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Series 2600-PCT-xB Parametric Curve Tracer

User's Manual

PCT-900-01 Rev. B August 2022

PCT-900-01B

KEITHLEY
A Tektronix Company

Series 2600-PCT-xB

Parametric Curve Tracer

User's Manual

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Safety precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with nonhazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30 V RMS, 42.4 V peak, or 60 VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories. Maximum signal levels are defined in the specifications and operating information and shown on the instrument panels, test fixture panels, and switching cards.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as protective earth (safety ground) connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a screw is present, connect it to protective earth (safety ground) using the wire recommended in the user documentation.

The symbol on an instrument means caution, risk of hazard. The user must refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The symbol on an instrument means warning, risk of electric shock. Use standard safety precautions to avoid personal contact with these voltages.

The symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The symbol indicates a connection terminal to the equipment frame.

If this symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation explains hazards that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in the user documentation explains hazards that could damage the instrument. Such damage may invalidate the warranty.

The **CAUTION** heading with the symbol in the user documentation explains hazards that could result in moderate or minor injury or damage the instrument. Always read the associated information very carefully before performing the indicated procedure. Damage to the instrument may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits — including the power transformer, test leads, and input jacks — must be purchased from Keithley. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. The detachable mains power cord provided with the instrument may only be replaced with a similarly rated power cord. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keithley to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call a Keithley office for information.

Unless otherwise noted in product-specific literature, Keithley instruments are designed to operate indoors only, in the following environment: Altitude at or below 2,000 m (6,562 ft); temperature 0 °C to 50 °C (32 °F to 122 °F); and pollution degree 1 or 2.

To clean an instrument, use a cloth dampened with deionized water or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., a data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Safety precaution revision as of June 2018.

Table of contents

Introduction 1-1

Welcome 1-1

Introduction to this manual 1-1

Available configurations 1-2

Extended warranty 1-2

Contact information 1-2

Instruments and connections 2-1

Introduction 2-1

Unpacking the PCT 2-1

About the Model 8010 High Power Device Test Fixture 2-2

About the Model 8020 High Power Interface Panel 2-3

Connections to protective earth (safety ground) 2-3

Interlock connections 2-4

Connect instruments to the Model 8010 2-5

Connect instruments to the Model 8020 2-6

Getting started with ACS Basic 3-1

Introduction 3-1

Installing and configuring the GPIB interface 3-1

TSP-Link system setup 3-2

Assign TSP-Link node numbers 3-2

Connect the instrument for communications 3-3

Software installation 3-4

Verify hardware configuration 3-5

Start ACS Basic 3-9

ACS Basic test modes 3-10

I-V applications for power MOSFETs 4-1

Section overview and equipment requirements 4-1

On-state characteristics 4-1

Configure the test fixture 4-1

Collecting I-V curves in TraceMode 4-4

Configure a fixed plot 4-11

Collecting I-V curves in MultiMode 4-13

Digitizing pulses and improving timing 4-26

Off-state characteristics 4-34

Configure the test fixture 4-34

Measuring leakage current in MultiMode 4-37

C-V applications on power MOSFETs 5-1

Overview and requirements 5-1

Background of MOSFET capacitance measurements 5-1

Safety precautions and discharge procedures 5-4

Discharging bias tee capacitance in the Model 8010 5-4

Discharging bias tee capacitance within the Model 8020 5-8

Discharge system capacitance from SMU front panel interface 5-10

Model 8010 connections 5-10

Model 8010 Crss test connections 5-10

Model 8010 Ciss test connections 5-12

Model 8010 Coss test connections 5-13

Model 8010 connections to the device for Crss 5-14

Model 8010 connections to the device for Ciss and Coss 5-15

Model 8020 connections 5-15

Model 8020 Crss test connections 5-16

Model 8020 Ciss test connections 5-17

Model 8020 Coss connections 5-18

Model 8020 test connections to the device 5-19

Perform connection compensations on C-V measurements 5-20

Ciss compensation 5-20

Coss compensation 5-27

Crss compensation 5-32

Make a Ciss measurement 5-38

Make a Coss measurement 5-46

Make a Crss measurement 5-57

Optimizing Crss measurement connections for difficult measurements 5-64

Troubleshooting FAQs 6-1

Missing cables 6-1

2600-PCT-1B and C-V measurements 6-1

2600-PCT-2B and C-V measurements 6-1

Custom tests in ACS Basic 6-2

Section 1

Introduction

In this section:

Welcome 1-1
Introduction to this manual 1-1
Available configurations 1-2
Extended warranty 1-2
Contact information 1-2

Welcome

The Keithley Instrument Parametric Curve Tracer provides configurations that are complete solutions configured with a variety of high quality instruments, cables, and test fixtures. This building block approach offers the advantages of easy upgrade or modifications to meet changing test needs. For example, a low cost 200 V at 10 A system can be purchased initially, and 50 A or 100 A capability can be added later. Additionally, you can use these instruments and accessories with different test system platforms, such as for reliability or device qualification testing.

Parametric Curve Trace configurations include everything you need to quickly develop a complete test system.

The ACS Basic Edition software provides complete device characterization, including both real-time trace mode for quickly checking fundamental device parameters like breakdown voltage and full parametric mode for extracting precise device parameters. ACS Basic Edition goes beyond traditional curve tracer interfaces by offering a broad array of sample device libraries. You have complete control of all test resources, allowing you to create more advanced tests than previously possible on a curve tracer.

Introduction to this manual

This manual describes how to set up and use the Parametric Curve Tracer and ACS Basic software, including:

- Assembling the PCT
- Getting started with ACS Basic
- Performing tests with the software, using both TraceMode and Parametric Test mode

This manual provides detailed applications to help you achieve success with your Keithley Instruments PCT.

Each application is presented with an overview of the application, followed by instructions to complete the application.

NOTE

For more detailed information on specific system components, refer to the documentation. For instruments, the documentation is available at tek.com/keithley. For ACS Basic, documentation is available from the Help menu.

Available configurations

Model		Collector / Drain Supply		Step Generator Base / Gate Supply	Auxiliary Supply
		High Voltage Mode	High Current Mode		
Low power	2600-PCT-1B	200 V / 10 A	200 V / 10 A	200 V / 10 A	N/A
High current	2600-PCT-2B	200 V / 10 A	40 V / 50 A	200 V / 10 A	200 V / 10 A
High voltage	2600-PCT-3B	3 kV / 120 mA	200 V / 10 A	200 V / 10 A	200 V / 10 A
High current and high voltage	2600-PCT-4B	3 kV / 120 mA	40 V / 50 A	200 V / 10 A	200 V / 10 A

The Keithley Instruments Model 2651A may be added to increase the high current mode to either 50 A or 100 A. Other available accessories include the PCT-CVU Multi-Frequency Capacitance-Voltage (C-V) Meter, the Model 8010 High Power Device Test Fixture, the Model 8020 High Power Interface Panel, and the CVU-200-KIT and CVU-3K-KIT bias tee kits.

Extended warranty

Additional years of warranty coverage are available on many products. These valuable contracts protect you from unbudgeted service expenses and provide additional years of protection at a fraction of the price of a repair. Extended warranties are available on new and existing products. Contact your local Keithley Instruments office, sales partner, or distributor for details.

Contact information

If you have any questions after you review the information in this documentation, please contact your local Keithley Instruments office, sales partner, or distributor. You can also call the Tektronix corporate headquarters (toll-free inside the U.S. and Canada only) at 1-800-833-9200. For worldwide contact numbers, visit tek.com/en/contact-tek.

Section 2

Instruments and connections

In this section:

Introduction 2-1
Unpacking the PCT 2-1
About the Model 8010 High Power Device Test Fixture 2-2
About the Model 8020 High Power Interface Panel 2-3
Connections to protective earth (safety ground) 2-3
Interlock connections 2-4
Connect instruments to the Model 8010 2-5
Connect instruments to the Model 8020 2-6

Introduction

You must connect the instruments to either the Model 8010 High Power Device Test Fixture or the Model 8020 High Power Interface Panel and then set up the TSP-Link network. The cables supplied with your PCT can be used with either fixture. This describes how to make these connections.

If you choose to install the instruments in a rack, install the instruments in the rack before connecting the instruments to the test fixture or interface panel. Please refer to the instructions in the rack mount kits for more information.

Unpacking the PCT

The PCT shipping container contains a box labeled “Open Me First” that contains all the instrument accessories and user documentation. In this box, the accessories for each instrument in your configuration are enclosed in individual boxes and bags. Each box includes a document describing the contents of the box.

On the same shipping pallet are each SMU of your PCT configuration and any other larger PCT accessories, such as a Model 8010 High Power Device Test Fixture, a Model 8020 High Power Interface Panel, the PCT-CVU instrument option, or the optional 200 V or 3 KV bias tee kits.

The PCT is generally connected to either a Model 8010 or a Model 8020. The following section provides overview for these devices.

About the Model 8010 High Power Device Test Fixture

The Model 8010 High-Power Device Test Fixture provides a safe, low noise, complete environment for testing a variety of packaged device types. The replaceable socket module test boards allow for a variety of package types, including the user-supplied socket types.

The Model 8010 allows you to connect one Model 2657A High Power SourceMeter for up to 3 KV testing. You can use one or two Model 2651A High Power SourceMeters for 15 A dc testing or 50 A or 100 A pulse testing. For lower power terminals, you can connect up to two other SourceMeters, such as Models 2611B, 2612B, 2635B, 2636B, 4200-SMU, or 4210-SMU.

The Model 8010 includes:

- Kelvin (remote sense) connections for five instruments
- Guarded pathways for picoampere level measurements even at 3 kV
- An access port for a variety of probes, such as scope or temperature
- Integrated protection circuits to protect Models 2611B, 2612B, 2635B, 2636B, 4200-SMU, and 4210-SMU from high voltage instruments
- Two independent test sockets, one for high current and one for high voltage

The test fixture is fully interlocked, providing safe operation for up to six different instruments. It is declared safe through CE marking and certified through nationally recognized testing laboratories.

The Model 8010 is shipped with two 8010-DTB high power socket module test boards installed. The boards include sockets for TO-247 and axial lead devices.

The high current side of the test fixture can be used with up to 100 amps pulsed, 15 amps dc, 200 V dc. Up to four measurement resources can be connected (two high current, two low power).

The high voltage side of the test fixture can be used with up to 3030 V dc at 120 mA, 200 V dc up to 10 A pulsed. Connections are provided for up to three measurement resources (one high voltage, two low power).

For information on the Model 8010, including fixture setup within a test system, see the *Model 8010 High Power Device Test Fixture User's Manual*, available at tek.com/keithley.

About the Model 8020 High Power Interface Panel

The Model 8020 has six measurement pathways accommodating 3 kV, 200 V, and 100 A measurements. You can configure five of the pathways with a variety of output connector types to match your probe station. You can configure four pathways with the optional bias tees. This provides high voltage C-V measurements on up to 4 pins of the device under test.

The Model 8020 comes with a selection of resistors that you can install to provide stability and extra protection to the device.

Additionally, the Model 8020 offers the following:

- A common LO reference
- Overvoltage protection for all 200 V channels, ideal for device testing configurations using 200 V SMUs and higher voltage SMUs
- A variety of connector types
- A single interlock interface for multiple instruments
- An interface for adding series resistor elements for measurement stability and absolute current limit
- Optional transient overcurrent protection on the 200 V channels
- Expansion ports to easily link multiple 8020 interface panels

The Model 8020 can be configured to suit your probe station and test system. Contact your Keithley Instruments applications engineer or see the *Model 8020 High Power Interface Panel User's Manual*, available at tek.com/keithley.

Connections to protective earth (safety ground)

WARNING

The ground wires must be attached to a known protective earth (safety ground) before powering on instruments. Failure to attach the ground wires to a known protective earth may result in electric shock.

Connections to protective earth (safety ground) are made at terminals labeled with the following symbol.

Figure 1: Protective earth (safety ground) symbol

For detailed Model 8010 and Model 8020 instrument connection diagrams, including safety ground details, see Connect instruments to the Model 8010 (on page 2-5) or Connect instruments to the Model 8020 (on page 2-6).

Interlock connections

NOTE

For proper interlock functionality, any instruments connected to the interlock must be powered on or disconnected from the interlock.

Each Parametric Curve Tracer configuration contains instruments that can output hazardous live voltages. To ensure operator safety, it is important to use the instrument interlock properly with the Model 8010 and Model 8020 test fixtures. Both the Model 8010 and Model 8020 include interlock connectors to interface with Series 2600B, Series 2650A, and 4200A-SCS instruments. Refer to the instrument connection diagrams later in this section for illustrations on how to connect to the individual SMU instruments.

With the Model 8010, the interlock switch is engaged when the lid is closed and latched. When the interlock switch is engaged, a light on the enclosure is illuminated. You can turn on a SMU output only when the interlock switch is engaged. If the lid is open, the interlock switch will not engage and any SMUs with outputs that are configured for high voltage will not turn on.

For the Model 8020, the Interlock OUT connector on its device connections panel side of the panel is designed for use with the supplied 8020-ILC-UNT interlock to unterminated cable. The interlock enables the high-voltage outputs of the connected instruments when the normally-open switch at the device under test (DUT) access point is closed.

The Model 8020 interlock is satisfied only when:

- The top cover to the 8020 is correctly installed and any top covers to other Model 8020s in the test configuration are also correctly installed
- The system interlock is engaged (all normally-open switches are closed at DUT access points of the test configuration)

When the 8020 interlock is satisfied, lights on the instrument connection and device connection panels of the 8020 are illuminated.

For detailed information on the interlock requirements for the Model 8010 or Model 8020, see the user's manual for that test fixture. For detailed information on the interlock requirements for a specific SMU, see the reference manual for that SMU.

