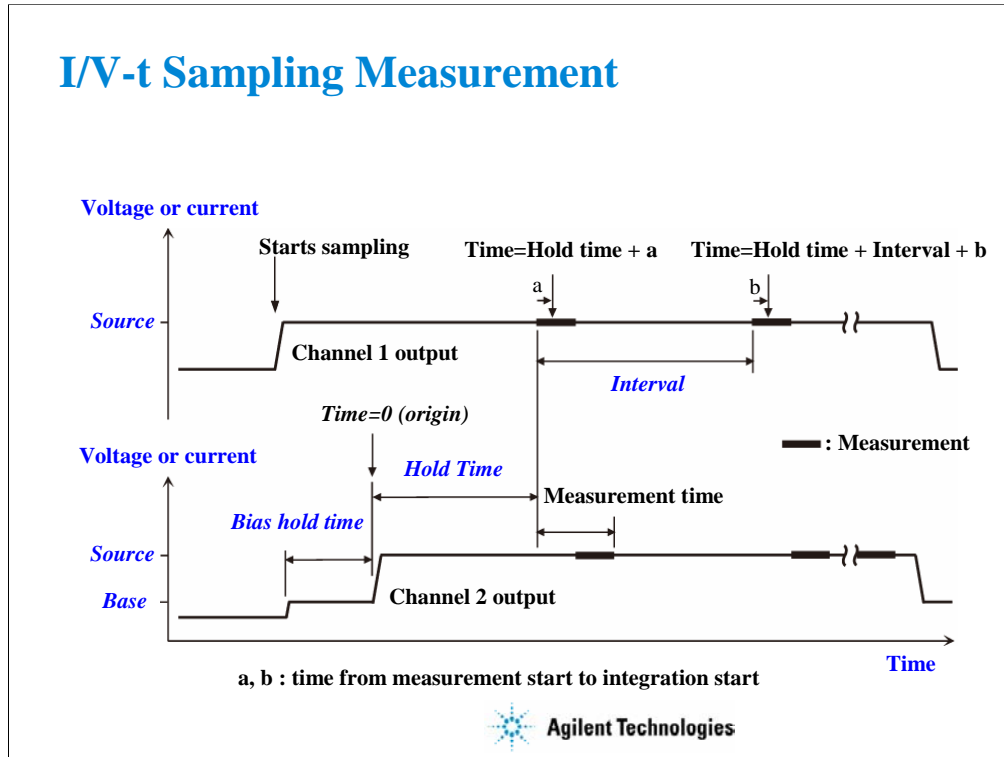
- "Range and ADC/Integ are disabled" with arrows pointing to the disabled buttons.
- "This box pops up only if VPULSE or IPULSE is set on Channel Setup." with an arrow pointing to the SMU Pulse section.
- "Maximum measurement value" with an arrow pointing to the Compliance field (100 mA), which is circled in red.



Default pulse conditions for the Measurement Setup are shown here. The base is 0, and the pulse duty cycle is 10 %. These settings are OK for this class exercise. Click the Single button to start a pulsed sweep measurement.

Range and ADC/Integ buttons are disabled for pulsed measurement. The measurement range is always the compliance range. And the integration time cannot be changed.

For example, if you change the Compliance value to 30 mA, the data beyond 30 mA cannot be measured.



B1500A supports the sampling measurement which performs the operation shown above.

With the SEQUENTIAL output sequence, the source channels start to force the Source value sequentially. Then the last source channel forces the Base value, and forces the Source value after the Bias hold time. After the Hold time, the measurement channels start measurement sequentially, and repeat this in the specified interval if the measurement channel is ready to measure. After the last sampling measurement, the source channels stop output sequentially.

The order of source output is defined in the Channel Setup. Top of the channels on the setup screen starts output first. And the following channels start output sequentially. After the measurement, the source channels stop output sequentially in the opposite order.

With the SIMULTANEOUS output sequence, the source channels start to force the Base value simultaneously. And the channels force the Source value after the Base hold time. After the Hold time, the measurement channels start measurement sequentially, and repeat this in the specified interval if the measurement channel is ready to measure. After the last sampling measurement, the source channels stop output simultaneously.

For the measurement channels which use the high resolution A/D converter, the order of measurement is defined in the SMU Range Setup. Top of the channels on the setup screen starts measurement first. And the following channels start measurement sequentially. For the measurement channels which use the high speed ADC, the channels start measurement simultaneously.

I/V-t Sampling Measurement

- LINEAR
 - Sampling interval: ≥ 2 ms
0.1 ms to 1.99 ms (limited)
 - Number of samples: 1 to 100001
- LOG
 - Sampling interval: ≥ 2 ms
 - Number of samples: 1 + number of data for 11 decades
 - Remaining data:
10/25/50/100/250/500 data are plotted into one decade
of the log scale in the same distance



There are two sampling mode. The linear sampling repeats the sampling in the specified interval until the number of measurement data reaches the specified number of samples. High speed sampling is available if the following conditions are satisfied. The high speed sampling allows you to set the sampling interval 0.1 ms to 1.99 ms in 0.01 ms step.

1. Sampling mode is LINEAR
2. High speed ADC is used for all measurement channels
3. Interval ≥ 0.08 ms + 0.02 x (number of measurement channels) ms

The log sampling repeats the sampling in the specified interval and gathers the measurement data which can be plotted on the log scale in the same distance. The sampling will be stopped when the number of measurement data reaches the specified number of samples.

Class Exercise

Sampling Measurement

You will:

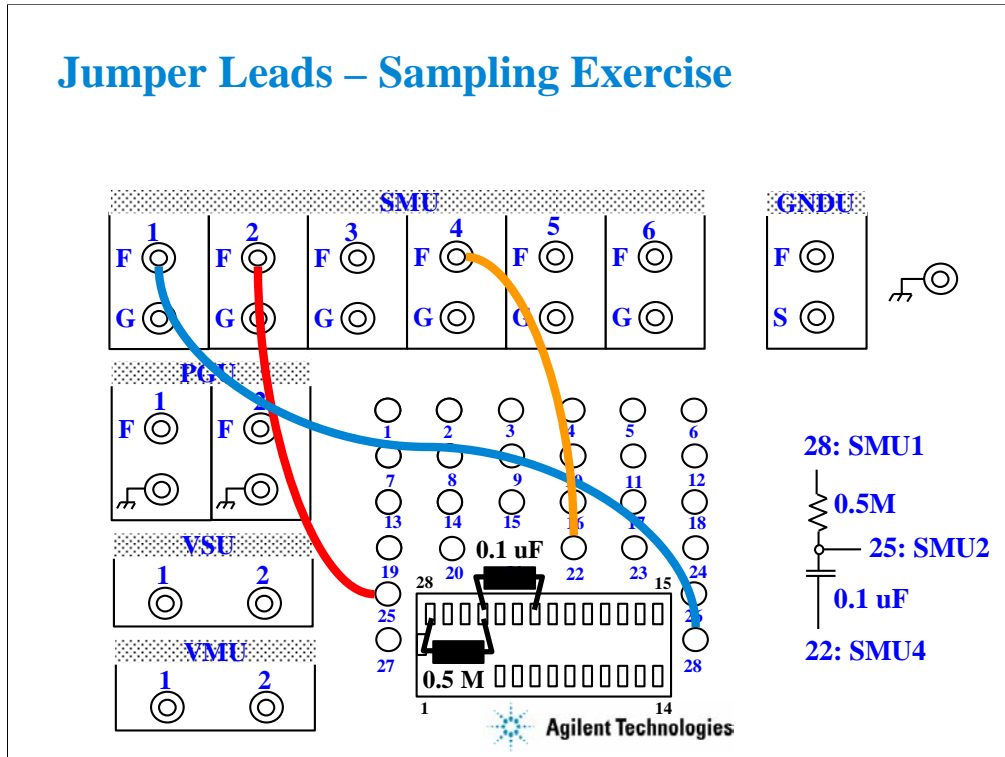
- Monitor the charging voltage of an RC circuit
- Learn LOG10 data interval
- Learn how to properly define a sampling algorithm

To Get Started:

- Use the instrument setup as same as the SMU pulse exercise
- Connect the RC components as shown in the next page
- Get and run the RC-sampling-log setup
- Change the range or ADC and perform append measurement

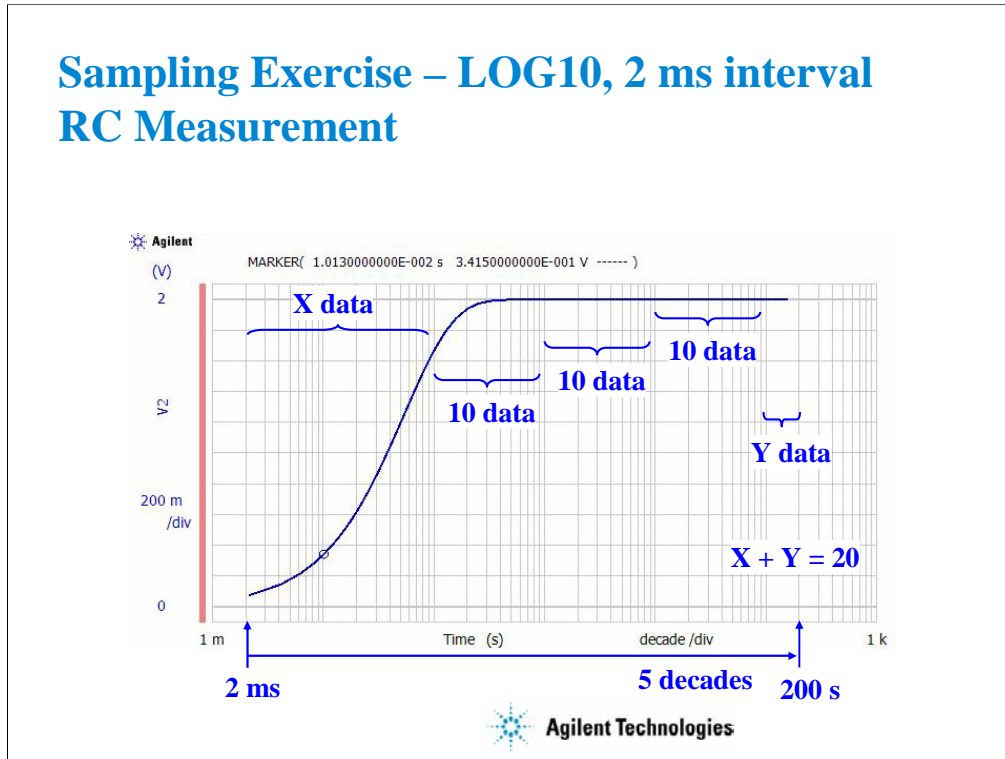


Jumper Leads – Sampling Exercise



The 0.5 M ohm and 0.1 uF values were chosen because these values are readily available, and they give a RC time constant suitable for observing 2 ms time steps.

Sampling Exercise – LOG10, 2 ms interval RC Measurement



The RC-sampling-log setup is for the LOG10 sampling with 2 ms interval and 51 samples.

LOG10 sampling obtains 10 data in one decade. And the data will be plotted on the log scale in the same distance. However this rule cannot be kept at the beginning of sampling because of long interval.

In this example, there are 10 data in each decade from 100 ms to 10 s, and 20 data in the remaining decades. The first data will be near zero second. See the List Display.

Sampling Exercise – LOG10, 2 ms interval

Index	Time	V2
19	100.13 ms	1.6674 V
20	126.13 ms	1.7874 V
21	158.14 ms	1.8764 V
22	200.13 ms	1.9385 V
23	252.13 ms	1.9727 V
24	316.13 ms	1.9886 V
25	400.13 ms	1.9959 V
26	502.13 ms	1.9983 V
27	632.13 ms	1.9989 V
28	796.13 ms	1.9992 V
29	1.00213 s	1.9996 V
30	1.26213 s	2 V
31	1.58813 s	1.9999 V
32	2.00013 s	2 V
33	2.51813 s	2.0004 V
34	3.17013 s	2.0001 V
35	3.99013 s	2.0004 V
36	5.02413 s	2.0001 V
37	6.32413 s	2.0003 V
38	7.96213 s	2.0004 V
39	10.02413 s	2.0002 V
40	12.62013 s	2.0003 V
41	15.88613 s	2.0002 V
42	20.00013 s	2.0002 V
43	25.17813 s	2.0003 V
44	31.69813 s	2.0001 V
45	39.90613 s	2.0003 V
46	50.23813 s	2.0002 V
47	63.24613 s	2 V
48	79.62213 s	2.0003 V
49	100.23813 s	2.0002 V

10 data/decade

10 data/decade

10 data/decade



Sampling Exercise Channel Setup

I/V-t Sampling Setup Name: RC-sampling-log

Channel Setup | Measurement Setup | Function Setup | Auto Analysis Setup | Display Setup

Channel Definition

Add Delete Up Down

Unit:	V Name:	I Name:	Mode:
SMU1:HP	V1	I1	V
SMU2:HP	V2	I2	I
SMU4:HR	V3	I3	COMMON

Miscellaneous Variables

Time Stamp Name: Time Index Name:

Variable for time data



Sampling Exercise Measurement Setup

The screenshot displays the Agilent I/V-t Sampling Measurement Setup interface. Key components include:

- I/V-t Sampling Setup:**
 - Channel Setup: Measurement Setup, Function Setup
 - Sampling Parameter:
 - Linear/Log: LOG10
 - Interval: 2 ms
 - No of Samples: 51
 - Total Sampling Time: 158.866 s
 - Output Sequence: SIMULTANEOUS
 - Hold Time: 0 s
 - Base Hold Time: 0 s
 - Constants:

Unit:	V Name:	I Name:	Mode:	Base:	Source:	Compliance:
SMU1:HP	V1	I1	V	0 V	2 V	100 mA
SMU2:HP	V2	I2	I	0 A	0 A	3 V
- SMU Range Setup:**

Unit:	Name:	Mode:	Range:	Range Change Rule:	Rate:
SMU1:HP	I1	LIMITED	1nA	BY FULL RANGE	High
SMU2:HP	V2	FIXED	2V		
SMU4:HR	I3	LIMITED	1nA		
- A/D Converter & Integration Time Setup:**
 - A/D Converter:

Unit:	Name:	ADC:
SMU1:HP	I1	HR ADC
SMU2:HP	V2	HS ADC
SMU4:HR	I3	
 - Integration Time:

Mode:	Factor:	Auto Zero:
High Resolution ADC: AUTO	6	OFF
High Speed ADC: AUTO	1	

Blue annotations highlight the 'FIXED range' for SMU2:HP and 'High speed ADC' for SMU2:HP.

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Use the FIXED range and the high speed A/D converter to get 2 ms interval.

Change the range to AUTO. Or change the ADC to the high resolution ADC. And perform append measurement. You may not get 2 ms interval at the beginning of sampling.

Negative Hold Time Available for Interval < 2 ms

-90 ms =< Hold Time =< -0.1 ms, 0.1 ms step



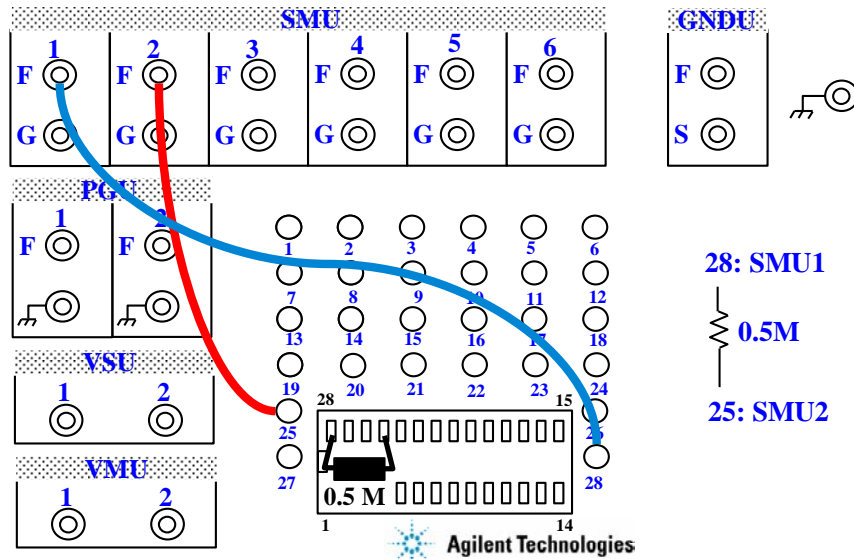
Agilent Technologies

For the sampling measurement, the available hold time value is 0 to 655.35 s, in 10 ms step.

However, the negative hold time -90 ms to -0.1 ms, in 0.1 ms step is also available for the high speed sampling which the Interval is less than 2 ms.

This measurement result example is obtained by the setup shown in the following pages.

Jumper Leads – Negative Hold Time



Negative Hold Time Channel and Measurement Setup

The screenshot displays the 'I/V-t Sampling' configuration window for a setup named 'R-samp1-neg-hold'. It is divided into two main sections: 'Channel Definition' and 'Sampling Parameter'.

Channel Definition: This section lists two channels. Channel 1 (SMU1:HP) has V Name 'V1', I Name 'I1', and Mode 'I'. Channel 2 (SMU2:HP) has V Name 'V2', I Name 'I2', and Mode 'COMMON'. A blue box highlights the 'Mode' dropdown for Channel 1, with the text 'Current source' next to it.

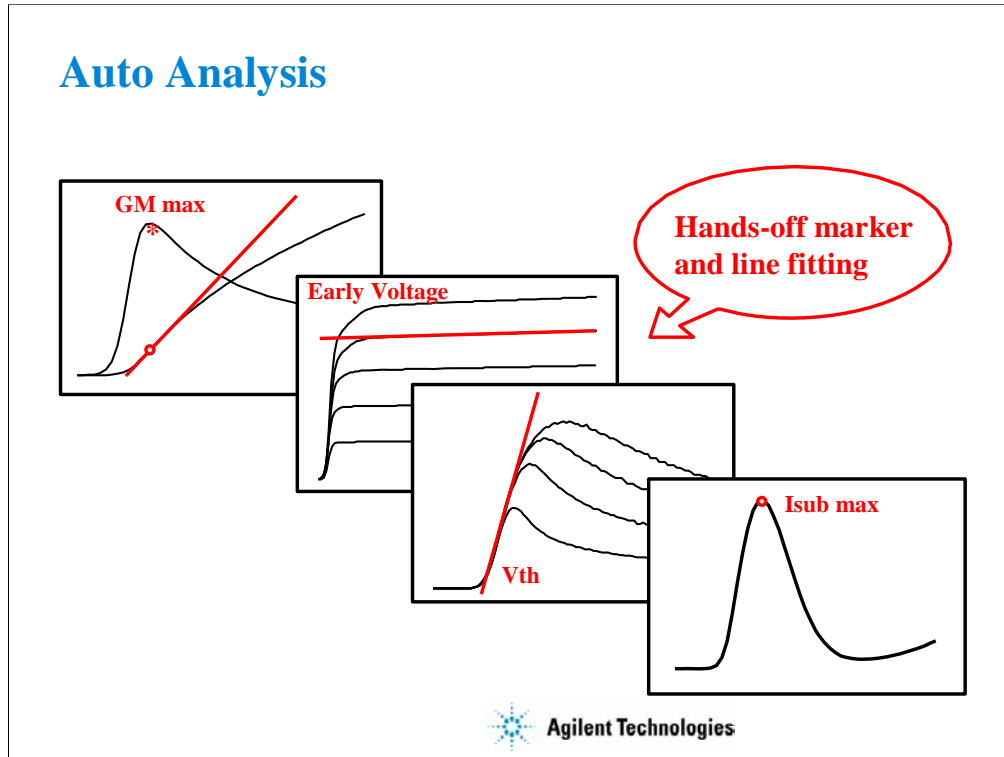
Sampling Parameter: This section includes the following settings:

- Linear/Log: LINEAR
- Interval: 200 us (highlighted with a blue box and the text 'Interval < 2 ms')
- No of Samples: 101
- Total Sampling Time: 20 ms
- Output Sequence: SIMULTANEOUS
- Hold Time: -5 ms (highlighted with a blue box and the text 'Negative Hold Time')
- Base Hold Time: 0 s

Constants: A table at the bottom summarizes the channel settings:

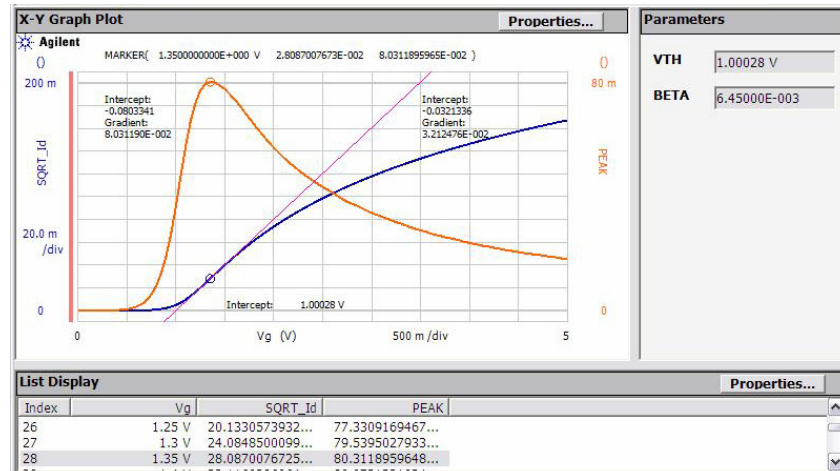
Unit:	V Name:	I Name:	Mode:	Base:	Source:	Compliance:
SMU1:HP	V1	I1	I	0 A	20 uA	20 V





Auto analysis automates the task of doing scalar calculation on swept data. Computed parameters such as V_{th} or GM_{max} can be displayed in the Parameters area on the Data Display window. The built-in user functions allow data to be plotted and analyzed according to any arbitrary formula. The B1500A has built-in functions such as axis intercepts, logs, regression lines, area integration, max/min, and many more. The ability to automatically extract important parameters such as threshold voltage without the need to manually manipulate screen cursors or markers is important in process development.

Auto Analysis Vth Example



Here we see a full-featured example of auto analysis. GMmax and Vth are automatically calculated each time a measurement is made. Even if you alter the analysis, say by moving the line, you can restore the original analysis by clicking the Apply button on the Auto Analysis Setup screen.

IMPORTANT!

Please note that formulas for auto analysis are not hard coded into the B1500A. You define the formulas, and so you can customize the method of performing the analysis.

V_{th} Measurement A Tedious Process Now Automated

- Plot square root of the drain current (SQRT Id)
- Plot rate of change of SQRT Id (PEAK)
- Find Peak Value of the PEAK plot
- Drop down to the SQRT Id plot
- Draw a tangent line on the SQRT Id plot
- Read the X-intercept of the tangent line as V_{th22}



In the previous example of graphically determining V_{th}, the above steps were automated. There are other definitions of V_{th} which are less complex, but now you don't have to worry about complexity. The B1500A can perform the process without you having to interact with the screen.

Not only automation removes human error, but also it allows computer controlled analysis to proceed without interruption.

Class Exercise

Auto Analysis

You will:

- Make a MOS threshold voltage (V_{th}) measurement
- Observe how parameters for the analysis are defined
- Observe how the user functions and analysis functions are used in the analysis

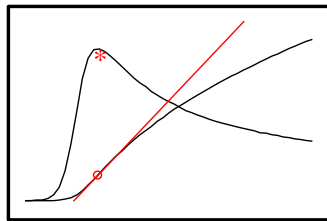
To Get Started:

- Use the standard MOS device and pin connections
- Get the GMMAX setup
- Make a measurement and turn the knob
- Click the Apply button to restore the analysis

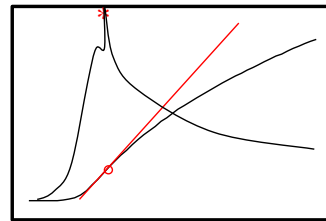


In this exercise you will observe how auto analysis works. You will understand each setup screen required to implement an auto analysis process.

V_{th} Measurement Damaged MOS FET Device?



Good
Continuous Curve
No Static Damage



BAD
Broken-Lumpy Curve
Severe Static Damage



The class exercise uses a packaged MOS FET device which is very susceptible to static damage. If the device has been handled or moved in and out of the socket a few times, you may see a BAD response as indicated above. Replace the device with a new one.

At the wafer level, you can have the same problems. Putting a charged probe with cables attached down on a gate junction can weaken or destroy the device. Also, the B1500A offset cancel (zero cancel) sends signals down to the probes. These voltages can damage a sensitive gate junction.

Vth Measurement Channel and Measurement Setup

VAR1

Unit: SMU3:HR
 Name: Vg
 Direction: Single
 Linear/Log: LINEAR
 Start: 0 V
 Stop: 5 V
 Step: 50 mV
 No of Step: 101
 Compliance: 100 mA
 Pwr Comp: OFF

Channel Definition

Unit	V Name	I Name	Mode	Function
SMU1:HP	Vsub	Isub	V	CONST
SMU2:HP	Vs	Is	COMMON	CONST
SMU3:HR	Vg	Ig	V	VAR1
SMU4:HR	Vd	Id	V	CONST

Timing

Hold: 0 s Delay: 0 s * Sweep: CONTINUE AT ANY status

Constants

Unit	V Name	I Name	Mode	Source	Compliance
SMU1:HP	Vsub	Isub	V	0 V	100 mA
SMU4:HR	Vd	Id	V	2 V	100 mA

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Nothing new here. This slide is included for completeness. You will notice that these variables are heavily used on the Function Setup screen.

Vth Measurement Function Setup

The screenshot shows two windows for setting up measurement functions. The top window is titled "User Function" and contains a table with columns for Name, Unit, and Definition. It lists two functions: Sqrt_Id and PEAK. The bottom window is titled "Analysis Function" and contains a table with columns for Name, Unit, and Definition. It lists two functions: VTH and BETA. Both windows have "Add", "Delete", "Up", and "Down" buttons.

User Function		
Name:	Unit:	Definition:
Sqrt_Id		sqrt(Id)
PEAK		diff(Sqrt_Id,Vg)

Analysis Function		
Name:	Unit:	Definition:
VTH	V	@L1X
BETA		@L1G^2



Here are definitions for the Y1-axis plot (SQRT_ID) and the Y2-axis plot (PEAK).

@L1X means the X-axis intercept of LINE 1.

@L1G^2 means the squared gradient value of LINE 1. In this case, it is just calculating line 1 slope. It is squared to account for the fact that the Y1-axis is a square root.

Click Help > Agilent EasyEXPERT Help to open the online help. And visit the Read Out Functions page for all of these functions.

Vth Measurement Display Setup Page

X-Y Graph					
	Name:	Scale:	Min:	Max:	
<input checked="" type="checkbox"/>	X:	Vg	Linear	0 V	5 V
<input type="checkbox"/>	Y1:	SQRD_Id	Linear	0	0.2
<input type="checkbox"/>	Y2:	PEAK	Linear	0	0.08

List Display		Parameters	
Add	Delete	Up	Down
<input type="checkbox"/>	Vg	<input type="checkbox"/>	VTH
<input type="checkbox"/>	SQRD_Id	<input type="checkbox"/>	BETA
<input type="checkbox"/>	PEAK		



VTH and BETA are values which will be displayed at the Parameters area on the Data Display window.

These variables are defined in the Function Setup screen.

Auto Analysis Analysis Setup Page

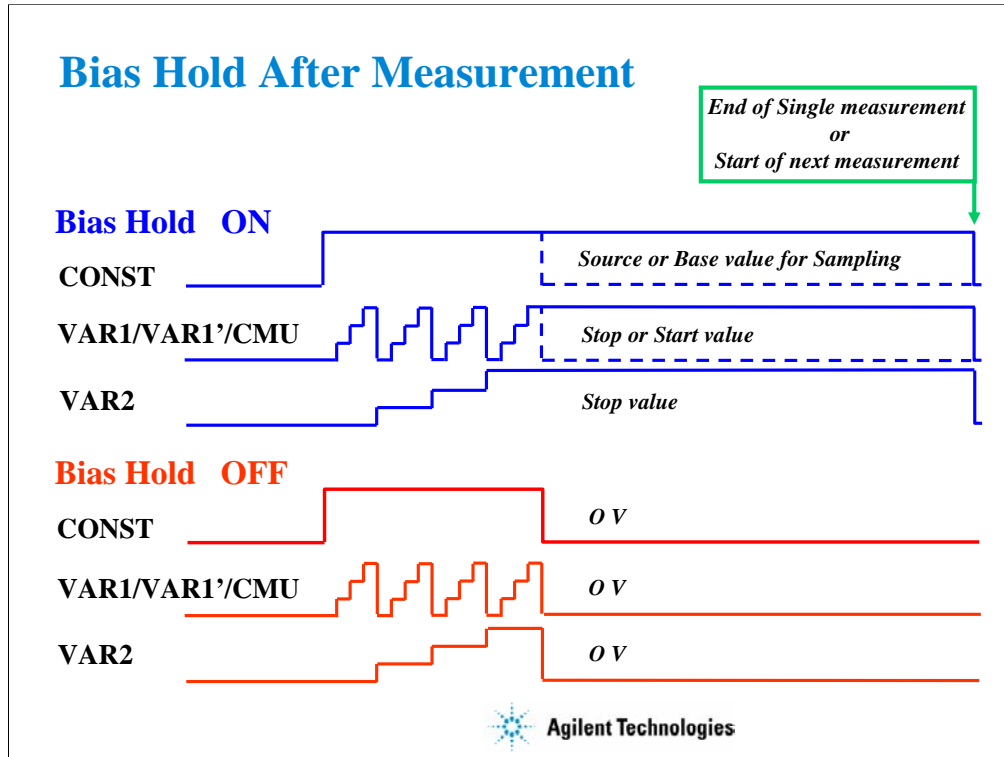
The screenshot displays the 'Auto Analysis Analysis Setup Page' with three main sections: Line 1, Line 2, and Marker.

- Line 1:**
 - Enable
 - Type: Normal Gradient Tangent Regression
 - Axis: Y1
 - First Point: X-Y Coordinate Data Condition
 - Condition: PEAK = max(PEAK) After
 - Second Point: X-Y Coordinate Data Condition
 - X: Y:
- Line 2:**
 - Enable
 - Type: Normal Gradient Tangent Regression
 - Axis: Y1
 - First Point: X-Y Coordinate Data Condition
 - X: Y:
 - Second Point: X-Y Coordinate Data Condition
 - X: Y:
- Marker:**
 - Enable
 - Condition: PEAK = max(PEAK) After



This screen is the heart of auto analysis. You define custom procedures for graphical analysis with fill-in-the-blank ease.

(End of This Class Exercise)



Bias hold function keeps bias output after a measurement is made. For instance, the user may need to keep one or more SMUs on between measurements to bias up a Vcc pin of an IC. Without this function, a user is forced to connect an external power supply. Now there is no need for extra supplies.

When this function is ON, the source channels apply the following value.

Constant source:	Base value or Source value (I/V-t sampling)
Constant source:	Source value (I/V Sweep or C-V Sweep)
VAR1/VAR1' source:	Start value or Stop value (I/V Sweep)
VAR2 source:	Stop value (I/V Sweep)
CMU: V Sweep)	Start value or Stop value (C-

Class Exercise

Bias Hold Function

You will:

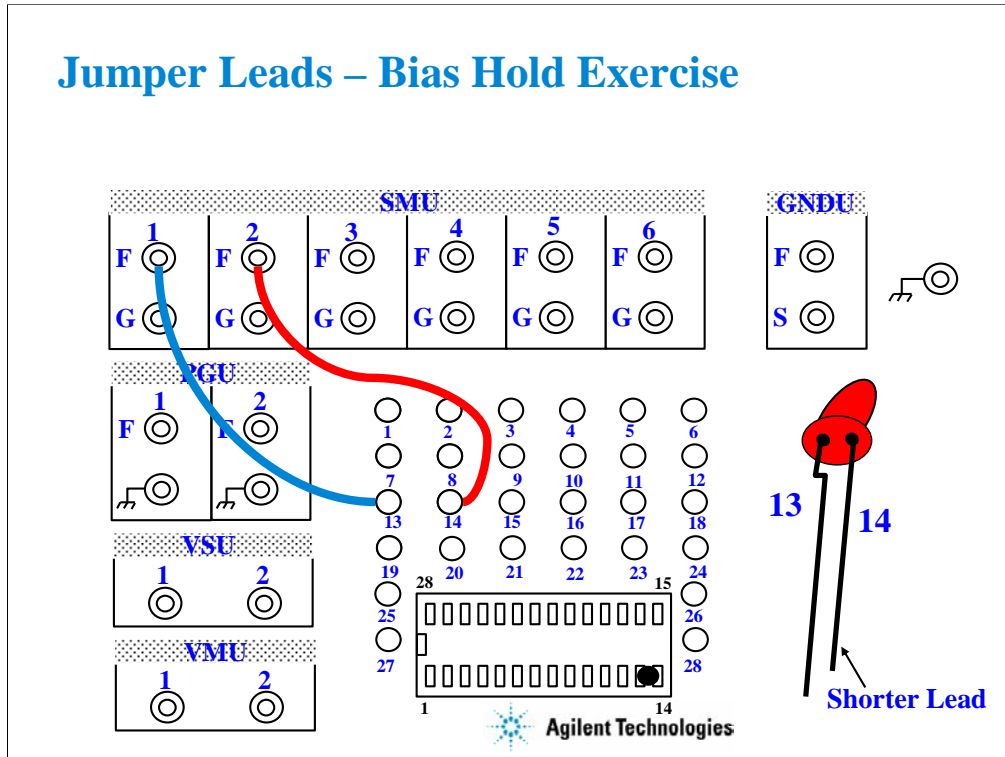
- Perform Repeat Measurement
- Measure the LED I-V characteristics
- Monitor LED during Repeat Measurement

To Get Started:

- Use the connection as same as the SMU pulse exercise
- Add an LED and jumper leads per following pages
- Get the LED setup

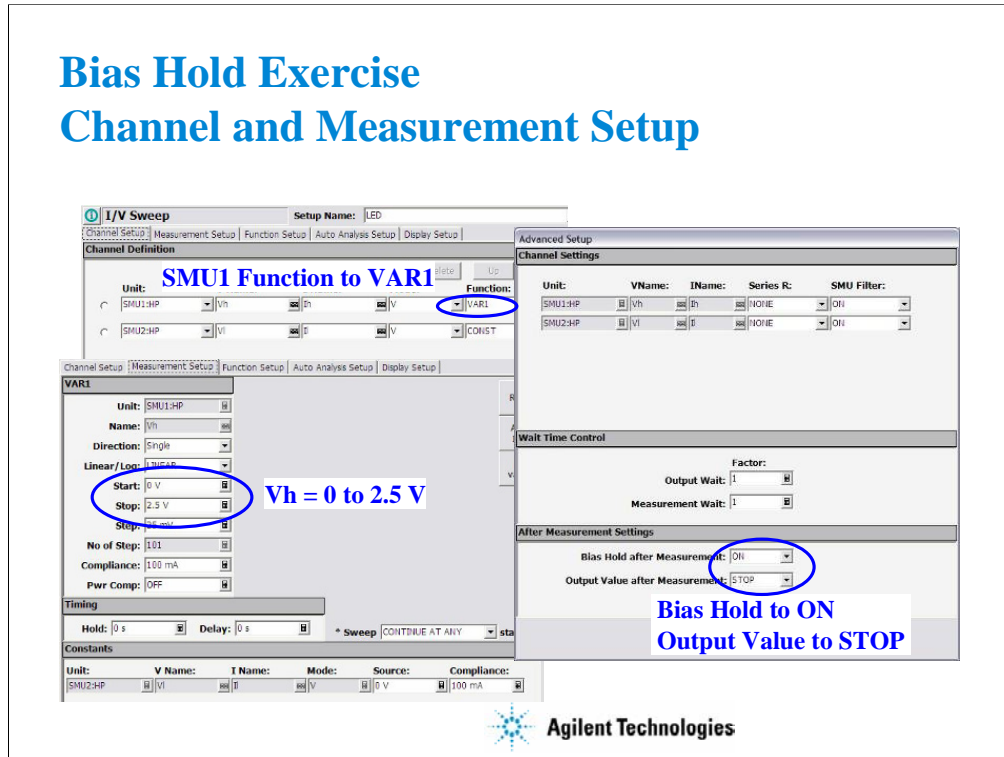


Jumper Leads – Bias Hold Exercise



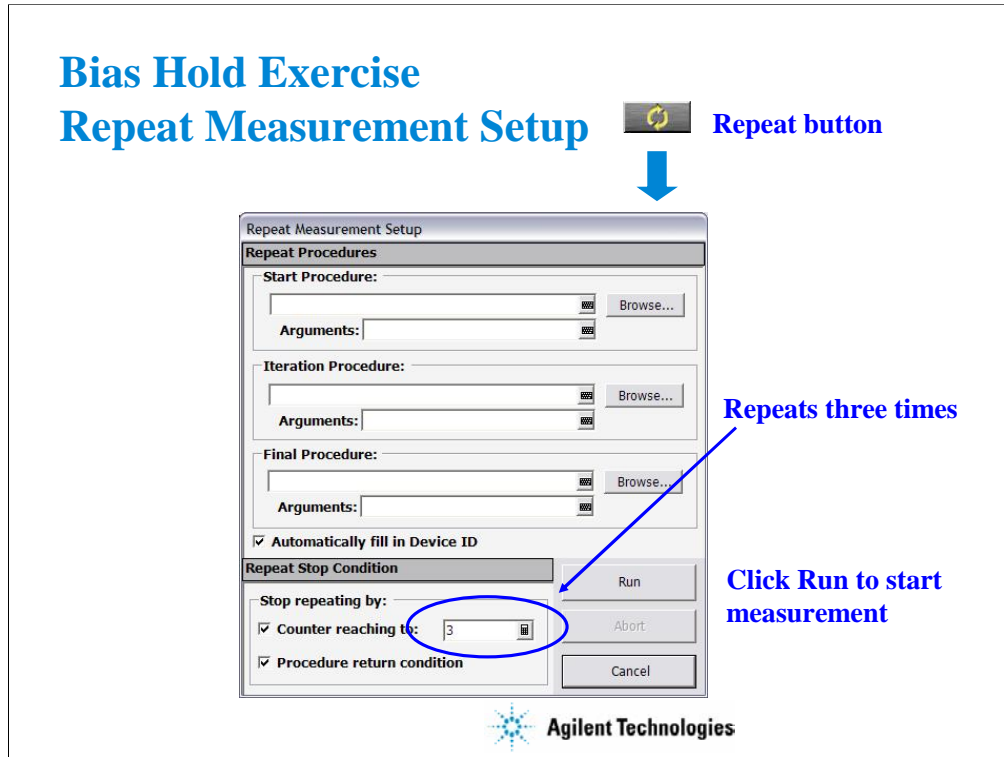
Connect test leads as shown. And add the LED between terminals 13 and 14 of the 28-pin dual in line socket.