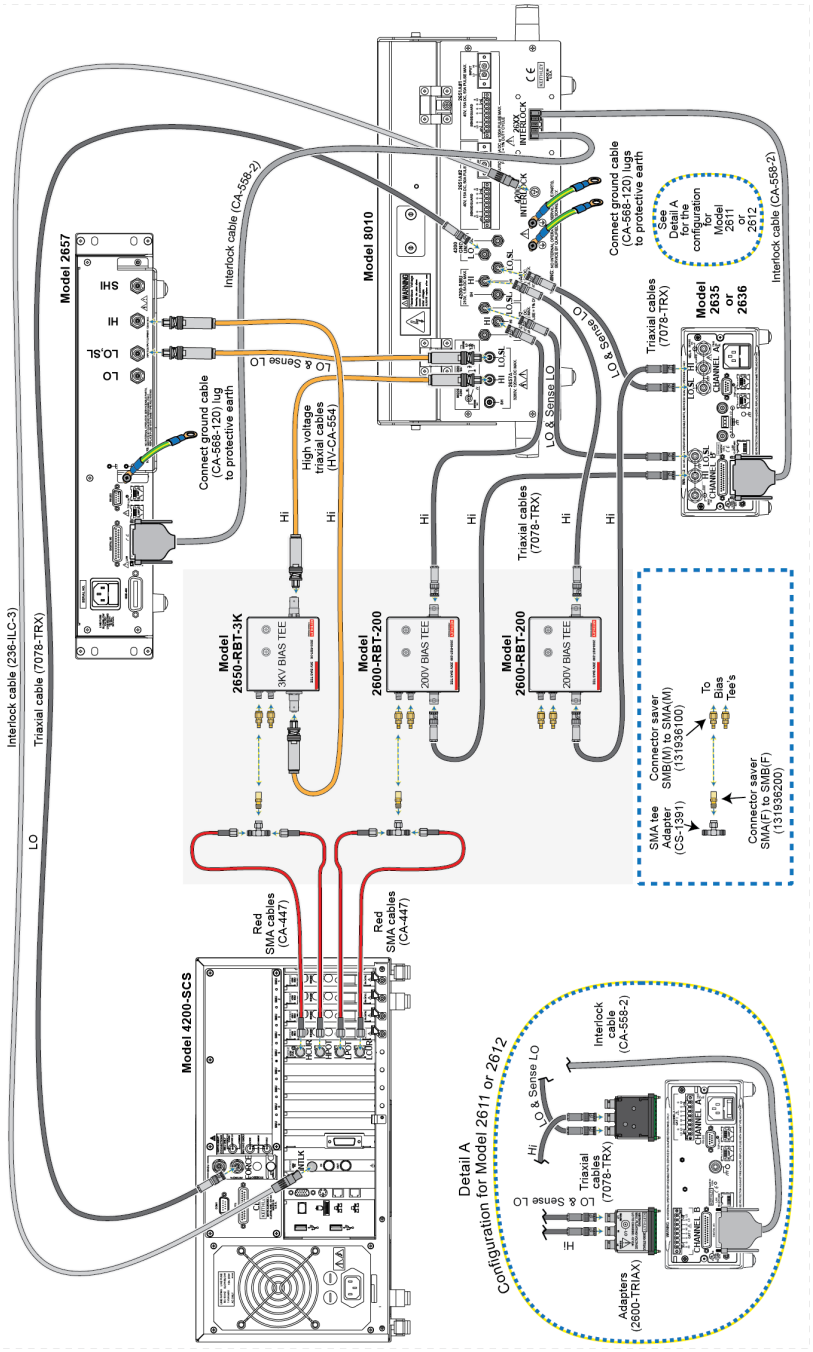
NOTE

There is no safety interlock on the Model 2651A because its output voltage is below hazardous levels. To activate Output Enable on the 2651A, refer to the *Model 2651A Reference Manual*. Output Enable can be activated using the front panel or by remote control.

Connect instruments to the Model 8010

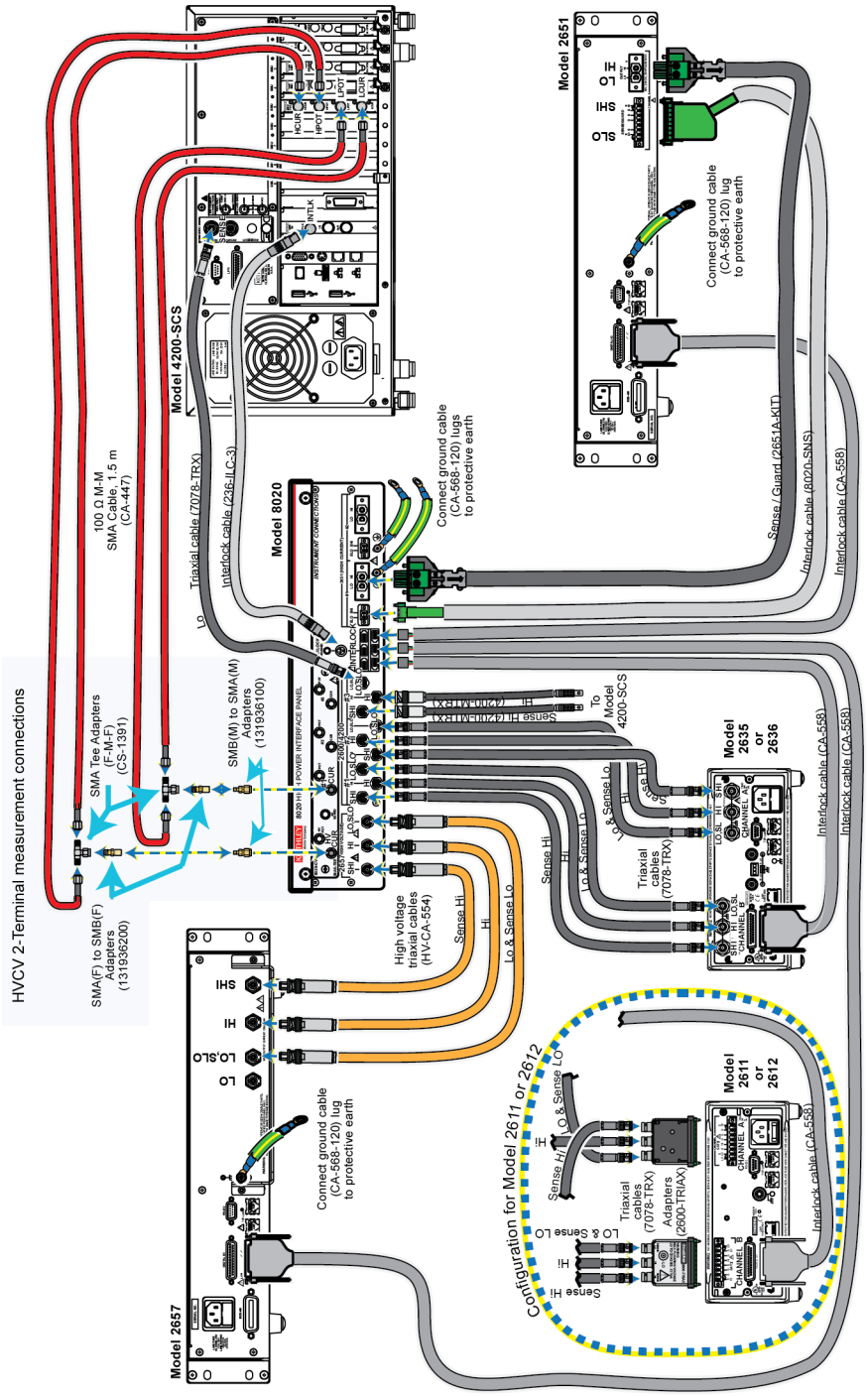
The following figure shows connections for I-V and C-V measurements. To make only connections for I-V measurements, refer to the *Model 8010 High Power Device Test Fixture User's Manual*.

Figure 2: Instrument connections to the Model 8010



Connect instruments to the Model 8020

Figure 3: Connecting instruments to the Model 8020



Section 3

Getting started with ACS Basic

In this section:

Introduction 3-1
Installing and configuring the GPIB interface 3-1
TSP-Link system setup 3-2
Software installation 3-4
Verify hardware configuration 3-5
Start ACS Basic 3-9
ACS Basic test modes 3-10

Introduction

ACS Basic Edition software is optimized for parametric testing of component and discrete (packaged) semiconductor devices. ACS Basic supports all Keithley source and measure instrument products, including Series 2600B, Series 2400, and Model 2651A and 2657A SourceMeter Instruments, and Model 4200A-SCS Parameter Analyzers.

ACS Basic has a large device test library to allow you to get a test up and running quickly.

This section outlines how to configure the instruments in the PCT to prepare for connection to ACS Basic, how to install the software, and how to get started using the software.

Installing and configuring the GPIB interface

NOTE

If you ordered the PCT-CVU for high-voltage capacitance measurements, a GPIB interface is installed on the Model 4200A-SCS that is included with the PCT-CVU. There is no need to use a separate computer or install the KUSB-488B. Go to TSP-Link system setup (on page 3-2).

ACS Basic software works with the following GPIB interfaces:

- KUSB-488
- KUSB-488A
- KUSB-488B
- KPCI-488
- KPCI-488A
- KPCI-488LP
- KPCI-488LPA
- NI USB-488
- NI PCI-488

If one of the above interfaces is already installed on your computer, please continue to TSP-Link system setup (on page 3-2).

The PCT is supplied with Keithley's Model KUSB-488B GPIB interface. If you are using a separate computer for software control, install the GPIB interface if there is not one already installed. Refer to the KUSB-488B documentation for instructions on installing the interface software.

TSP-Link system setup

ACS Basic automatically assigns the SMU identification numbers based on the TSP-Link setup. The numbers differ based on your PCT configuration.

Assign TSP-Link node numbers

Each instrument in the TSP-Link network must have a unique TSP-Link node number. In addition, ACS Basic requires that you set the master node to TSP-Link node number 1 and that each node that is connected to the master has an incremental node number. For example, if you have a TSP-Link network with three nodes, you must assign the instruments to the nodes 1, 2 and 3. Do not skip numbers.

In PCT configurations, use the Model 2636B as the master node, assigned to node 1.

If the PCT includes a Model 2657A , assign the 2657A to node 2.

The Model 2651A in a PCT-2B configuration should be assigned to node 2. If you have a second 2651A, assign it to the subsequent node.

The Model 2651A in a PCT-3B or -4B configuration should be assigned to node 3.

While other node configurations are possible, these assignments allow for simpler use of the default ACS Basic tests.

To assign a node number from the front panel of the instrument:

1. Press the **MENU** key.
2. Select **TSPLINK > NODE**.
3. Press the navigation wheel and select the node number.
4. Press the **ENTER** key to save the node number.
5. Press the **EXIT** key as needed to return to the main display.

Connect the instrument for communications

All configurations require a KUSB-488B or similar GPIB adapter cable connecting the instrument and your computer. For additional connections, see the following details for your PCT configuration.

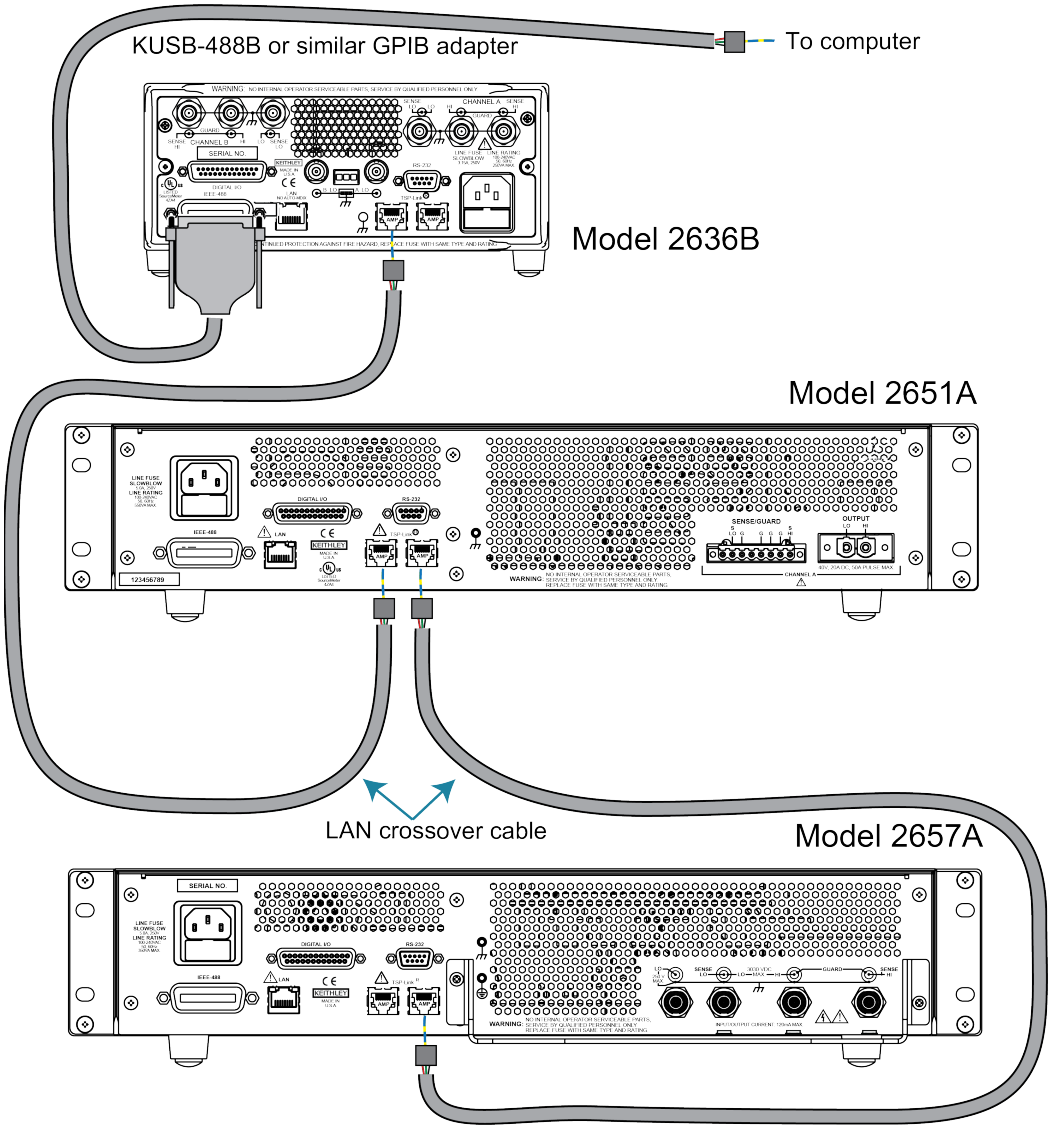
The **2600-PCT-1B** configuration is shipped with the Model 2636B. The KUSB-488B or similar GPIB adapter cable linking the Model 2636B and your computer is the only connection.

The **2600-PCT-2B** configuration is shipped with the Models 2636B and 2651A. For this configuration, connect the TSP-Link port of the Model 2636B to the TSP-Link port of the Model 2651A.

The **2600-PCT-3B** configuration is shipped with the Models 2636B and 2657B. For this configuration, connect the TSP-Link port of the Model 2636B to the TSP-Link port of the Model 2657A.

The following figure shows a **2600-PCT-4B** configuration. The -4B configuration is shipped with the Models 2636B, 2651A, and 2657B.

Figure 4: Communications connections



Software installation

See the ACS Basic release notes, available at tek.com, for instructions on installing the software.

NOTE

It is recommended that you review the ACS Basic release notes. The release notes contain valuable information about known issues and provide guidance on how to handle issues that you may encounter.

Verify hardware configuration

Before starting ACS Basic, you need to set up the hardware for your test configuration.

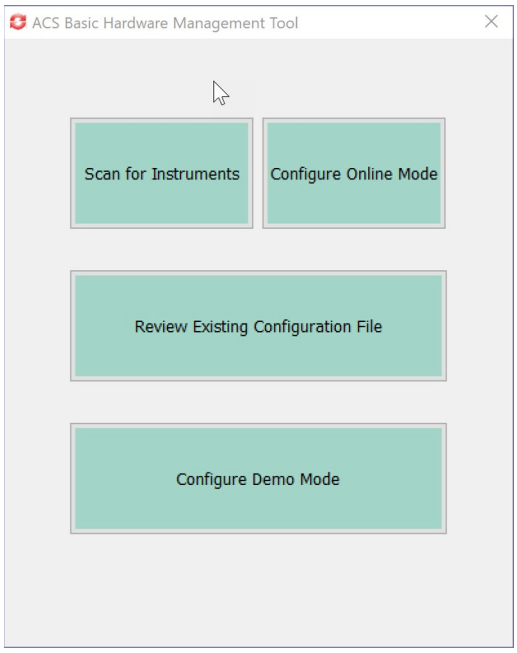
NOTE

ASC Basic checks for hardware changes when it starts up. You need to run ACS Hardware Management whenever the hardware is changed.

To manage the hardware:

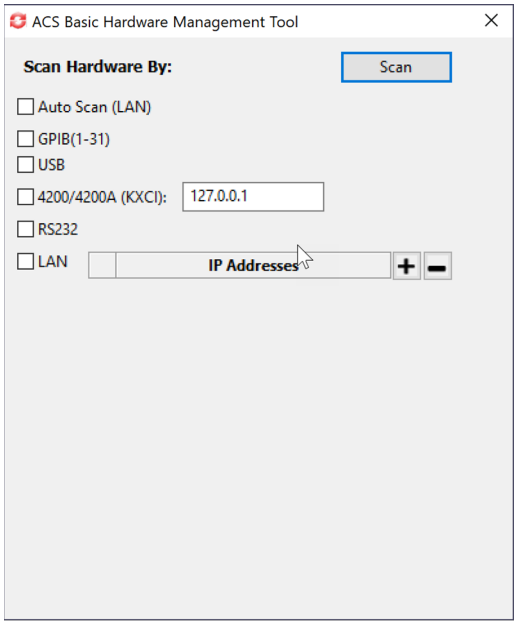
1. From **Start**, select **Keithley ACS Basic HardwareManagement**. The dialog shown in the following figure is displayed.

Figure 5: Hardware Management Tool options



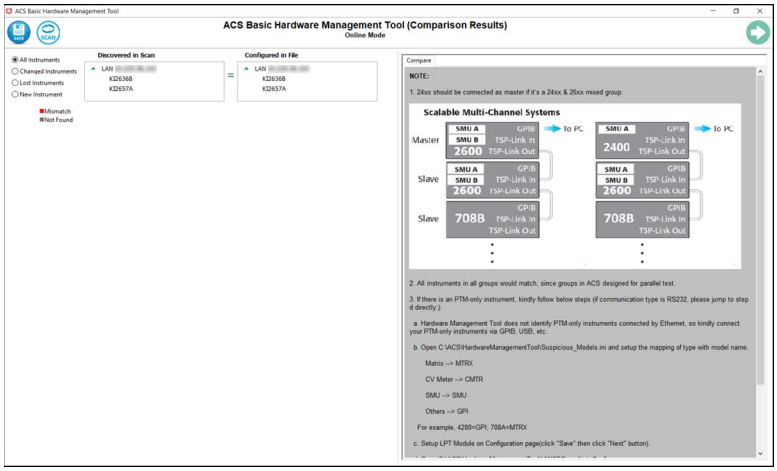
2. Select **Scan for Instruments**. The Scan Hardware By dialog is displayed, as shown in the following figure.

Figure 6: Scan Hardware By dialog



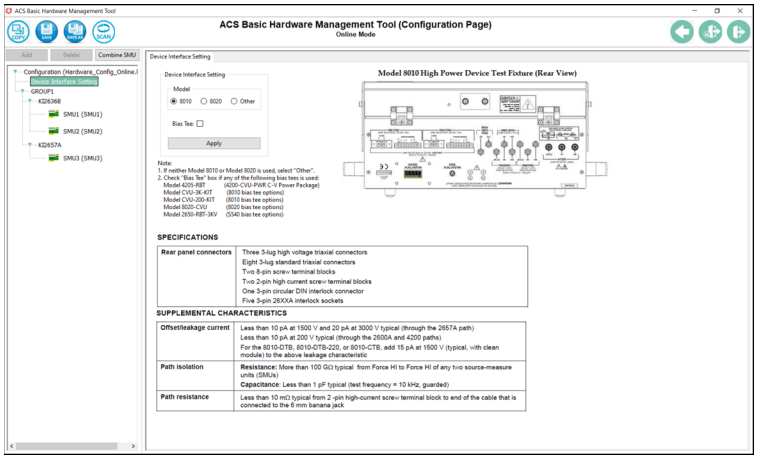
3. Select the options for your test. You can choose:
   - **Auto Scan (LAN):** Instruments are on the same subnet as the system computer (the first three fields of the IP address are the same).
   - **GPIB:** Instrument addresses from 1 to 30 are supported.
   - **Prober GPIB Address:** Default value is 31.
   - **USB**
   - **4200/4200A (KXCI):** Enter the IP address in the text box.
   - **RS-232**
   - **LAN:** Use **IP Addresses** to add or remove an IP address. To add an IP address, select **+** to add a field. Enter the IP address. To remove an IP address, select the address and select **–**.
4. Select **Scan**. ACS Basic compares the instruments that were previously configured with the present online instrument configuration. When the scan is complete, the Comparison Results dialog is displayed, as shown in the following figure.

Figure 7: Comparison results



5. Verify the instruments. If you need to delete an instrument, right-click the instrument and select **Delete**.
6. Select **Save**. The Configuration Page (Online Mode) opens.
7. Select **Device Interface Setting**. The information shown in the following figure is displayed.

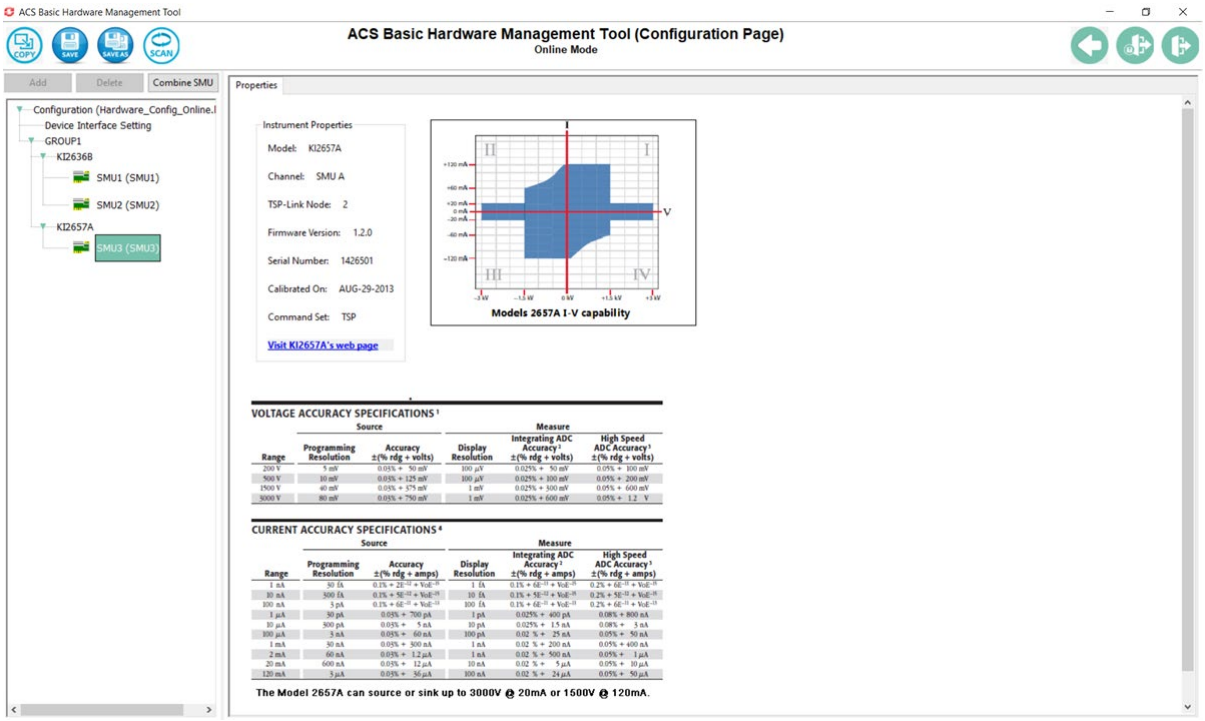
Figure 8: Device Interface Setting



8. Select the **Model** of the device interface.
9. If you are using a bias tee (CVU-3K-Kit, CVU-200-KIT, 8020-CVU, or Model 4205-RBT), select **Bias Tee**.
10. Select **Apply**.

11. To set up the instruments, select an instrument from the left pane. An example of the Configuration Page with a 2657A selected is shown in the following figure.

Figure 9: Configuration Page of the Hardware Management Tool



12. From this page, you can:
    - **Add an instrument:** Select **Add**. The instrument must be connected to the test system.
    - **Delete an instrument:** Select the instrument in the tree and select **Delete**.
    - **Combine SMU instruments:** Select the SMU instruments and select **Combine SMU**.
13. Select **Save**.
14. Close the Hardware Management Tool.
15. Restart ACS Basic.

NOTE

ACS Basic automatically assigns the SMU numbers. The numbers differ based on your PCT configuration and TSP-Link node numbers. See Assign TSP-Link node numbers (on page 3-2) for the recommended TSP-Link configuration.

NOTE

For more information on using the Hardware Management Tool, refer to the ACS Basic documentation.

If one or more SMUs are missing:

- Ensure that the GPIB adapter is securely attached to instrument and is working.
- Ensure that all instruments are powered on.
- Ensure that all TSP-Link cables are secure.

After checking the instruments, select **Scan** to scan the hardware configuration again.

Start ACS Basic

CAUTION

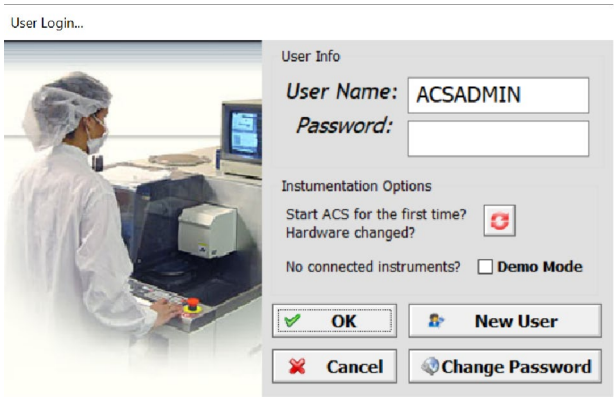
FATAL ERROR POSSIBLE. To avoid fatal errors to instruments, never start the ACS Basic software until all the instruments have completed self-testing. If you are using Series 2600 and 2600B instruments with TSP-Link, always power-on the subordinate instruments first and then the master. Since the master scans through all the linked subordinate instruments, it must be powered on after all the subordinate machines are turned on, or errors may occur when you start ACS Basic.

Before you open the ACS Basic software, make sure that all instruments are turned on and all self-tests have completed.

To start the ACS software:

1. Select the ACS software icon on the desktop of your computer. The User Login dialog opens, as shown in the following figure.

Figure 10: User login



2. Type a user name and password in the User Name and Password fields. The default user name is ACSADMIN; however, there is no default password.
3. Select **OK**. The software start window opens.
4. You can create more than one new user account at this time. To create a new account, select **New User**. To change the password, select **Change Password**.

NOTE

When you start the ACS Basic software, the startup time depends on how many instruments are in the hardware configuration group. For example, if there are several instruments, the startup time is longer.

ACS Basic test modes

ACS Basic has three test modes: SingleMode, MultiMode, and TraceMode.

In **SingleMode**, ACS Basic opens and runs a single test on a single device at a time.

In **MultiMode**, you can create multiple test modules on one or more devices and organize them into a single project. For example, MultiMode can perform multiple tests on a single device (target application) or multiple tests on multiple devices (secondary use case). You can work with external instruments such as DMMs and switches in MultiMode much easier than in any other mode.

TraceMode provides interactive operation with a SMU. TraceMode is useful for quickly checking the operating boundaries of a device and for verifying its basic functionality.