Bias Hold Exercise Channel and Measurement Setup



Set the SMU1 Function to VARI1. The VARI1 output 0 to 2.5 V is enough to light the LED.

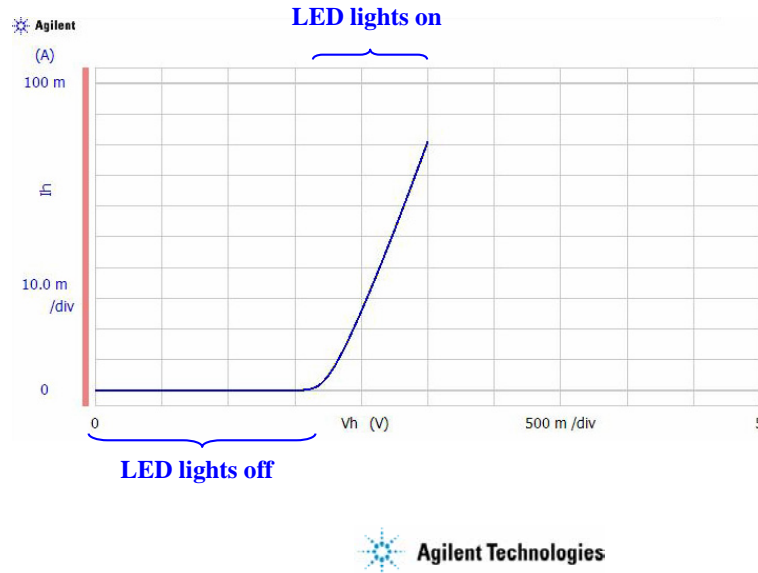
Set the Bias Hold after Measurement field to ON to enable the bias hold function. And set the Output Value after Measurement field to STOP. This setup keeps 2.5 V output between sweep measurements. So the LED can light between the measurements.



Click Repeat button to open this window which is used to set and run the repeat measurement.

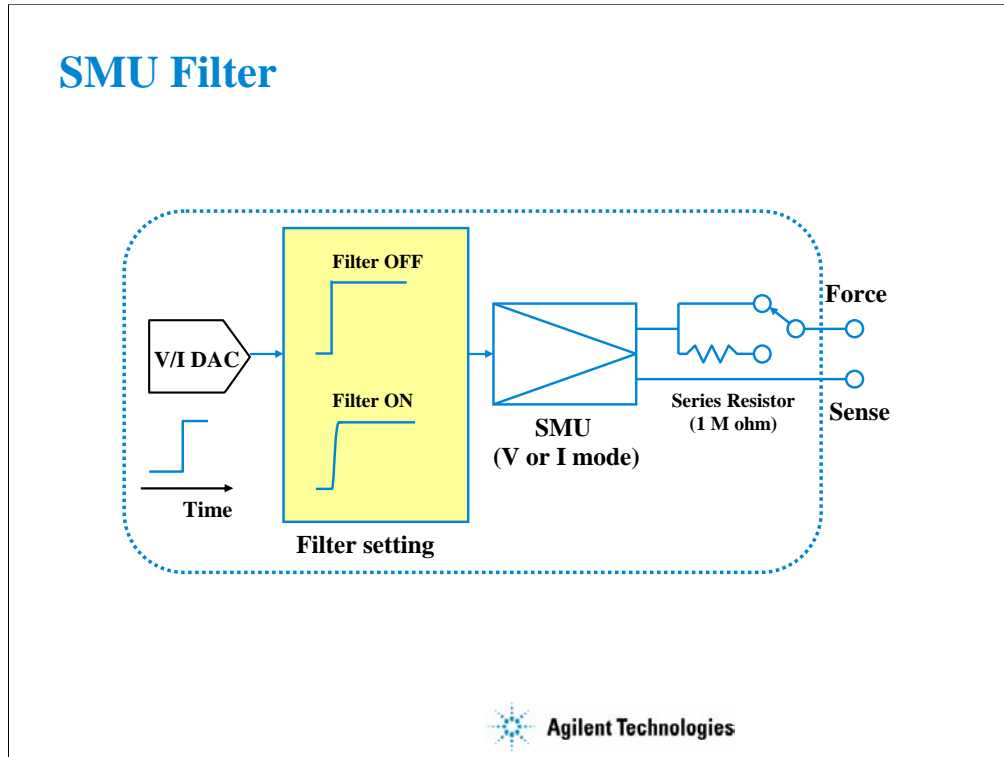
This example performs the LED I-V sweep measurement three times and then finishes the repeat measurement.

Bias Hold Exercise



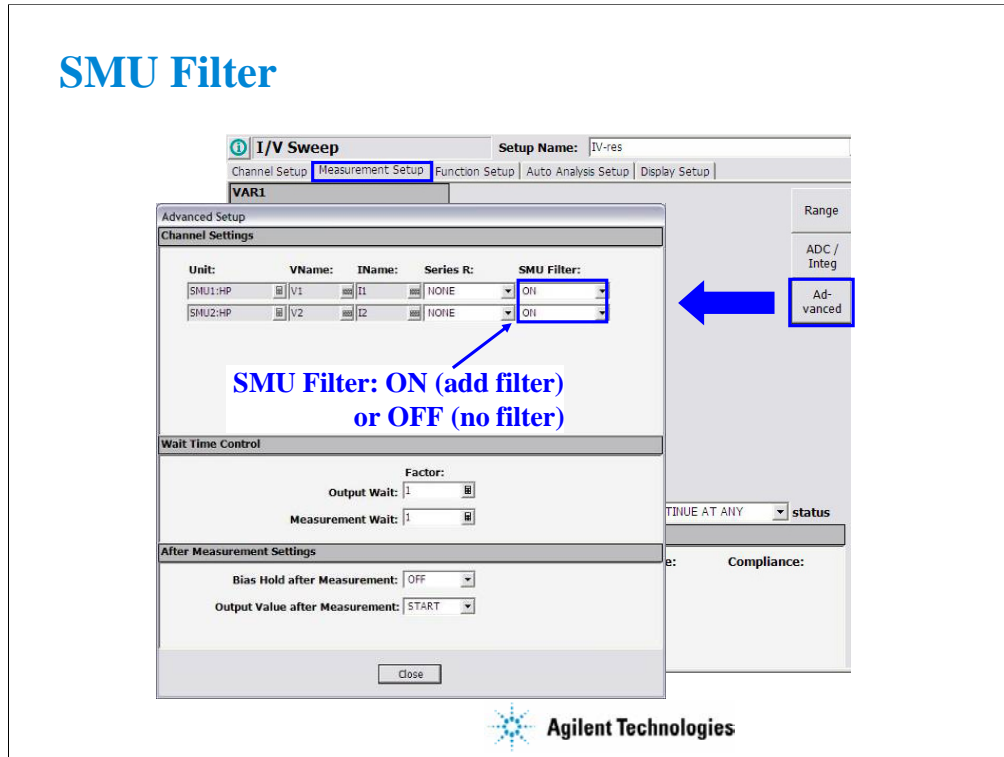
During the measurement, leave the fixture lid open. And monitor the LED. This measurement does not force dangerous voltage.

At the start of measurement, LED lights off. Beyond the threshold voltage, the LED lights on. After the measurement, the LED keeps lighting until start of the next sweep measurement. And this cycle is repeated until the end of the repeat measurement. After the repeat measurement, the LED lights off.



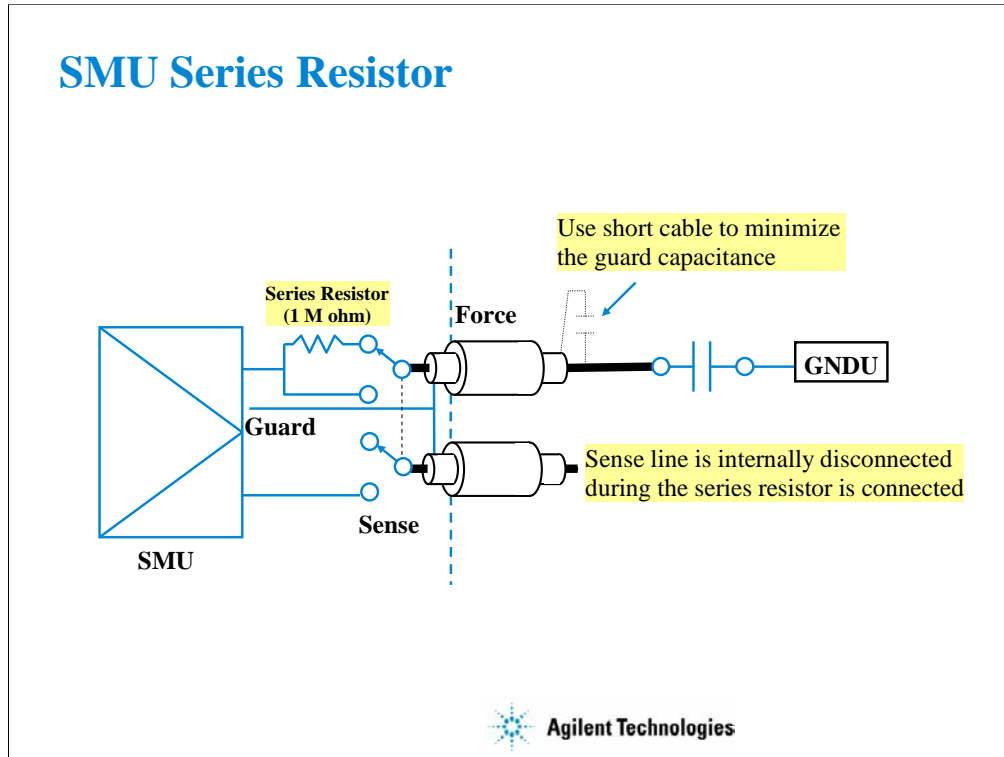
The filter is mounted on each SMU. It assures clean source output with no spikes or overshooting. However, using a filter may increase the SMU settling time. If measurement speed is top priority, set the SMU Filter OFF.

SMU Filter



To change the SMU filter setup, open the Advanced Setup window by clicking the Advanced button on the Measurement Setup screen. And specify ON or OFF by using the SMU Filter pull down menu.

In the power on state, the Classic Test sets the SMU Filter to ON.



The series resistor (approx. 1 Mohm) is mounted on each SMU. The series resistor may be used for the device protection, negative resistance measurement, and so on. It depends on the characteristics of test device and measurement environment.

Note that the series resistor may not be effective for device protection. For example, the breakdown measurement may damage the device even if the series resistor is used.

If you use a series resistor, the voltage you set is applied to the near side of the series resistor. Thus, the voltage will be divided by the series resistor and the device under test. Then, the measurement data is not compensated.

Restrictions:

The series resistor cannot be used for the measurements that use the HRSMU connected to the ASU or the measurements that use 1 A range of the HPSMU.

Class Exercise

SMU Series Resistor

You will:

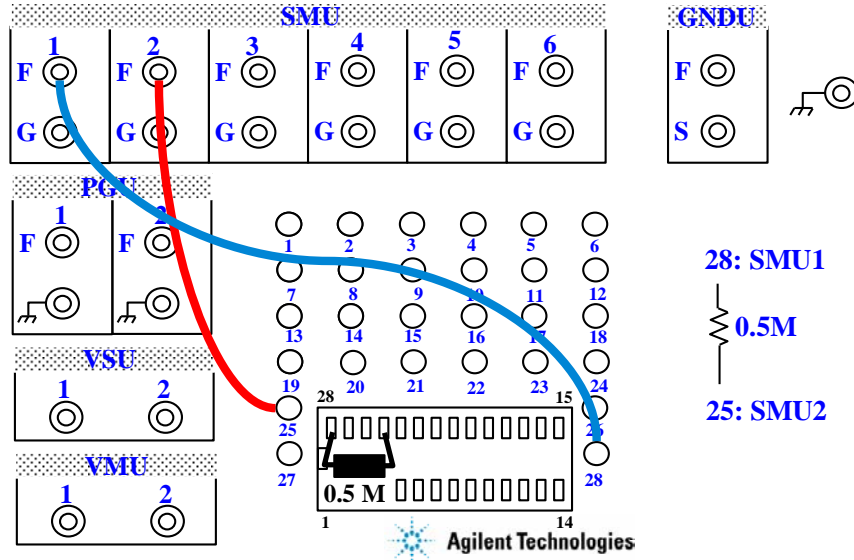
- Measure 0.5 M ohm without Series Resistor
- Measure the same device with Series Resistor
- Learn how the Series Resistor works

To Get Started:

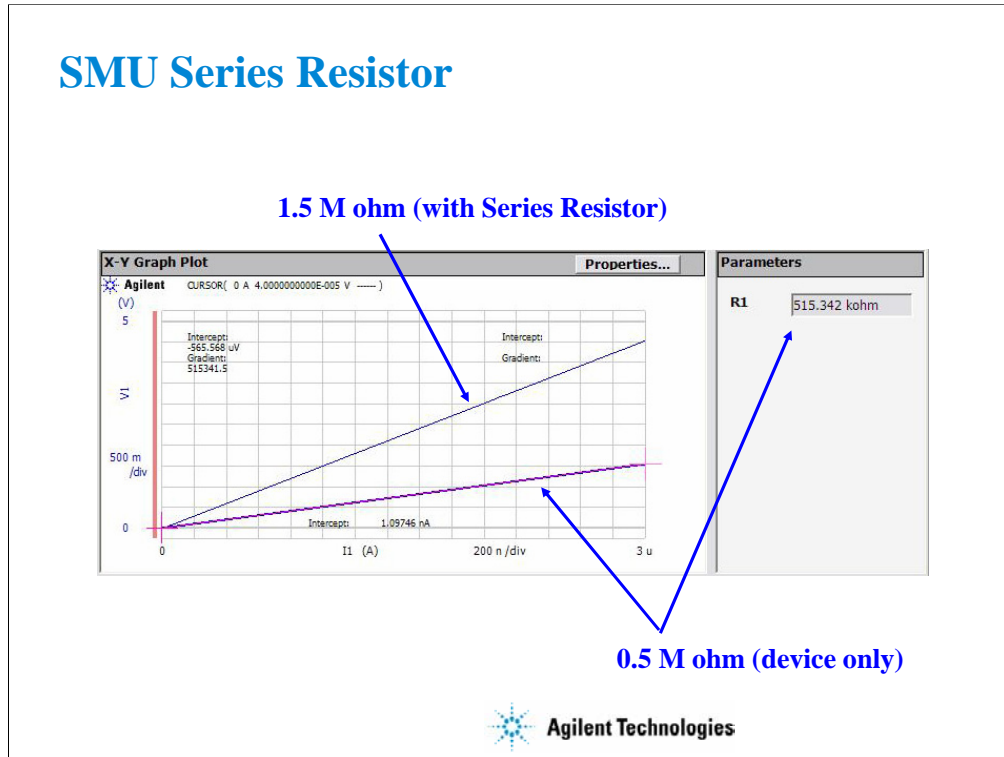
- Use the instrument setup as same as the SMU pulse exercise
- Connect 0.5 M ohm as shown in the next page
- Get and run the IV-res setup
- Set the Series Resistor and perform Append measurement



Jumper Leads – SMU Series Resistor



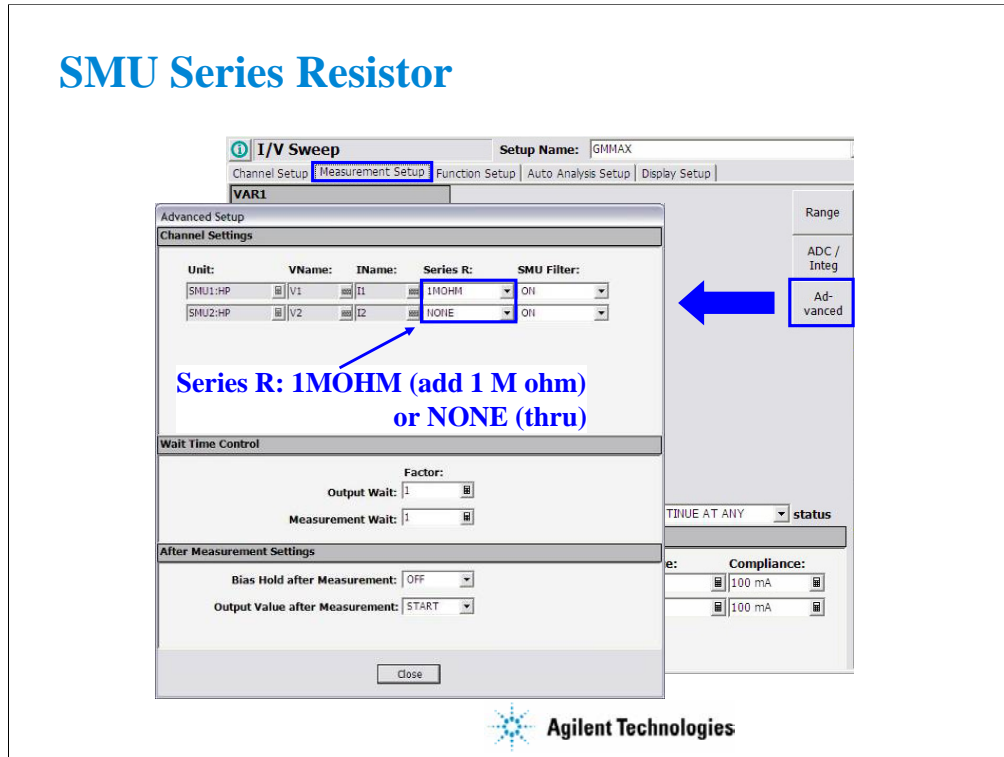
SMU Series Resistor



The measurement result without the SMU series resistor shows about 0.5 M ohm I-V characteristics. By setting the SMU series resistor, the measurement result shows about 1.5 M ohm characteristics.

The IV-res setup uses the analysis function and auto analysis function to draw the regression line and get the slope of the line. For the definition, see the Function Setup screen and the Auto Analysis Setup screen.

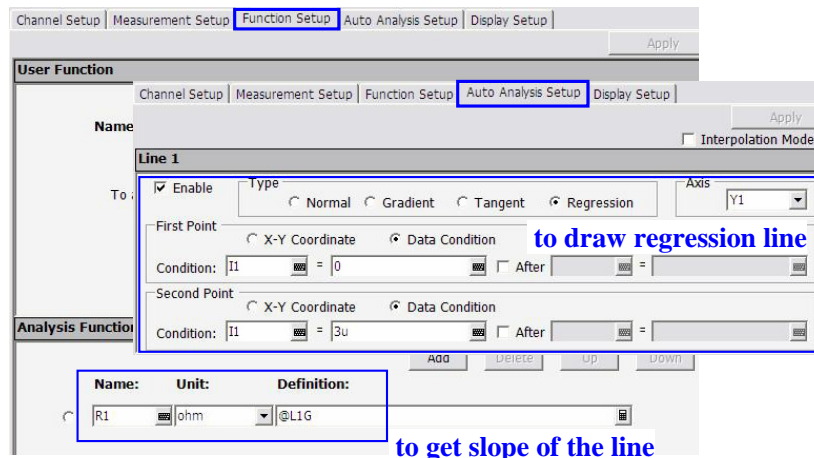
SMU Series Resistor



To change the SMU series resistor setup, open the Advanced Setup window by clicking the Advanced button on the Measurement Setup screen. And specify NONE or 1MOHM by using the Series R pull down menu.

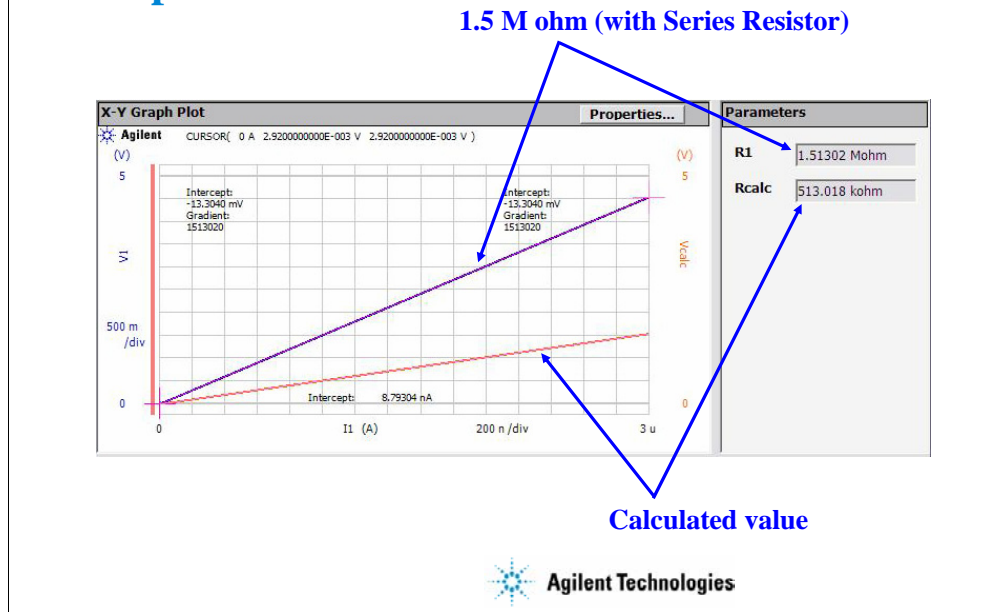
In the power on state, the Classic Test sets the Series R to NONE.

SMU Series Resistor Function Setup and Auto Analysis Setup



The analysis function and the auto analysis function are used to calculate the resistance value. This auto analysis setup will draw the regression line for the X-Y1 curve. And the analysis function @L1G is used to pass the slope of the line to the R1 variable.

SMU Series Resistor Compensation



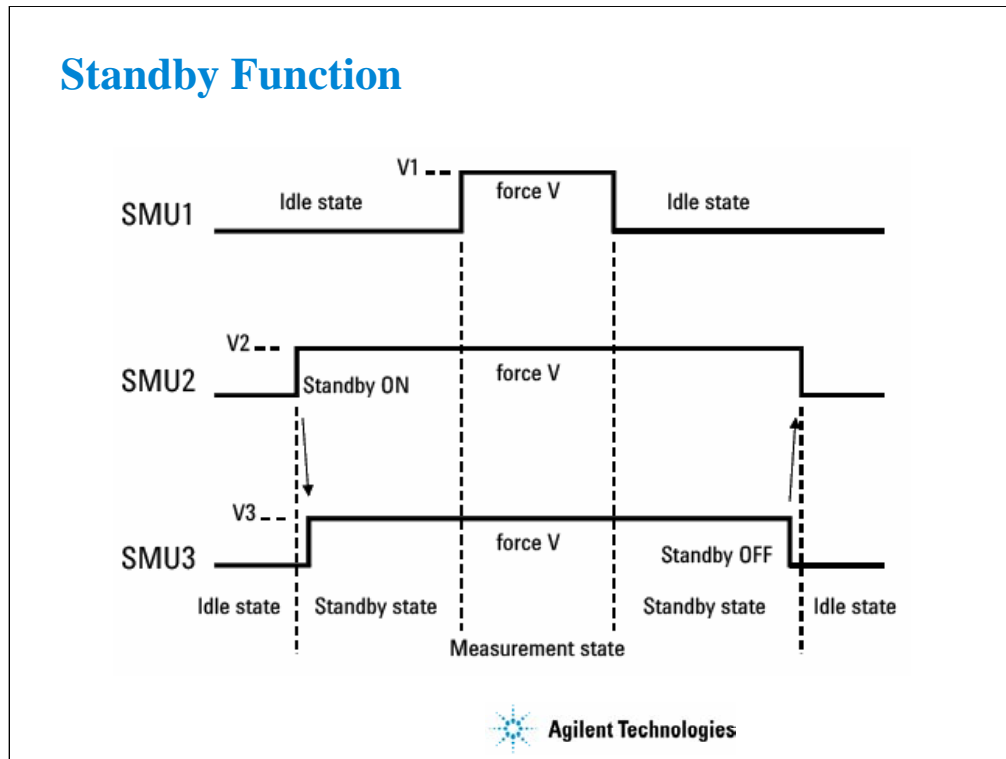
If you use the SMU series resistor, you will need to compensate the measurement data to eliminate the effects of the series resistor (1 M ohm).

This is a compensation example by using the following user function.

$$V_{\text{calc}} = V_1 - I_1 * 1000000$$

The Rcalc value is obtained by using the analysis function and the auto analysis function as same as the IV-res setup.

This compensation example is shown in the Rcalc setup.

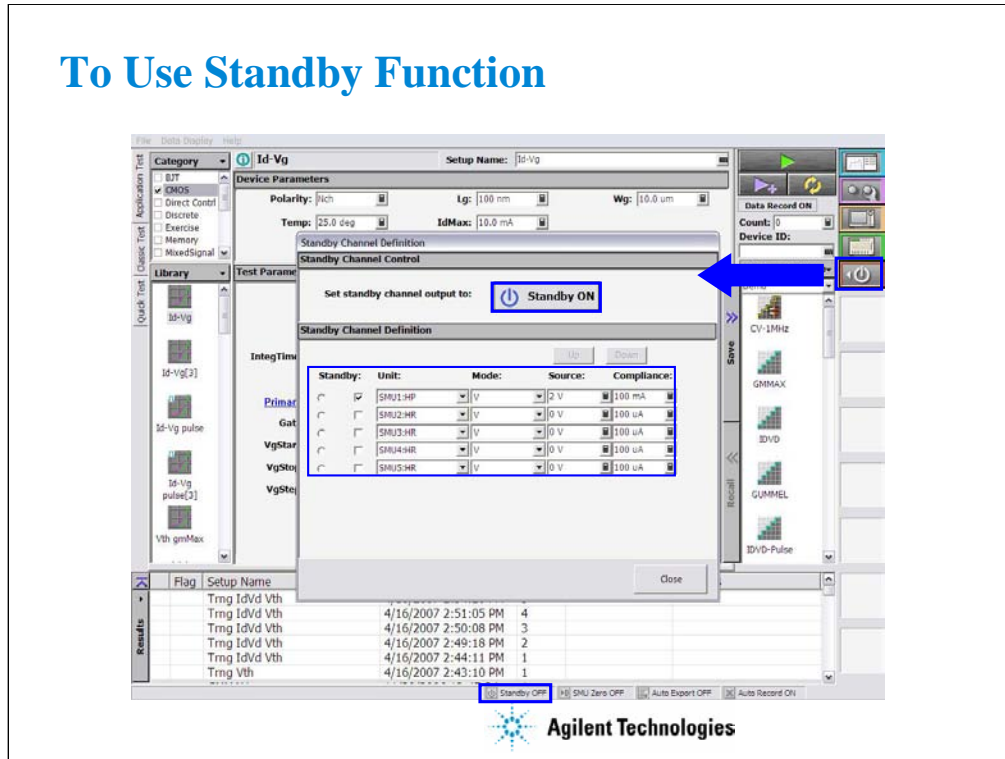


Standby function sets any SMUs (except HRSMU with ASU) to specific output values and compliances before starting or after stopping measurement. Standby function is useful for power supplies of complicated device (eg. Smart TEG), defect analysis, and so on.

This slide shows the standby and measurement operation in the following setup. This example assumes that the channel setup is defined in the Standby Channel Definition as follows in the order, and the output value in the standby state is the same as the output value in the measurement state.

- SMU1: Voltage source, non-standby channel
- SMU2: Voltage Source, standby channel
- SMU3: Voltage Source, standby channel

To Use Standby Function



- Click the Standby Channel Definition button to open the Standby Channel Definition window.
- Define Standby channels (Unit, Mode, Source, and Compliance).
- Click the Standby ON button to set standby channel outputs. The Standby indicator will change from OFF to ON.

In This Module

- CMU Fundamentals
- Classic Test Environment
- CMU Calibration
- SCUU for IV/CV Switching
- GSWU for Accurate Capacitance Measurement
- ASU for IV/CV Switching



Note:

B1500A Multi Frequency CMU



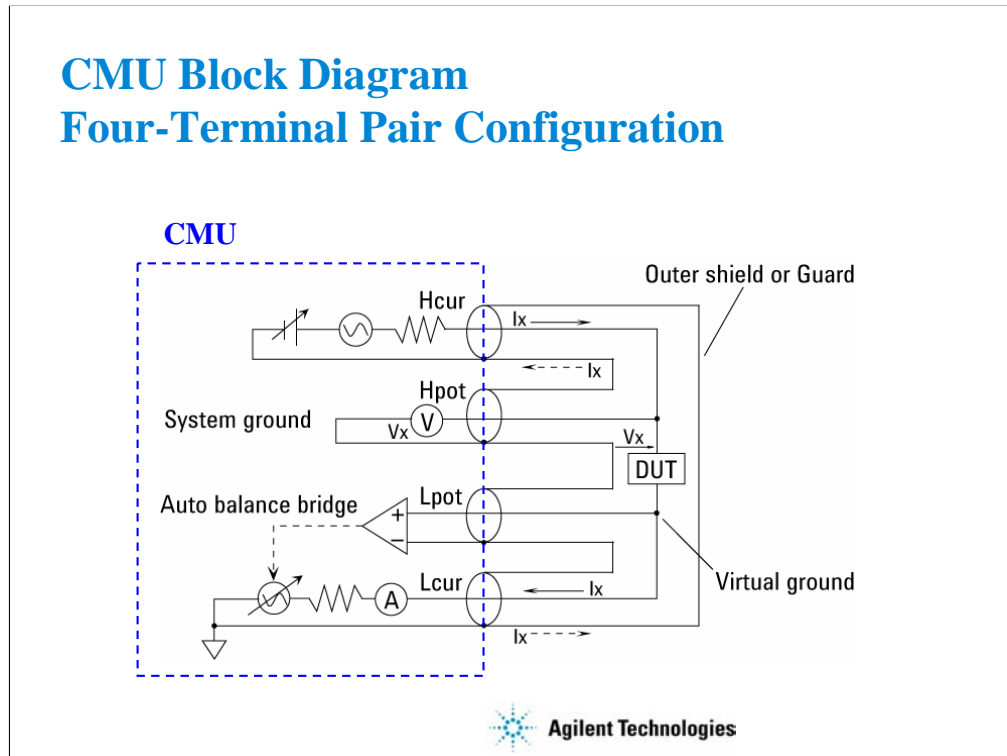
- Occupies 1 slot of B1500A
- Four terminal pair configuration
- Spot & Sweep measurements
- Faster measurement time
- 1 kHz to 5 MHz frequency range
- +/-25V DC bias
(+/-100V with SCUU)
- Cable length auto detection (1.5 or 3 m)
- Higher accuracy below 100pF



The multi frequency CMU (capacitance measurement unit) adds the CV measurement capability to the B1500A. You can now perform both IV and CV measurements by using the B1500A one box without an external capacitance meter.

Key features of the CMU are listed above.

CMU Block Diagram Four-Terminal Pair Configuration

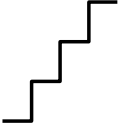
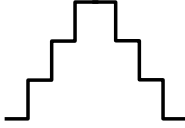


Generally, any mutual inductance, interference of the measurement signals, and unwanted residual factors in the connection method incidental to ordinary termination methods will have significant effects on the measurements, especially at a high frequency. The CMU employs the four-terminal pair (4TP) 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

C-V Sweep Source

	Single Sweep	Double Sweep
Linear Sweep		

Up to +/- 25 V, using only CMU
Up to +/- 100 V, using SCUU (Agilent N1301A-100)

 Agilent Technologies

CMU supports the linear single sweep and the linear double sweep. The CMU 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 CMU can force up to 25 V DC bias. The DC bias can be expanded up to 100 V by using the SCUU (SMU CMU unify unit) that is used to switch the IV measurement and the CV measurement automatically. For the SCUU, see the following pages in this module.

Class Exercise

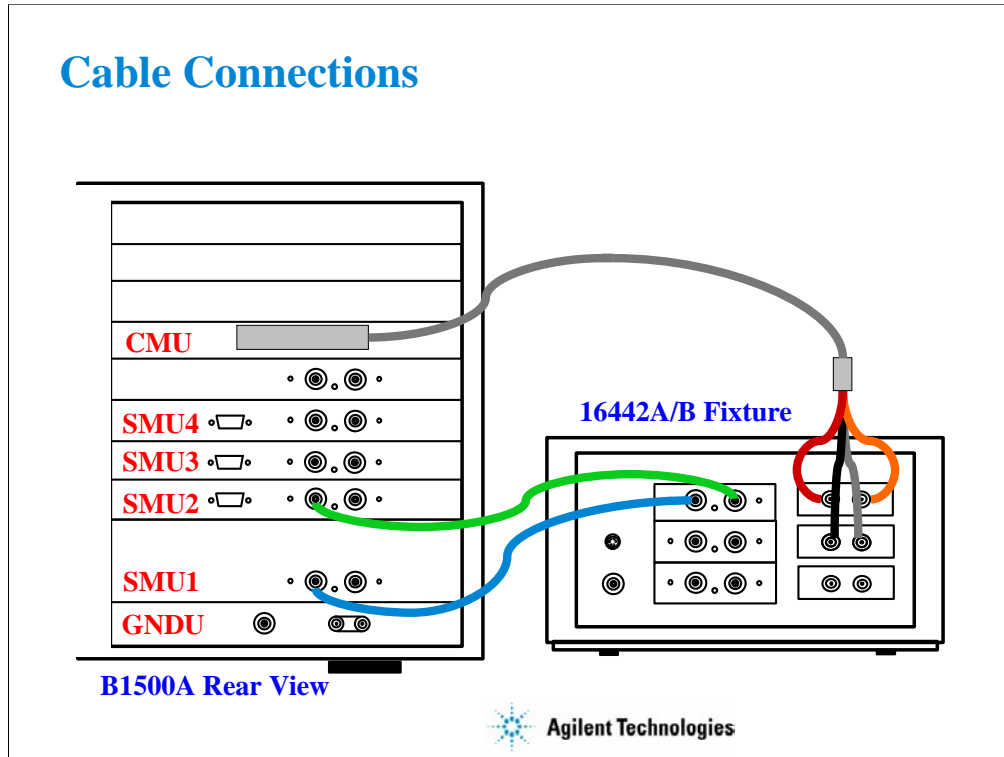
C-V Sweep Measurement

- You will make the MOS FET C_{gs} - V_g measurement
- You will learn how to properly define a C-V sweep algorithm

To Get Started:

- Use the next several pages as you guide
- Get the CV-1MHz setup
- Follow the instructions on the following pages





The following cables are required to perform this class exercise.

CMU cable (Agilent N1300A-001/002), 1 ea.

Triax cable (Agilent 16494A-001/002), 2 ea.

One side of the CMU cable forms the attachment used to join and fix it to the CMU. And the other side provides four BNC connectors used to connect the fixture as shown.

Connect the cables between the B1500A and the test fixture as follows.