In the following sections of this manual, you will learn how to perform common power semiconductor tests in MultiMode and in TraceMode.

Section 4

I-V applications for power MOSFETs

In this section:

Section overview and equipment requirements 4-1
On-state characteristics 4-1
Off-state characteristics 4-34

Section overview and equipment requirements

This section provides step-by-step instructions to use the Parametric Curve Tracer (PCT) to perform common tests on a sample power MOSFET device. These tests include collecting family of curves (V_{ds-Id}) on a power MOSFET and measuring leakage current (I_{dss}) using the ACS Basic software.

The following instructions are tailored to the 2600-PCT-4B, which has both high voltage and high current capability. However, the test parameters can be adjusted to suit the PCT configuration and instrumentation that you have.

The PCT is provided with a sample test device, located in the PCT-DOC-KIT box of the “Open Me First” box. The sample device is a 1000 V MOSFET and is available from onsemi as part number FQH8N100C. You can download a datasheet for this part from the manufacturer's website at onsemi.com (onsemi.com/).

NOTE

This section refers to SMUs that are numbered as suggested in Assign TSP-Link node numbers (on page 3-2). Your configuration may vary.

On-state characteristics

Configure the test fixture

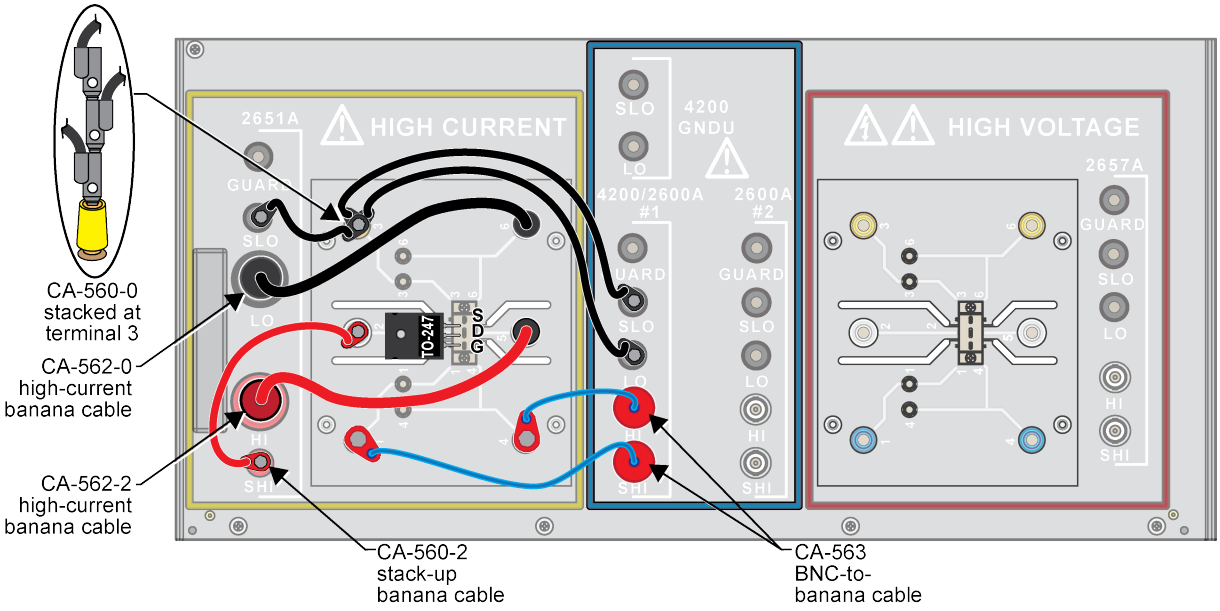
NOTE

The PCT supports either the Keithley Instruments Model 8010 or Model 8010 test fixtures. For instructions on how to connect instruments to the 8010 or 8020, refer to Instruments and connections (on page 2-1). To make connections to the device, see the following procedure for your test fixture.

To configure the Model 8010 test fixture:

1. On the High Current side of the fixture, insert the test device into the test socket. Place the device with the Gate pin closest to the front of the test fixture.
2. Wire the test fixture as shown in the following figure:
   - Connect the 2651A HI and SHI signals to the Drain terminal.
   - Connect the 2600A #1 HI and SHI signals to the Gate terminal.
   - Connect the LO and SLO signals from both SMUs to the Source terminal.

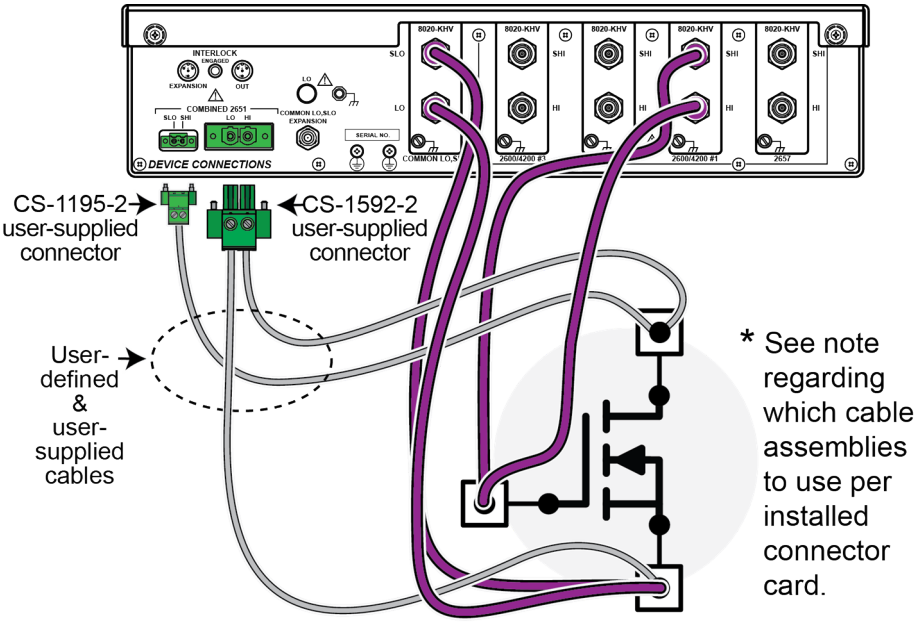
Figure 11: Three-terminal DUT with one or two 2651A instruments and Series 2600A instrument connected



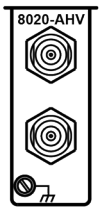
To configure the Model 8020 test fixture:

1. Wire the test fixture as shown in the following figure:
   - Connect both COMMON LO, SLO signals and the COMBINED 2651 LO signal to the Source terminal of the device.
   - Connect the COMBINED 2651 SHI and HI signals to the Drain terminal of the device.
   - Connect both 2600/4200 SHI and HI signals to the Gate terminal of the device.

Figure 12: 8020 test fixture configuration (device side)

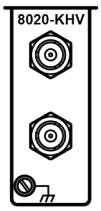


* Cable assemblies will depend upon the connector card the user installs



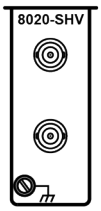
Connector Card: 8020-AHV

Cable Assembly: User supplied



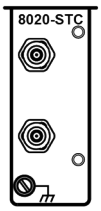
Connector Card: 8020-KHV

Cable Assembly: Model HV-CA-554



Connector Card: 8020-SHV

Cable Assembly: User supplied



Connector Card: 8020-STC

Cable Assembly: Model 7078-TRX or Model 4200-TRX

Collecting I-V curves in TraceMode

TraceMode allows you to generate rapid visual results of device characteristics and to have real-time control of one of the test parameters. This example application instructs you on how to collect a family of curves on a MOSFET device.

These instructions demonstrate how to do the following tasks:

- Configure TraceMode
- Gather a family of curves on a MOSFET using TraceMode
- View and save data in TraceMode

An overview of the steps to do the test are:

1. Enter TraceMode of ACS Basic
2. Load the IdVd_StepVg test for the nPowerMOSFET device into the project
3. Configure the settings to match the DUT
4. Run the test
5. View and save the data

NOTE

TraceMode supports the Series 2400, Series 2600B, and the Series 2650A SMUs. However, you cannot connect a Series 2400 and a Series 2600B instrument to the same device. If you are using a Series 2400 on one device terminal, you must use a Series 2400 instrument on the other device terminals. TraceMode only supports the SCPI protocol for Series 2400 SMUs.

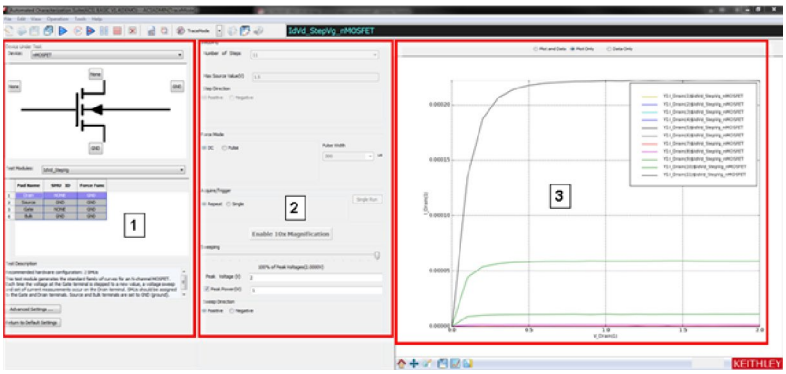
You can use a Series 2600B and a Series 2650A instrument in any combination.

TraceMode provides interactive control of SMU instruments to achieve real-time performance. Only Series 2600B instruments (Models 2601B, 2602B, 2611B, 2612B, 2635B, or 2636B), Series 2650A (Models 2651A or 2657A) and Series 2400 instruments (Models 2400, 2401, 2410, 2420, 2425, 2440) are supported. ACS Basic can perform dc and pulse tests on Series 2600B and 2650A instruments in TraceMode, but it can only perform dc measurements on Series 2400 instruments.

See the following figure. The GUI includes:

1. Device setting: Used to map the SMU, select the test module, and set the advanced settings.
2. Test setting: Used to set the test information when the test module is enabled.
3. Trace Test Data: Used to show the test result.

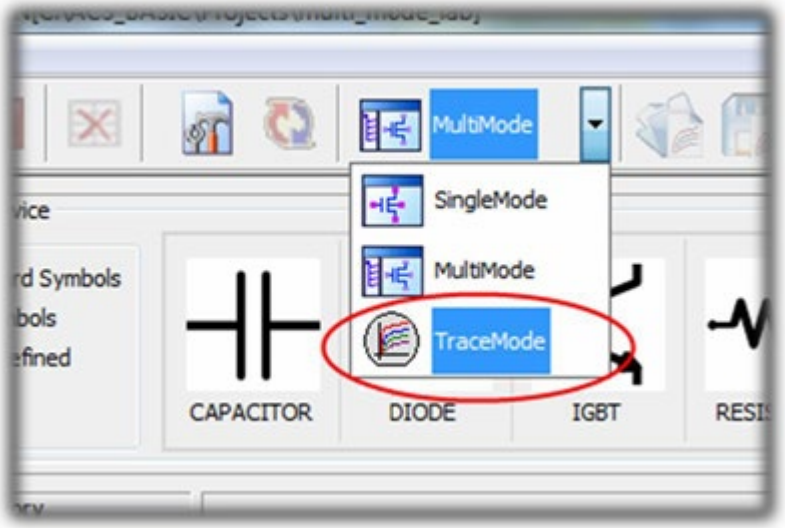
Figure 13: TraceMode GUI



To collect curves in TraceMode:

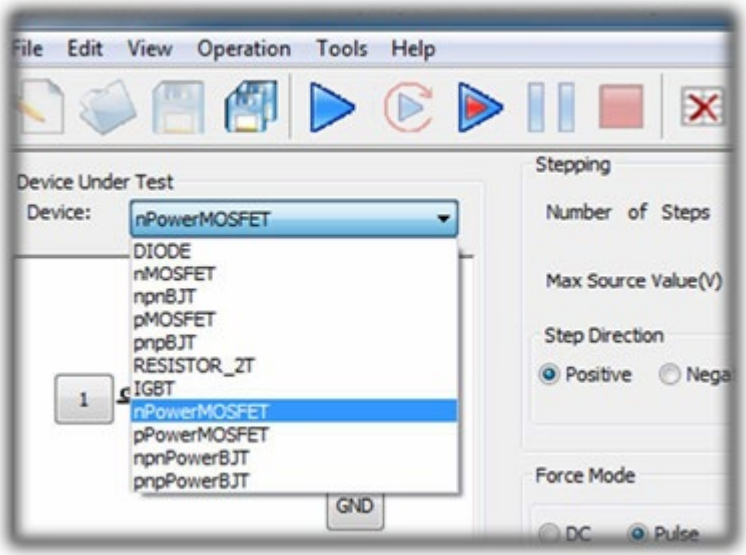
1. Launch ACS Basic.
2. From the MultiMode menu, select **TraceMode**.

Figure 14: Select TraceMode



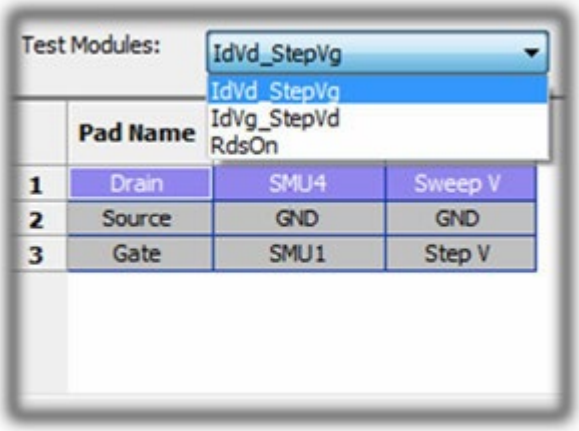
3. From Device, select **nPowerMOSFET**.