SMU1 : SMU1

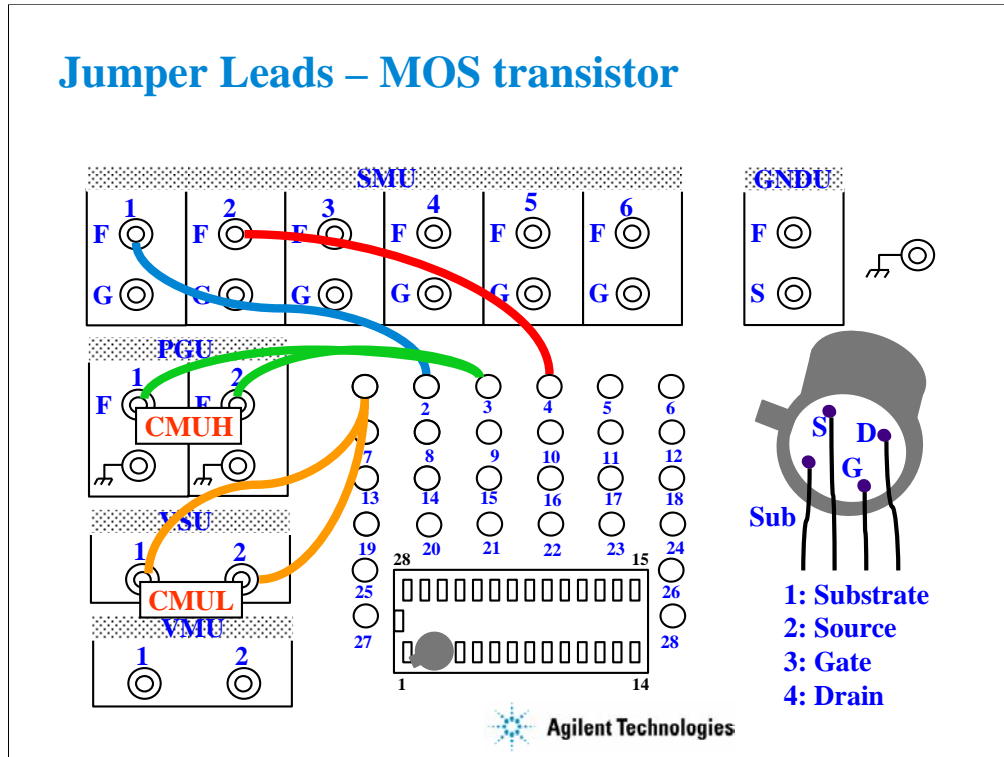
SMU2 : SMU2

Hcur : PGU1 (red)

Hpot : PGU2 (orange)

Lcur : VSU1 (black)

Lpot : VSU2 (gray)



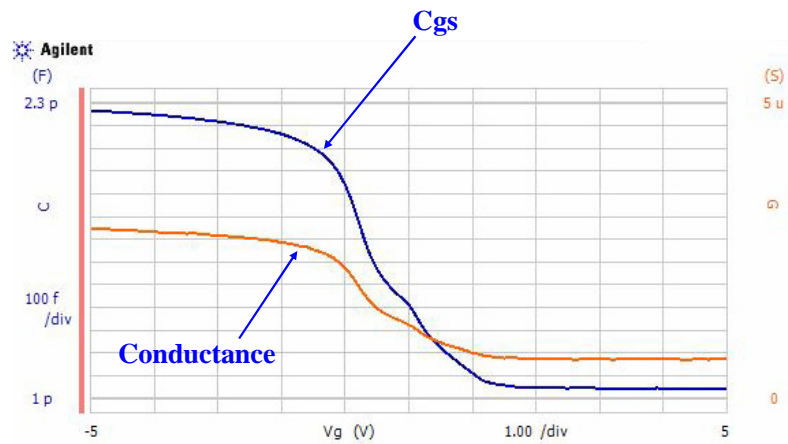
For all class exercises, you need the 28-pin dual in line socket which comes standard with the 4145 fixture (16058A) or the newer fixture (16442A/B). Either fixture works fine.

With the 16442A/B fixture, note that there are two SMU numbering schemes....3 SMUs with force and sense, or six SMUs with force only. For this class example we will use the six (6) SMU scheme. On older fixtures, this scheme is shown in light blue lettering. In newer fixtures, this scheme is shown in white reverse background lettering.

This class exercise requires six jumper leads to connect the DUT. Connect the jumper leads between the following terminals.

- SMU1 : terminal 2
- SMU2 : terminal 4
- PGU1 : terminal 1
- PGU2 : terminal 1
- VSU1 : terminal 3
- VSU2 : terminal 3

Capacitance Measurement Measurement Example



This is the measurement example of the MOS FET C_{gs} - V_g characteristics.

To make the measurement, set SMU1 and SMU2 to COMMON. And set the CMU as shown in the next page.

Capacitance Measurement Measurement Setup

Selects measurement parameters

DC bias:
-5 V to +5 V

Frequency
and Oscillation level

Integration time

Agilent Technologies

1. Select the Cp-G mode, and enter the C Name and G Name.
2. Set the Start, Stop, and Step to specify the DC bias sweep condition.
3. Set the Frequency List to specify the measurement frequency.
4. Set the AC Level to specify the AC signal level (oscillation level).
5. Set the Integration Time as you like.

(End of This Class Exercise)

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



CMU 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.

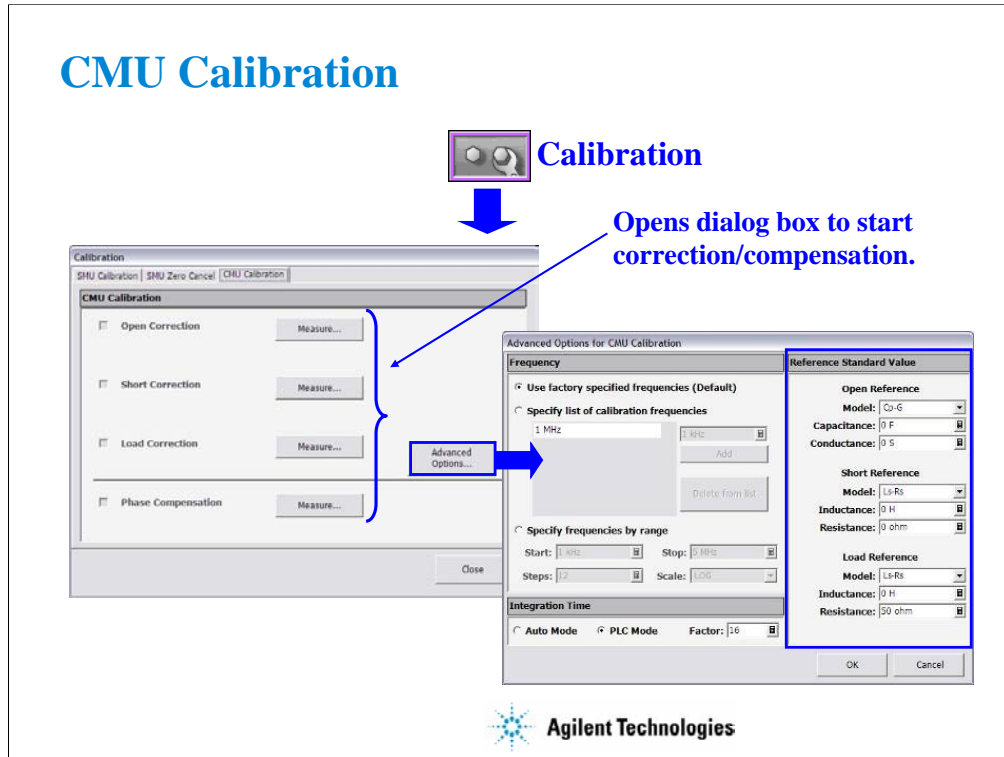
At least perform the phase compensation and the open correction. They only need to open the measurement terminals.

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 measurement terminals for CMUH and CMUL, and perform the Phase Compensation by clicking the Measure... button.

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

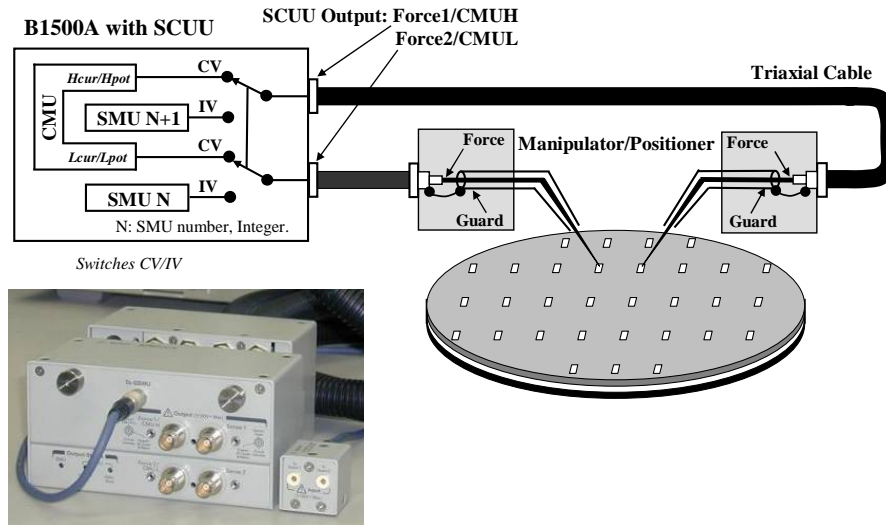
If you can make the short condition, short the measurement terminals, and perform the Short Correction.

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

Note:

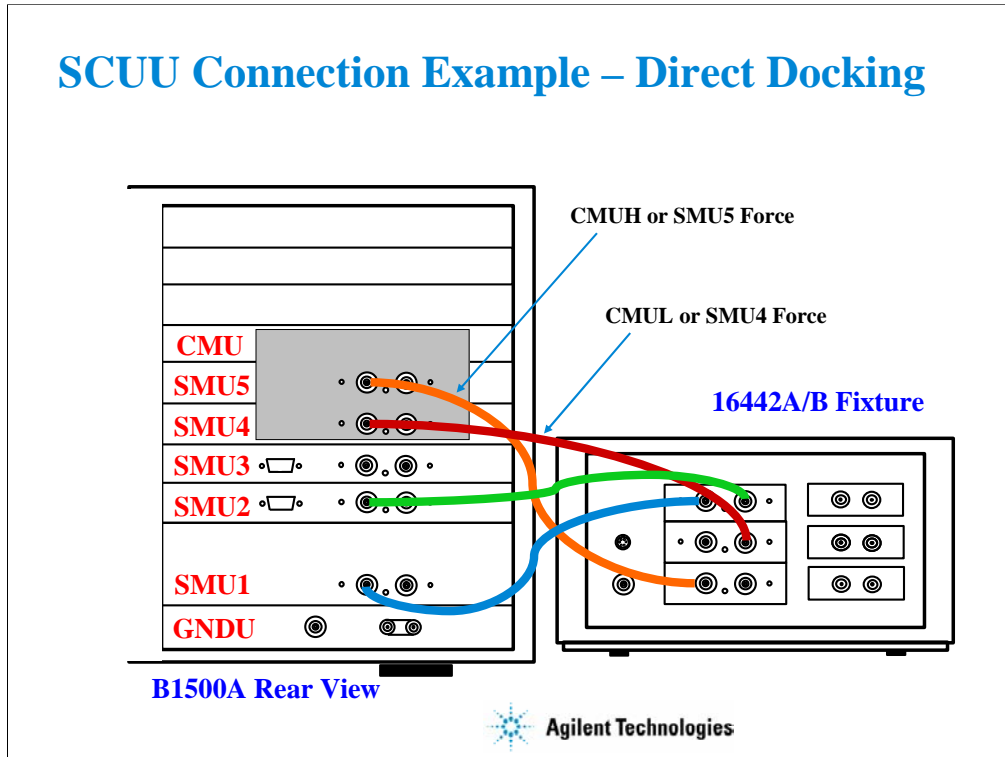
If you use the calibration standard, define the reference data before starting the calibration. It must be defined in the Reference Standard Value on the Advanced Options for CMU Calibration window.

SCUU – for IV/CV Switching



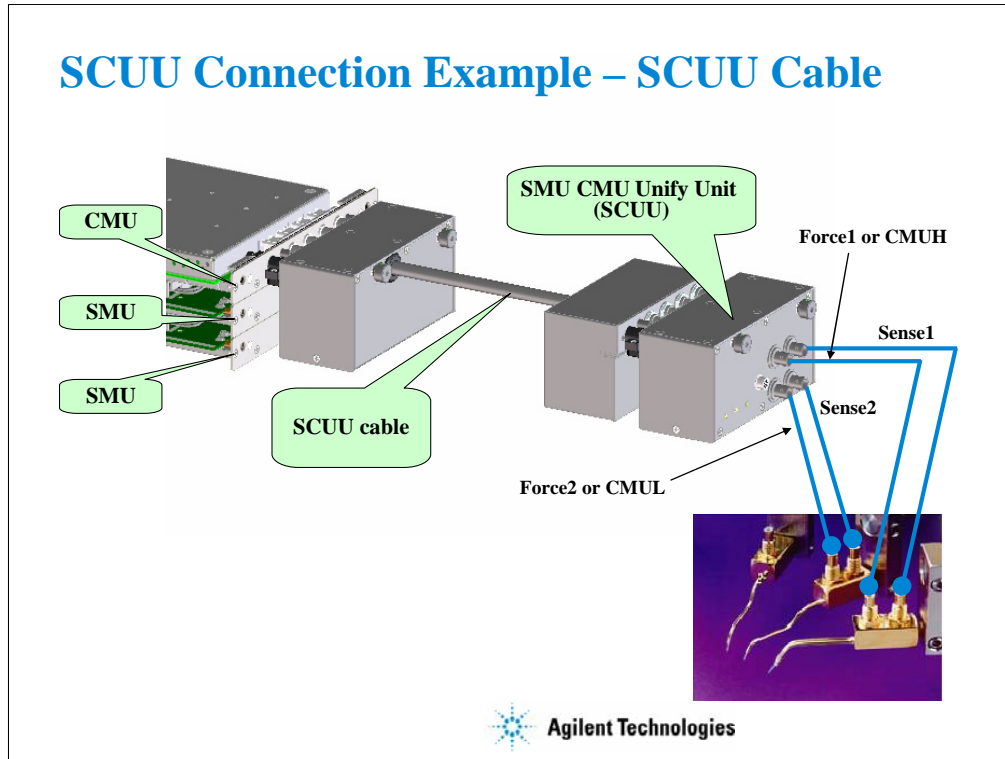
You have a very hard time switching between CV and IV measurements (you may actually devote separate probe stations to CV and IV just to avoid having to change cables). In addition, great care has to be taken when cabling to a capacitance meter to insure that all of the capacitance measurements are properly compensated.

The SCUU removes all of these worries and makes connection simple and easy. In addition, the B1500A software automatically takes care of the multiplexing based upon the type of algorithm selected from the front panel.



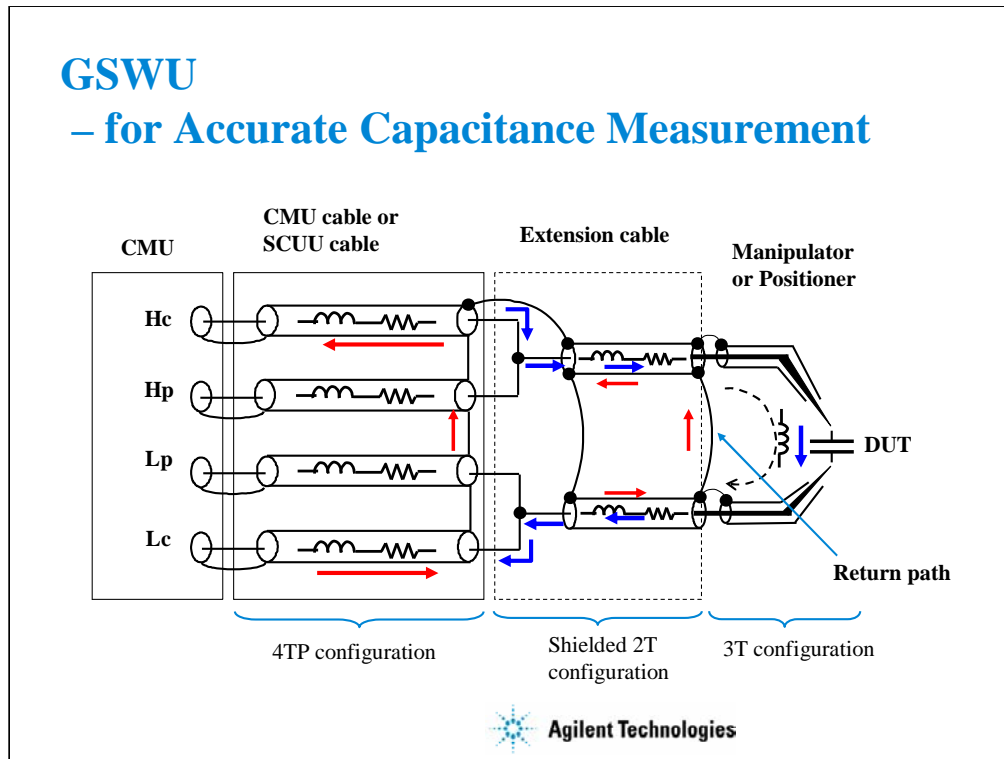
Before connecting the SCUU, turn the B1500A off. And restart the B1500A after connection is completed. The B1500A cannot recognize the SCUU without restart after connection.

Use normal triaxial cables or Kelvin triaxial cables to connect between the SCUU and the test fixture.



To install the SCUU near the manipulators/positioners, use the N1301A-102 SCUU cable.

To realize accurate capacitance measurement, use the N1301A-200/201/202 GSWU & cable. See the next section.



This slide shows the typical cable connections for the capacitance measurement. Note the following tips to perform the measurement accurately.

- Extend the four terminal pair configuration as close as possible to the device side
- Make the return path at the end of the extension cables (coaxial cables)

The return path is effective for:

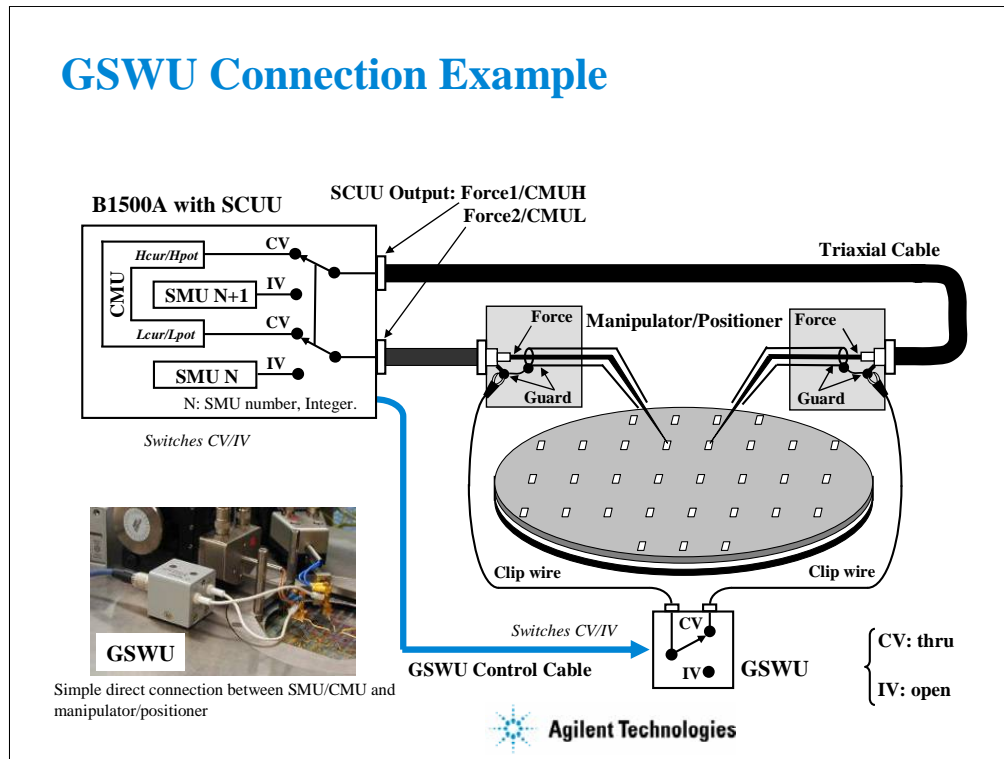
- reducing the residual inductance of the measurement cable
- stabilizing the residual inductance when measurement cable distance is changed (moved)

The residual inductance will be roughly 1/10 to 1/30 compared with no return path.

To make the return path, use the GSWU (Ground Switch Unit) which was developed to make the setup easily. The GSWU is the accessory available only for the B1500A equipped with the CMU and the SCUU.

Note:

For the accurate measurement, it is recommended to make the return path at the point as close as possible to the device side.



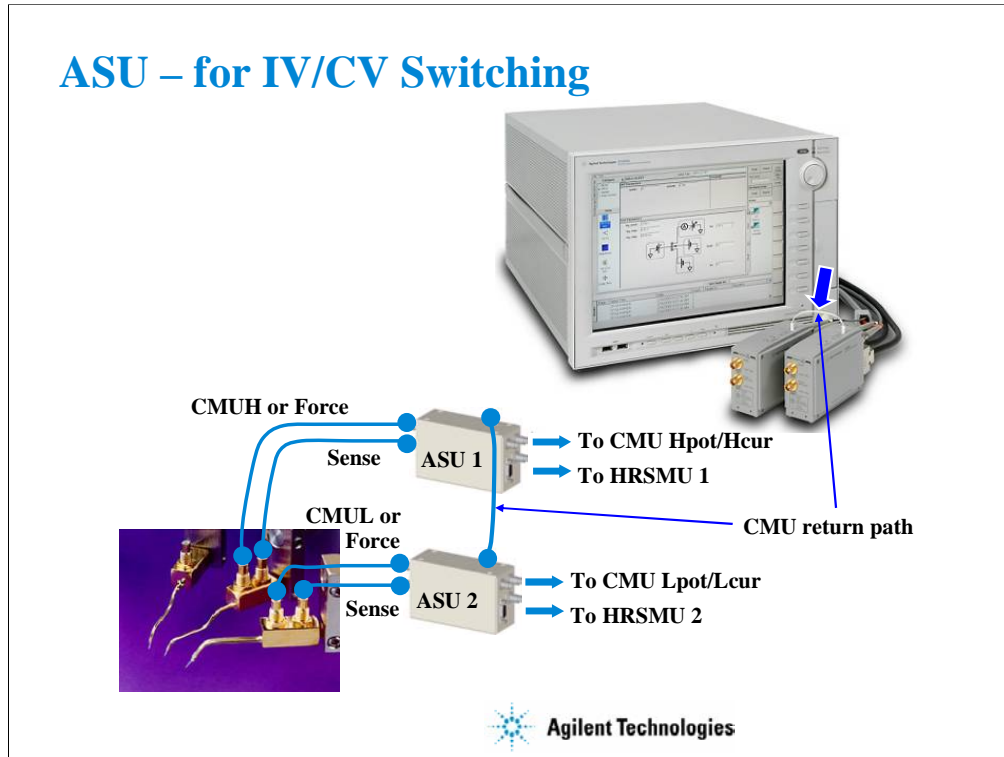
1. Place the GSWU at the appropriate location near the manipulators/positioners.
2. Connect the GSWU control cable between the GSWU and the SCUU.
3. Connect a clip wire between the GSWU and the outer conductor of the manipulator/positioner connected to Force1/CMUH.
4. Connect a clip wire the GSWU and the outer conductor of the manipulator/positioner connected to Force2/CMUL.

When the SMU paths (IV) are available for the manipulators/positioners, the GSWU opens between the outer conductors. However, when the CMU paths (CV) are available, the GSWU connects them together to make the return path of measurement current.

By using the EasyEXPERT software, cable length between the CMU and the SCUU is automatically detected, and the GSWU switch control is automatically performed. Also, capacitance error compensation is also automatically performed if the compensation data are available.

Note:

When the SMU paths are available for the manipulators/positioners, the connection between the outer conductors must be broken because they are connected to the SMU guard terminals separately and the guard terminals must be disconnected from anything at the end of the extension.



The ASU (Atto Sense and Switch Unit) is available for the B1500A installed with the HRSMU. Using the ASU permits use of the 1 pA range. Also the ASU can switch the measurement resources, HRSMU or an instrument connected to the AUX input connectors.

The ASU has input connectors, one triaxial and two coaxial. The triaxial connector must be connected to the HRSMU Force terminal, and the coaxial connectors must be connected to the other resource such as CMU. Also the ASU has the control connector to be connected to the HRSMU by using the ASU cable.

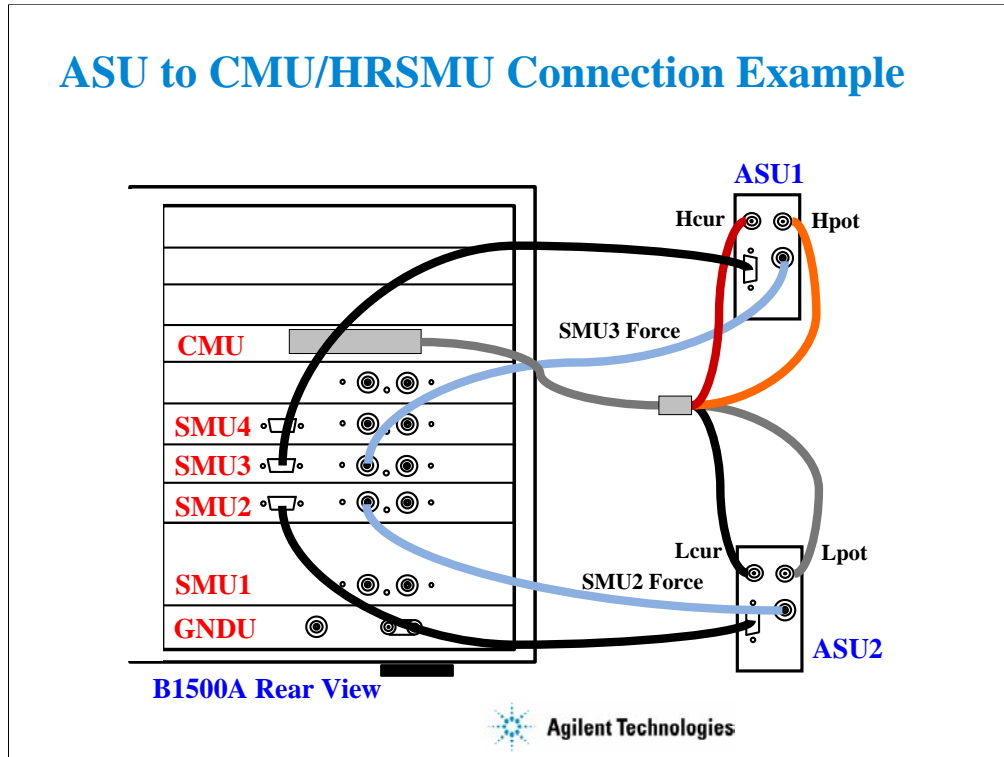
The ASU has output connectors, two triaxial, that must be connected to the DUT interface such as manipulators or probe card. When the measurement resource is the HRSMU, they are the Force/Sense connectors for the Kelvin connection. And when the resource is not the HRSMU, the CMU/AUX is connected to the Force, and the Sense is not used.

If you connect the CMU, two ASUs are required. Then the ASU's CMU-pot/CMU-cur connectors must be connected to the Hpot/Hcur of the CMU. And the other one must be connected to the Lpot/Lcur in like manner.

To realize accurate impedance measurements using the four-terminal pair measurement method, connect the CMU return terminals of ASUs together.

Note:

For the accurate measurement, it is recommended to make the return path at the point as close as possible to the device side.



To connect the ASUs, use the following cables.

CMU cable (Agilent N1300A-001/002), 1 ea.

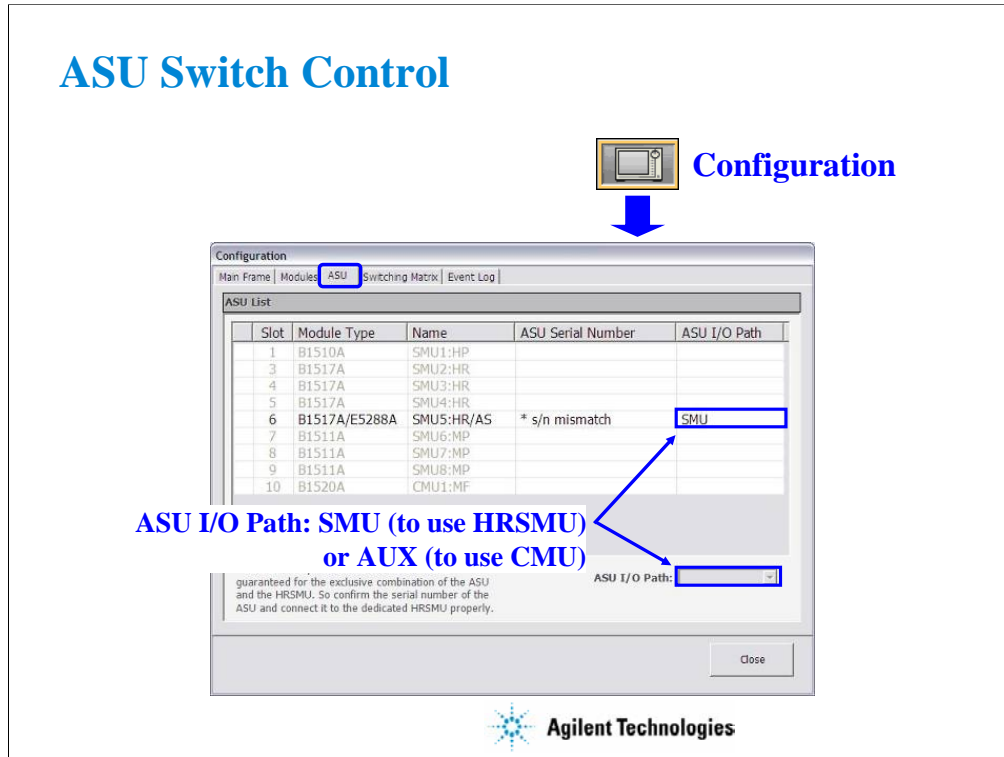
Triax cable (a part of Agilent B5288A-001/002), 2 ea.

D-sub cable (a part of Agilent B5288A-001/002), 2 ea.

One side of the CMU cable forms the attachment used to join and fix it to the CMU. And the other side provides four BNC connectors used to connect two ASUs as shown.

The triax cable and the D-sub cable are connected between ASU and HRSMU.

Before starting the ASU connection, turn the B1500A off. And restart the B1500A after the connection is completed. The B1500A cannot recognize the ASUs without restart after the connection.



To control the ASU switch connection, open the Configuration window and display the ASU tab screen. Then highlight the B1517A/B5288A row and set the ASU I/O Path, SMU or AUX by using the ASU I/O Path pull down menu.

Set SMU when you use the HRSMU.

Set AUX when you use the CMU or the other resource connected to the ASU's AUX In.

If the ASU Serial Number field shows its serial number, the HRSMU-ASU combination is correct.

If the ASU Serial Number field shows *s/n mismatch, the combination is wrong.

The B1500A can work with this wrong combination however it cannot satisfy its specifications. The specifications are guaranteed for the correct combination of HRSMU and ASU.

9

Modifying Application Test Definitions

In This Module

- **To Open Application Test Definition**
- **To Modify Test Definition**
- **To Use Debug Tools**
- **To Use Built-in Functions**
- **To Add Data Display**
- **To Use Auto Analysis**
- **To Define Test Output**
- **To Use Test Setup Internal Variables**
- **To Use Vector Data to Modify Test Definition**



Modification Overview

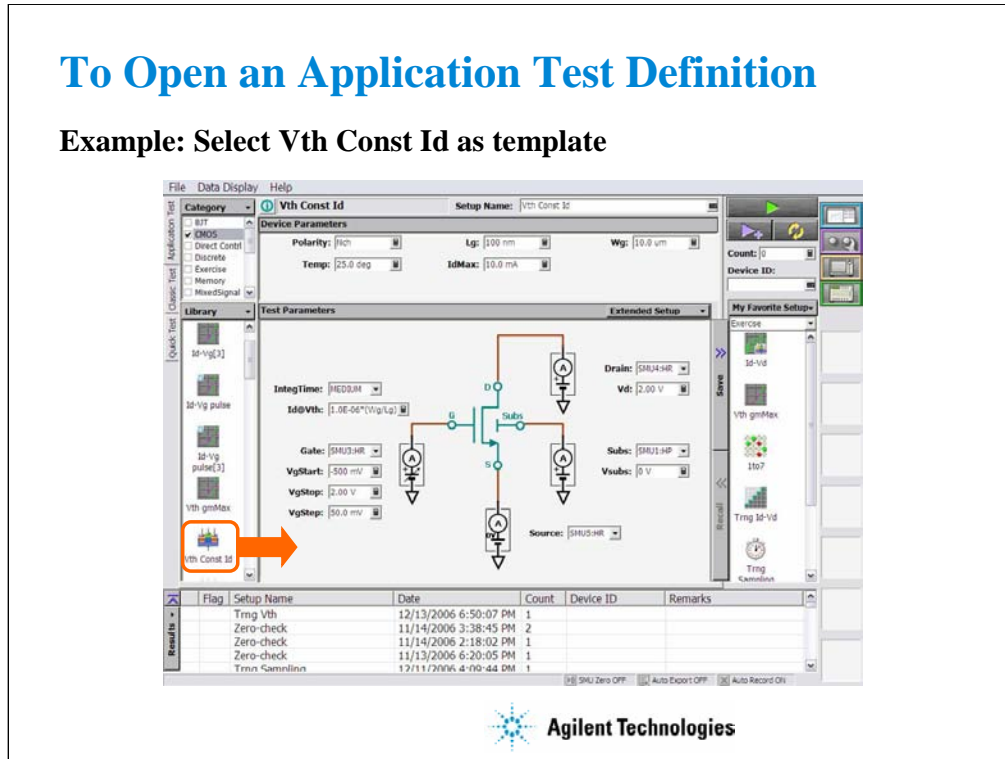
- 1. Open an application test definition to be modified**
- 2. Open test definition editor**
- 3. Save the definition as your test definition**
- 4. Modify the definition as you like**
- 5. Resave and close the definition**
- 6. Export your test definition as your backup**



This module explains the modification example using the Vth Const Id test definition. After the modification, the new definition can perform the Vth Const Id measurement, display the Id-Vg curve, and additionally display the gm-Vg curve.

To Open an Application Test Definition

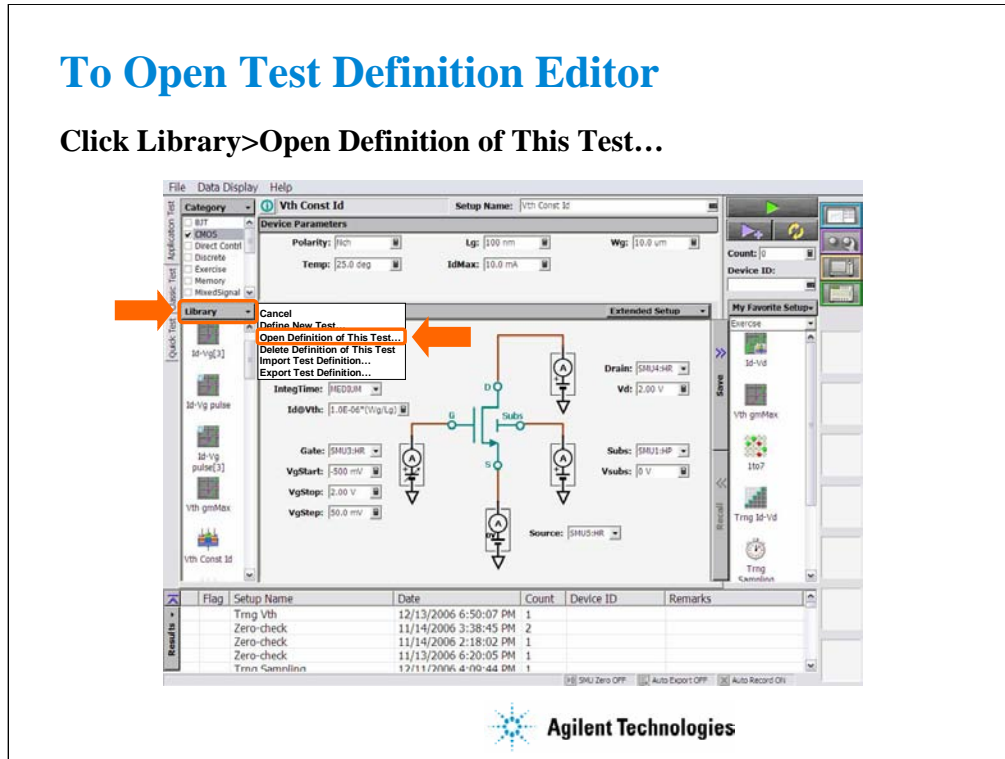
Example: Select Vth Const Id as template



Click a test definition in Library list area, and click Select button to open the test definition.
For example, open Vth Const Id.

To Open Test Definition Editor

Click Library>Open Definition of This Test...

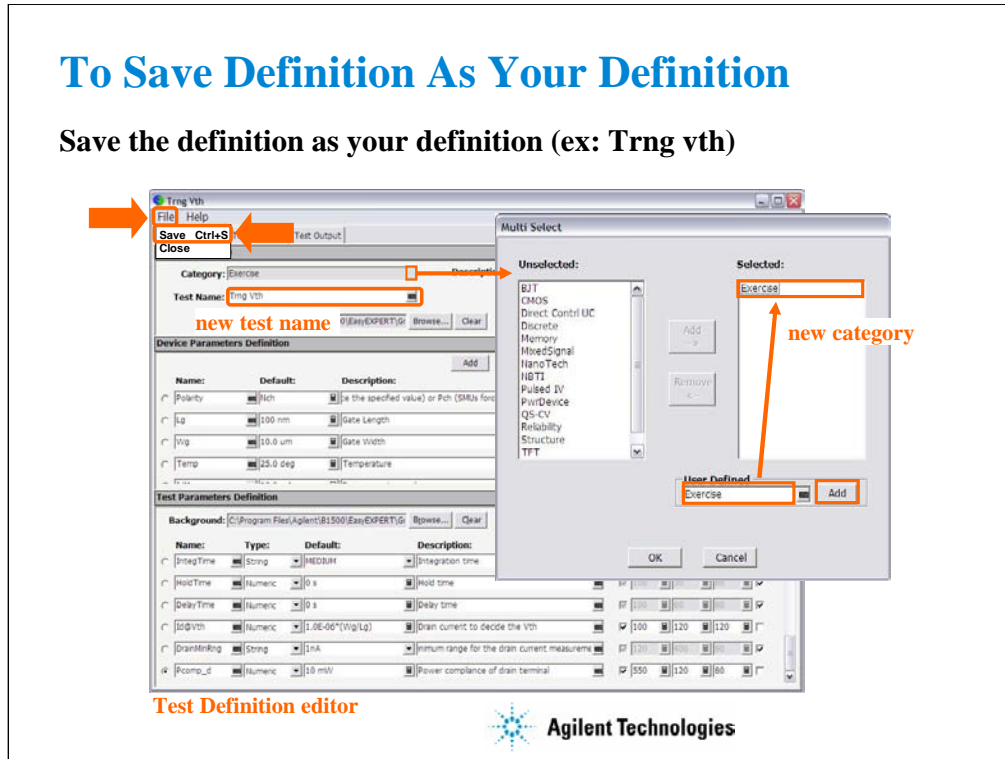


Click Library and select Open Definition of This Test... to open the test definition editor.