Figure 15: Select nPowerMOSFET



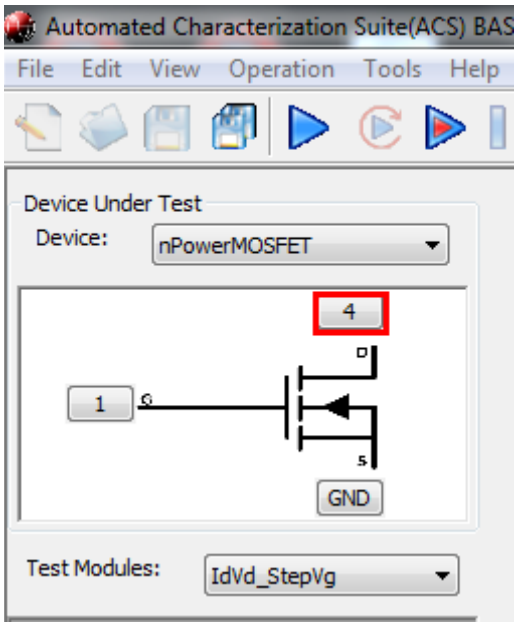
4. From Test Modules, select **IdVd_StepVg**. The test loads with default settings and sample data.

Figure 16: Selecting IdVd_StepVg



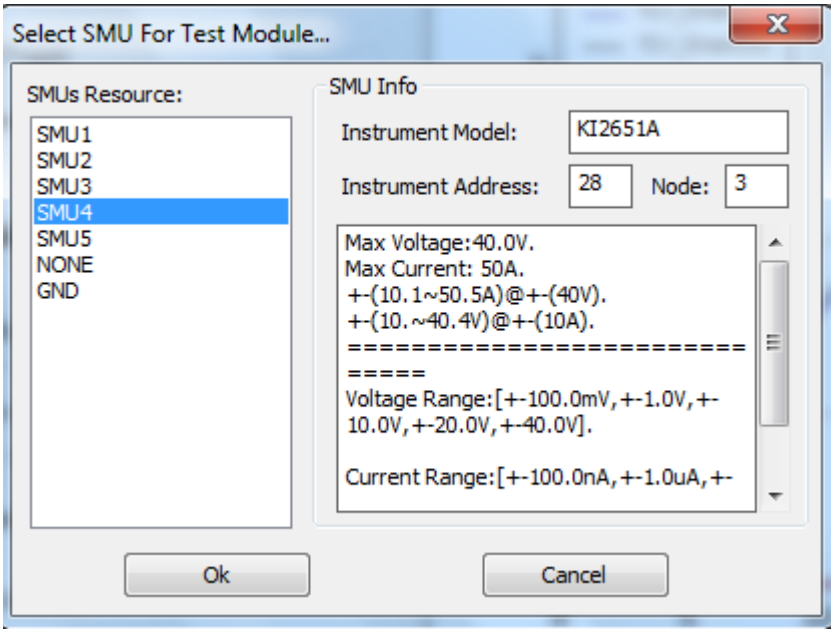
5. Connect a SMU to the device terminal by selecting the button next to the device terminal and selecting the appropriate SMU. In the following example, SMU 4 is connected to the Drain terminal.

Figure 17: Selecting a device terminal for SMU assignment



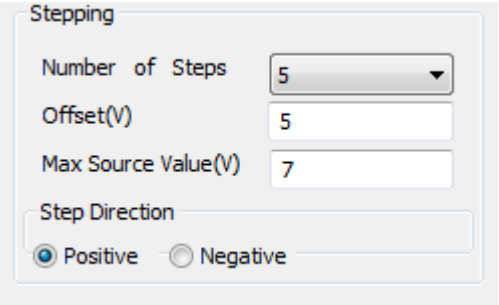
6. Select the SMU resource to connect to this device terminal. In this example, the high current SMU (2651A, SMU 4) is connected to the Drain.

Figure 18: SMU 4 settings



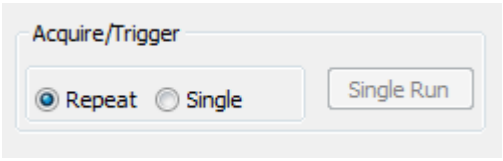
7. Select **Ok**.
8. Repeat these steps for the remaining device terminals. For this example, connect 2636A Channel A (SMU1) to the gate and connect the Source to the GND terminal, which represents the Common LO terminal.
9. Change the Stepping values. In this example, the gate SMU steps from 5 V to 7 V in 0.5 V increments. Therefore, set the Number of Steps to 5, the Offset Value to 5 V, the Max Source Value (V) to 7, and the Step Direction to Positive, as shown in the following figure.

Figure 19: Stepping settings



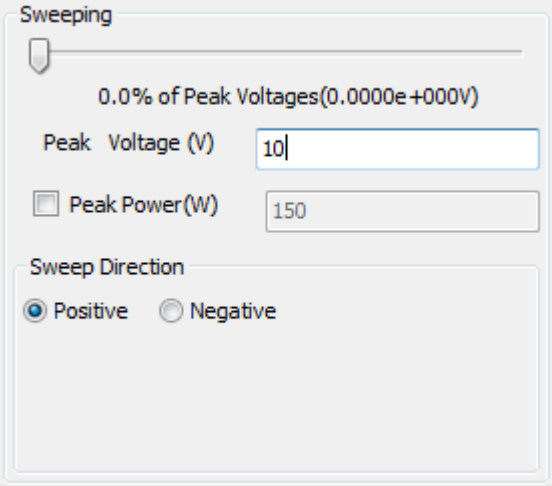
10. For Acquire/Trigger, select **Repeat**, as shown in the following figure. The Acquire/Trigger option selects whether the sweep runs once or repeatedly in force mode.

Figure 20: Force Mode setting



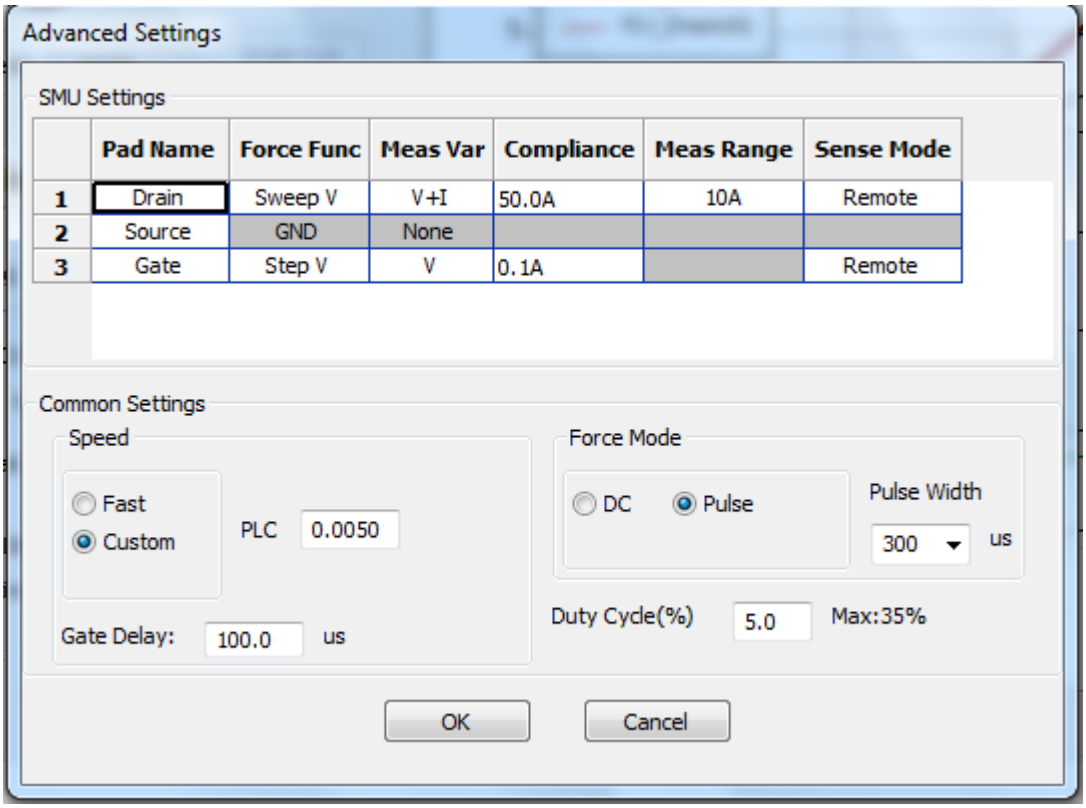
11. Move the Sweeping slider to 0% so that no voltage is applied to the DUT when you start the test, as shown in the following figure.
12. For this example, change the Peak Voltage to 10 and make sure that the Sweep Direction is Positive.

Figure 21: Sweeping slider at 0 percent of peak voltage



13. Select the Advanced Settings button near the lower-left part of the application window to display the Advanced Settings dialog, as shown in the following figure.

Figure 22: Advanced Settings dialog



NOTE

The Advanced Settings are automatically configured based upon the type of test being run. However, values can be changed to accommodate the DUT.

14. Adjust the following Advanced Settings:
    - Sense Mode: Remote for the Gate and Drain SMU
    - On the drain, change Compliance to 10 A and Meas Range to 10 A
    - On the gate, change the Compliance to 100 mA
    - Change the Duty Cycle to 5%

NOTE

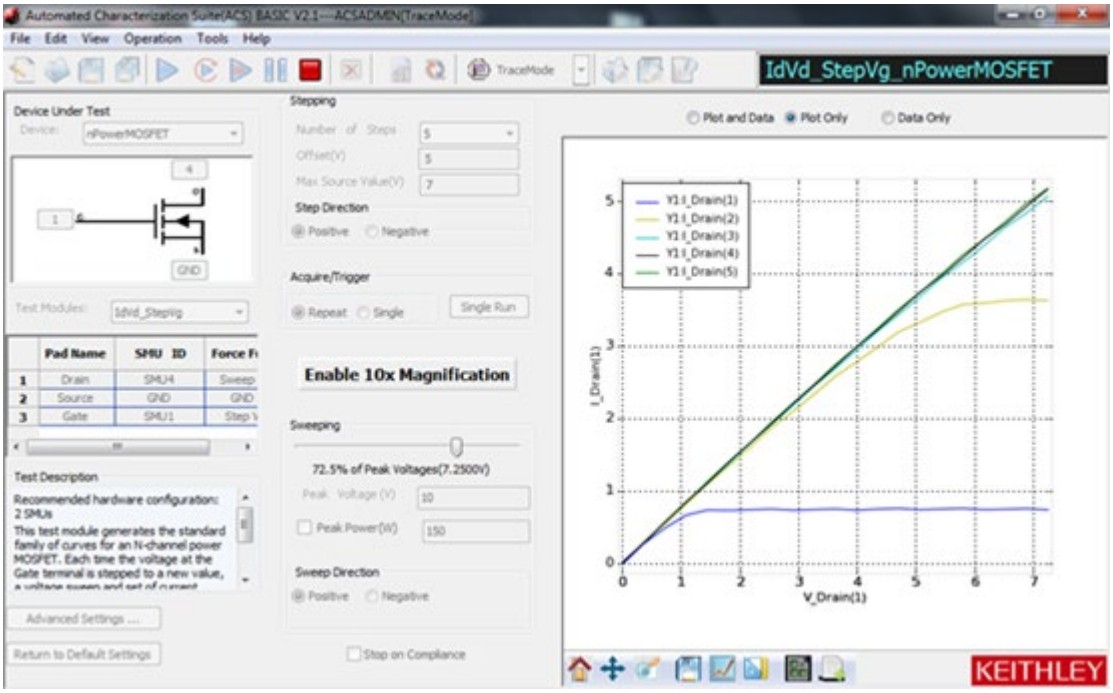
The pulse duty cycle of the pulses impacts the update rate of the display. Using a lower duty cycle allows higher current without thermal stress to the device. However, a lower duty cycle means that the display does not update as quickly as in this example.

15. Select **OK**.
16. Select **Run** to begin the test.

Figure 23: Run icon

17. Move the Sweeping slider to adjust the peak voltage. Notice that the I-V curves sweep out further as you move the slider right.

Figure 24: Test results



NOTE

You can also use the arrows keys on the keyboard to adjust the slider. The up and down arrow keys result in coarse changes in the sweeping voltage of 10% of peak voltage The left and right arrow keys result in fine changes in the sweeping voltage of 1% of peak voltage.

18. To stop the test, select **Stop** at the top of the application window.

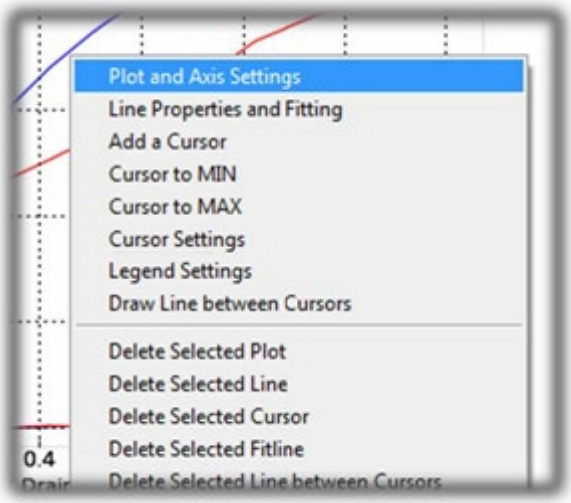
Configure a fixed plot

As you increase the sweep voltage, the graph automatically scales to fit the collected data into the plot.