The following pages show the modification example to display the gm-Vg curve given by the Vth Const Id test result.

To Save Definition As Your Definition

Save the definition as your definition (ex: Trng vth)



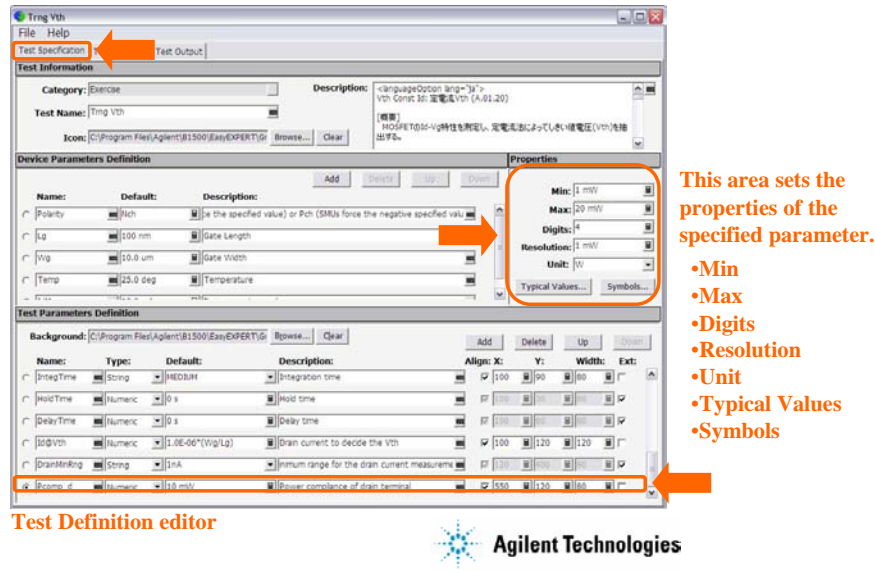
Create a new Category (ex. Exercise), and change the Test Name (ex. Trng Vth).

After changing the test name, save the test definition. Saving the definition will change the window title to the new test name. Window title will be changed from Vth Const Id to Trng Vth in this example.

In this example, the Trng Vth definition belongs to the Exercise category only.

To Modify Test Definition

Change default values and add parameters (ex: Pcomp_d)



On the Test Specification tab screen, you can add new parameters or change parameter settings.

This example changes the default value of the Module parameters for the MOS FET class exercise typical setup and adds the Pcomp_d test parameter (drain terminal power compliance).

The Module parameter default values are changed as follows. See the actual settings on the test definition editor.

Drain: SMU4
Gate: SMU3
Source: SMU2
Subs: SMU1

The Pcomp_d parameter is defined as follows.

Name=Pcomp_d, Type=Numeric, Default=1 mW, Description=Power compliance for drain terminal, Align=check, X=550, Y=120, Width=80, Ext=unchecked

Properties: Min=1 mW, Max=20 mW, Digits=4, Resolution=1 mW, Unit=W

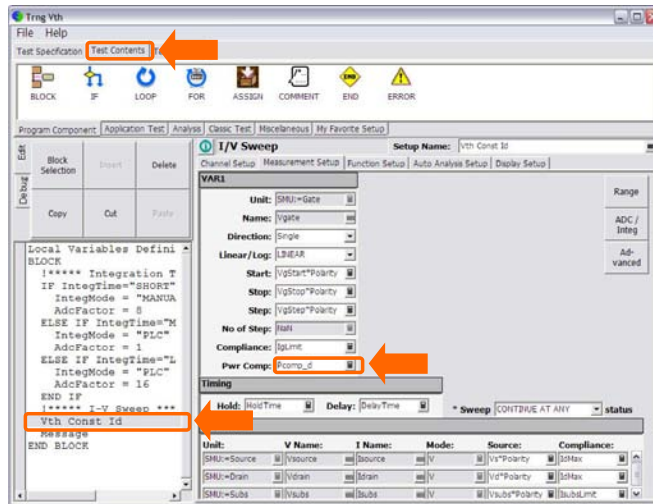
For Align, X, Y, and Width values, consult the settings of the other parameters for the same terminal (ex. Drain). For example, Pcomp_d must be located between Vd and Subs entry fields (see application test screen on the main window). So X and Width should be the same as the settings of Vd, and Y should be between 90 and 180 (see the actual settings of Vd and Subs on the test definition editor).

Typical Values... button opens a dialog box used to define the typical values used for the selections of the parameter value in the Application Test mode. For example, set 2 mW to 20 mW in 2 mW step for Pcomp_d.

Symbols... button opens a dialog box used to map a numeric value to a string. For example, Value=1 and Symbol=ON are set, typing ON enters 1, and typing 1 enters ON. The value must satisfy the Min, Max, Digits, and Resolution settings. The value and the symbol must be one by one. The definition is effective only for the parameter.

To Modify Test Definition

Change or set test parameters (ex: Pcomp_d)



Test Definition editor



On the Test Contents tab screen, you can change the test execution flow (program flow), measurement conditions, display setup, and so on.

To add the Pcomp_d parameter to the measurement setup, click the Vth Const Id line in the program list. And in the I/V Sweep setup editor, display the Measurement Setup tab screen. And enter Pcomp_d to the Pwr Comp entry field.

To Modify Test Definition

Change display setup and define external variables

External variables must be defined before making the matching table.

Test Definition editor

External variable	Measurement data
Vth_constId	Vth
GM_data	gm
VG_data	Vgate
ID_data	Idrain

External variable

Test setup internal variable

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On the Display Setup tab screen, you can change the graph scale Min/Max values or add/delete the list parameters.

This example makes the matching table between the External variables and the Measurement data. The measurement data can be referred outside the test setup via the external variable.

Where, the measurement data means the variables used in the test setup. And the external variables means the parameters defined in the Test Specification, the Local Variable Definition, or the Test Output's Analysis Parameter Definition.

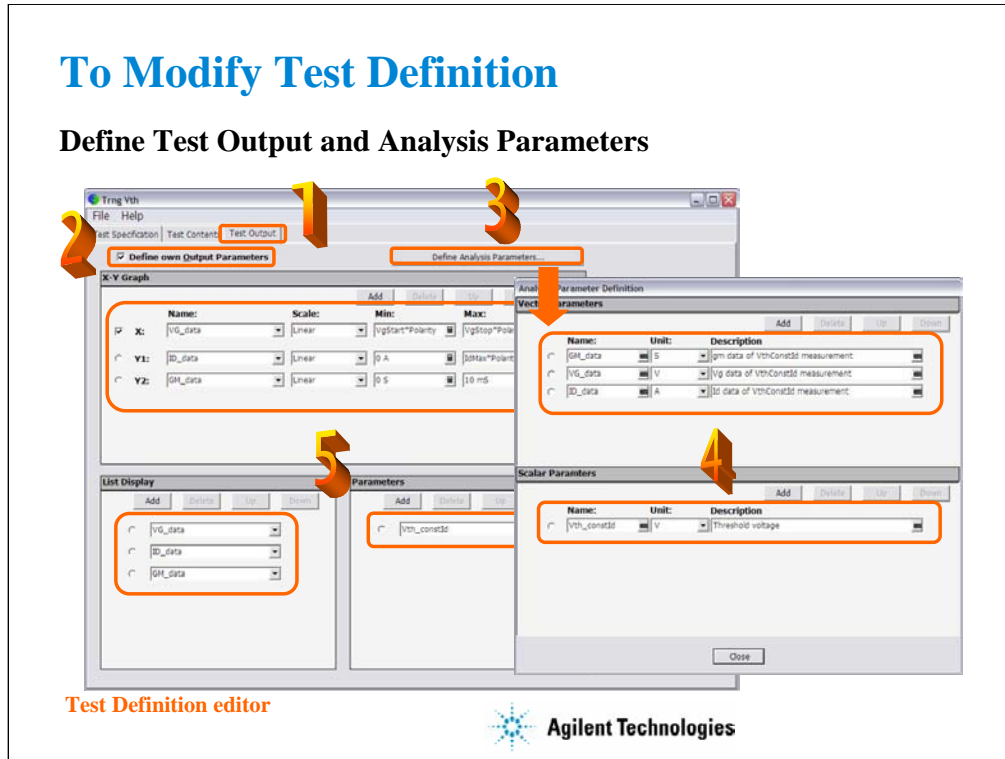
This example sets the matching table as follows.

Vth_constId external variable: Vth internal variable
 GM_data external variable: gm internal variable
 VG_data external variable: Vgate internal variable
 ID_data external variable: Idrain internal variable

External variables must be defined before making the matching table. In this example, the variables are defined in the Analysis Parameter Definition. See the next page.

To Modify Test Definition

Define Test Output and Analysis Parameters



Test Definition editor



This example defines the Test Output and the Analysis Parameters.

1. Display the Test Output screen.
2. Check the Define own Output Parameters.
3. Click the Define Analysis Parameters button.
4. Define the analysis parameters (ex. GM_data, VG_data, ID_data, and Vth_constID).
5. Define the X-Y Graph, List Display, and Parameters.

Note

External variables must be defined before making the matching table shown in the previous page. In this example, the following parameters can be the external variables.

Parameters defined in the Test Specification

Variables defined in the Local Variable Definition

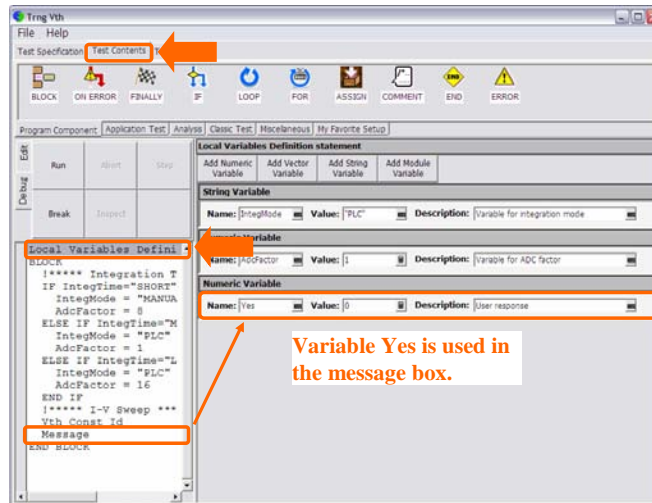
Variables defined in the Analysis Parameter Definition (this example)

Note

If this test definition is used in the other test definition, the analysis parameters can be referred outside this test definition. This means that the analysis parameters can be the Measurement data in the External Variable Setup as shown in the previous page.

To Modify Test Definition

Add local variable (ex: Yes for Message box)



Test Definition editor



Click Local Variables Definition line to display the local variable list. And define variables.

This example defines Yes variable as follows. This variable is used in a message box. See the next page.

Name=Yes, Value=0, Description=User response

To Modify Test Definition

Define Message box

This message box asks you clicking the OK button to display the gm curve.

This setup displays the message "To display the gm curve, click OK." on the message box.

This setup makes the OK button on the message box.

The value of the local variable Yes is set to 1 from 0 by clicking the OK button.

Test Definition editor

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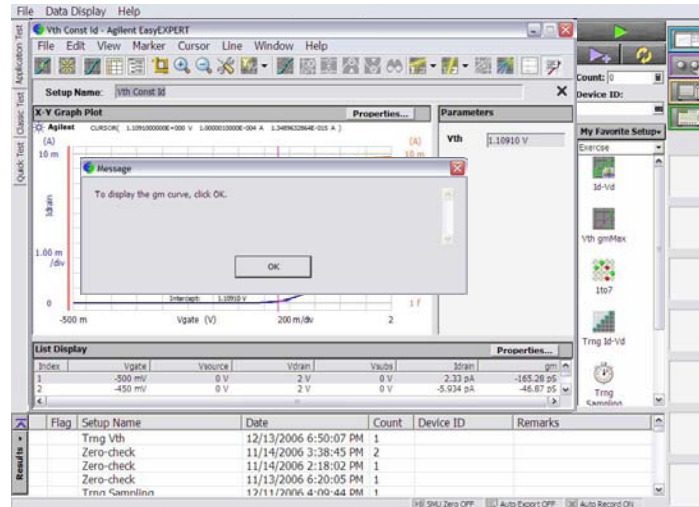
Click the Message line in the program list. And define the message box.

This example defines the message box that opens after the Vth Const Id measurement and displays a message and the OK button.

1. Enter the message.
2. Enter the button name.
3. Select the variable used to keep the status of the button.
4. Repeat 2 and 3 for all buttons you want to add.

To Modify Test Definition

Example: Displaying Message box



In this modification example, the message box opens after the Vth Const Id measurement is completed. This message box asks you clicking the OK button to display the gm curve.

Class Exercise

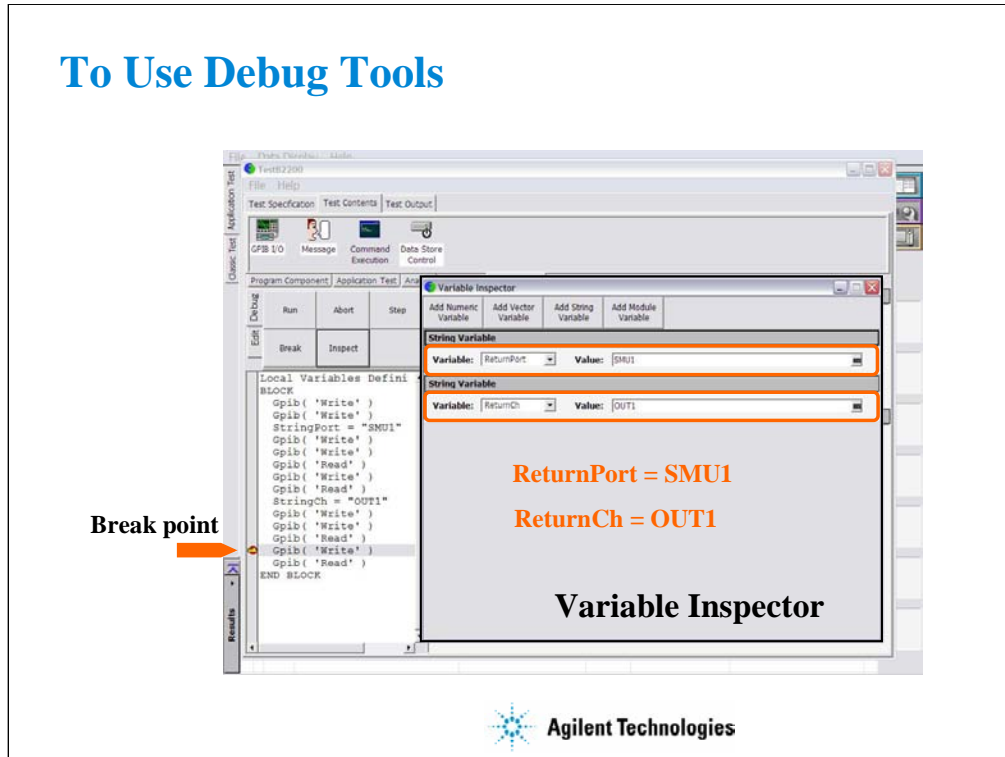
Modify test definition.

1. **Open Id-Vd test definition.**
2. **Modify it as follows.**
 - to move marker and tangent line to $V_{\text{drain}}=1$ point if Yes is clicked after Id-Vd test.
 - to perform V_{th} gmMax test if Yes is clicked.
3. **Use the debug tools.**
4. **Save the definition as a new one (ex. Trng IdVd Vth).**
5. **Perform the test.**
6. **Export the new definition, and import it.**



1. Add the Yes variable to the Local Variable Definition.
2. Insert the following lines between the lines Id-Vd and END BLOCK.
Message
IF Yes=1
 Auto Analysis
END IF
Message
IF Yes=1
 Vth gmMax
END IF
3. Define the first message box.
Message: Do you perform auto analysis?
Button1 Label: Yes, Selected: Yes
Button 2 Label: No, Selected: (blank)
4. Define the second message box.
Message: Do you perform Vth gmMax test?
Button1 Label: Yes, Selected: Yes
Button 2 Label: No, Selected: (blank)
5. Define the IF statements.
Condition Expression: Yes=1
6. Define the Auto Analysis.
Line 1: Enable, Tangent, Axis: Y1, Data Condition: $V_{\text{drain}}=1$
Marker: Enable, Condition: $V_{\text{drain}}=1$
7. Change the Vth gmMax test parameters as follows.
Drain: Drain
Gate: Gate
Source: Source
Subs: Subs

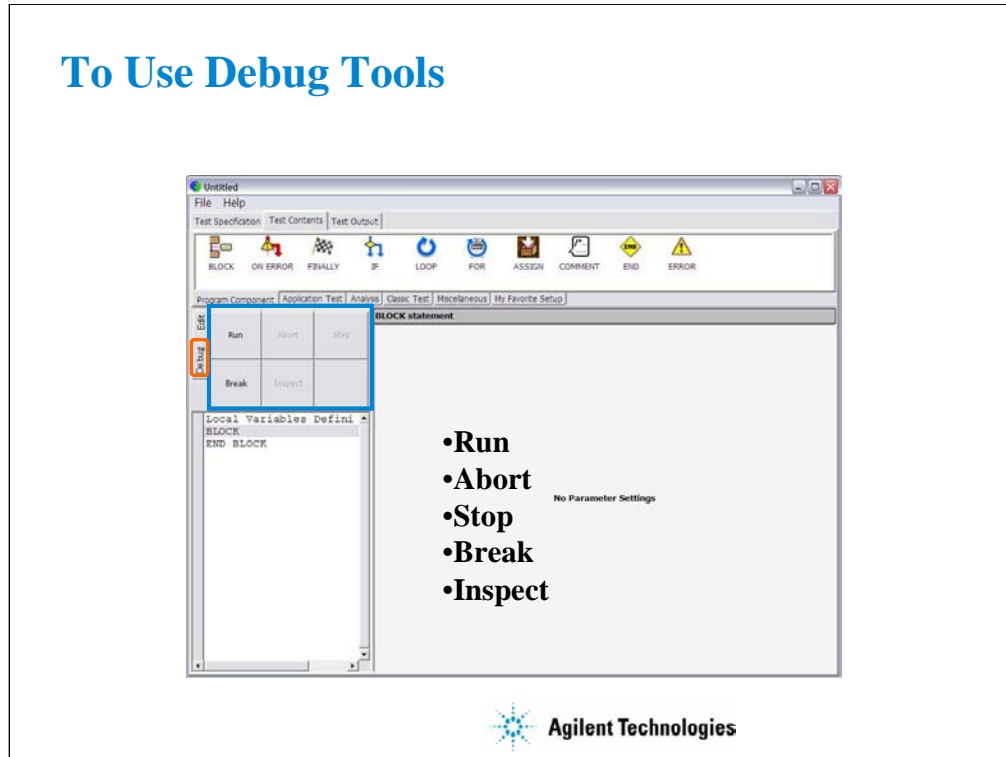
To Use Debug Tools



This slide shows an example of using the Variable Inspector for debugging. Confirm whether the correct values are passed to the variables properly.

Set the break point, and click the Run button. After the program is paused, click the Inspect button. The Variable Inspector is displayed. You can check the values by using the variable display fields. The field can be displayed by using the Add XXXX Variable button. XXXX will be Numeric, Vector, String, or Module.

To Use Debug Tools

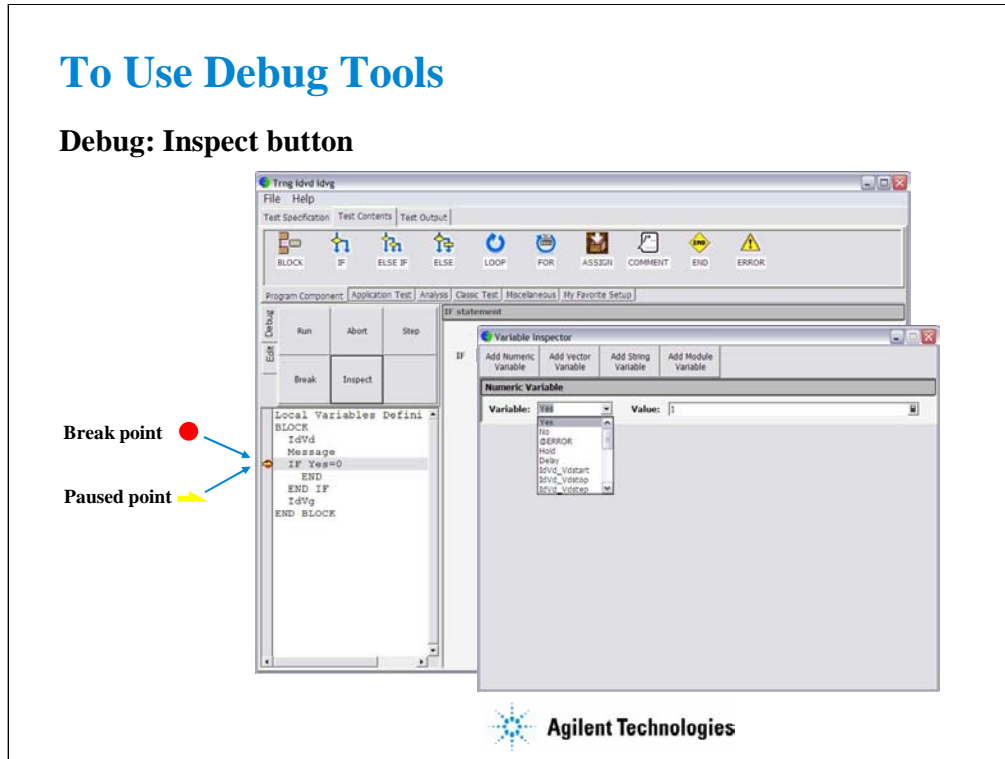


The Debug tab menu provides the following buttons:

- Run button starts the debug (executes the test flow). During execution, the label changes to Pause. Clicking Pause button pauses the execution, and changes the label to Run that is used to continue the debug (execution).
- Abort button aborts the debug (execution).
- Step button executes the highlighted line of the test flow. Clicking the button repeatedly continues the execution by a line.
- Break button sets/releases the break point. For the break point, this button releases the break point from the highlighted line. Program execution will break at the break point automatically.
- Inspect button is available when the debug (execution) is paused or broken. This button opens the Variable Inspector used to monitor value of device parameters, test parameters, analysis parameters, local variables, or system variables.

To Use Debug Tools

Debug: Inspect button



The Variable Inspector is displayed by clicking the Inspect button after the program is paused, and is used to monitor or change the value of the device parameters, test parameters, analysis parameters, local variables, or system variables. For the vector variables, only data monitor is available. The Variable Inspector provides the following buttons to add the variable monitor area.

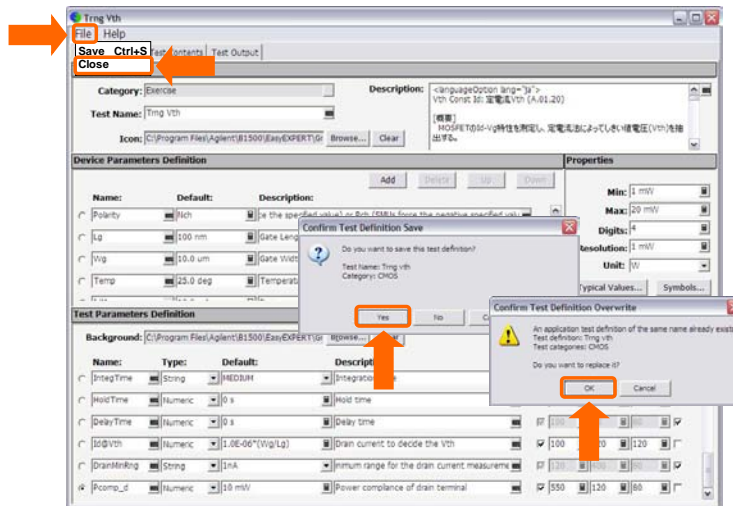
- Add Numeric Variable
- Add Vector Variable
- Add String Variable
- Add Module Variable

The following functions are available for the menu displayed by clicking the banner of the variable monitor area.

- Up: This button shifts the variable monitor area upward.
- Down: This button shifts the variable monitor area downward.
- Remove: This button deletes the variable monitor area.

To Resave and Close Your Test Definition

Close the definition editor, and overwrite your test definition



Test Definition editor

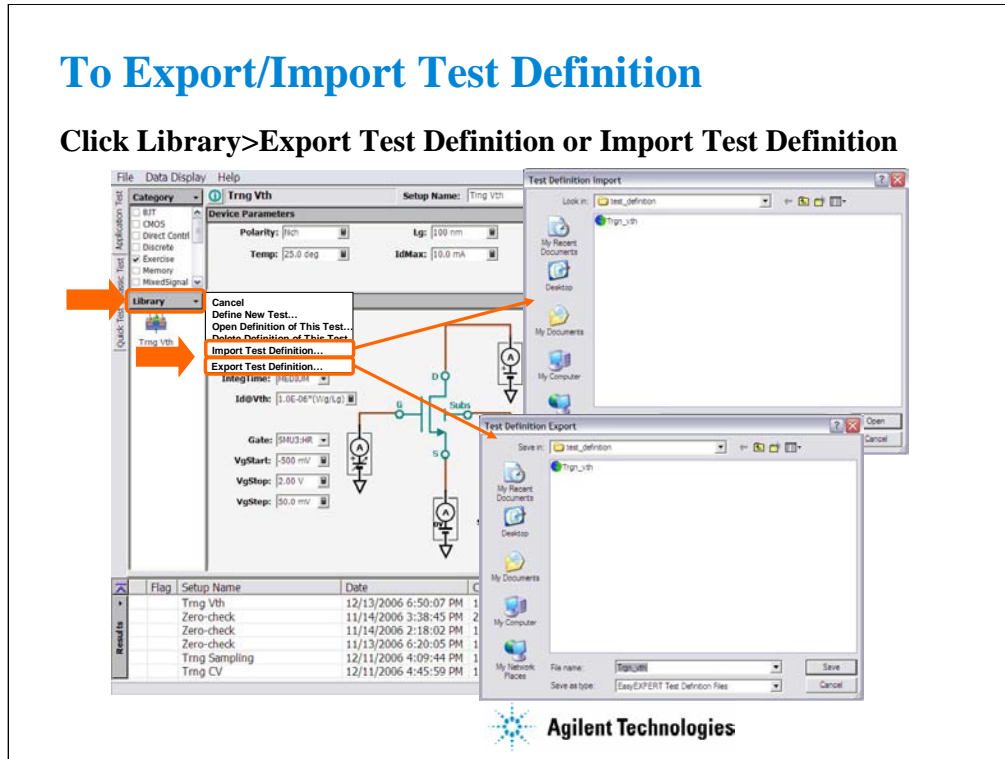


After you create your test definition, save the definition and close the Test Definition editor.

Click File > Close. Confirm Test Definition Save dialog box is opened. Click Yes to save your test definition and continue the close operation. The Confirm Test Definition Overwrite dialog box is opened. Click OK to overwrite your test definition.

To Export/Import Test Definition

Click Library>Export Test Definition or Import Test Definition



The test definition can be exported as the EasyEXPERT test definition file format or XML file format. And the file can be imported to the EasyEXPERT later.

To Use Built-in Functions

Absolute value:	abs(A)
Averaging:	avg(A), mavg(A,B)
Data conversion:	string(A), value(A)
Difference:	delta(A)
Differentiation, integration:	diff(A,B), integ(A,B)
Exponent, logarithm:	exp(A), lgt(A), log(A)
Maximum, minimum:	max(A), min(A)
Reading data :	getNumericData(A), getVectorData(A)
Square root:	sqrt(A)
Trigonometric function:	acos(A), asin(A) , atan(A), atan2(A,B), cos(A), sin(A), tan(A)



The EasyEXPERT software provides the built-in functions to calculate the display data and parameter or to get the test result data. The built-in functions can be used in the user function and analysis function of the test setup, and in the test execution flow of the test contents.

The following functions are also available.

at(A,B), at(A,B,C), ceil(A), cond(A,B,C,D), dim1Size(A), dim2Size(A), floor(A), index(A,B), isValid(A), setDeviceId(A), storeAt(A,B,C,D), substring(A,B,C), swmToModule(A)

For details of the functions, see User's Guide or online help.

To Use Built-in Functions

User function setup example

Local Variables Definition

```
BLOCK  
  Message  
  IF Yes1  
    IDVg  
  END IF  
  Auto Analysis  
  Message  
  IF Yes1  
    VG = getVectorData(Vg)  
    ID = getVectorData(Id)  
    GM = getVectorData(gm)  
    VTH = getNumericData(Vth)  
    GM_MAX = getVectorData(gmMax)  
  END IF  
END BLOCK
```

User Function

Name	Unit	Definition
gm	S	diff(Id, Vg)
gmMax	S	max(gm)

Analysis Function

Name	Unit	Definition
Vth	V	MAX(gm)

External Definitions:

- VG=getVectorData(Vg)
- ID=getVectorData(Id)
- GM=getVectorData(gm)
- VTH=getNumericData(Vth)
- GM_MAX=getVectorData(gmMax)

Internal Definitions:

- gm = diff(Id, Vg)
- gmMax = max(gm)

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This is an user function setup example. This example uses the diff function to calculate gm values and the max function to get the maximum gm value.

Also, the getVectorData and getNumericData functions are used in the test execution flow to get the test result data.

To Use Read Out Functions

Marker index value:	@MI
X coordinate value:	@MX, @CX
Y coordinate value:	@MY, @MYn, @CY, @CYn
Regression line parameter:	@L1CO, @L2CO
Line slope:	@L1G, @L1Gn, @L2G, @L2Gn
Line X intercept:	@L1X, @L2X
Line Y intercept:	@L1Y, @L1Yn, @L2Y, @L2Yn
Intersection of lines:	@IX, @IY, @IYn

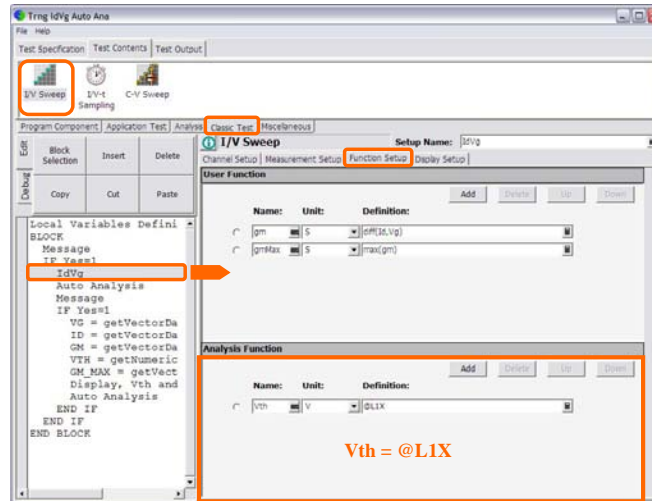
n: integer. 1 to 8.



The EasyEXPERT software provides the read out functions to read the marker position, cursor position, line slope, line intercept, and so on. The read out functions can be used in the analysis function of the test setup.

To Use Read Out Functions

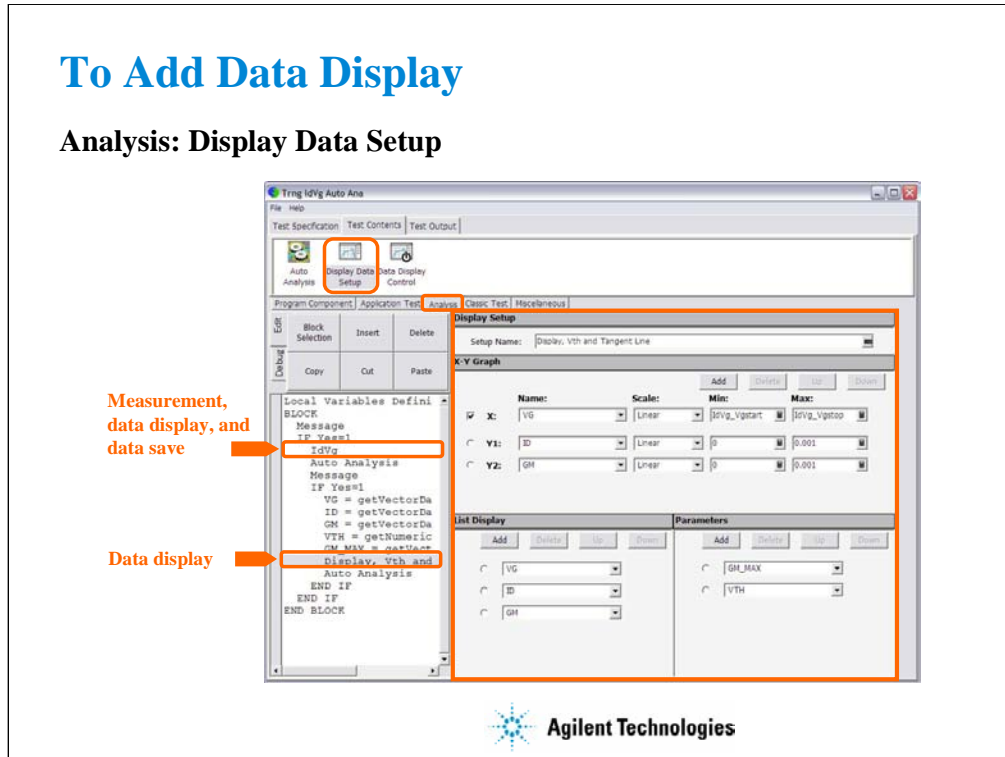
Analysis function setup example



This is an analysis function setup example. This example uses the @L1X function to get the X intercept value of the line 1.

To Add Data Display

Analysis: Display Data Setup



The test setup performs measurement, displays the test result, and stores the test result data to the test record.

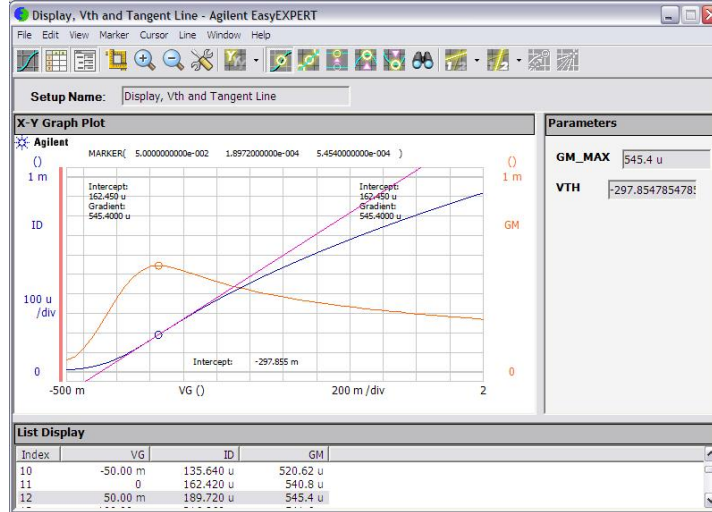
In addition to the default test result display, you can make additional data display by using the Display Data Setup statement. The statement provides the user interface as same as the Display Setup of the Classic Test or the Test Output of the test definition. The above example displays the ID-VG/GM-VG curves, GM_MAX and VTH values, and tangent line by using the extra Data Display and Auto Analysis function. See next slide.

Note:

This additional display data cannot be saved to the data record. However only the last display data can be saved if the Test Output has not been set.

To Add Data Display

Additional data display example

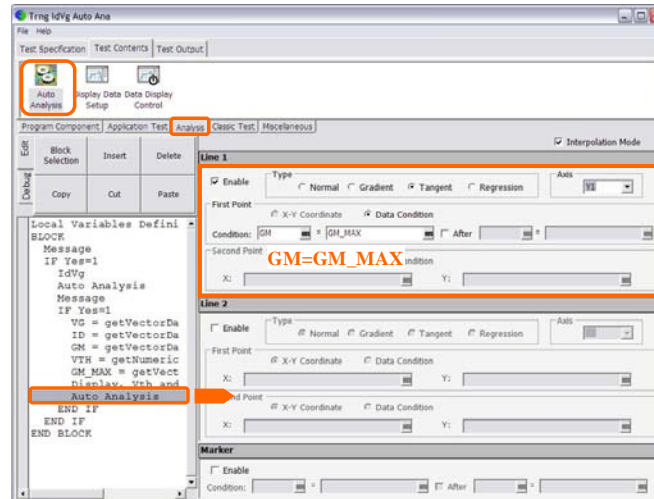


This is a test result example displayed on the Data Display window.
 The auto analysis setup for this example is shown in the next page.

To Use Auto Analysis Function

Analysis: Auto Analysis

- Line 1
- Line 2
- Marker



The Auto Analysis statement is used to apply the automatic analysis function to the last test result before this statement. When the test finishes, the function automatically draws lines, a marker, or both on the X-Y Graph of the Data Display window. This statement provides the same GUI as the Auto Analysis setup in the Classic Test.

You can set up two lines and one marker for the automatic analysis function by using the setup editor.

In the Line 1 and Line 2 areas, you can set up the lines to be drawn.

In the Marker area, you can set up the marker.

This example draws the tangent line for the Y1 data at the maximum GM point.

To Control Test Result Data Outputs

Analysis: Data Display Control



Data Display: OFF/ON

Miscellaneous: Data Store Control



Data Store: OFF/ON



By the default setting, the results of the tests defined in your test definition are displayed on the Data Display window and are stored to the data record.

You can control the data display of the tests by using the Data Display Control statement. Insert the statement, and remove the check from the Enable Data Display box to disable the data display.