To change the graph to be fixed:

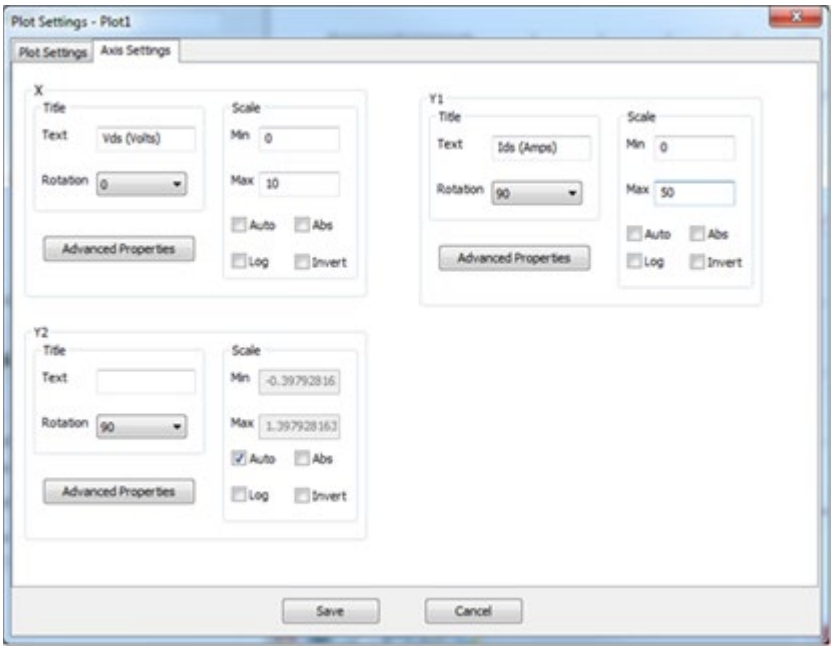
1. Right-click in the plot, then select **Plot and Axis Settings**.

Figure 25: Select Plot and Axis Settings



2. Select **Axis Settings**.

Figure 26: Plot Settings dialog



3. Change the following options for the X-Axis Scale:
   a. Clear Auto
   b. Change the X-Axis Scale Min to 0
   c. Change the X-Axis Scale Max to 10

4. Make the following modifications to the Y-Axis Scale:
   a. Clear Auto
   b. Change the Y-Axis Scale Min to 0
   c. Change the Y-Axis Scale Max to 10
5. Change the X and Y Axis Title Text:
   a. Re-name the X-Axis title to **Vds (Volts)**
   b. Re-name the Y-Axis title to **Ids (Amps)**
6. Select **Save**.

Collecting I-V curves in MultiMode

In SingleMode and MultiMode, you program all test parameters before test operation. Tests run without operator intervention or interaction. These modes are useful for generating precise data on the DUT and for extracting device parameters from the data set.

In this example application, you collect a family of curves on the sample MOSFET.

This example application demonstrates how to do the following tasks:

- Create a MultiMode project in ACS Basic
- Add tests to the project using the built-in test libraries
- Configure a test in MultiMode
- View, append, and save data in MultiMode

To make connections to the test fixture for this test, refer to Configure the test fixture (on page 4-1).

To do the test:

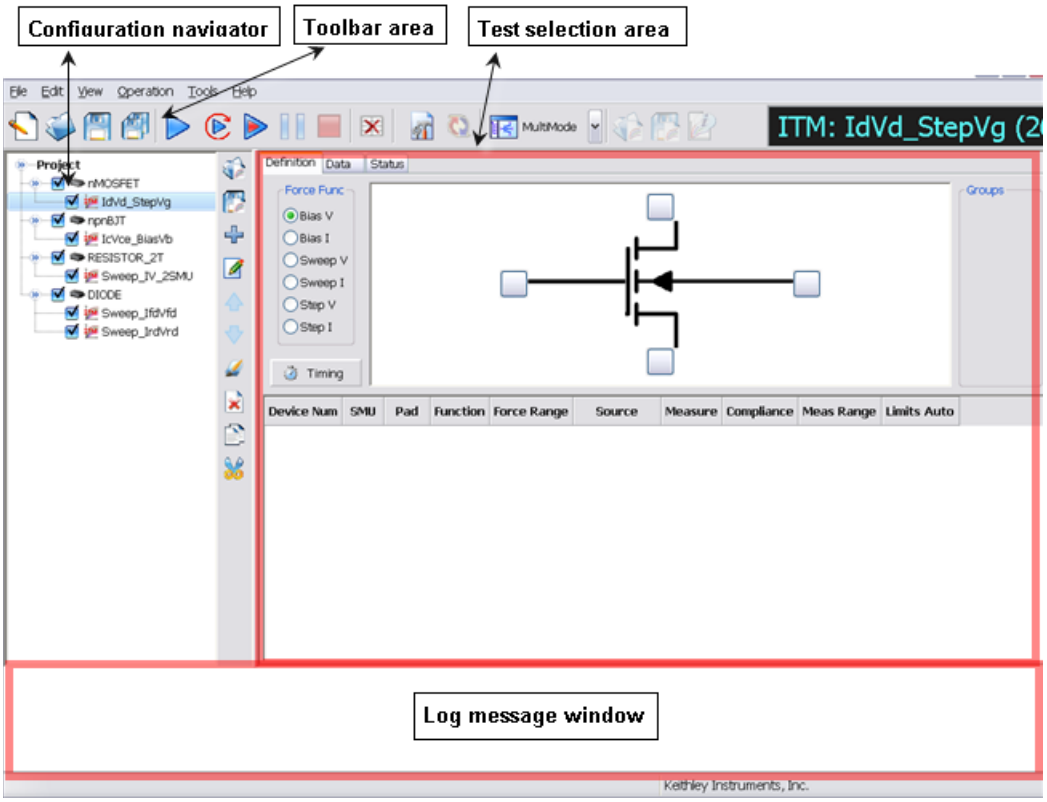
1. Place the DUT into the Model 8010 test fixture and configure the connections
2. Enter MultiMode of ACS Basic
3. Create a new MultiMode project
4. Load the IdVd_StepVg test for the nPowerMOSFET device into the project
5. Configure the settings to match the device under test
6. Run the test
7. Save the data

MultiMode GUI overview

The configuration navigator, shown in the following figure, has the following logical hierarchy:

- Project
  - Device 1
    - Test module 1 (ITM, STM, or PTM)
    - Test module 2 (ITM, STM, or PTM)
  - Device 2
    - Test module 1 (ITM, STM, or PTM)
    - Test module 2 (ITM, STM, or PTM)

Figure 27: MultiMode user interface



The configuration navigator is the primary interface for building, editing, and viewing a project plan, and for specifying and accessing each project plan component.

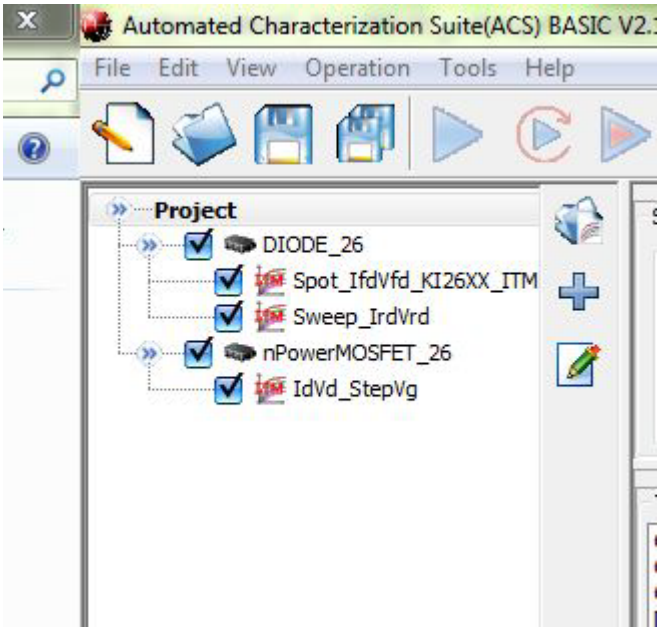
When you select a navigator component (test or device) you can do the following:

- Add a new component
- Delete an existing component
- Run the tests associated with this component

Selecting a navigator component opens the configuration interface on the right panel, which includes settings, test results, and status information.

Typical project plan components of the configuration navigator are shown in the following figure.

Figure 28: Project plan components of the configuration navigator view



The project plan components include:

- **Project Plan:** Defines and sequences all devices tested, and all tests and operations to be performed at each. It typically corresponds to one die on a wafer.
- **Device Plan:** Defines and sequences all tests for a specific device, including transistors, diodes, and resistors.
- **ITM:** Completely defines a parametric test without programming, using a series of configured graphical user interfaces that show data numerically and graphically in real time. Provides for the display of both raw data and analyzed data.

Set up a new MultiMode project

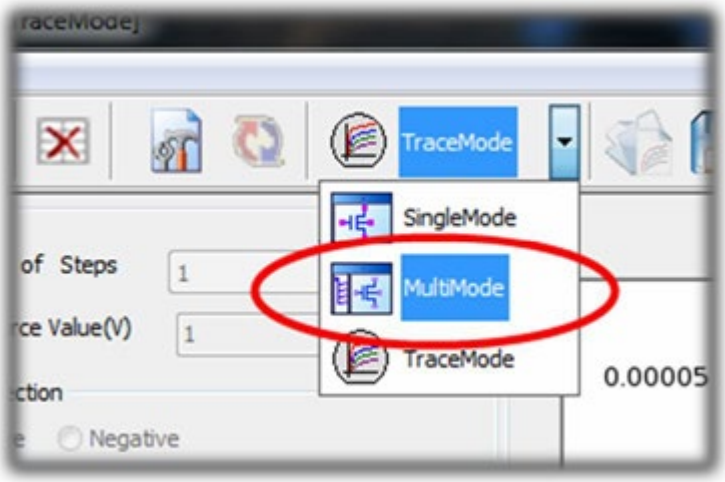
You can use the ACS Basic MultiMode to create multiple test modules on one or more devices and organize them into a single project. You can work with external instruments, such as DMMs and switches, in MultiMode more easily than in any other mode.

MultiMode starts with the most recently used MultiMode project. In this application, you replace it with a new project.

To set up a new MultiMode project:

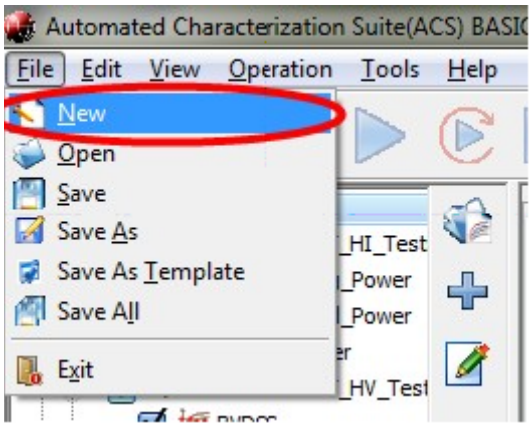
1. Start ACS Basic, if it is not already open.
2. From the Mode Selection list, select **MultiMode**.

Figure 29: Select MultiMode



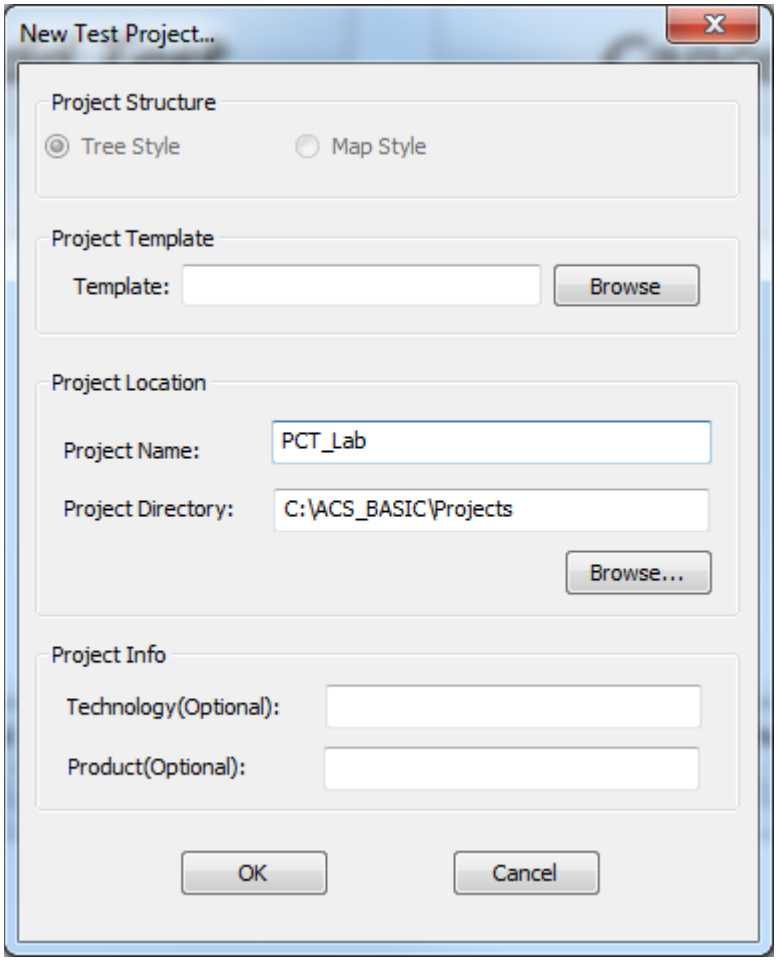
3. From the File menu, select **New**.

Figure 30: Create a new project



4. Select **No** to the prompt to save the current project. The New Test Project dialog opens, as shown in the following figure.

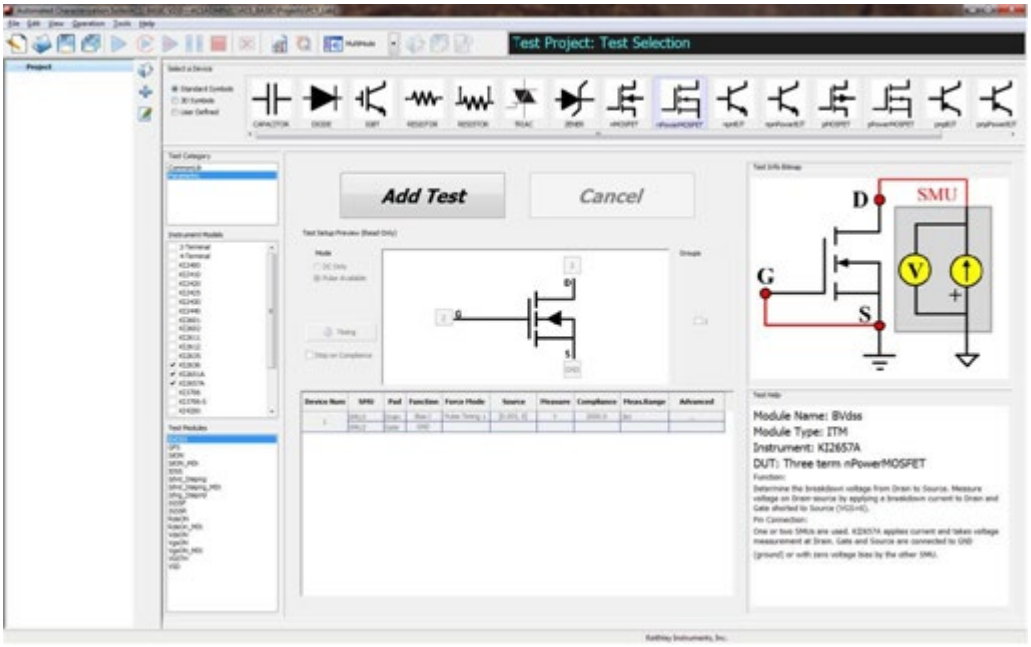
Figure 31: New Test Project dialog



5. In the Project Name field, enter a project name.
6. Select **OK**.

When the new project opens, the project navigation pane on the left is empty and the test libraries area fills the remainder of the window. The test libraries area is the easiest way to add devices and tests to your project.

Figure 32: Project navigation and test libraries

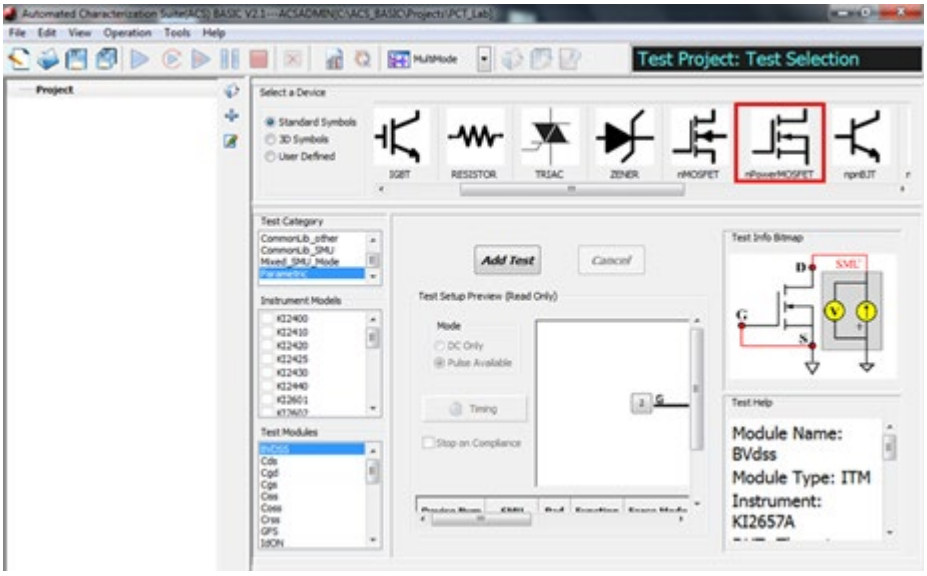


Add the IdVd_StepVg test to the project

To add the IdVd_StepVg test to the project:

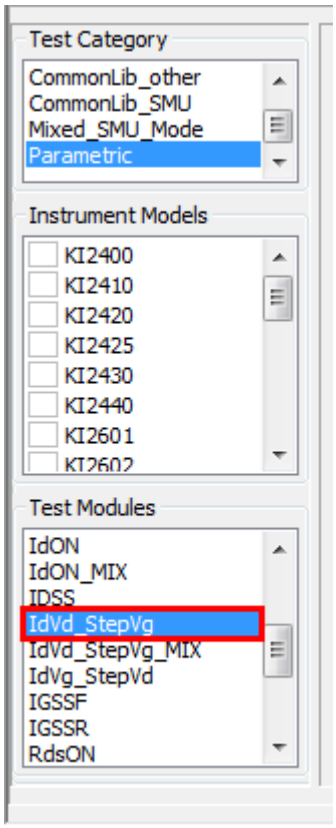
1. From the Select a Device pane, select **nPowerMOSFET**.

Figure 33: nPowerMOSFET selected on the Select a Device pane



2. Select the **IdVd_StepVg** test from the Test Modules pane at the bottom left of the window.

Figure 34: Select the IdVd_StepVg test module

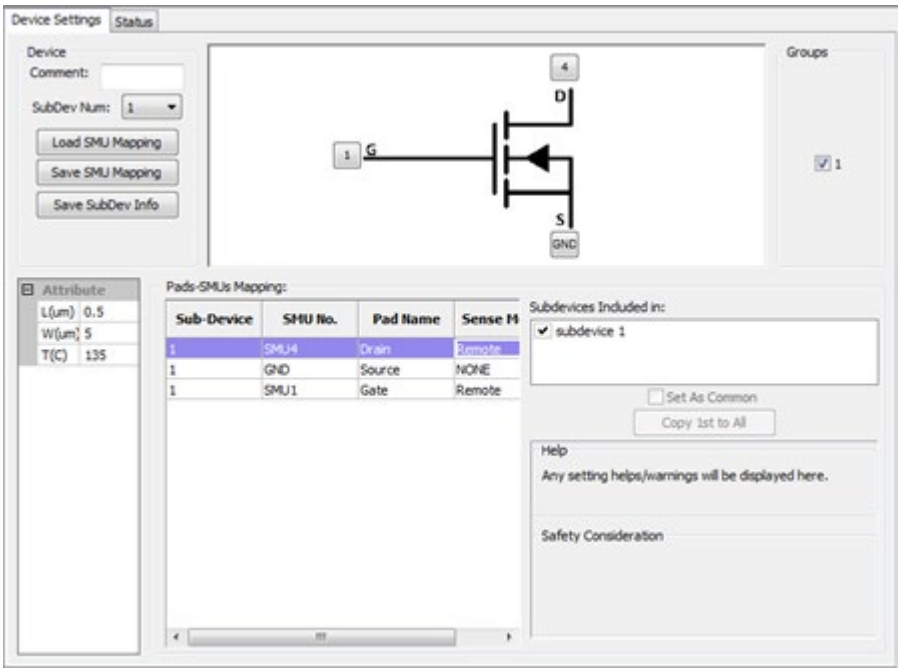


3. Select **Add Test**. The device and test are added to your project tree.

Figure 35: Device and test added to project tree

4. In the Project Tree, select the device **nPowerMOSFET_26**. The Device Settings dialog opens.

Figure 36: Device Settings dialog



In the Device Settings dialog, you can configure which SMU is connected to which pin of the device, set the SMU sense mode, and assign a name to the pad. This SMU mapping applies to all tests in the project tree under the device.

When you add the test to the project, ACS Basic automatically assigns SMUs to the pins. You should verify that the pin assignments are correct:

- Make sure that the high current SMU (for this example, Model 2651A, SMU 4) is connected to the drain
- Make sure that the 2636A Channel A (SMU 1) is connected to the gate
- Make sure that both the gate and drain are configured for remote sense
- Make sure that the source terminal is connected to GND

Configure the test

You configure the settings each test in the Test Definition dialog. From this dialog, you can set every aspect of how your test runs. Many of the settings are preconfigured, but you need to make some changes for this application.

NOTE

You can check your SMU assignments by hovering the mouse cursor over the pad numbers in the device diagram.

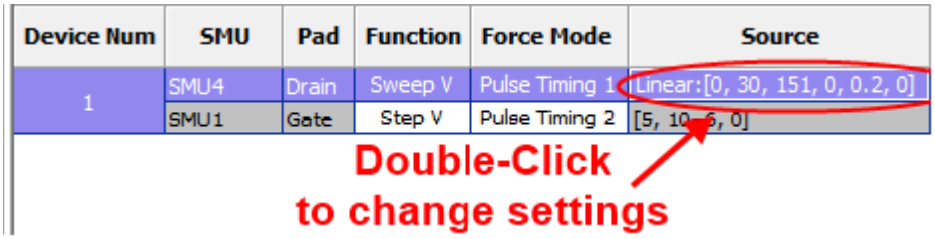
NOTE

This section refers to SMUs that are numbered as suggested in Assign TSP-Link node numbers (on page 3-2). Your configuration may vary.

To set up the IV curve test:

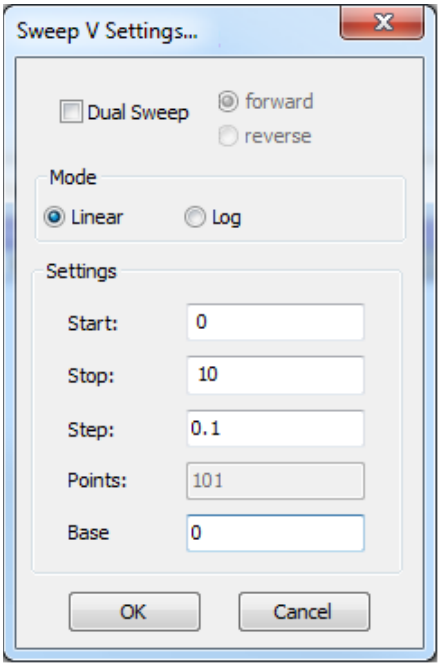
1. In the project navigator, select the test named **IdVd_StepVg**.
2. For SMU4 (drain), confirm that Compliance is set to **10 A**.
3. For SMU4 (drain), set the Meas. Range to **10A**.
4. For SMU1 (gate), confirm that Compliance is set to **0.1 A**.
5. For SMU4 (drain), double-click the **Source Settings** cell to open the Sweep V Settings dialog.

Figure 37: Sweep V settings



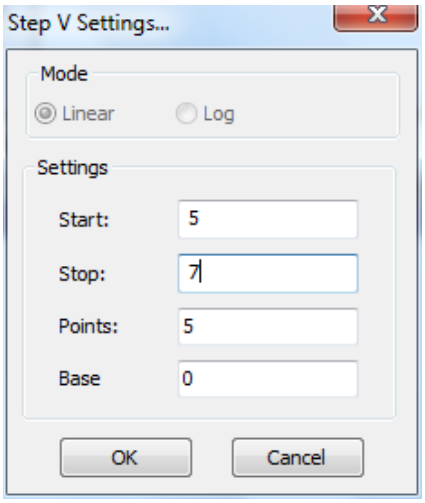
6. Set the Mode to **Linear**.
7. Set the Start value to **0**.
8. Set the Stop value to **10**.
9. Set the Step value to **0.1**.
10. Set the Base value to **0**.
11. Select **OK**.

Figure 38: Modified Sweep V Settings



12. For SMU1 (gate), double-click the **Source Settings** cell to open the Step V Settings dialog.
13. Set the Start value to **5**.
14. Set the Stop value to **7**.
15. Set the Points value to **5**.
16. Set the Base value to **0**.
17. Select **OK**.

Figure 39: Modified Step V Settings



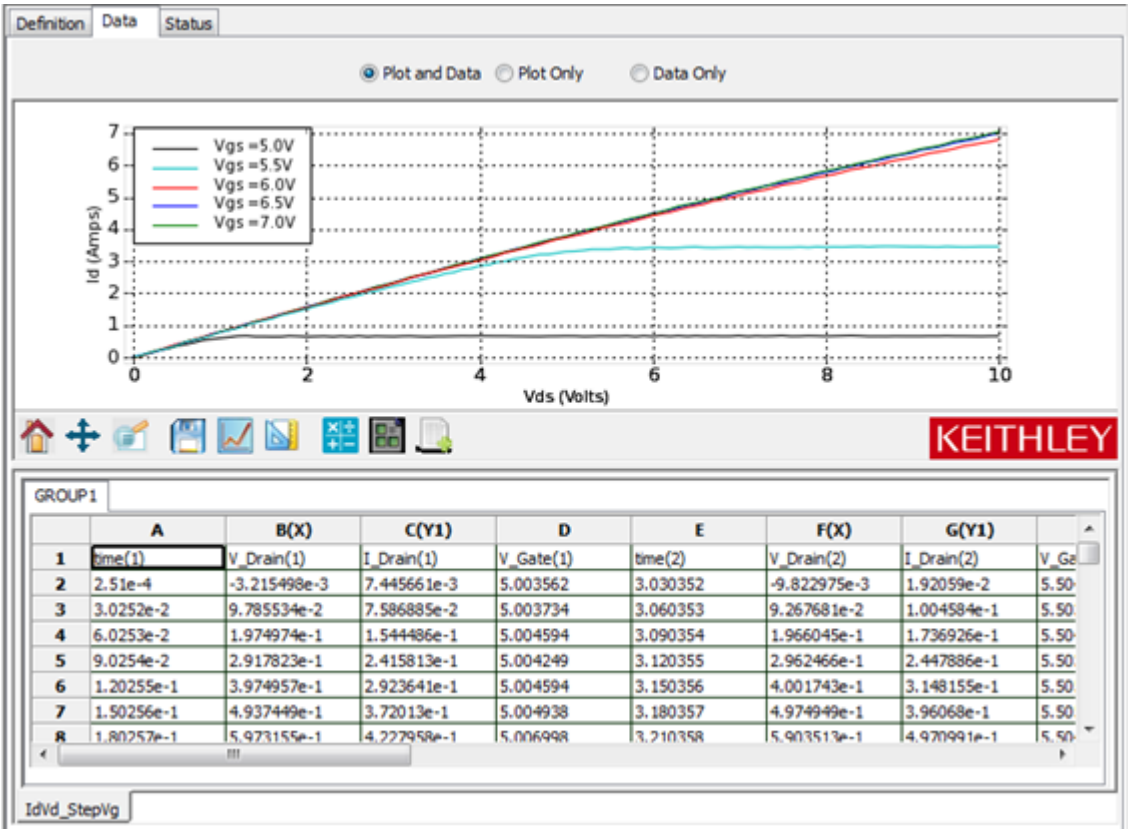
Run the test

The Data tab contains the data from the last time the test was run. Because this test is new, it contains sample data. When the test is run, the new data overwrites the sample data.