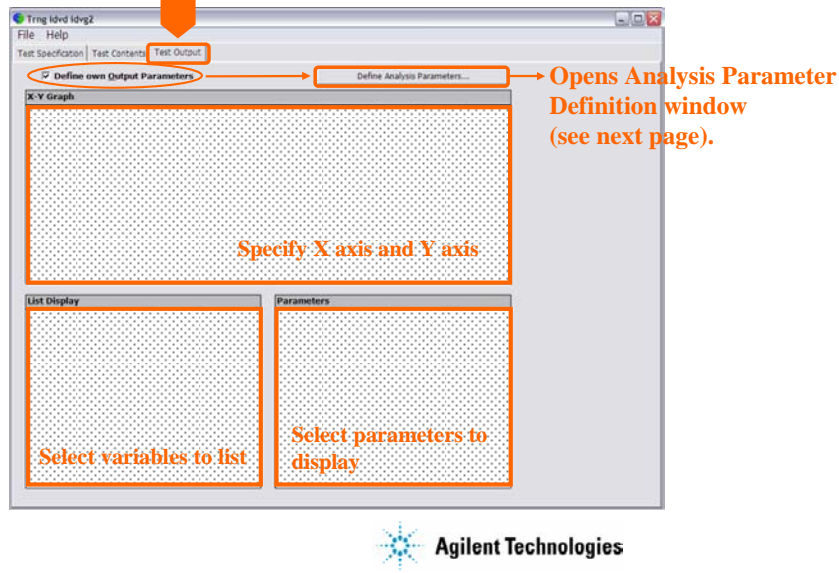
You can also control the data storage of the tests by using the Data Store Control statement. Insert the statement, and remove the check from the Enable Creating Test Result Record box to disable the data storage.

The functions cannot control the following data output. They are always enabled.

- Data output by the Test Output of the test definition
- Data output by the last test setup if the Test Output has not been set

To Define Test Output

1. Define analysis parameters.
2. Set display parameters.



The test output setup is optional. If you have the following requirements, define the analysis parameters and set the display parameters.

- To send the test result data to the subsequent tests in an application test
- To make the program branching depends on the test result
- To make the calculation using the test data in the Test Contents
- To display/record the test result of this application test

At first, define the analysis parameters:

- Check the Define own Output Parameters box.
- Click the Define Analysis Parameters... button. The Analysis Parameter Definition window is opened.
- Declare the analysis parameters. See next slide.
- Click the Close button.
- Set the display parameters. See below.

The X-Y Graph area is used to set the X axis and Y axis of the X-Y Graph Plot area on the Data Display window.

- Name: Name of variable to plot on the X axis
- Scale: Linear or Log
- Min: Minimum value of the specified axis
- Max: Maximum value of the specified axis

The List Display area selects the variables to be listed on the List Display area of the Data Display window. Up to 20 variables can be set.

The Parameters area selects the variables to be listed on the Parameters area of the Data Display window. Up to 20 parameters can be set.

To Define Test Output Analysis Parameters

Define Analysis Parameters...



Name:	Unit:	Description
VG	V	Gate Voltage
ID	A	Drain Current
GM	S	Transconductance
GM_MAX	S	Maximum Transconductance

Name:	Unit:	Description
VTH	V	Threshold Voltage



Define the analysis parameters as shown below:

At the Vector Parameters area or the Scalar Parameters area:

- Click the Add button.
- Enter the Name, Unit, and Description of the parameter.

For the sweep output/measurement data, use the vector parameter.

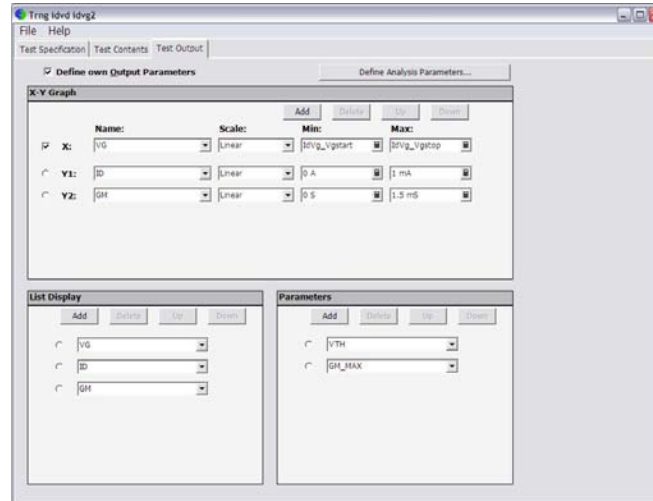
For the spot output/measurement data, use the scalar parameter.

For the data given by the max() and min() built-in function, use the vector parameter.

In this example, VG, ID, and GM are the vector parameter and VTH is the scalar parameter.

GM_MAX is the vector parameter because the max() built-in function is used to calculate this value.

To Define Test Output Display Parameters



This example sets:

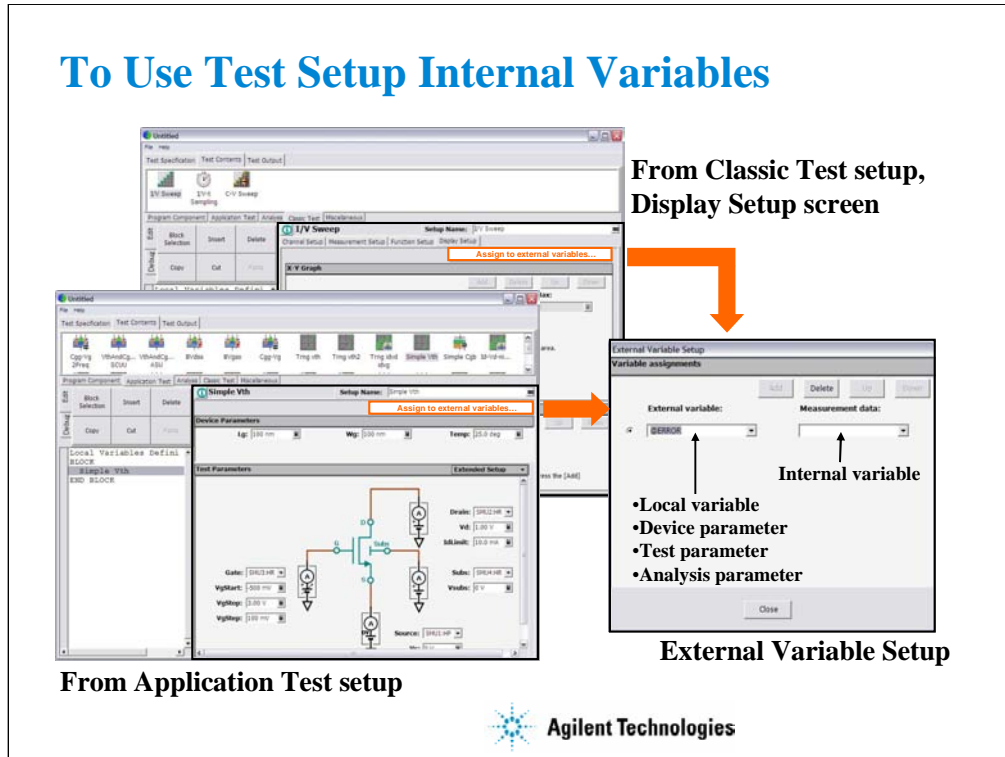
X-Y Graph: ID-VG plot for Y1-X graph and GM-VG plot for Y2-X graph

List Display: VG, ID, and GM

Parameters: GM_MAX and VTH

All parameters must be defined in the Analysis Parameter Definition window shown in the previous slide.

To Use Test Setup Internal Variables



You may want to read the parameters/variables used in Classic Test setup or Application Test setup defined in the Test Contents. Then use the External Variables Setup window used to make a mapping table between the test setup internal variables/parameters and the external variables (local variables, device parameters, test parameters, or analysis parameters).

To open the External Variable Setup window from a classic test setup:

- Specify the classic test.
- Click the Display Setup tab.
- Click the Assign to external variables... button.

To open the External Variable Setup window from an application test setup:

- Specify the application test.
- Click the Assign to external variables... button.

Note

Application test internal parameter/variable to be connected to an external variable must be the analysis parameter in its test definition.

To Use Test Setup Internal Variables Setup example

Assign to external variables...



External variable:	Measurement data:
VTH	Vth
VG	Vg
GM	gm
GM_MAX	gmMax
ID	Id

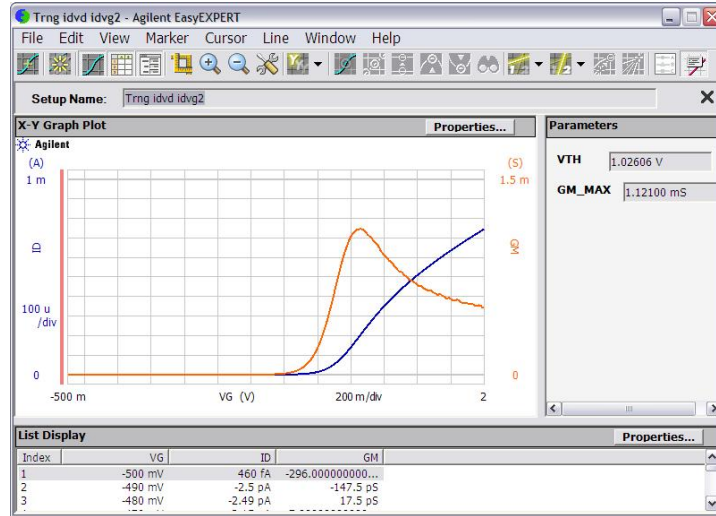


This example makes the mapping table between the test setup internal parameters and the analysis parameters.

- Define VTH, GM_MAX, VG, ID, and GM as the analysis parameters.
- Set these analysis parameters to the display parameters.
- Open the External Variable Setup dialog box.
- Assign VTH to the internal parameter Vth.
- Assign VG to the internal parameter Vg.
- Assign GM to the internal parameter gm.
- Assign GM_MAX to the internal parameter gmMax.
- Assign ID to the internal parameter Id.

For the example definition, open the Trng idvd idvg2 definition stored in the %data folder on the Manual CD-ROM. The Manual CD-ROM stores the example test setup and definition data used in this manual.

To Use Test Setup Internal Variables Result example



This is a result example of the test output setup shown in the previous pages.

To Use Test Setup Internal Variables Using built-in functions

Local Variables Definition

BLOCK

IdVg ← Test setup

VG = getVectorData("Vg")

ID = getVectorData("Id")

GM = getVectorData("gm")

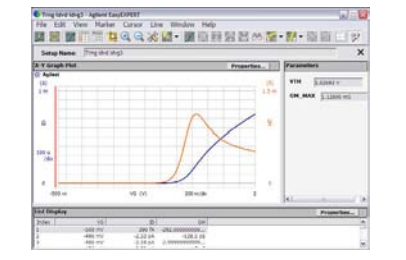
GM_MAX = getVectorData("gmMax")

VTH = getNumericData("Vth")

IdVd ← Test setup

END BLOCK

Display parameters of the last Data Display window



Vg, Id, gm, gmMax, and Vth
must be the display
parameters of IdVg.



This example shows another way to read the value of the internal variables (Vg, Id, gm, gmMax, and Vth). In this example, you do not use the mapping table but use the getVectorData and getNumericData built-in functions. The functions can be used to read the value of parameters displayed on the last data display.

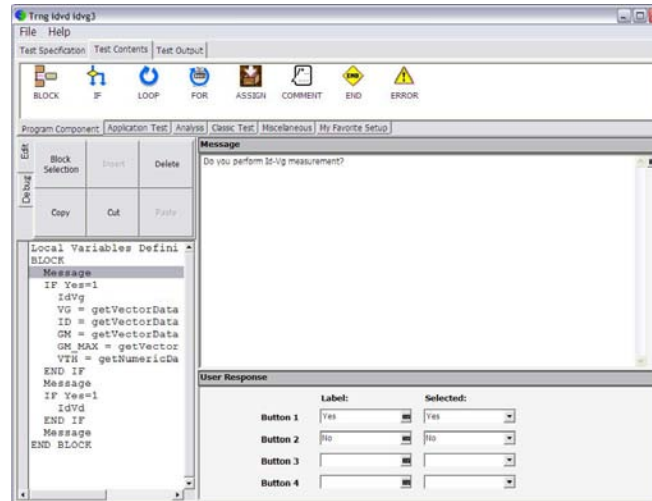
To read the value:

- Define VG, ID, GM, GM_MAX, and VTH as the analysis parameters.
- Set these analysis parameters to the display parameters.
- Insert the ASSIGN statements to add the formula shown above.

Note

Application test internal parameter/variable to be connected to an external variable must be the analysis parameter in its test definition.

To Use Test Setup Internal Variables Using built-in functions, setup example



This example sets the following test flow:

Local Variables Definition ! Defines Yes variable

BLOCK

Message ! Do you perform Id-Vg measurement?

IF Yes=1

IdVg ! Classic test setup for Id-Vg measurement

VG=getVectorData("Vg")

ID=getVectorData("Id")

GM=getVectorData("gm")

GM_MAX=getVectorData("gmMax")

VTH=getNumericData("Vth")

END IF

Message ! Do you perform Id-Vd measurement?

IF Yes=1

IdVd ! Classic test setup for Id-Vd measurement

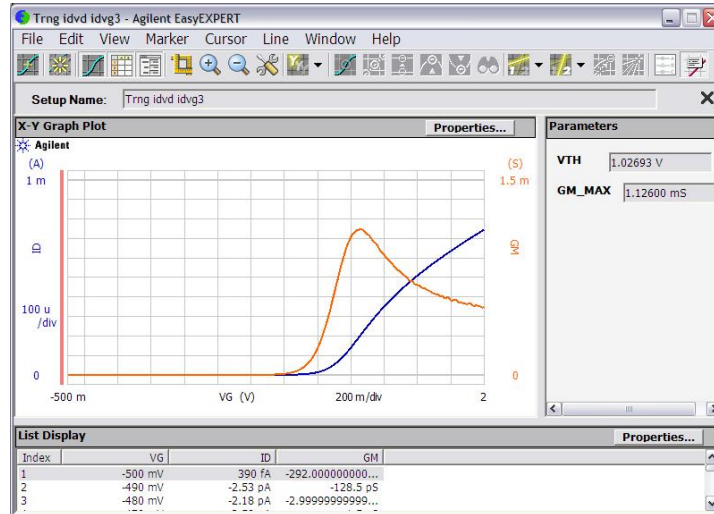
END IF

Message ! Click OK to display VTH and GM_MAX values and end the test

END BLOCK

For the example definition, open the Trng idvd idvg3 definition stored in the %data folder on the Manual CD-ROM. The Manual CD-ROM stores the example test setup and definition data used in this manual.

To Use Test Setup Internal Variables Using built-in functions, result example



This is a result example of the test output setup shown in the previous pages.

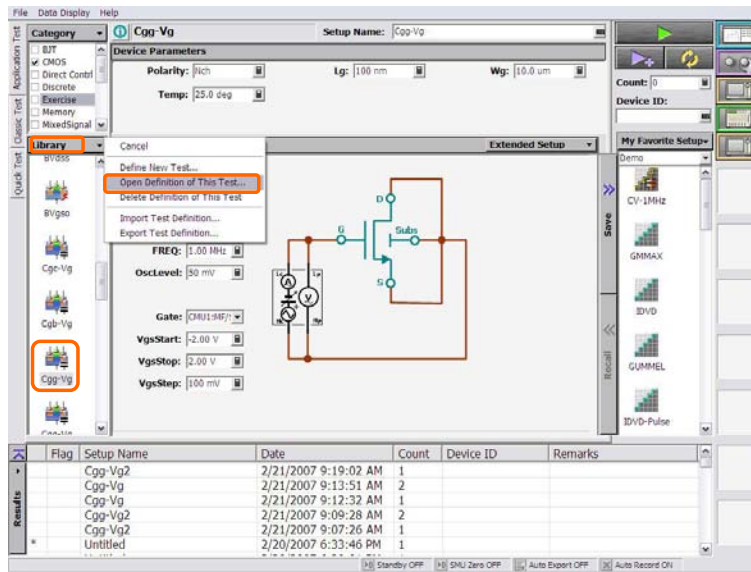
Class Exercise

Modify test definition using vector data.

1. **Open the Cgg-Vg test definition.**
2. **Modify it for the multiple frequency test using a vector data. See next several pages.**
3. **Use the debug tools.**
4. **Save the definition as a new one (ex. Trng Cgg-Vg).**
5. **Perform the test.**
6. **Export the new definition, and import it.**

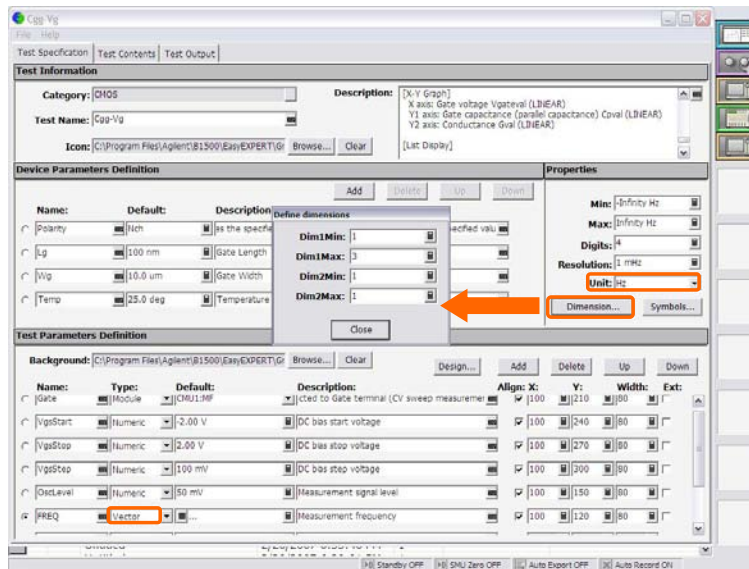


To open test definition of Cgg-Vg Application Test



Select the Cgg-Vq Application Test in the CMOS Category.
Click the Library button > Open Definition of This Test....

To set properties of vector data

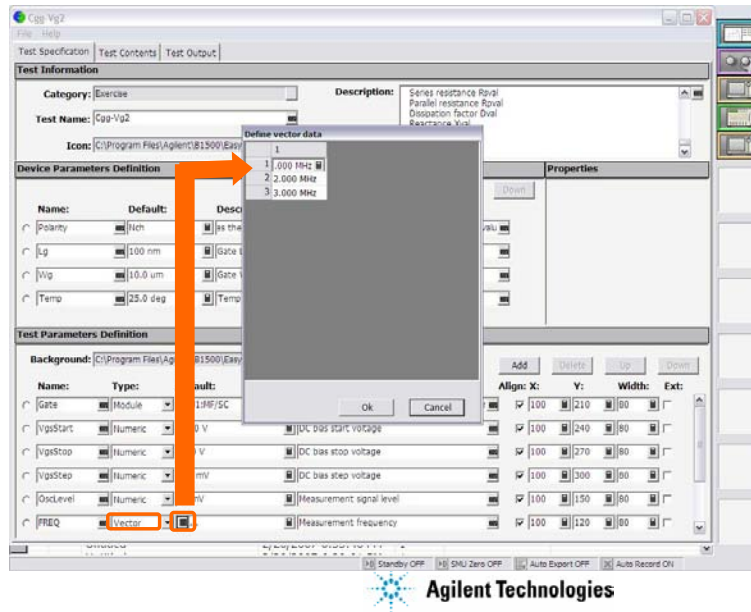


Select the Type of FREQ parameter to Vector.

Select the Unit of Properties to Hz.

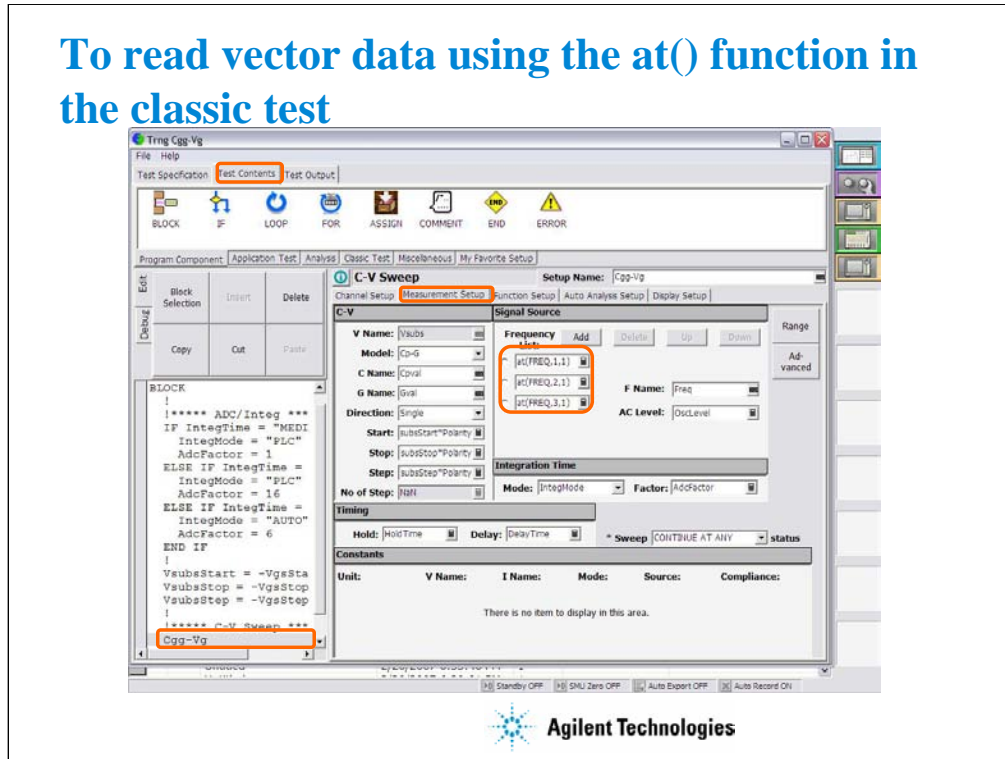
Click the Dimension... button and set Dim1Max (3 for this example).

To set vector data using Define vector data window



Click the Grid button to open the Define vector data window. Enter a vector data (1 MHz, 2 MHz, 3MHz) for this example.

To read vector data using the at() function in the classic test



Click the Test Contents tab.

Select the Cgg-Vg line.

Click the Measurement Setup tab and set the Frequency List using the at() functions.





10 Creating Your Test Definitions

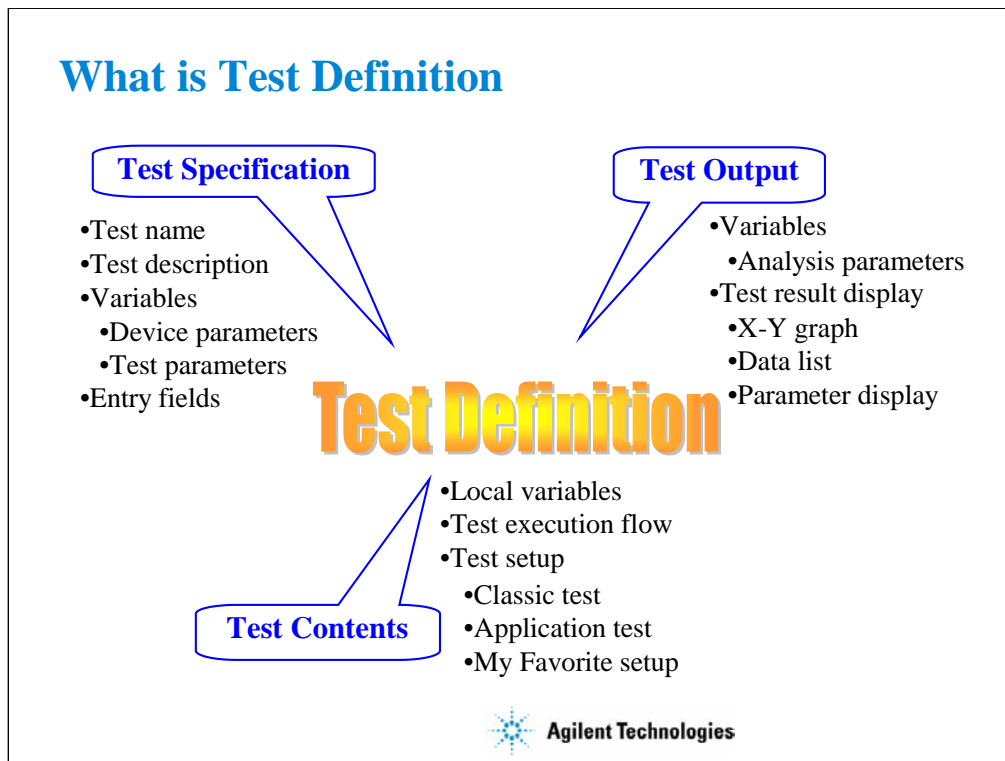


In This Module

- **What is Test Definition**
- **What is Test Contents**
- **To Open Test Definition Editor**
- **To Define Test Specification**
- **To Define Test Contents**
- **Available Elements**
- **Available Variables**



This section explains how to create your test definition. You will perform the above tasks to create the definition.

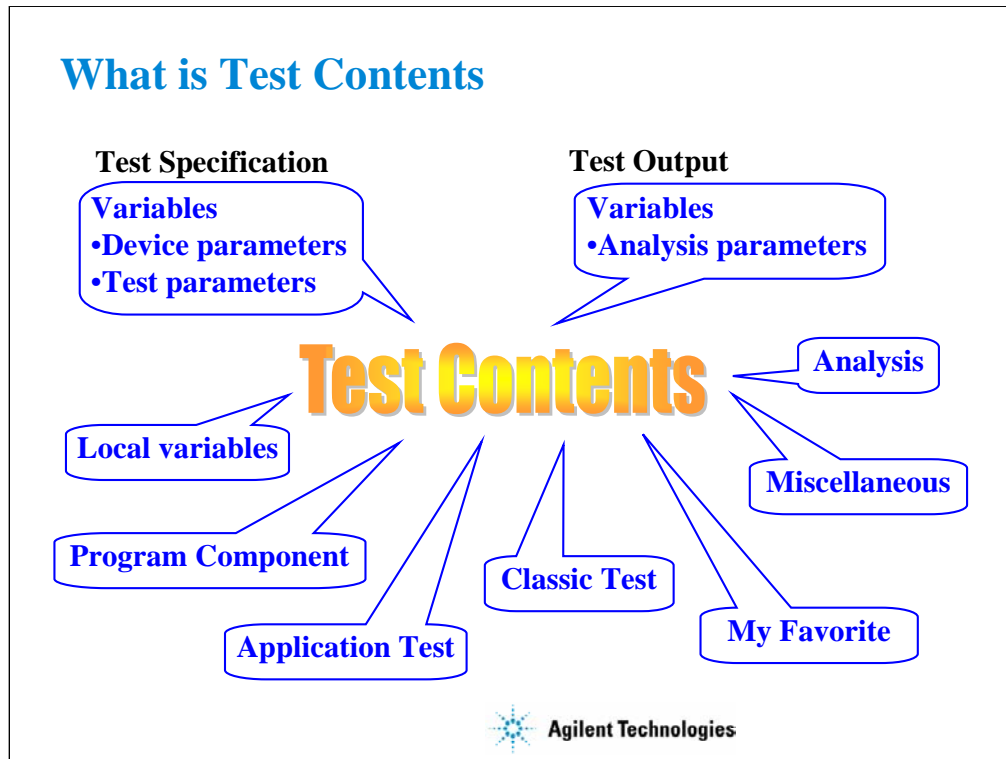


Test definition consists of test specification, test contents, and test output setup. The test specification contains test name, description, device parameters, and test parameters. The parameters will be the variables used to pass the test conditions to the test execution flow or test setup defined in the test contents. Especially for the test parameters, you can specify the position of entry field for each parameter. You can see the entry fields when the main screen displays this application test setup. The test contents are the core of the test definition. You will define the local variables, test execution flow, and test setup. You can define the test setup by selecting application tests, classic tests, or my favorite setup, and entering the test conditions.

The test output setup is optional. If you have the following requirements, declare the analysis parameters and define the display parameters on the Test Output tab screen. See “To Define Test Output” in Module 9.

- To send the test data to the subsequent tests
- To make the program branching depends on the test data
- To display/record the calculation result using the test data
- To display/record the test data of this application test

You can use the device parameters, test parameters, and analysis parameters in the test execution flow (program flow) of the test contents without declaration of local variables.

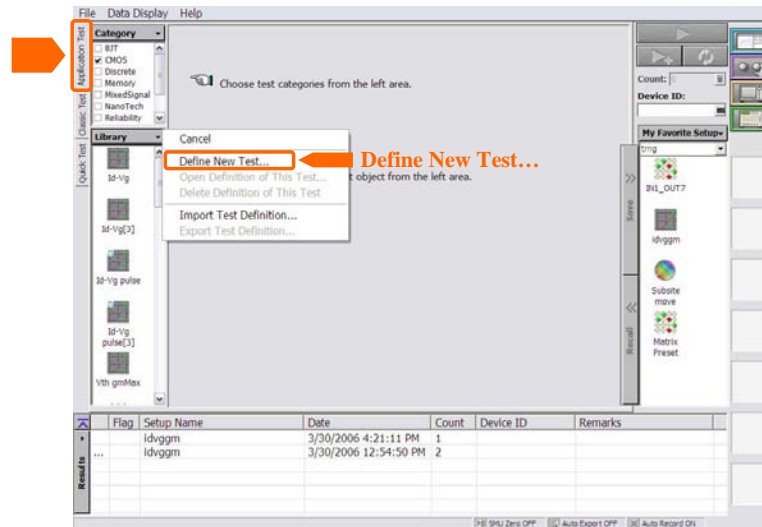


Test contents are the test execution flow (program flow), and is the core of the test definition. In the test contents, the following elements can be defined.

- Local variables
- Program components
- Application tests
- Classic tests
- My Favorite setup
- Analysis components
- Miscellaneous components
- Device parameters defined in the test specification
- Test parameters defined in the test specification
- Analysis parameters defined in the test output

The program is executed from top to bottom in the test execution program list.

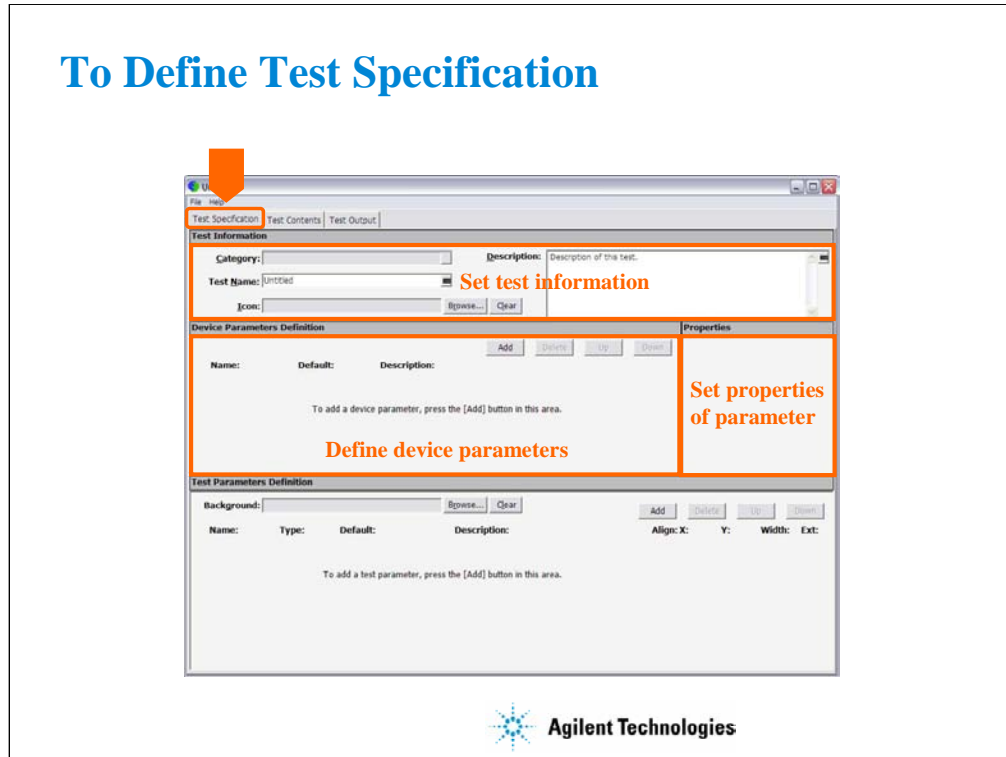
To Open Test Definition Editor



To start test definition, open the test definition editor.

Select the Application Test tab, click the Library button, and select the Define New Test... function. The test definition editor will be opened. See next slide.

To Define Test Specification



The test definition editor provides three tabs, Test Specification, Test Contents, and Test Output. At first define the test specification. Click the Test Specification tab.

In the Test Information area:

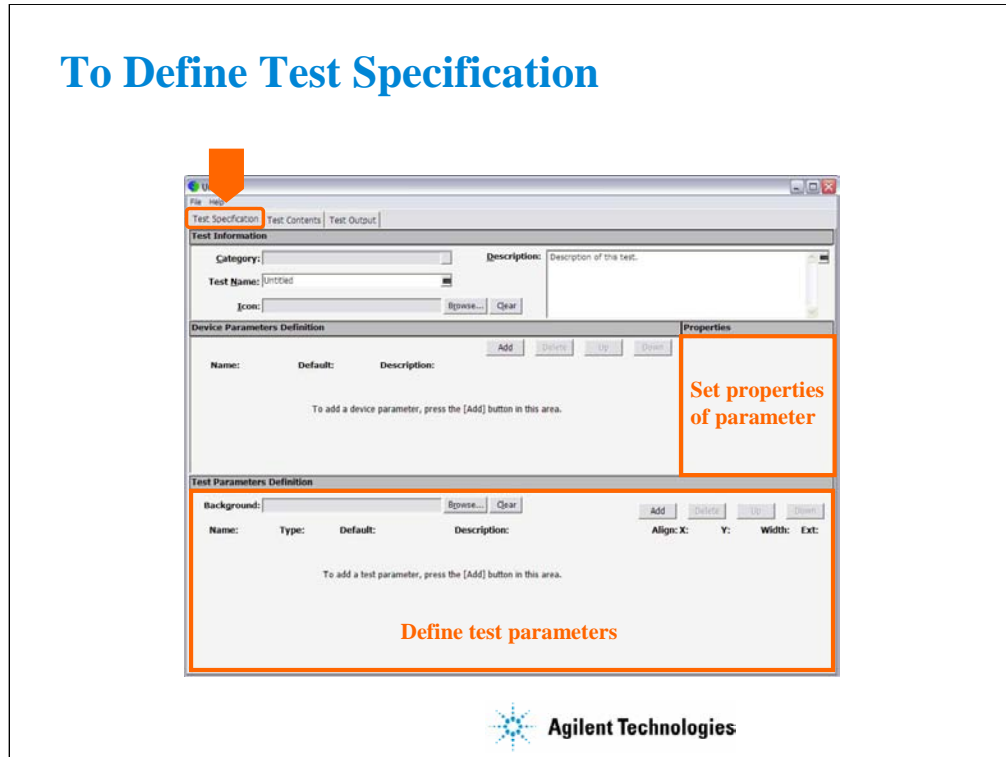
- Click the right button in the Category field to specify the category the new test definition belongs.
- Enter the Test Name.
- Select the Icon that will be displayed on the list area below the Library button of the main screen. It is the image file used to select the test definition. See previous slide.
- Enter the Description of the test.

In the Device Parameters Definition area:

- Click Add button to display the entry fields for the parameter.
- Set the Name, Default value, and Description for the parameter. When you add a parameter, you will see the entry fields at the Properties area. The area shows you the properties (minimum value, maximum value, number of effective digits, resolution, and unit) for the device parameter or the test parameter specified by the radio button put on the left of the parameter name.

For the Typical Values... button and the Symbols... button, see online help or User's Guide.

To Define Test Specification

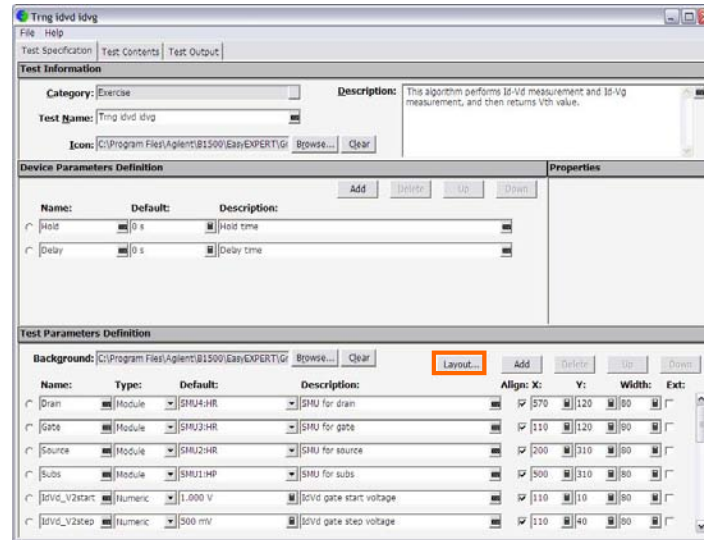


In the Test Parameters Definition area:

- Select the Background that will be displayed on the application test setup area of the main screen. Usually it is the image that shows the device connections.
- Set the Name, data type, Default value, and Description for the parameter. When you add a parameter, you will see the entry fields at the Properties area. The area shows you the properties (minimum value, maximum value, number of effective digits, resolution, and unit) for the device parameter or the test parameter specified by the radio button put on the left of the parameter name.
- Set the X, Y, and Width values to specify the position of entry field displayed on the application test setup area.
- Check the Align box to set the X origin of entry field to the left edge of the entry field. Uncheck this box to set it to the left edge of the parameter name placed left next to the entry field.
- Check the Ext box. The entry field will be put on the Extended Test Parameters dialog box that is displayed by clicking the Extended Setup button on the application test setup area of the main screen.

Setup example

Test Specification



This example sets:

Category: Exercise (This category may be created by the class exercise in Module 9)

Test Name: Trng IdVd IdVg

Icon: MOSFET.bmp

Device parameters:

Hold and Delay

Background: Vth_Const_Id.PNG

Test parameters:

Drain, Gate, Source, Subs, Idcomp, Igcomp

IdVd_V1start, IdVd_V1step, IdVd_V1stop, IdVd_V2start, IdVd_V2step, IdVd_V2nop

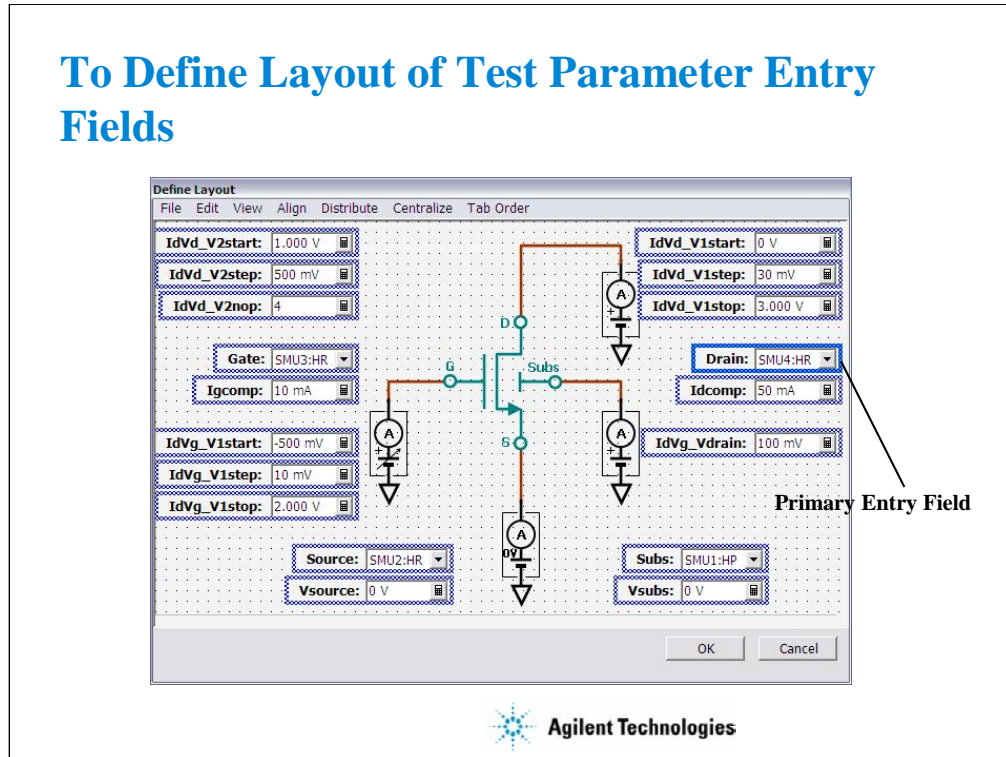
IdVg_V1start, IdVg_V1stop, IdVg_V1step, IdVg_Vdrain

Vsource, Vsubs

Entry field properties: 80 (width) x 30 (distance in vertical direction)

Press the Layout... button to open the Define Layout dialog box.

To Define Layout of Test Parameter Entry Fields



The Define Layout dialog box is used to define the layout of the test parameter entry fields displayed on the application test setup screen.

The following methods are available for selecting the entry fields.

- Click on the entry field. Multiple entry fields can be selected by clicking on the entry field while holding down the Ctrl key on the keyboard.
- Drag the mouse to draw a rectangle around multiple entry fields.
- Select Select All from the EDIT menu to select all entry fields.

The selected entry fields are outlined by the blue rectangles. The primary entry field, which is the base for layout operations, is surrounded by a highlighted blue rectangle. Only one primary entry field can be selected. To change the primary entry field, click on a selected entry field. The entry field is always that was most recently clicked will be the primary entry field.

The following methods are available for releasing (unselecting) the selected entry fields.

- Click the selected entry field while holding down the Shift key on the keyboard.
- Click outside of the selected entry fields to release all selected entry fields.

The following methods are available for defining the layout of the selected entry fields.

- Drag & drop with the mouse to move the selected entry field(s).
- Change the X/Y values in the property window to move the selected entry field(s).
- Press the arrow keys on the keyboard to move the selected entry field(s).
- Use the functions in the Align menu to align the selected entry field(s) to the primary entry field.
- Use the functions in the Distribute menu to evenly distribute the selected entry fields horizontally or vertically.
- Use the functions in the Centralize menu to move the horizontal or vertical center of all selected entry fields to the horizontal or vertical center of the entry field area.

For more information, see online help or User's Guide.

Result example

Parameter entry fields

The screenshot displays the Agilent Test Setpoint Editor interface for a test setup named 'Trng idvd idvg'. The interface is divided into several sections:

- Category:** Trng idvd idvg
- Device Parameters:** Hold: 0 s, Delay: 0 s
- Test Parameters:**
 - IdVd_V2start: 1.000 V
 - IdVd_V2step: 500 mV
 - IdVd_V2stop: 0 V
 - Gate: SRU2:HR
 - Igcomp: 10 mA
 - IdVg_V1start: 500 mV
 - IdVg_V1step: 10 mV
 - IdVg_V1stop: 2.000 V
 - Source: SRU2:HR
 - Vsource: 0 V
- Extended Setup:**
 - IdVd_V1start: 0 V
 - IdVd_V1step: 30 mV
 - IdVd_V1stop: 3.000 V
 - Drain: SRU4:HR
 - Idcomp: 50 mA
 - IdVg_Vdrain: 100 mV
 - Subs: SRU1:HP
 - Vsubs: 0 V

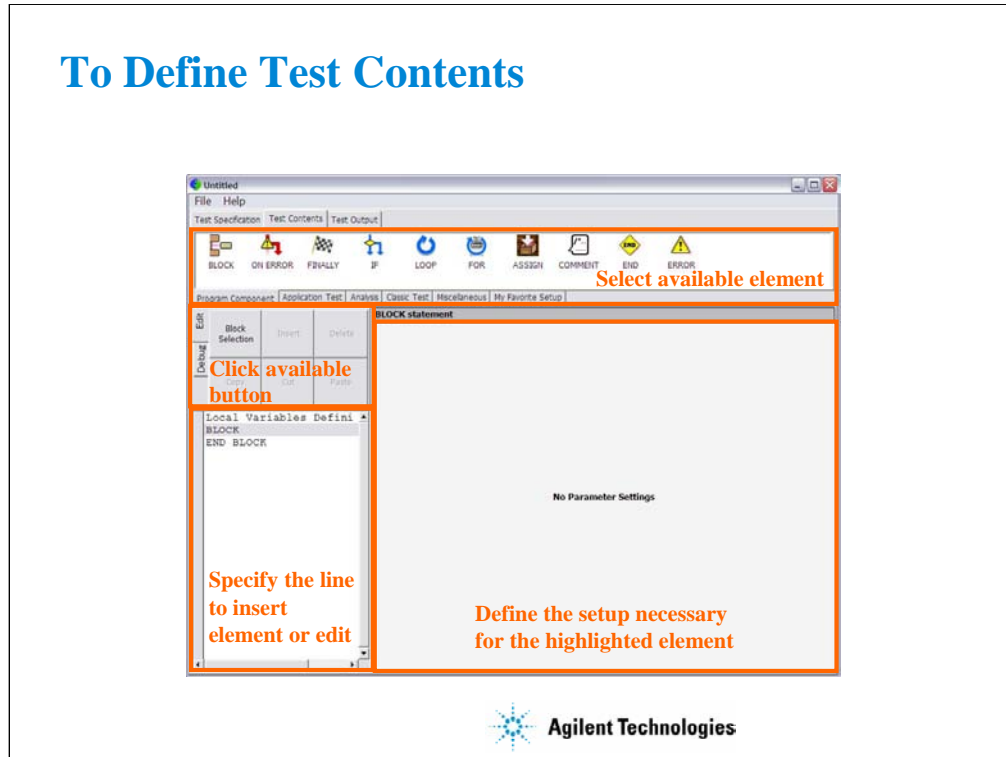
The central area shows a circuit diagram with a MOSFET and various measurement points. At the bottom, a table lists the test results:

Flag	Setup Name	Date	Count	Device ID	Remarks
	Trng IdVd Vth	12/14/2006 7:30:43 PM	1		
	Trng Vth	12/13/2006 6:50:07 PM	1		
	Zero-check	11/14/2006 3:38:45 PM	2		
	Zero-check	11/14/2006 2:18:02 PM	1		
	Zero-check	11/13/2006 6:20:05 PM	1		
	Trng Sampling	12/11/2006 4:09:44 PM	1		



This is a result example of the test specification setup shown in the previous pages.

To Define Test Contents



Define the test contents as shown below:

- Click the Test Contents tab.
- Click the Local Variable Definition line to highlight the line. The right open space displays the Local Variables Definition statement setup editor.
- Define the local variables used in this test execution flow (program flow).
- Click the line that an element has to be inserted.
- Click an element of Program Component, Application Test, Analysis, Classic Test, or Miscellaneous tab menu.
- Click the Insert button of the Edit tab menu. The element will be inserted between the highlighted line and the next line.
- Repeat this to create the test execution flow.

Available elements

	Program Component
	Application Test
	Analysis
	Classic Test
	Miscellaneous
	My Favorite

Agilent Technologies

Available elements are shown above. The Program Component provides the typical program statements such as IF, LOOP, FOR, and so on. They are used to control the test execution flow. The Application Test, Classic Test, and My Favorite are used to define the test setup/test condition. The Analysis provides the elements used to control auto analysis function and data display. And the Miscellaneous provides other useful elements. For details of elements, see online help or user's guide.

Available variables

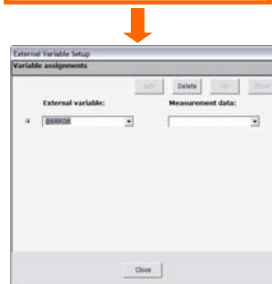
Test Contents
•Local variables

Test Specification
•Device parameters
•Test parameters

Test Output
•Analysis parameters

Do not set the same name for variables and parameters. The name must be unique.

Assign to external variables...



You can connect the variables in test setup with

- Local variables
- Device parameters
- Test parameters
- Analysis parameters



In the test execution flow (program flow), you can use the following variables.

- Variables defined by the Local Variables Definition component
- Device parameters defined in the Test Specification
- Test parameters defined in the Test Specification
- Analysis parameters defined in the Test Output

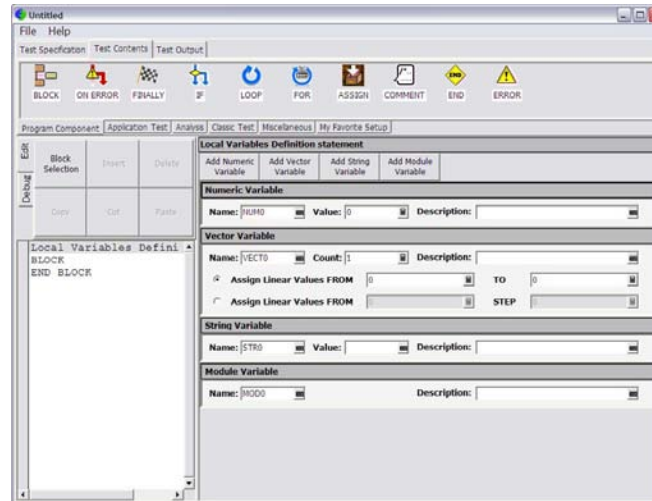
You may want to read the parameters/variables used in Classic Test setup or Application Test setup defined in the Test Contents. Then use the External Variables Setup dialog box or built-in functions. They can connect the test setup internal variables/parameters to the external variables listed above. For the example variable connections, see “To Use Test Setup Internal Variables” in Module 9.

Note

Application test internal parameter/variable to be connected to an external variable must be the analysis parameter in its test definition.

Defining local variables

Local Variables Definition



Add Numeric Variable button displays the Numeric Variable area that provides the following fields.

- Name: Numeric variable name
- Value: Initial value of the variable
- Description: Additional information for the variable

Add Vector Variable button displays the Vector Variable area that provides the following fields.

- Name: Vector variable name. Two dimensional array.
- Count: Number of elements, or array size
- Description: Additional information for the variable

This area also provides the following radio button used to specify how to set the initial value of the array data automatically.

- Assign Linear Values FROM [value of first element] TO [value of last element]

If $Count > 1$, this sets $first\ value + (N-1) \times (last\ value - first\ value) / (Count - 1)$ to the N -th element. If $Count = 1$, this sets $first\ value (=last\ value)$ to the element.

- Assign Linear Values FROM [value of first element] STEP [step value]

This sets $first\ value + (N-1) \times step$ to the N -th element.

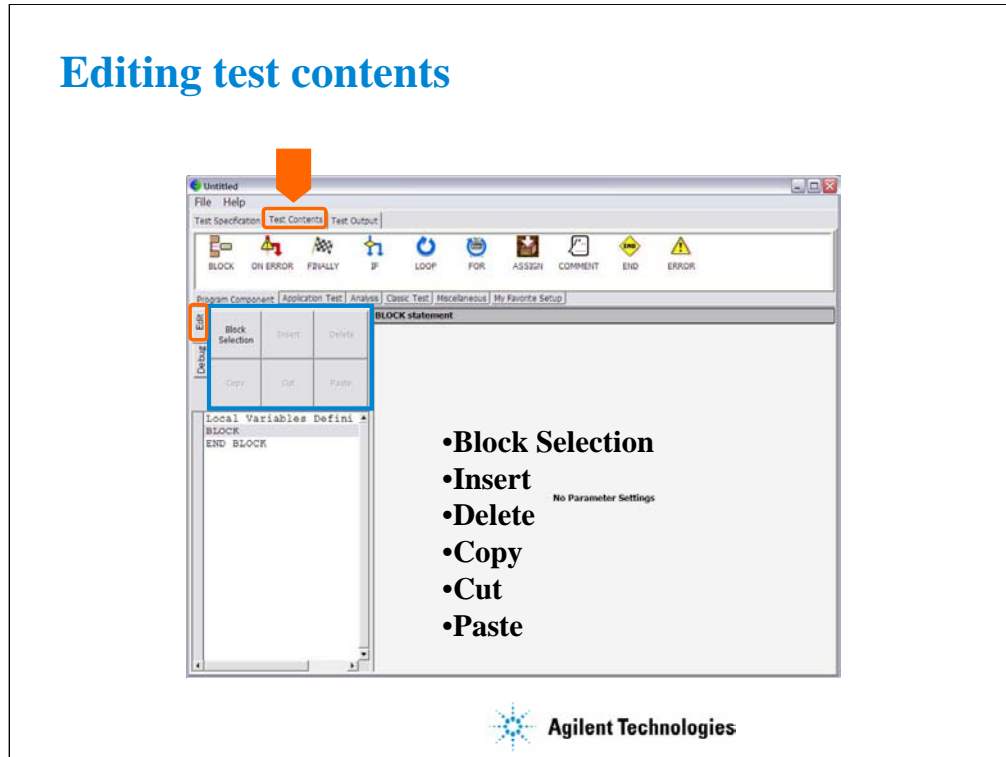
Add String Variable button displays the String Variable area that provides the following fields.

- Name: String variable name
- Value: Initial value of the variable
- Description: Additional information for the variable

Add Module Variable button displays the Module Variable area that provides the following fields.

- Name: Module variable name
- Description: Additional information for the variable

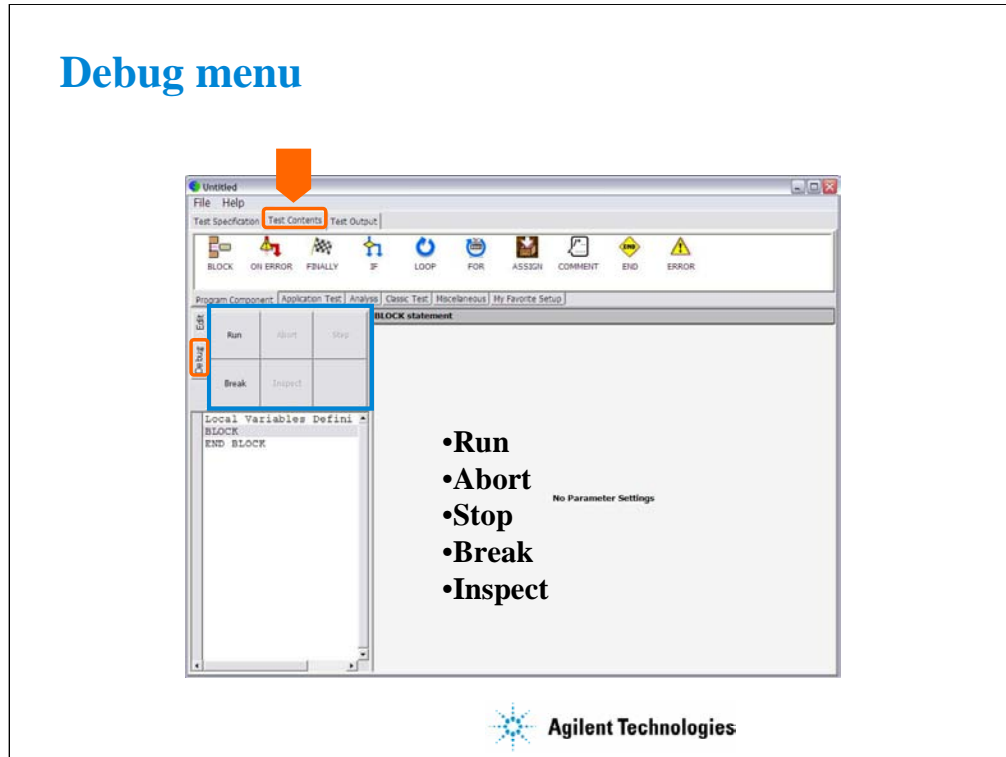
Editing test contents



The Edit tab provides the following buttons:

- Block Selection/Line Selection toggle button selects the edit target selection mode. In the line selection mode, clicking line just selects the line. In the block selection mode, clicking line selects the block the line belongs to.
- Insert button inserts the specified element between the highlighted line and the next line.
- Delete button deletes the highlighted line.
- Copy button copies the highlighted line to the clipboard.
- Cut button moves the highlighted line to the clipboard.
- Paste button inserts the line in the clipboard between the highlighted line and the next line.

Debug menu



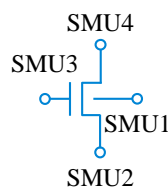
The Debug tab menu provides the following buttons:

- Run button starts the debug (executes the test flow). During execution, the label changes to Pause. Clicking Pause button pauses the execution, and changes the label to Run that is used to continue the debug (execution).
- Abort button aborts the debug (execution).
- Step button executes the highlighted line of the test flow. Clicking the button repeatedly continues the execution by a line.
- Break button sets/releases the break point. For the break point, this button releases the break point from the highlighted line. Program execution will break at the break point automatically.
- Inspect button is available when the debug (execution) is paused or broken. This button opens the Variable Inspector used to monitor value of device parameters, test parameters, analysis parameters, local variables, or system variables.

Class Exercise

Create test definition and perform test.

1. Open test definition editor.
2. Define Test Specification (see previous page)
3. Define Test Contents shown below.
4. Save the definition as Trng idvd idvg.
5. Use debug tools to check the definition.
6. Connect device, and perform test.

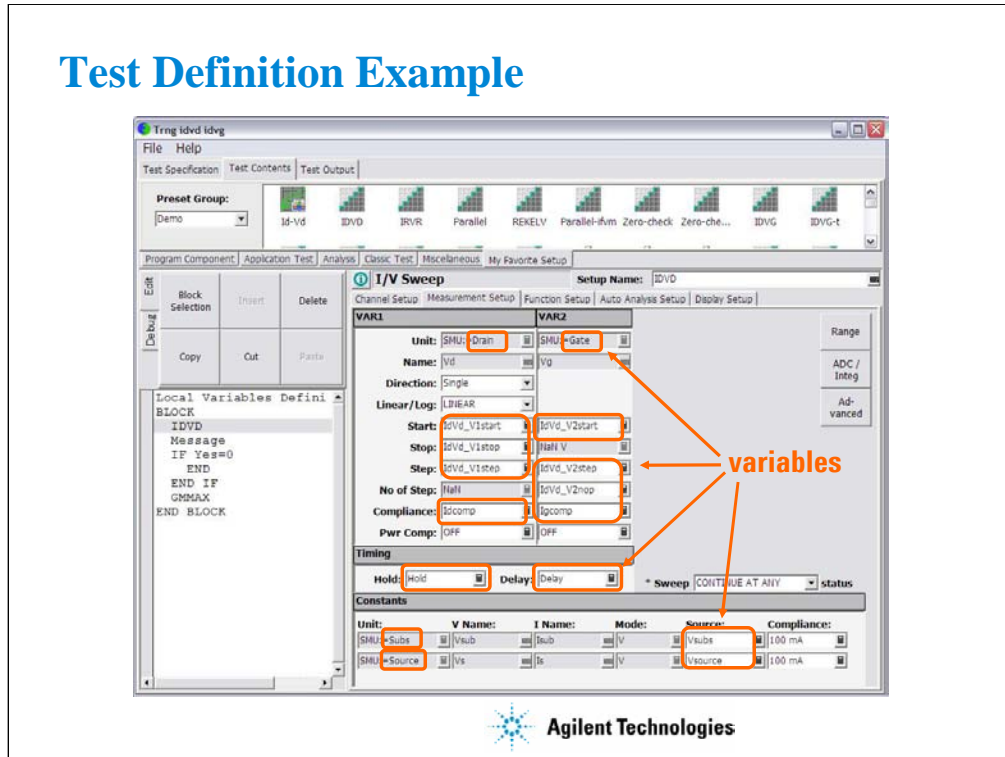


Test Contents:

Local Variables Definition

```
BLOCK
  IDVD
  Message
  IF Yes=0
    END
  END IF
  GMMAX
END BLOCK
```

Test Definition Example

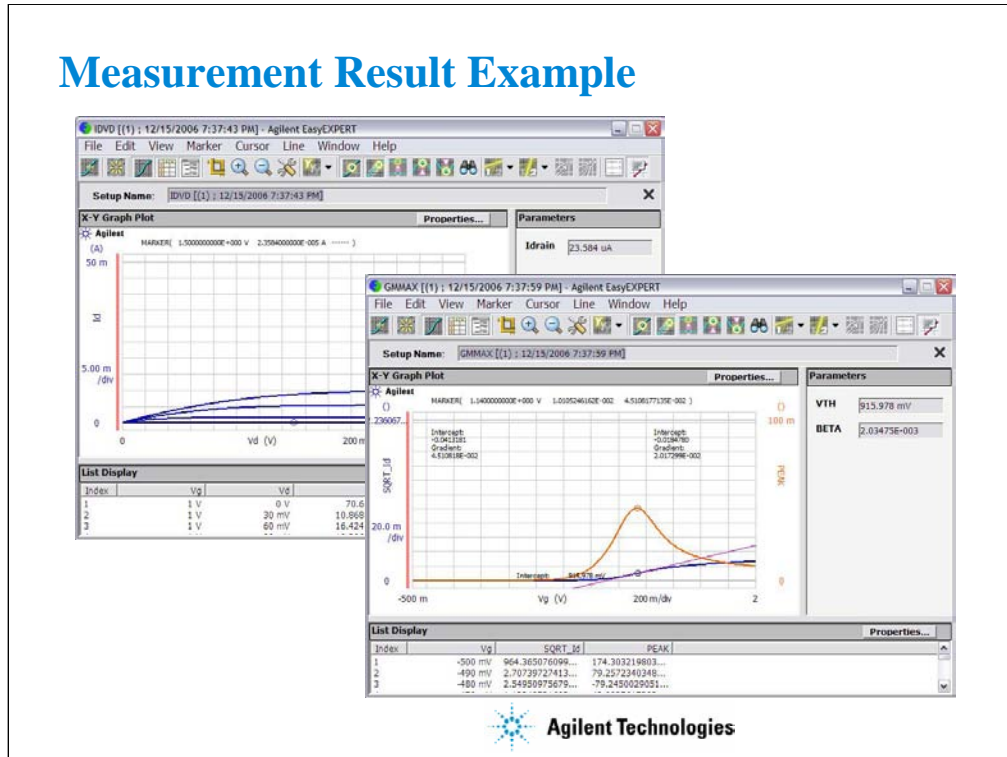


Use IDVD and GMMAX in the Demo preset group (My Favorite Setup) for the test setup.

Use the variables defined in the Test Specification to set the Unit on the Channel Setup, the source values on the Measurement Setup, the Min and Max values on the Display Setup, and so on.

For the example definition, open the Trng idvd idvg definition stored in the %data folder on the Manual CD-ROM. The Manual CD-ROM stores the example test setup and definition data used in this manual.

Measurement Result Example



This is a test result example displayed on the Data Display window.



In This Module

- **To Control External GPIB Devices**
- **To Call Execution Files**
- **To Perform Repeat Measurements**
- **Prober Control Script**



To Control External GPIB Devices

Miscellaneous: GPIB I/O

- Write String** to send a string command to GPIB device
- Write Value** to send a command to GPIB device
- Read String** to read a string value from GPIB device
- Read Value** to read a numeric value data from GPIB device
- Read List** to read a vector data from GPIB device
- Read STB** to read status byte of GPIB device

GP-IB Control Group Execution Trigger

Device Clear

Go To Local

Local LockOut



You can control external GPIB devices from the EasyEXPERT by using the GPIB I/O statement. The GPIB I/O statement provides the write/read functions shown above. Select a write function and enter the necessary parameters to send a command to the GPIB device. Select a read function and enter the necessary parameters to read response from the GPIB device. For details, see online help or User's Guide.

The followings are the GPIB Control functions.

- Group Execution Trigger: Sends a trigger to the specified GPIB device.
- Device Clear: Sends a device clear to the specified GPIB device.
- Go To Local: Returns the specified GPIB device to the local state.
- Local LockOut: Locks the specified GPIB device.

Note:

Before starting, enable System Controller. See Module 12. Also establish the GPIB connection with the external GPIB devices.

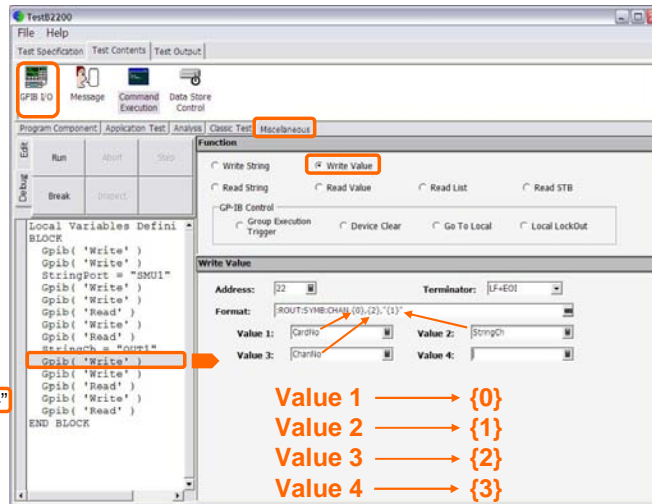
To Control External GPIB Devices

Agilent B2200 control example

To send command

Programming image:

```
*RST
:ROUT:FUNC ACON
(enter "SMU1" to StringPort)
:ROUT:SYMB:PORT {0},{1}"
:ROUT:SYMB:PORT? {0}
(reads string data)
*OPC?
(reads operation complete flag)
(enter "OUT1" to StringCh)
:ROUT:SYMB:CHAN {0},{2},"{1}"
:ROUT:SYMB:CHAN? {0},{2}
(reads string data)
*OPC?
(reads operation complete flag)
```



This slide shows an example setup of the GPIB I/O statement. This is a component of the test contents used to control the Agilent B2200 switching matrix.

This example uses the Write Value function to send the following command to the B2200.

```
:ROUT:SYMB:CHAN {0},{2},"{1}"
```

where, {0} is CardNo, {1} is StringCh, and {2} is ChanNo.

The followings are the reference of the setup editor.

- Address: GPIB address of the device
- Terminator: EOI, LF, CR/LF, LF+EOI, CR/LF+EOI, or NONE (no terminator)
- Format: Command (header and parameters) sent to the device
- Value 1: Value for {0}
- Value 2: Value for {1}
- Value 3: Value for {2}
- Value 4: Value for {3}

{0}, {1}, {2}, and {3} are variable available in the Format field only.

Note:

Use double quotes to enter a string to a local variable by using the Assign statement.

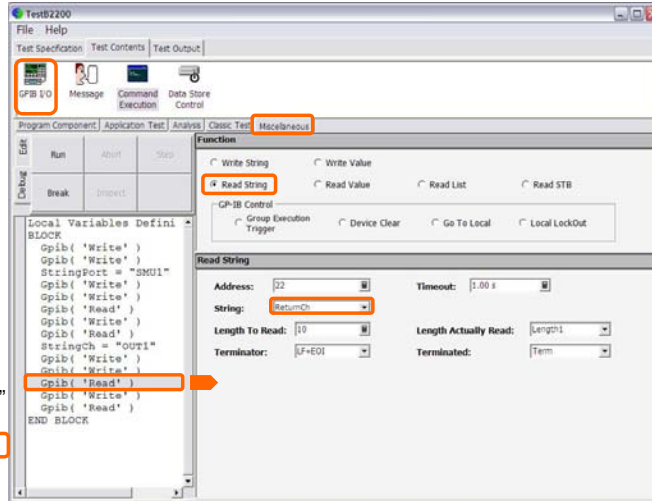
To Control External GPIB Devices

Agilent B2200 control example

To read data

Programming image:

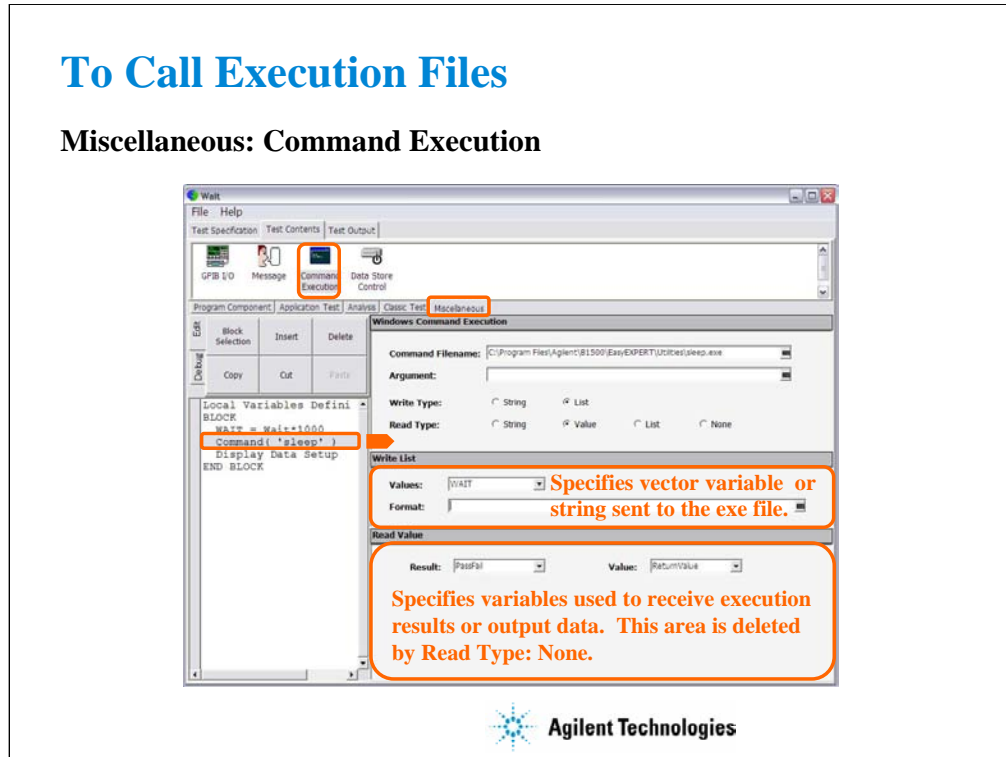
```
*RST
:ROUT:FUNC ACON
(enter "SMU1" to StringPort)
:ROUT:SYMB:PORT {0},{1}
:ROUT:SYMB:PORT? {0}
(reads string data)
*OPC?
(reads operation complete flag)
(enter "OUT1" to StringCh)
:ROUT:SYMB:CHAN {0},{2},{1}
:ROUT:SYMB:CHAN? {0},{2}
(reads string data)
*OPC?
(reads operation complete flag)
```



This example uses the Read String function to read the response from the B2200. This example reads the :ROUT:SYMB:CHAN? query command response. The result (ReturnCh value) must be OUT1.

To Call Execution Files

Miscellaneous: Command Execution



You can call the execution file (EXE file) from the EasyEXPERT. Use the Command Execution statement and define the setup editor as shown in this example.

- Command Filename: Execution file name (command name)
- Argument: Command parameter or argument
- Write Type: String or List (vector data)
- Read Type: String, Value (numeric data), List (vector data), or None (no read data)

If you specify Write String, enter the string sent to the command.

If you specify Write List, enter the name of vector variable sent to the command, and specify the format of data element sent to the command. See next slide.

In the Read String/Value/List area, specify the variables used to receive execution result and output data. There is no entry field for Read Type: None.

- Result: Numeric variable name. Used to store the execution result.
- Value: Numeric variable name for Read Value, or vector variable name for Read List. Used to store the returned data.
- String: String variable name. Used to store the returned data.
- Length Actually Read: Numeric variable name. Used to store the byte length of the returned data.

The above example calls the sleep.exe file used to insert the wait time for program execution. The WAIT value must be defined in msec. After the normal command execution, the sleep.exe returns 1 for Value and 0 for Result. The sleep.exe file is stored in the following folder.

C:\Program Files\Agilent\B1500\EasyEXPERT\Utilities

To set Format field

{I[,A][:F]}

- **I** List data index. Or index of element. Integer.
- **[,A]** Character length of the specified data element. Positive integer for right-aligned, or negative integer for left-aligned. Optional.
- **[:F]** Format identifier. C, D, E, F, G, N, P, R, or X. Lower case is available. Optional.

Example:

{0,5:E} First element, 5 characters, exponential notation.

{1:G} Second element, general.

{2,10} Third element, 10 characters, general.



The Format field is used to specify the data format of List (vector variable). The strings shown in the above example can be defined in the Format field.

In the strings, the list data index is mandatory. The character length and format identifier are omissible. Then the length is not limited, and the format G is set.

C or c: Circulation

D or d: Decimal numeral

E or e: Exponential notation

F or f: Fixed point

G or g: General

N or n: Numeric

P or p: Percent

R or r: Round trip

X or x: Hexadecimal numeral

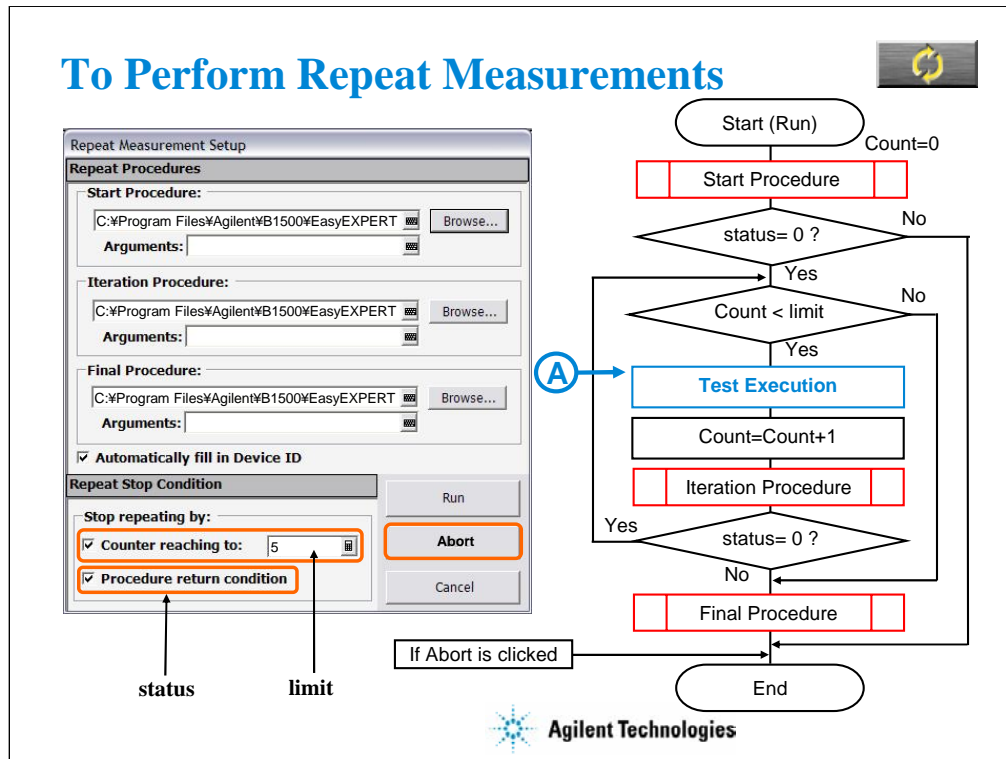
For the format, see online help or manual of the Agilent T&M Programmers Toolkit.

Exercise 12

Try to improve your test definition as you want.

- **To Use Built-in Functions**
- **To Use Read Out Functions**
- **To Control External GPIB Devices**
- **To Call Execution Files**





Repeat measurement is performed as shown in this flowchart. The status is a response returned by the start/iteration procedure. The Count is the accumulated number of test executions. They are the stop condition of the repeat measurement.

The repeat measurement stop function is enabled by the following check boxes.

- Counter reaching to
- Procedure return condition

If the first box is checked and the limit value is specified, the repeat measurement will be stopped if $Count \geq limit$. To perform the repeat measurement, set the limit value more than the number of devices under test or remove check from this box.

If the second box is checked, the repeat measurement will be stopped if status is not 0.

When the second box is checked, the device ID automatic setup function is available and is enabled/disabled by using the following check box. The function enters the device_id value to the Device ID of the test result record. The device_id is a response returned by the start/iteration/subsite procedure.

- Automatically fill in Device ID

The Repeat Measurement Setup dialog box provides the following action buttons.

- Run: Starts repeat measurement.
- Abort: Stops repeat measurement immediately.
- Cancel: Closes the Repeat Measurement Setup dialog box.

Start/Iteration/Final Procedure:

Enter the full path name of the procedure. For example, enter as follows.

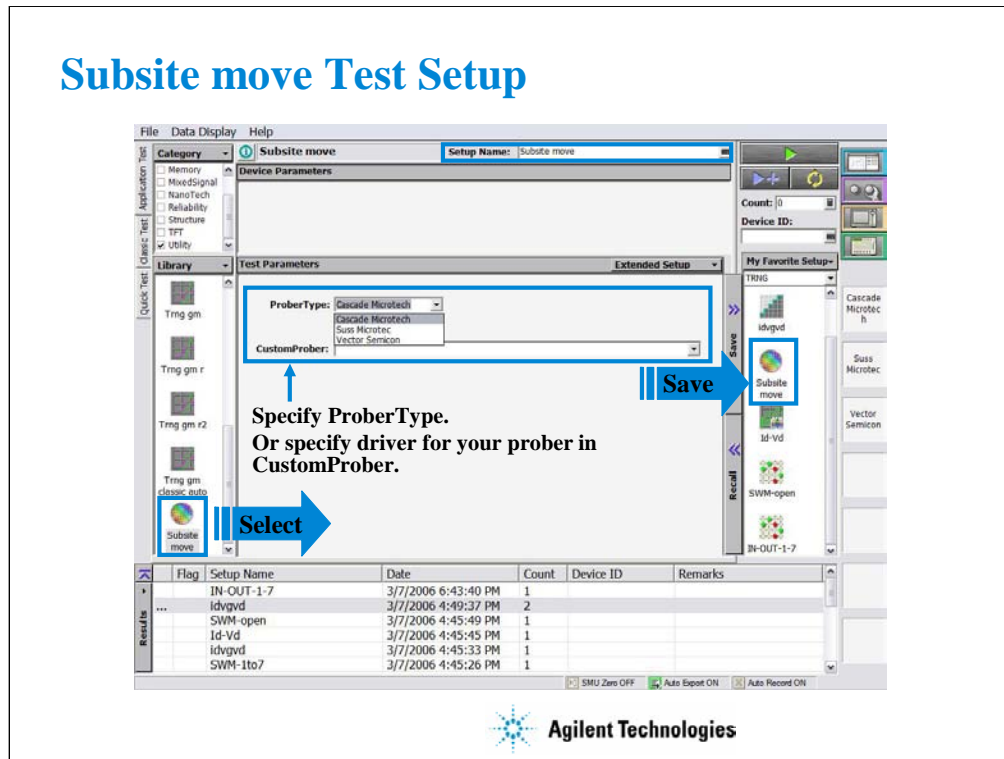
C:\Program Files\Agilent\B1500\EasyEXPERT\Utilities\ProberControl\%suss\Start_suss.exe

Arguments:

Enter the options of the procedure. See the following pages describing about procedures. For example, enter -a GPIB0::5::INSTR -I C:\temp\prb.log.

If you use the sub die move operation (subsite procedure), the flowchart must be changed. See page 11-18.

Subsite move Test Setup



If you do not use the sub die (subsite) move operation, skip this page.

Click Application Test tab and open the Subsite move test setup in the Utility category. On the Subsite move setup screen, specify ProberType (Cascade, Suss, or Vector) or driver for your prober in CustomerProber, and save it as a setup in your preset group (My Favorite Setup). Then you can use the setup for your quick test. See next page.

The Subsite move setup moves wafer chuck to the next subsite, reads device ID from the prober, and sets it to the Device ID of the test result record.

For more details of the test setup, open the Test Definition window.

In the Subsite move test definition, an execution file callProbeDvr.exe is used. This file is used to send Subsite_xxxx.exe to the prober specified by the prober_info.ini file and receive the response; status and device_id. The callProberDvr.exe has the following input/output parameters.

Input: Full path of Subsite_xxxx.exe

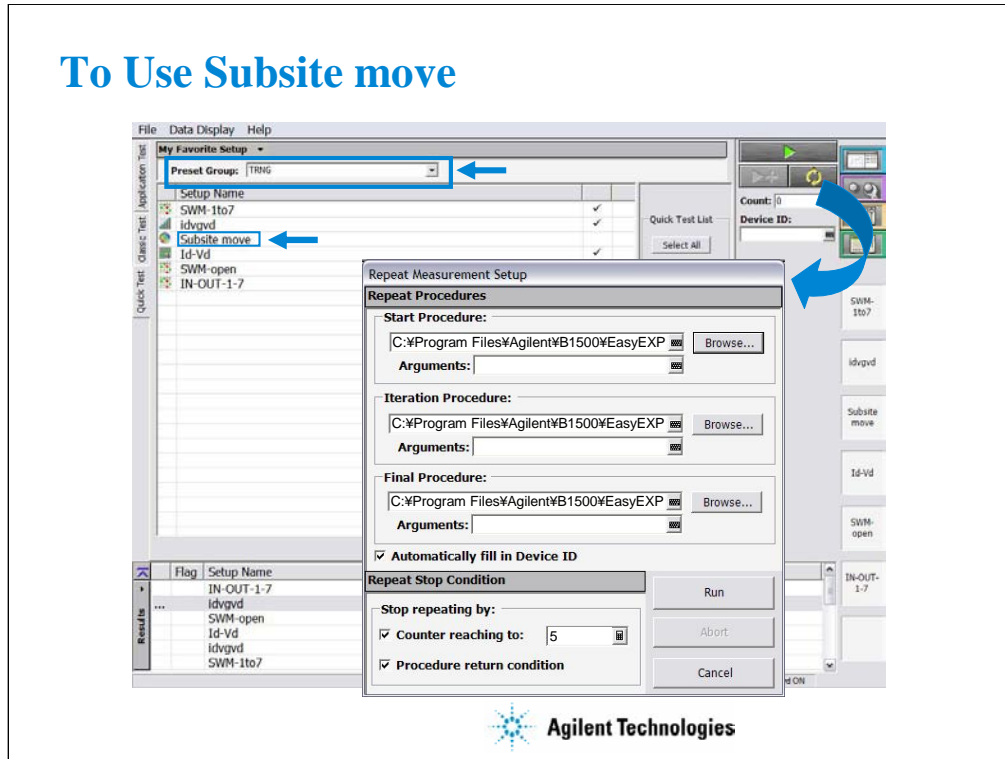
Output: status; 0 (no error) or 1 (error)

Output: device_id

Note:

The callProberDvr.exe refers to the prober_info.ini file for the GPIB address and log file name. Do not set the Arguments of Subsite_xxxx.exe.

To Use Subsite move



If you do not use the sub die (subsite) move operation, skip this page.

To perform the test with the sub die move operation, do as follows.

1. Add the Subsite move test setup to your preset group (My Favorite setup).
2. Set your preset group and test setups in the Quick Test tab screen.
3. Open the Repeat Measurement Setup dialog box.
4. Specify the procedures and the repeat measurement condition.
5. Start repeat measurement.

The Subsite move setup must be entered after measurements for a sub die.

Prober Control Script

- **Prober information file** **Use prober control script in EasyEXPERT Repeat Measurement Setup window**
 prober_info.ini
 - **Start Procedure**
 Start_xxxx.exe
 - **Iteration Procedure**
 Iterator_xxxx.exe
 - **Final Procedure**
 Final_xxxx.exe
 - **Subsite Procedure**
 Subsite_xxxx.exe
- xxxx:**
- **cascade**
 - **suss**
 - **vector**



Prober control script is sample program used for semi-automatic prober control. The Agilent EasyEXPERT can call the script by using the Repeat Measurement Setup window.

See page 11-9 to call the script and perform repeat measurement.

See page 11-14 for the prober information file.

See page 11-13 for the start procedure.

See page 11-15 for the iteration procedure.

See page 11-16 for the final procedure.

See page 11-17 for the subsite procedure.

To use the prober control script, specify the start/iteration/final procedure in the Repeat Measurement Setup dialog box (see page 11-9). And use the Subsite move test setup in your quick test to control sub die move. The Subsite move setup uses the subsite procedure for moving wafer chuck to the next subsite. See page 11-10 and 11-11.

Start_xxxx.exe

- Arguments:** -a GPIB_address
-l log_file_name

Example:
-a GPIB0::5::INSTR -l C:¥temp¥prb.log

- Response:** XML format data

```

<Response>
  <Break>status</Break>
  <Target>device_id</Target>
</Response>

```

status: 0 (no error) or 1
device_id: prefix:coordinate

Example:

```

<Response>
  <Break>0</Break>
  <Target>waf1a:3 1</Target>
</Response>

```

```

graph TD
    Start([Start]) --> A[Displays Device ID Entry dialog box]
    A --> B[Updates prober_info.ini file]
    B --> C[Displays Start Confirmation dialog box]
    C --> D[Moves to the first position]
    D --> E{Prober error?}
    E -- Yes --> C
    E -- No --> F[Gets X-Y coordinate]
    F --> G{Prober error?}
    G -- Yes --> C
    G -- No --> H[Chunks up]
    H --> I[Returns response]
    I --> End([End])

```

Agilent Technologies

To specify the start procedure in the Repeat Measurement Setup dialog box, enter the full path name of Start_xxxx.exe into the Start Procedure field.

After the repeat measurement is started, this procedure displays the Device ID Entry dialog box and waits for your input. On the dialog box, enter a string used for the prefix of device_id. After that, you will see the Start Confirmation dialog box that is used to confirm your wafer setup status. Load wafer and perform wafer alignment, then click OK on the dialog box. The procedure moves wafer chuck to the first probing position, checks the prober status, gets the X-Y coordinate of the probing position, and sets the wafer chuck to the UP position. At last, the procedure returns the response.

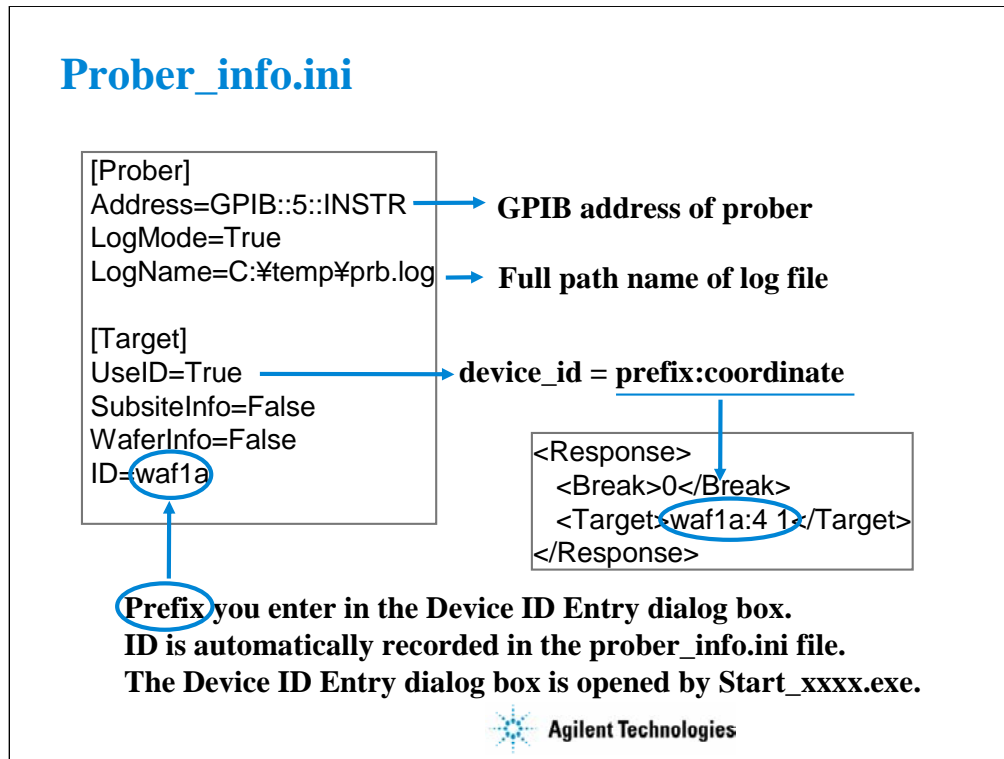
The status is 0 or 1. It is used for the EasyEXPERT repeat measurement stop function. When the Procedure return condition box is checked in the Repeat Measurement Setup dialog box, the repeat measurement will be stopped if status is not 0.

The device_id is a string for the Device ID of the test result record. When the Automatically fill in Device ID box is checked in the Repeat Measurement Setup dialog box, the device_id will be entered to the Device ID of the test result record.

If you use the subsite procedure, the flowchart must be changed. See page 11-18.

Note:

To ignore the Arguments, set the GPIB address and log file name in the prober_info.ini.



The prober information file is necessary to execute the prober control script. Before starting tests, open this file, edit it as you want, and overwrite it. The name must be prober_info.ini.

The prober_info.ini file stores the information shown below.

- Address: GPIB address of prober
- LogMode: Log file creation mode; True or False
- LogName: Log file name (full path)
- UseID: Device ID creation mode; True or False
- SubsiteInfo: Set always False. This is just a place holder.
- WaferInfo: Set always False. This is just a place holder.
- ID: Ignore this variable. This is just a pass parameter.

If the procedures specify the `-a` option, the Address value is not used.

If the procedures specify the `-l` option, the LogName value is not used.

To create a log file, set LogMode=True.

To use the prefix:coordinate format for the device_id value, set UseID=True. If UseID=False, the device_id value will be coordinate, not prefix:coordinate. The prefix will be the value entered in the Device ID Entry dialog box that is opened by Start_xxxx.exe. This function is available when the Automatically fill in Device ID check box is checked.

Iterator_xxxx.exe

- Arguments:** -a GPIB_address
-l log_file_name

Example:
-a GPIB0::5::INSTR -l C:\temp\prb.log

- Response:** XML format data

```

<Response>
  <Break>status</Break>
  <Target>device_id</Target>
</Response>
                
```

status: 0 (no error) or 1
device_id: prefix:coordinate

Example:

```

<Response>
  <Break>0</Break>
  <Target>waf1a:4 1</Target>
</Response>
                
```

```

graph TD
    Start([Start]) --> ChuckDown[Chuck down]
    ChuckDown --> Error1{Prober error?}
    Error1 -- Yes --> Return1[Returns response]
    Return1 --> End([End])
    Error1 -- No --> MoveNext[Moves to the next position]
    MoveNext --> Error2{Prober error?}
    Error2 -- Yes --> Return1
    Error2 -- No --> GetCoord[Gets X-Y coordinate]
    GetCoord --> Error3{Prober error?}
    Error3 -- Yes --> Return1
    Error3 -- No --> ChuckUp[Chuck up]
    ChuckUp --> Return1
    Return1 --> End
    
```

Agilent Technologies

To specify the iteration procedure in the Repeat Measurement Setup dialog box, enter the full path name of Iterator_xxxx.exe into the Iteration Procedure field.

The procedure is called after the measurement is completed for a die. This procedure sets wafer chuck to the DOWN position, moves it to the next probing position, checks the prober status, gets the X-Y coordinate of the probing position, and sets the wafer chuck to the UP position. At last, the procedure returns the response.

The status is 0 or 1. It is used for the EasyEXPERT repeat measurement stop function. When the Procedure return condition box is checked in the Repeat Measurement Setup dialog box, the repeat measurement will be stopped if status is not 0.

The device_id is a string for the Device ID of the test result record. When the Automatically fill in Device ID box is checked in the Repeat Measurement Setup dialog box, the device_id will be entered to the Device ID of the test result record.

If you use the subsite procedure, the flowchart must be changed. See page 11-18.

Note:

To ignore the Arguments, set the GPIB address and log file name in the prober_info.ini.

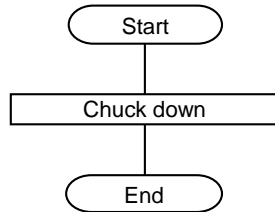
Final_xxxx.exe

- Arguments: -a GPIB_address
-l log_file_name

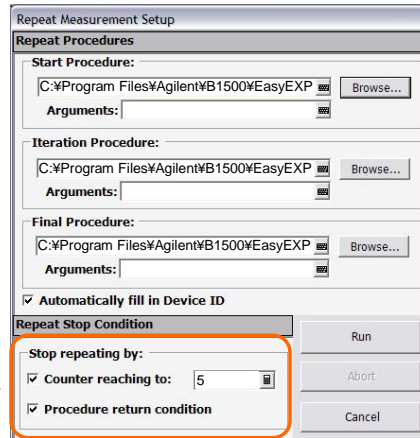
Example:

-a GPIB0::5::INSTR -l C:\temp\prb.log

- Response: none



Stop condition →



To specify the final procedure on the Repeat Measurement Setup dialog box, enter the full path name of Final_xxxx.exe into the Final Procedure field.

The procedure is called after one of the stop condition is detected. This procedure sets wafer chuck to the DOWN position.

Note:

To ignore the Arguments, set the GPIB address and log file name in the prober_info.ini.

Subsite_xxxx.exe

- Arguments:** `-a GPIB_address`
`-l log_file_name`

Example:
`-a GPIB0::5::INSTR -l C:\temp\prb.log`

- Response:** XML format data

```

<Response>
  <Break>status</Break>
  <Target>device_id</Target>
</Response>

```

status: 0 (no error) or 1
device_id: prefix:coordinate

Example:

```

<Response>
  <Break>0</Break>
  <Target>waf1a:3 1</Target>
</Response>

```

```

graph TD
    Start([Start]) --> ChuckDown[Chuck down]
    ChuckDown --> PE1{Prober error?}
    PE1 -- No --> MoveNext[Moves to the next subsite]
    PE1 -- Yes --> PE2{Prober error?}
    MoveNext --> PE2
    PE2 -- No --> GetCoord[Gets X-Y coordinate]
    PE2 -- Yes --> PE1
    GetCoord --> ChuckUp[Chuck up]
    ChuckUp --> RetResp[Returns response]
    RetResp --> End([End])

```

To realize sub die move operation, you need to define Subsite_xxxx.exe in your test definition and create your application test setup. However, you do not need to take care of this procedure by using the Subsite move test setup included in the application library. The Subsite move setup moves wafer chuck to the next subsite, reads device ID from the prober, and sets it to the Device ID of the test result record.

Open the Subsite move test setup and save it as a setup in your preset group (My Favorite Setup). Then you can use the setup for your quick test.

Note:

To use the Subsite move setup, set the GPIB address and log file name in the prober_info.ini. And ignore the Arguments for Subsite_xxxx.exe.

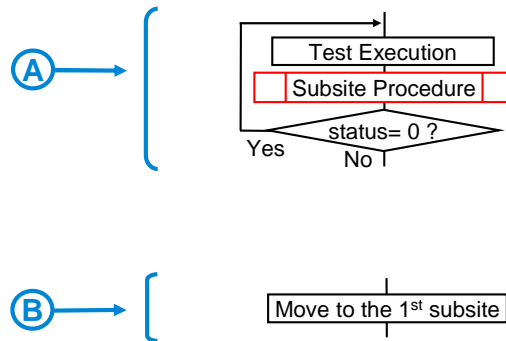
Note:

If you use a Suss prober, the number of Subsite move setups used in your quick test (die test) is important. It must be N-1; N is the number of subsites defined in the prober.

The status is 0 or 1. It is used for the EasyEXPERT repeat measurement stop function. When the Procedure return condition box is checked in the Repeat Measurement Setup dialog box, the repeat measurement will be stopped if status is not 0.

The device_id is a string for the Device ID of the test result record.

To Change Execution Flow



If you use the subsite procedure, change the flowchart as follows.
On the page 11-9, replace the box A with the block A shown above.
On the page 11-13 and 11-15, insert the box B shown above to the position B of the flowchart.

In This Module

- **Function Status Indicators**
- **Automatic Data Export and Data Record**
- **Data Record ON/OFF**
- **Calibration**
- **Configuration**
- **XSLT Filters**
- **To Enable System Controller**
- **To Start Desktop EasyEXPERT**
- **To Use 415x Setup File Converter**



This module describes the above topics. You will understand what is the status indicator, what is the automatic data export function and the automatic data record function, what is the Data Record ON/OFF, how to perform selftest and calibration, how to perform SMU zero offset cancel, and so on.

Function Status Indicators

	Count	Device ID	Remarks
4 PM	7		
57 AM	3		
PM	2		
PM	1		
AM	2		
AM	1		

Standby OFF
 SMU Zero OFF
 Auto Export OFF
 Auto Record ON

Automatic data record ON ⇒ OFF
 Auto Record OFF

Automatic data export OFF ⇒ ON
 Auto Export ON

SMU zero offset cancel OFF ⇒ ON
 SMU Zero ON

Standby function OFF ⇒ ON
 Standby ON

Status indicators let you know the status OFF or ON of the following functions. The indicators are placed at the bottom of the main screen.

Standby function OFF/ON: Shows the status of the Standby function OFF or ON.

SMU Zero OFF/ON: Shows the status of the SMU zero offset cancel function OFF or ON.

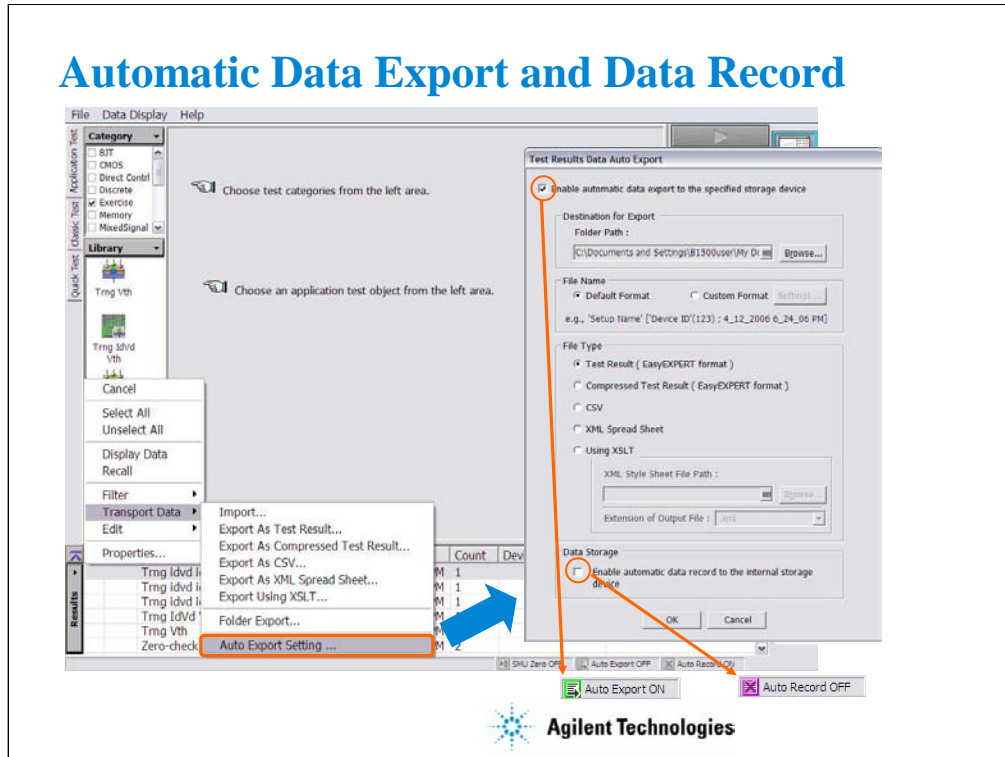
Auto EXPORT OFF/ON: Shows the status of the automatic data export function OFF or ON.

Auto Record ON/OFF: Shows the status of the automatic data record ON or OFF.

The functions can be set to ON or OFF as shown in the following pages.

For the Standby function, see Module 7.

Automatic Data Export and Data Record



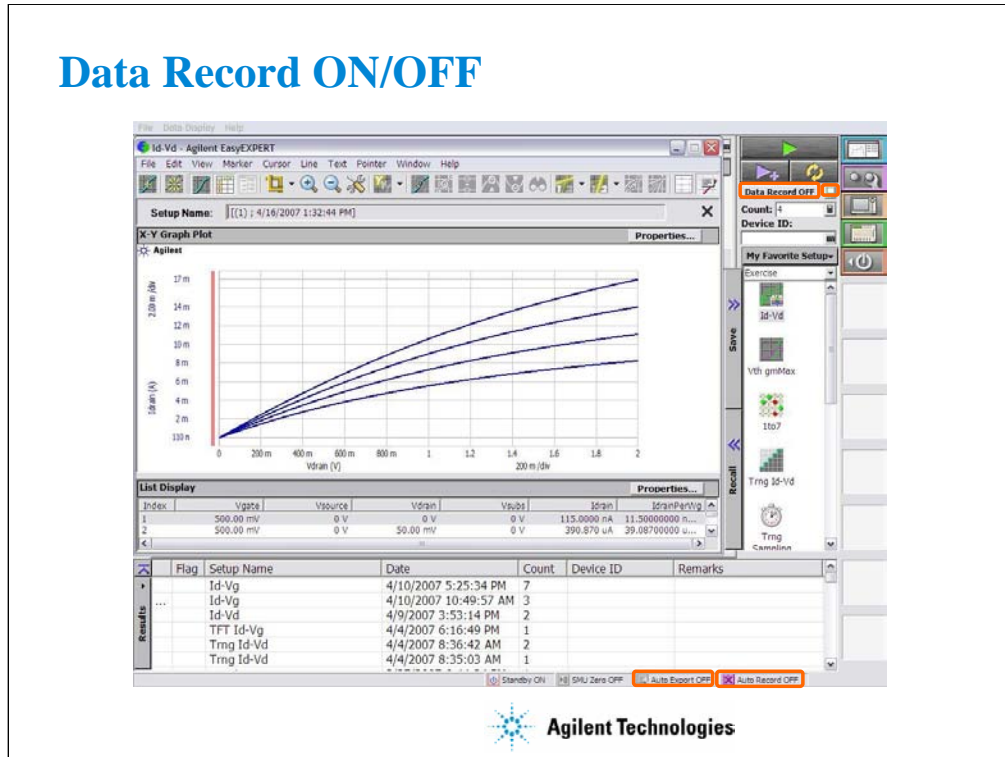
The automatic data export function and the automatic data record function can be enabled or disabled by using the Test Results Data Auto Export dialog box. This dialog box is displayed by selecting the Results > Transport Data > Auto Export Setting... menu.

The automatic data export function is used to export the test result data to the storage device you specify. You can specify the destination (storage device), exported file name, and file type. To set the automatic data export function to ON, check the Enable automatic data export to the specified storage device check box.

The automatic data record function is used to save the test result data to the internal HDD automatically. This function can be disabled (set to OFF) if the automatic data export function is enabled (set to ON). To set the automatic data record function to OFF, uncheck the Enable automatic data record to the internal storage device check box.

For more information, see online help or User's Guide.

Data Record ON/OFF

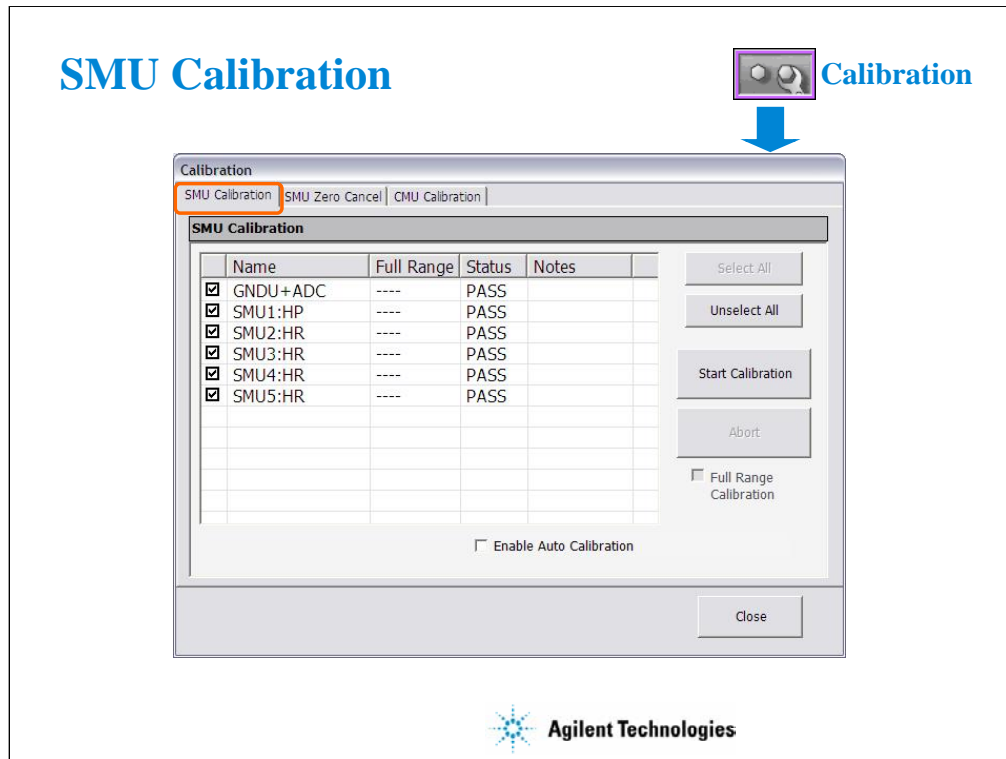


Data Record ON/OFF toggle button changes the status of the automatic data record function and the automatic data export function. It will also display the present data record status (Data Record ON or Data Record OFF).

The Data Record ON is the default measurement mode of the B1500A.

If the status is changed to Data Record OFF, both automatic data record function and automatic data export function are set to OFF. If a measurement is performed in this state, a button will appear to the right side of this toggle button. Clicking the button will save the last measurement data as a test result record. Data Record OFF is high speed measurement mode without automatic data record and automatic data export and is useful for probe contact check, defect analysis, and so on.

If the status is changed to Data Record ON, both automatic data record function and automatic data export function are returned to their previous state which is the state before the data record status was changed from Data Record ON to Data Record OFF.



The Calibration window is opened by clicking the Calibration button. The SMU calibration screen of this window is used to perform the calibration of SMUs. The list area of this screen lists Name, Full Range, and Status.

Name: Name of module. To select, check the left check box.

Full Range: For the high resolution SMU (HRSMU) connected to the atto sense/switch unit (ASU). Full range calibration on or off.

Status: Calibration status. Pass or fail.

Notes: Error information when calibration failed.

To perform the self-calibration, specify the modules, open the measurement terminals of the corresponding modules, and click the Start Calibration button.

Full Range Calibration:

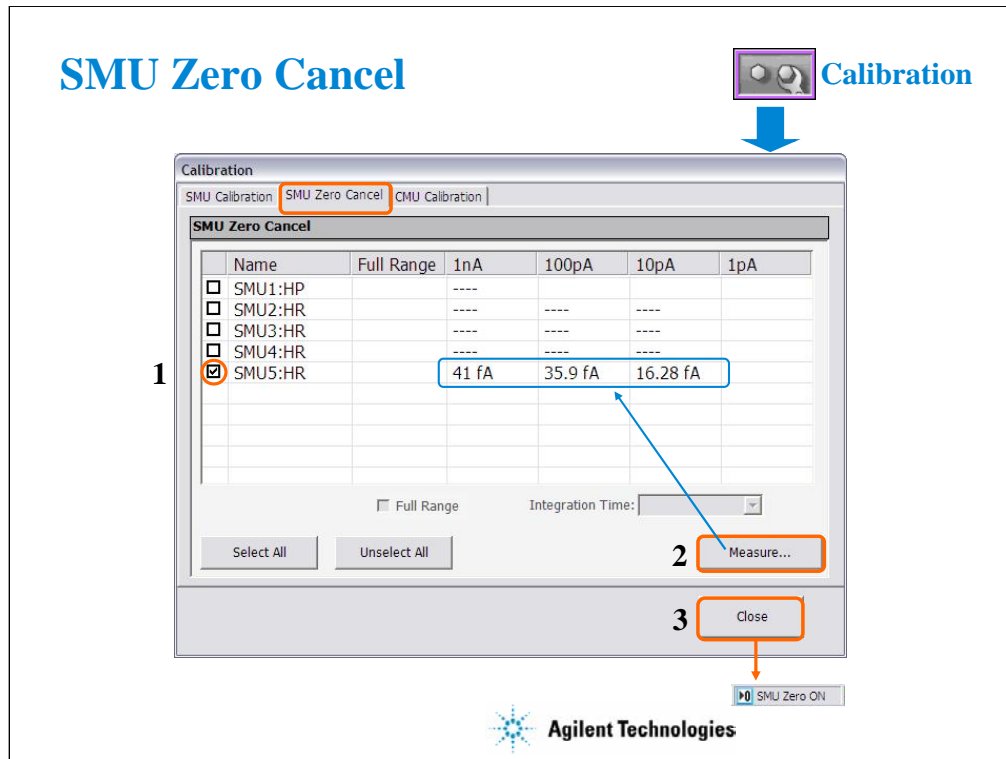
For the HRSMU connected to the ASU. Enables or disables the full range calibration. If this box has been unchecked, the B1500 does not use the 1 pA range.

Enable Auto Calibration:

Enables or disables the auto-calibration capability. If this box has been checked (function ON), and the B1500 automatically starts calibration for all modules every 30 minutes if the output switches of all modules are off for 30 minutes.

NOTE:

To perform calibration correctly, open the measurement terminals. If auto-calibration is enabled, do not forget to open the measurement terminals or disconnect the device under test from the terminals after measurement.



The SMU Zero Cancel screen is used to perform the SMU zero offset current measurement and set the SMU zero offset cancel function.

This function subtracts the offset current from the current measurement raw data, and returns the result as the measurement data. This function is used to compensate the error factor (offset current) caused by the measurement path such as the measurement cables, manipulators, or probe card.

To enable this function, perform the following procedure.

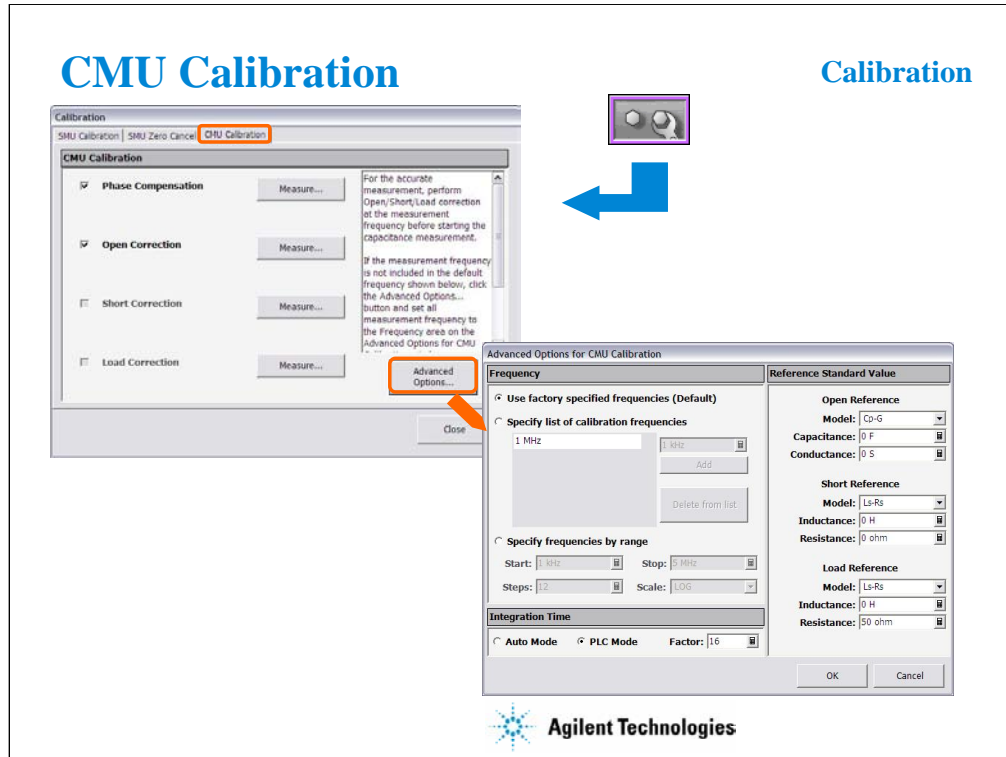
1. Check the left box of the Name column to specify the module to enable this function.
2. Click the Measure... button to perform the zero offset current measurement and wait until the measurement is completed. The measurement data will be displayed in the appropriate cell.
3. Click the Close button to enable the zero offset cancel function.

To disable the function, uncheck the left box of the Name column, and click the Close button.

Note:

The offset cancel is not available for measurement over 100 nA range. For 10 nA range measurement, the offset cancel is performed by using the 1 nA range offset value. For measurement by a range less than 10 nA, the offset value measured by each range is used.

For more information, see online help or User's Guide.



The CMU Calibration screen is used to perform the measurement data correction of the multi frequency capacitance measurement unit (MFCMU). For the easy way, perform the phase compensation and the open correction at least. The check boxes left of the Open/Short/Load Correction and the Phase Compensation are effective after the corresponding measurement is performed.

Measure...: Opens a dialog box used to perform correction/compensation data measurement. To perform the measurement, follow the dialog box.

Advanced Options...: Opens the “Advanced Options for CMU Calibration” dialog box used to set the frequencies for the correction data measurement and the reference values of the working standard. See the next page.

To perform the open correction and the phase compensation, open the measurement terminals.

To perform the short correction, connect the measurement terminals together.

To perform the load correction, connect your load standard between the high terminal and the low terminal.

NOTE:

For a more accurate measurement, perform Open/Short/Load correction at the measurement frequency before starting the capacitance measurement.

If the measurement frequency is not included in the list of default frequencies below, click the Advanced Options... button and set the measurement frequency on the Frequency area of the Advanced Options for CMU Calibration window.

Default frequencies:

1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, 5 MHz

Advanced Options for CMU Calibration



This dialog box is opened by clicking the Advanced Options... button, and is used to set the information required to measure the open/short/load correction data and the phase compensation data. This dialog box provides the following action button.

OK: Applies the setup changes and closes this dialog box.

Cancel: Cancel the setup changes and closes this dialog box.

Frequency: You can select the measurement frequency setup mode from the following modes.

Measurement frequency setup modes:

Default (Use factory specified frequencies): Usually, select this mode. 23 points are automatically set. They are 1 k, 2 k, 5 k, 10 k, 20 k, 50 k, 100 k, 200 k, 500 k, 1 M, 1.2 M, 1.5 M, 2 M, 2.5 M, 2.7 M, 3 M, 3.2 M, 3.5 M, 3.7 M, 4 M, 4.2 M, 4.5 M, and 5 MHz.

Specifies by list: Select this mode when you want to set the frequencies independently. The frequency must be 1 kHz to 5 MHz. The number of frequencies must be 1 to 101. Click Add to open a dialog box, and enter the value. For the unnecessary value, highlight the value and click Delete.

Specifies by range: Select this mode when you want to set the frequencies sequentially and automatically. Specify the start frequency, the stop frequency, the number of steps, and the scale LINEAR/LOG. The start frequency must be less than the Stop value and at least 1 kHz. The stop frequency must be more than the Start value and no more than 5 MHz. The number of steps must be 2 to 1001.

NOTE:

If the device measurement frequency is not equal to the correction data measurement frequency, calculation will be performed automatically to get the correction data for the device measurement frequency, and the calculated correction data will be used for the data correction of the measurement data.

Advanced Options for CMU Calibration

The screenshot shows a dialog box titled "Advanced Options for CMU Calibration". It is divided into two main sections: "Frequency" and "Reference Standard Value".

Frequency Section:

- Use factory specified frequencies (Default)
- Specify list of calibration frequencies
 - Input field: 1 MHz
 - Input field: 1 kHz
 - Buttons: Add, Delete from list
- Specify frequencies by range
 - Start: 1 kHz
 - Stop: 5 MHz
 - Steps: 12
 - Scale: LOG

Integration Time Section (highlighted with a red box):

- Auto Mode
- PLC Mode
- Factor: 16

Reference Standard Value Section:

- Open Reference:**
 - Model: Cp-G
 - Capacitance: 0 F
 - Conductance: 0 S
- Short Reference:**
 - Model: Ls-Rs
 - Inductance: 0 H
 - Resistance: 0 ohm
- Load Reference:**
 - Model: Ls-Rs
 - Inductance: 0 H
 - Resistance: 50 ohm

Buttons: OK, Cancel



Integration Time area defines the integration time used for measuring phase compensation data or open/short/load correction data. The number of averaging samples (Mode=AUTO) or the averaging time (Mode=PLC) is set.

Mode: A/D converter operation mode, AUTO or PLC.

Factor: Factor for the initial value. For details, see online help or user's guide.

Advanced Options for CMU Calibration

Advanced Options for CMU Calibration

Frequency

Use factory specified frequencies (Default)

Specify list of calibration frequencies

1 MHz 1 kHz Add

Delete from list

Specify frequencies by range

Start: 1 kHz Stop: 5 MHz

Steps: 12 Scale: LOG

Integration Time

Auto Mode PLC Mode Factor: 16

Reference Standard Value

Open Reference

Model: Cp-G

Capacitance: 0 F

Conductance: 0 S

Short Reference

Model: Ls-Rs

Inductance: 0 H

Resistance: 0 ohm

Load Reference

Model: Ls-Rs

Inductance: 0 H

Resistance: 50 ohm

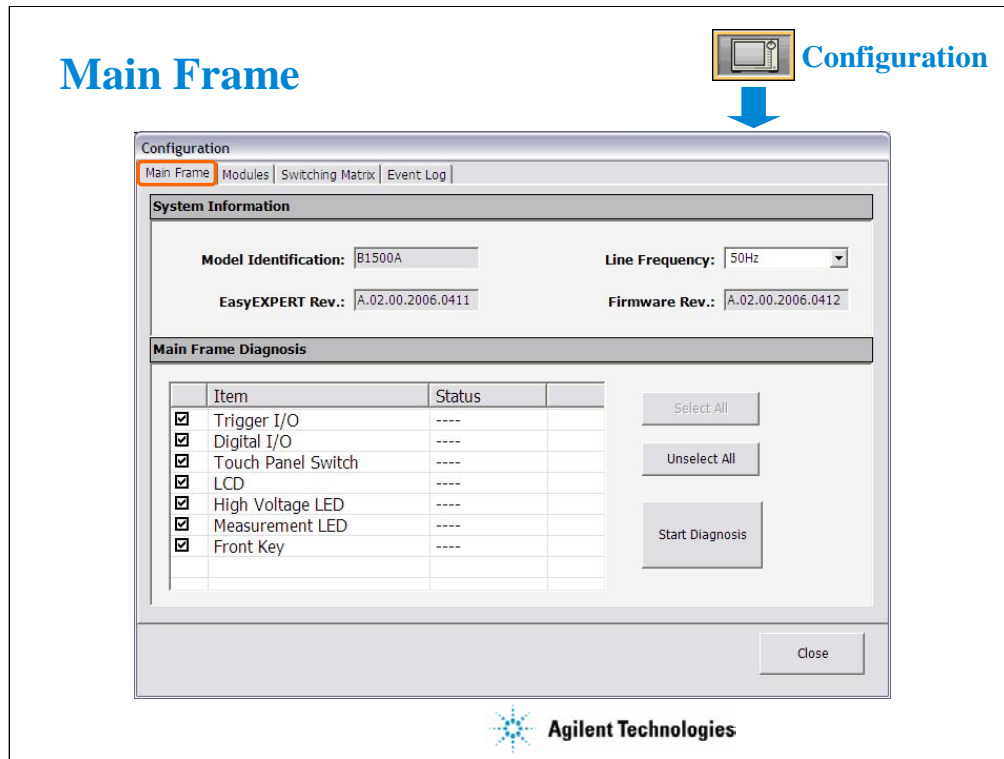
OK Cancel



Reference Standard Values area provides the following entry fields used to set the reference values of the open/short/load standard. If you use the standard, enter the reference values to the entry fields. OPEN Reference: Capacitance and Conductance. If you do not use the reference, enter 0 in the both fields.

SHORT Reference: Inductance and Resistance. If you do not use the reference, enter 0 in the both fields.

LOAD Reference: Inductance and Resistance



The Configuration window is opened by clicking the Configuration button, and is used to display the system information and event log, as well as to perform diagnostics and self-test.

The Main Frame screen is used to display the system information and perform diagnostics.

Model Identification: Displays the instrument ID. B1500A.

Line Frequency: Sets the power line frequency, 50 Hz or 60 Hz.

EasyEXPERT Rev.: Displays the revision number of the EasyEXPERT.

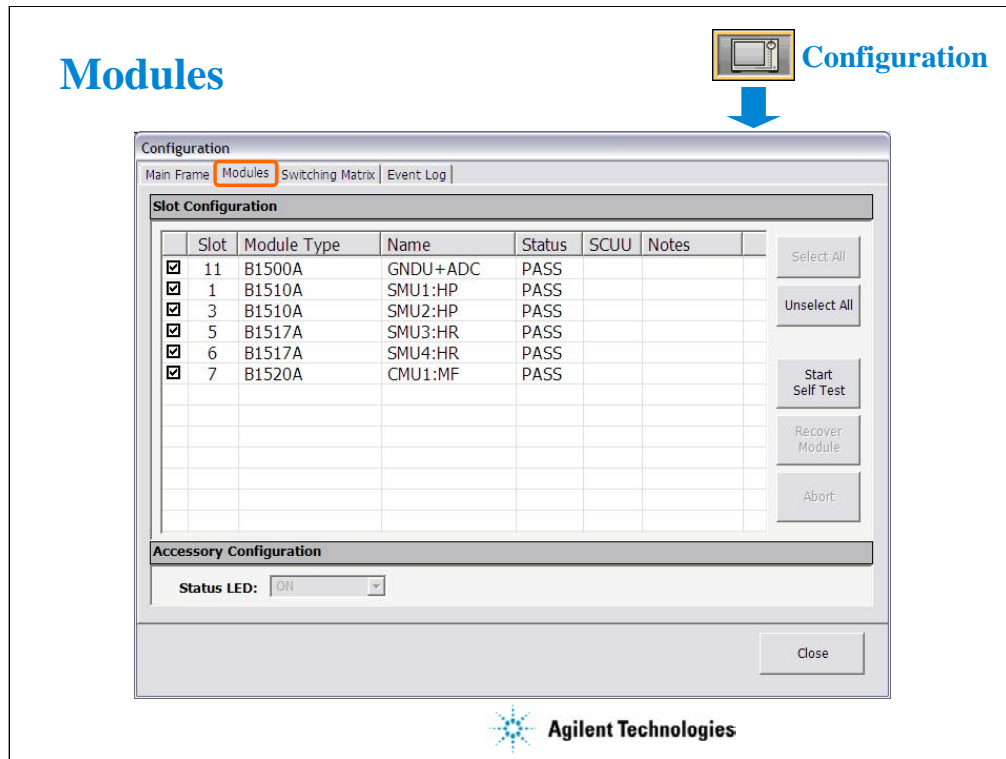
Firmware Rev.: Displays the revision number of the B1500 firmware.

Main Frame Diagnosis: This area lists Item and Status.

Item: Name of diagnostics item. To select, check the left check box.

Status: Diagnostics status. Pass or fail.

To perform diagnostics, specify the items to perform and click the Start Diagnosis button. A dialog box is opened. Follow the dialog box to perform the diagnostics. Some items need your judgement, pass or fail. Also you will need to connect an adapter, press keys, check LEDs, and so on.



The Modules screen is used to perform self-test of modules.

Slot: Slot number where the module is installed. To select, check the left check box.

Module Type: Module model number

Name: Module name

Status: Self-test status, Passed, Failed, Recovered, or ---- (self-test has not been performed)

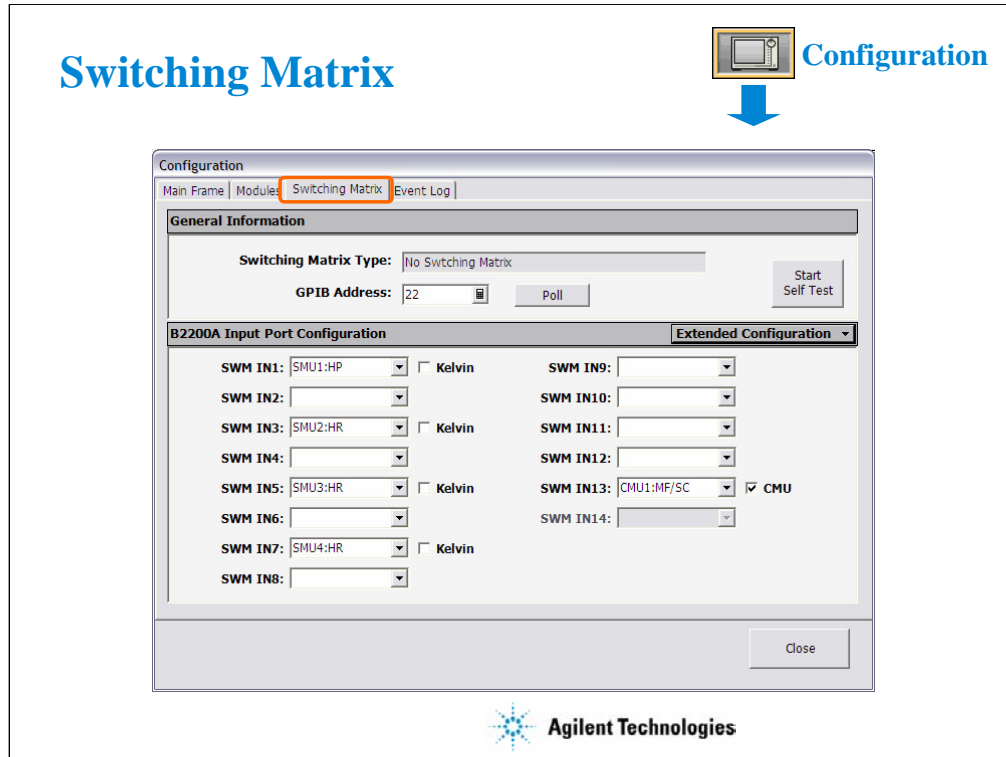
SCUU: Specifies if the module is connected to the SCUU.

Notes: Error information when the module self-test failed.

To perform self-test, specify the modules, open the measurement terminals of the corresponding modules, and click the Start Self Test button.

Recover Module button is for the service use only. This button makes the failed modules respond again. This button does not solve the problem that causes the Failed status.

Status LED: Enables (ON) or disables (OFF) the status indicator (LED) of the ASU (Atto Sense and Switch Unit) and the SCUU (SMU CMU Unify Unit).



The Switching Matrix screen is used to establish the GPIB connection with Agilent B2200A/B2201A switching matrix and define the B2200A/B2201A input port connections.

Switching Matrix Type: Displays the type of the switching matrix. B2200A Femto Leakage Switch Mainframe, B2201A 14ch Low Leakage Switch Mainframe, or No Switching Matrix.

GPIB Address: Specifies the GPIB address of the B2200A/B2201A. 1 to 30.

Poll: Confirms if the B2200A/B2201A with the specified GPIB Address is connected to the B1500A.

Start Self Test: This button starts the B2200A/B2201A selftest.

SWM IN: SWM IN1 to SWM IN14 mean the B2200A/B2201A input ports 1 to 14 respectively. Enter the label used to specify the input port to the right entry field. The port name and the connected module name can be the label. : (colon) cannot be used.

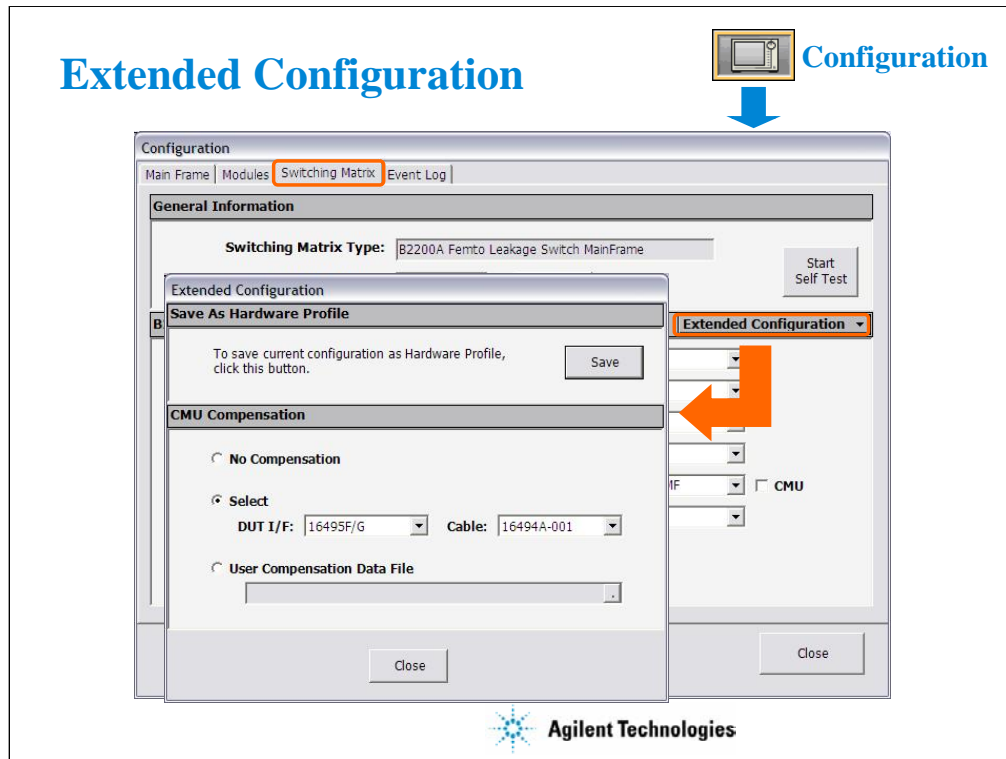
If the Kelvin check box is checked, the coupled even number port is grayed out.

If the CMU check box is checked, the SWM IN14 is grayed out.

Kelvin: Check this box if this port is used for the Kelvin connection.

CMU: To perform capacitance measurement, check this check box and set SWM IN13 to CMU1:MF. And connect MFCMU to B2200A/B2201A Input 13 and 14. To perform capacitance compensation, see User's Guide.

Extended Configuration: This button opens the Extended Configuration dialog box.



This dialog box is opened by clicking the Extended Configuration button in the Configuration window Switching Matrix screen.

Save as Hardware Profile is used to save the hardware profile that is the B2200A/B2201A hardware configuration and the measurement module connection. Click the Save button to save the present hardware profile. The hardware profile can be made for each workspace individually.

CMU Compensation is used to select the compensation mode of the capacitance measurement using the B2200A/B2201A. Click one of the radio buttons, No Compensation, Select, and User Compensation. For the capacitance compensation, see User's Guide.

- No Compensation:

Select this radio button if you do not need the capacitance compensation. The raw data without compensation is displayed and saved.

- Select:

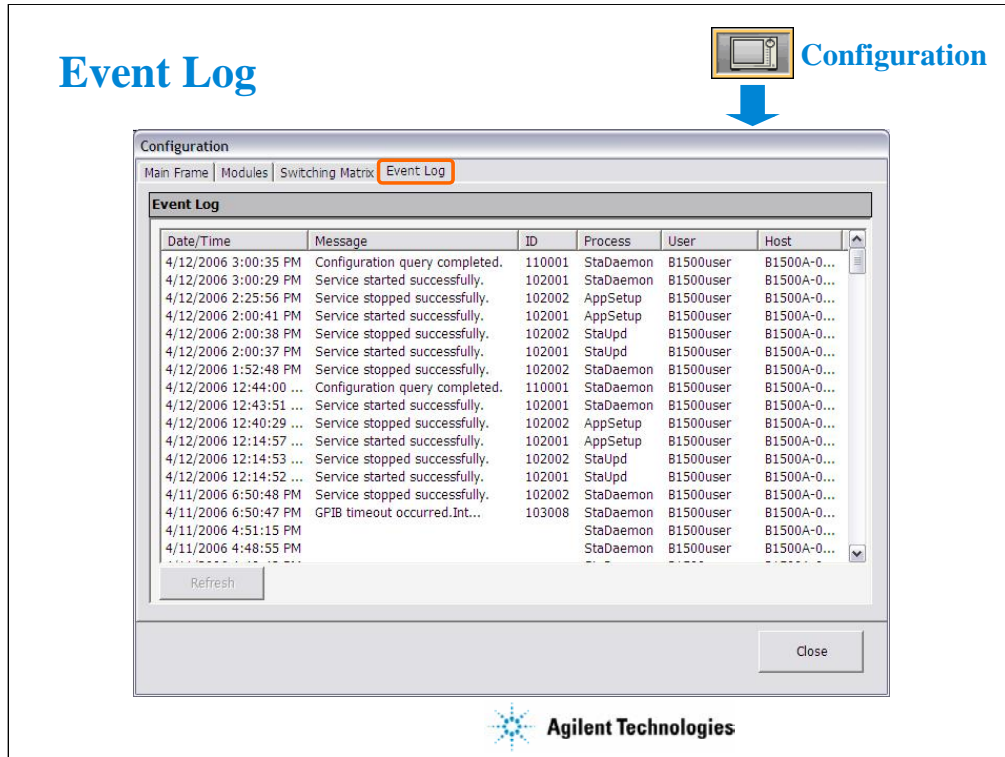
Select this radio button to perform the capacitance compensation for the path from the B2200A/B2201A input ports to Agilent 16495F/G connector plate or Agilent B2220A probe card interface. The data after compensation is displayed and saved.

DUT I/F field is used to specify the model number of the path you use. The selections are the 16495F/G and B2220A.

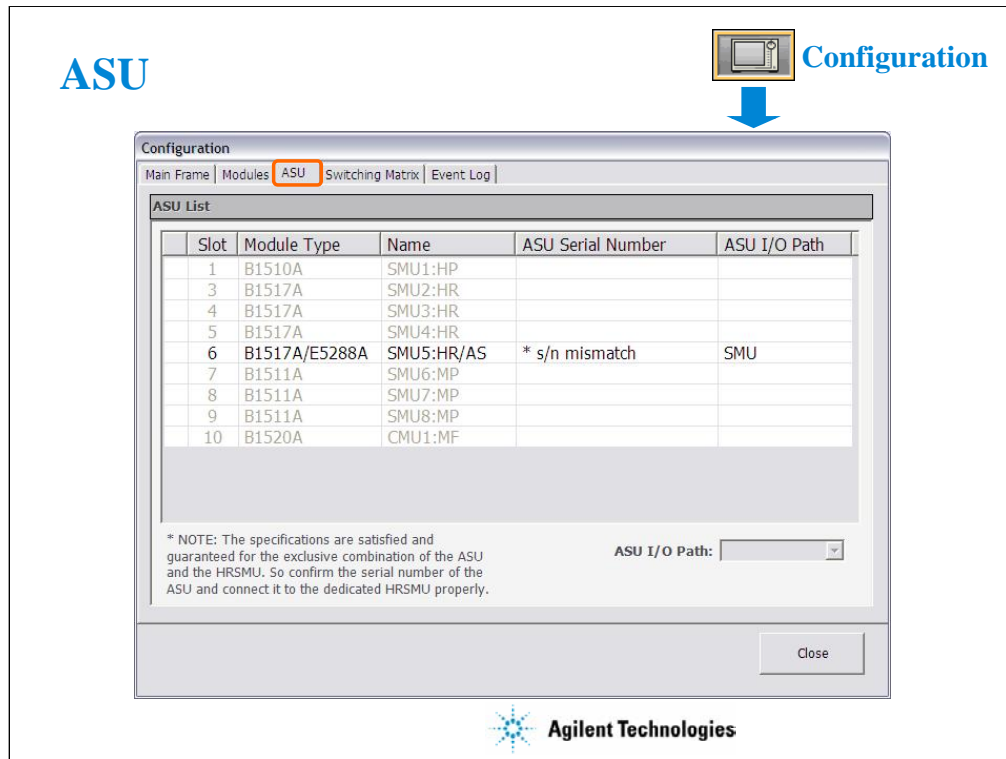
Cable field is used to specify the model number of the cable from the B2200A/B2201A output to the DUT I/F. The selections are the 16494A/B/C-001/002/005. This mode cannot perform the capacitance compensation for the cables to positioner/manipulator or the probe card.

- User Compensation Data File:

Select this radio button to perform the capacitance compensation for the path from the B2200A/B2201A input ports to the end of positioner/manipulator or probe card. See User's Guide. The data after compensation is displayed and saved.



The Event Log screen displays the event log.
Date/Time: Displays date and time of the event.
Message: Event message
ID: Process ID of the event
Process: Process name
User: User name. Windows login name.
Host: Host name of the B1500
 The Refresh button refreshes the event log.



The ASU screen is available if the B1500A installs the HRSMU connected to the ASU (Atto Sense/Switch Unit), and shows the ASU information.

Slot: Slot number

Module Type: Type of module

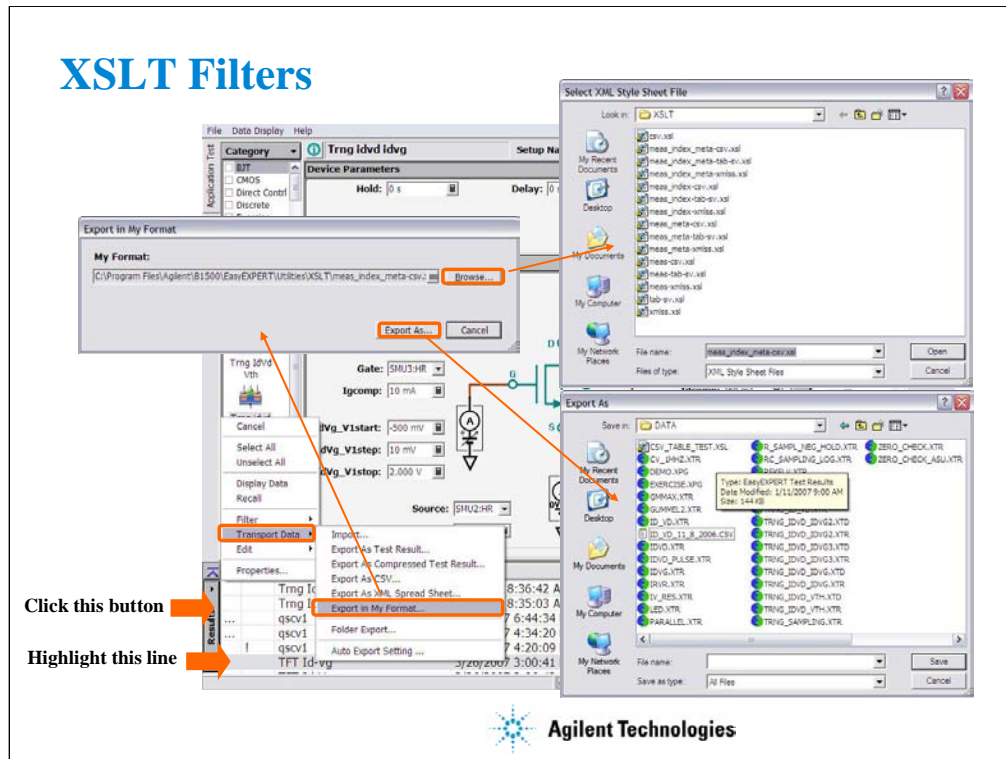
Name: Module name or SMU name

ASU Serial Number: Serial number of the ASU connected to the HRSMU. This cell does not show the serial number if no ASU is connected or unpaired ASU is connected.

ASU I/O Path: ASU input to output connection, SMU or AUX

If the ASU I/O Path field is set to SMU, the ASU makes the path from the ASU Force input to the ASU output.

If the ASU I/O Path field is set to AUX, the ASU performs automatic switching in every test. The ASU makes the path from the AUX In input to the ASU output for the test without the HRSMU and makes the path from the ASU Force input to the ASU output for the test with the HRSMU.



The XSLT (XSL-Transformation, eXtensible Stylesheet Language Transformation) filter files are used to export test records. The fifteen filter files listed below are stored in the C:\Program Files\Agilent\B1500\EasyExpert\Utilities\XSLT folder.

Filter files that contain *csv* in the file name export test record in the format that uses a comma (,) as data separator.

Filter files that contain *tab-sv* in the file name export test record in the format that uses a tab as data separator.

Filter files that contain *xmlss* in the file name export test record in the XML Spread Sheet format.

Three filter files for exporting the measurement data only
meas-csv.xml, meas-tab-sv.xml, meas-xmlss.xml

Three filter files for exporting the measurement data with the index
meas-index-csv.xml, meas-index-tab-sv.xml, meas-index-xmlss.xml

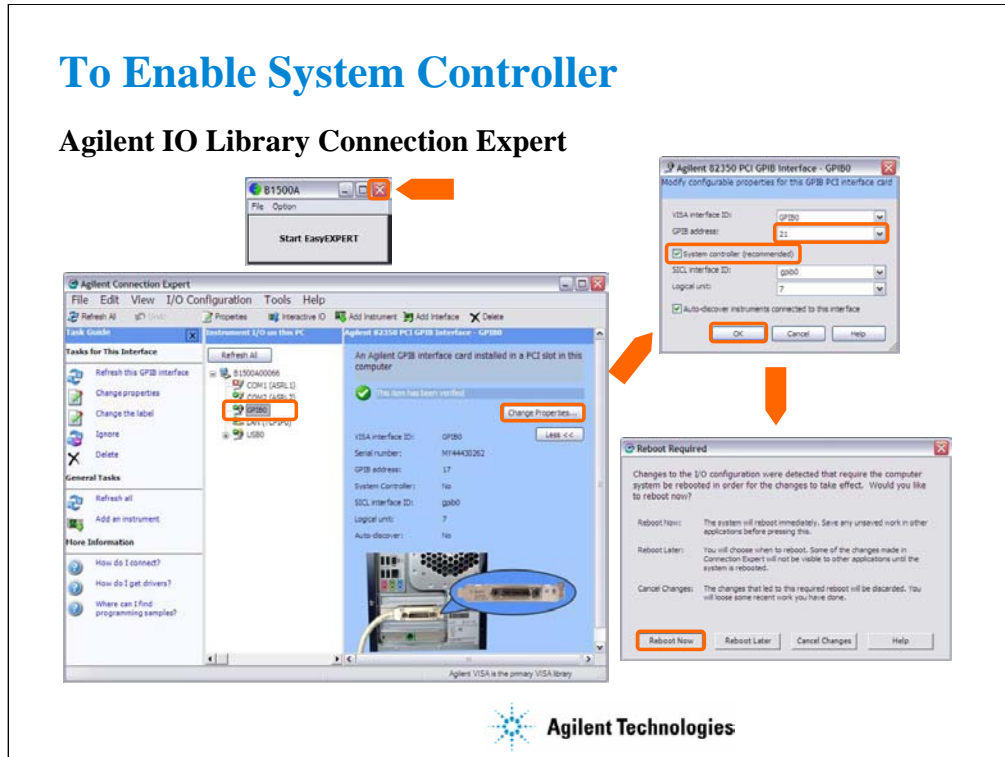
Three filter files for exporting the measurement data with the meta data
meas-meta-csv.xml, meas-meta-tab-sv.xml, meas-meta-xmlss.xml

The meta data contains the test name, the setup name, the record time of the test results, the device ID, the counter number, the flag of the test results, and the remarks on the test results.

Three filter files for exporting the measurement data with the index and the meta data
meas-index-meta-csv.xml, meas-index-meta-tab-sv.xml, meas-index-meta-xmlss.xml

Three filter files for exporting all data including the test setup
csv.xml, tab-sv.xml, xmlss.xml

For more information, see online help or User's Guide.



To control external GPIB devices, the B1500A must be set to system controller. Exit the EasyEXPERT, and close the Start EasyEXPERT window. After that, launch the Agilent Connection Expert by clicking Start, All Programs, Agilent IO Library Suite, and Agilent connection Expert.

On the Agilent Connection Expert, change the GPIB configuration of the B1500A.

- Select GPIB0.
- Click Change Properties... button.
- Change GPIB address to 21 that is the typical address number for the system controller.
- Check System controller box.
- Click OK button.
- Reboot the B1500A.

To Start Desktop EasyEXPERT

Important:
To set the same configuration as the B1500A, copy the following file from B1500A to your PC. The location must be the same.

¥Documents and Settings¥All Users¥Application Data¥Agilent Technologies, Inc¥EasyEXPERT¥UnitConfigB1500A.xml

Agilent Technologies

To open the Start EasyEXPERT window, click Start > Programs > Start EasyEXPERT menu. The Option menu provides the functions used to open the following dialog box.

Gpib Configuration:

Select Online if the B1500A is connected to your computer and you want to control the B1500A through GPIB. Or else select Offline.

Database Backup Creation Wizard:

Use this function to create the EasyEXPERT database backup (xdb file).

Database Restoration Wizard:

Use this function to restore the EasyEXPERT database backup. The wizard can restore the xdb file or the backup which is a copy of the folder that contains the EasyEXPERT database.

EasyEXPERT Database:

Specify the EasyEXPERT Database path if you want to move the database to the other folder.

After that, click the Start EasyEXPERT button to launch Desktop EasyEXPERT.

Note:

Desktop EasyEXPERT supports most B1500A/EasyEXPERT functions. However, some functions are not supported on an external computers due to differences in hardware and so on.

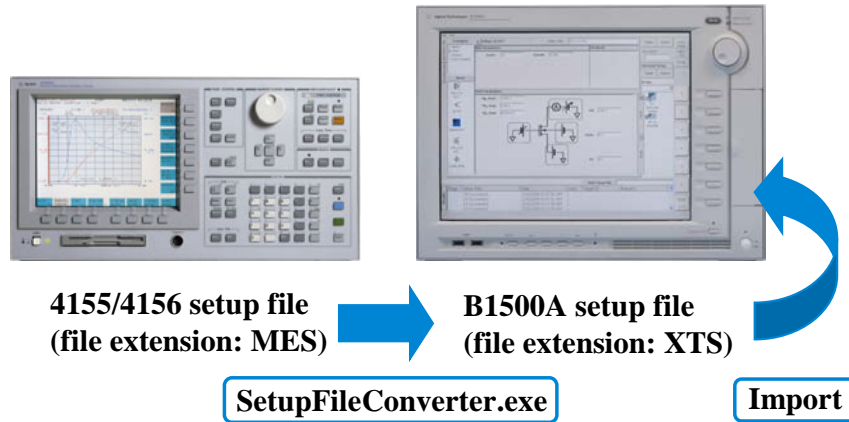
Note:

For the installation procedure, see the readme file stored in the Desktop EasyEXPERT CD-ROM.

Note:

To use the same module configuration as the B1500A, copy the UnitConfigB1500A.xml file to your PC which the Desktop EasyEXPERT runs. The file is stored in the B1500A hard disk drive. The location is shown in the slide. The file must be copied to the same location in your PC.

415x Setup File Converter



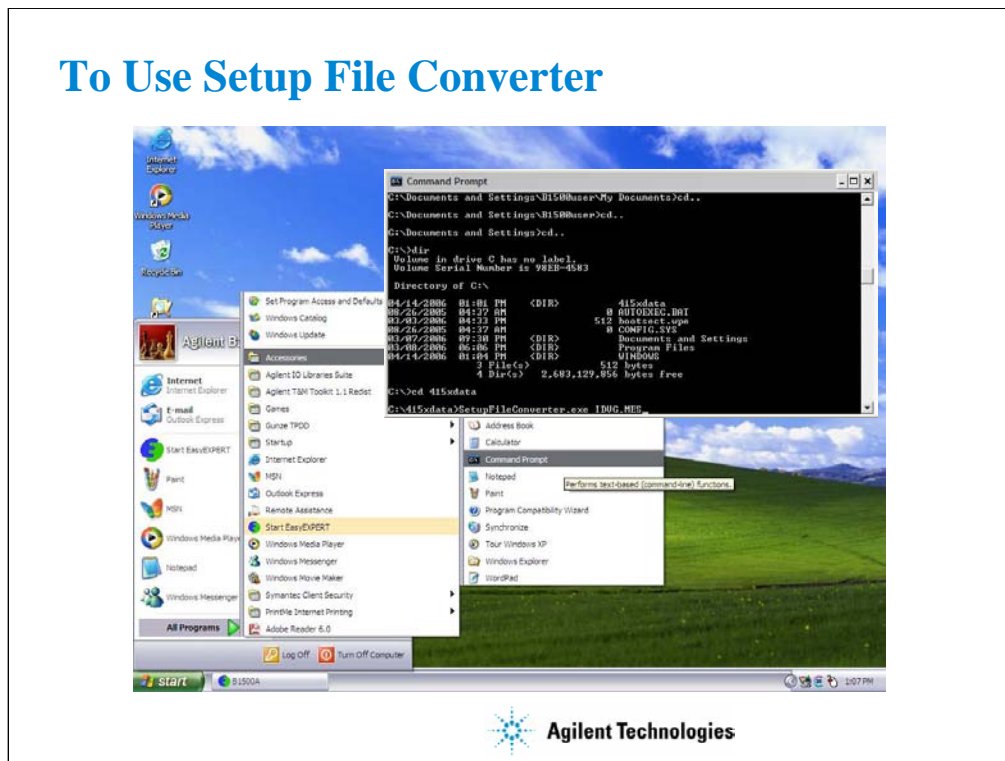
Execution example:

```
C:¥Mydata>SetupFileConverter.exe setup1.mes  
C:¥Mydata>SetupFileConverter.exe *.mes
```



To control the B1500A, you can reuse the 4155/4156 setup file (.MES file) by converting the .MES file to the EasyEXPERT setup file (.XTS file). The file conversion can be done by the SetupFileConverter.exe file. To execute the file conversion, see Module 12.

To Use Setup File Converter



To convert the 4155/4156 setup file (.MES file) to the EasyEXPERT setup file (.XTS file), use SetupFileConverter.exe, and perform the following procedure. The SetupFileConverter.exe file is stored in the following folder.

C:\Program Files\Agilent\B1500A\EasyEXPERT\Utilities

1. Create your working folder (for example, C:\415xdata).
2. Copy your .MES files to this folder.
3. Copy SetupFileConverter.exe file to this folder.
4. Launch the DOS Prompt window.
5. Go to your working folder (for example, C:\> cd 415xdata).
6. Execute SetupFileConverter.exe as shown below.

Example:

C:\415xdata> SetupFileConverter.exe *.MES

All .MES files in your working folder will be converted to the EasyEXPERT setup file format. And the .XTS files will be created in this folder.

If you do not specify the parameter, help message will be displayed by executing the file. For more information, see the setup converter readme file, online help, or User's Guide.