To run the test:

1. Select the Data tab of the Test dialog.
2. Select **Run** (▶) to start the test. Once data collection is complete, the test stops.
3. At the top of the Data tab, select **Plot Only** to get a better view of the plot.
4. Select **Data Only** to get a better view of the data in the spreadsheet.
5. Select **Plot and Data** to return to the dual view.
6. As the test runs and ACS Basic collects data, the curves are displayed on the graph.

Figure 40: Test result curves and data



	A	B(X)	C(Y1)	D	E	F(X)	G(Y1)	
1	time(1)	V_Drain(1)	I_Drain(1)	V_Gate(1)	time(2)	V_Drain(2)	I_Drain(2)	V_Ga
2	2.51e-4	-3.215498e-3	7.445661e-3	5.003562	3.030352	-9.822975e-3	1.92059e-2	5.50
3	3.0252e-2	9.785534e-2	7.586885e-2	5.003734	3.060353	9.267681e-2	1.004584e-1	5.50
4	6.0253e-2	1.974974e-1	1.544486e-1	5.004594	3.090354	1.966045e-1	1.736926e-1	5.50
5	9.0254e-2	2.917823e-1	2.415813e-1	5.004249	3.120355	2.962466e-1	2.447886e-1	5.50
6	1.20255e-1	3.974957e-1	2.923641e-1	5.004594	3.150356	4.001743e-1	3.148155e-1	5.50
7	1.50256e-1	4.937449e-1	3.72013e-1	5.004938	3.180357	4.974949e-1	3.96068e-1	5.50
8	1.80257e-1	5.973155e-1	4.227958e-1	5.006998	3.210358	5.903513e-1	4.970991e-1	5.50

You can also run the test without overwriting the existing data. This is useful for comparing data between two devices or doing a before and after comparison after making some changes to the test settings or device connections.

To run the test and append data:

1. Select **Append Run** to start the test.

Figure 41: Append Run icon

After the test runs, the appended data is graphed on the plot next to the original data. An additional tab on the datasheet holds the new data. Since no changes were made, the curves of the appended data should align with the original curves. If the curves align, this is a good indicator that you are making settled measurements. If they do not align, there could be a problem with your test configuration.

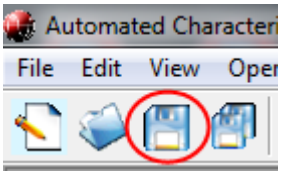
Save project and data

When you save the project with Save All, all your test settings and collected data are saved with it so the next time you load ACS Basic and open the test, your settings and data are still there. You can also save the data to a Microsoft Excel spreadsheet or to a .csv file for analysis in another application.

To save a project:

1. Select **Save** in the top toolbar.

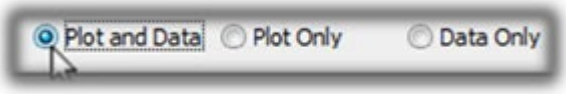
Figure 42: Save a project



To save test data:

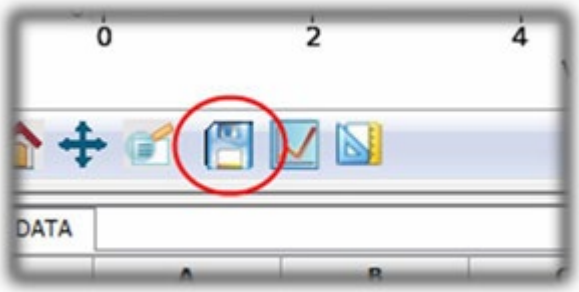
1. Above the plot in the test results window, select the data to be saved. You can select Plot and Data, Plot Only, or Data Only. For this example, select **Plot and Data**.

Figure 43: Data view options in test results



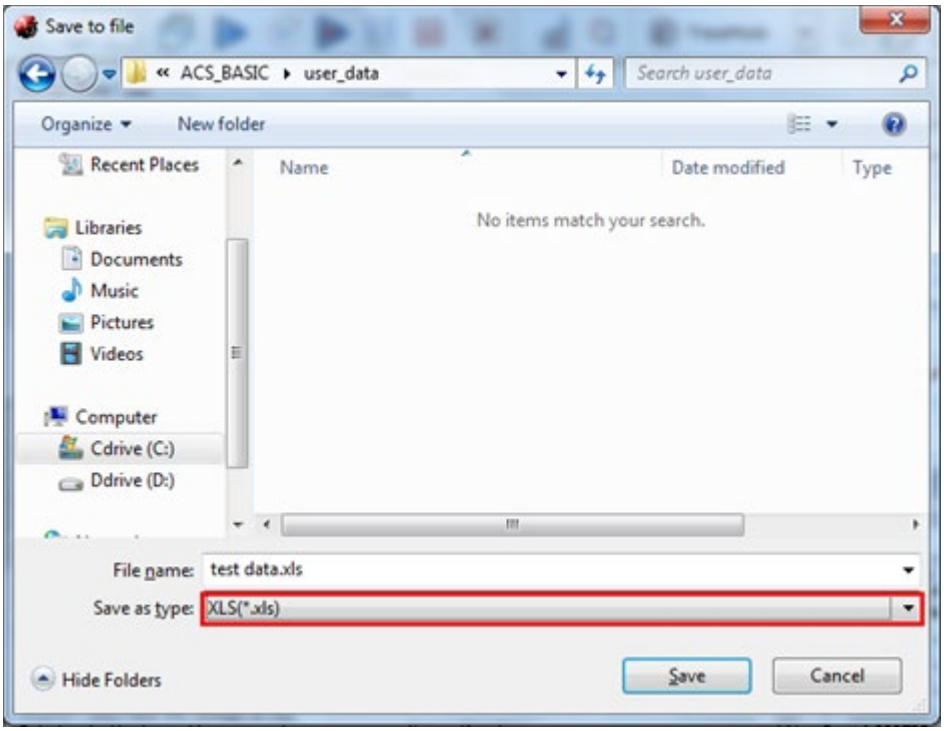
2. Select **Save** at the bottom of the plot.

Figure 44: Save test data



3. From **Save as Type**, select the data type. The default is .xls. You can also save in .csv, .png, .ps, .eps., and .svg formats.

Figure 45: Save to File dialog



Digitizing pulses and improving timing

For many devices, you must adjust the measurement timing to produce good test results.

In particular, you may need to increase the pulse width to give the test signal more time to settle before making the measurement. Often test engineers use an oscilloscope to see what the pulse looks like and determine the proper pulse width and measurement time from this information. The Series 2650A SMUs feature a built-in 18-bit fast analog-to-digital (ADC) converter that can digitize the pulse without the need of the oscilloscope. This application demonstrates how to use the fast ADC to digitize the output of the SMU to examine the shape of the pulse.

To introduce you to digitizing pulses, this application shows you how to:

- Adjust timing settings
- Digitize the pulse from a data point in the test
- Plot digitized data
- Read the digitized pulse to configure the correct timing settings

To make connections to the test fixture for this test, refer to Configure the test fixture (on page 4-1).

To do the test, you do the following steps:

1. Configure the test fixture.
2. Load the IdVdStepVg test that was created in MultiMode (on page 4-4).
3. Configure the test to digitize a pulse.
4. Configure the plot to display the digitized data.
5. Adjust the timing settings and then use the digitize function to review the changes.

Configure the test to digitize a pulse

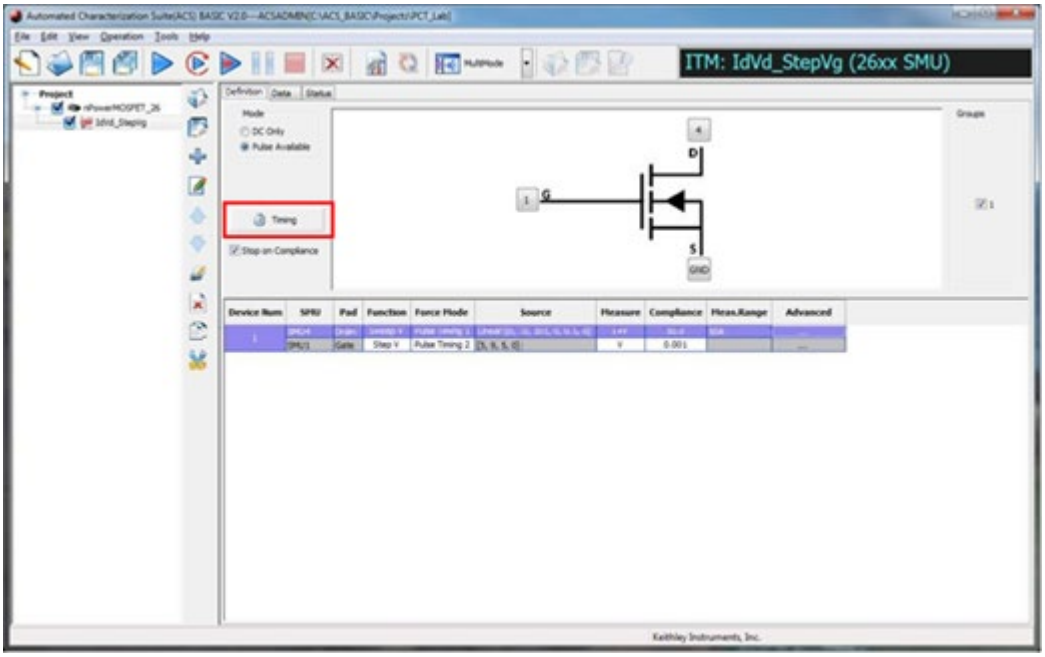
NOTE

For instructions on creating a new IdVd_StepVg test, refer to Add the IdVd_StepVg test to the project (on page 4-18).

To configure the test to digitize a pulse:

1. Select the **IdVd_StepVg** test.
2. Select the **Definition** tab.
3. Select **Timing**, highlighted in the following figure, to open the ITM Timing dialog.

Figure 46: Timing button



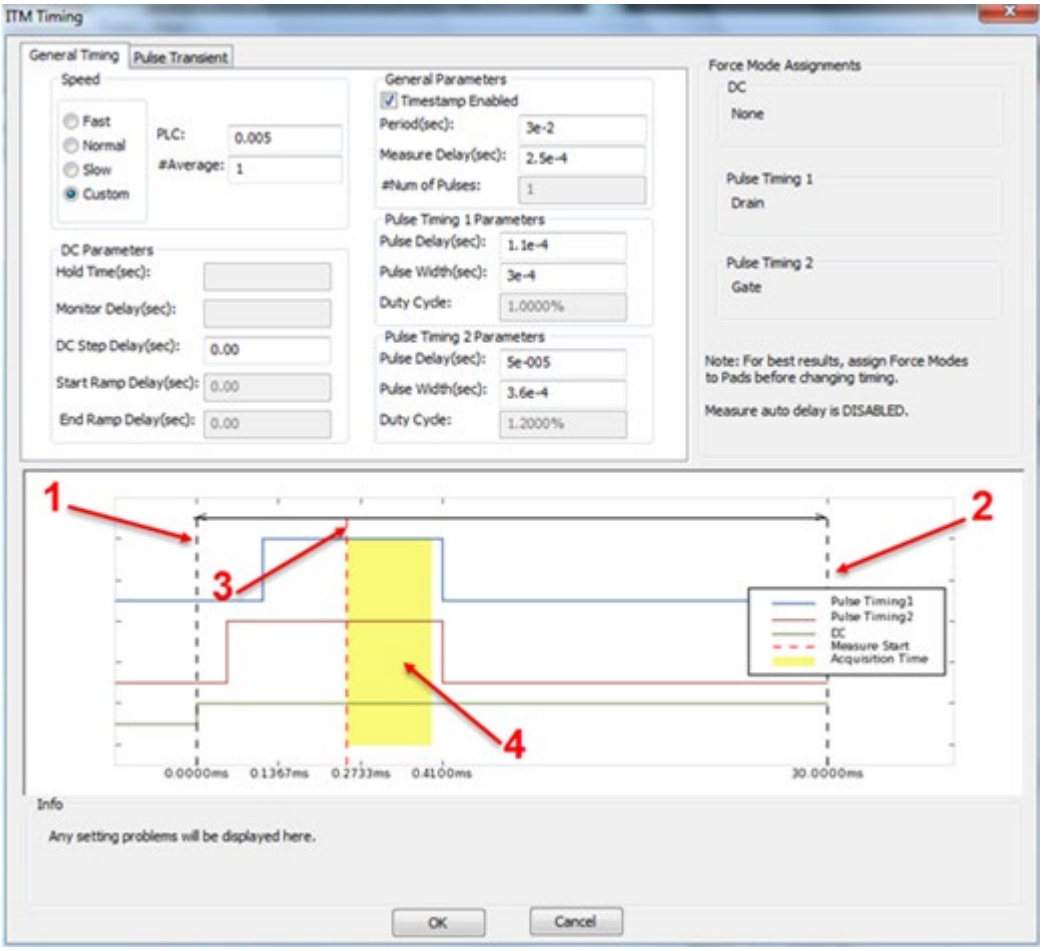
Configure the General Timing tab settings

You configure the SMU output timing and measurements in the General Timing tab of the ITM Timing dialog. The following table describes each of the setting categories.

ITM Timing dialog, General Timing tab setting categories

Category	Function
Speed	Adjust the measurement aperture of the integrating ADC and configure any averaging.
DC Parameters	Timing settings for outputting dc signals. Most of these settings can only be changed if the test is running under DC Only Mode, which is set in the Test Definition dialog.
General Parameters	Settings for the period between data points and for when the measurement is made relative to the start of the period.
Pulse Timing 1 and 2 Parameters	Configure the Pulse Width of any pulse signals and specify when the pulse is output relative to the start of the period.
Force Mode Assignments	Displays which SMUs are assigned to each of the three timing configurations.

Figure 47: ITM Timing dialog



In the previous figure, the output preview is based on the settings for the DC Parameters, Pulse Timing 1 Parameters, and Pulse Timing 2 Parameters.

Preview output definitions

1	Start of a period
2	End of a period
3	Measurement trigger time
4	Measurement aperture (area)

To ensure good pulsed measurements, this aperture must be in the width of the pulse. It should also be placed far enough from the leading edge of the pulse to ensure that the signal has settled before the measurement is started.

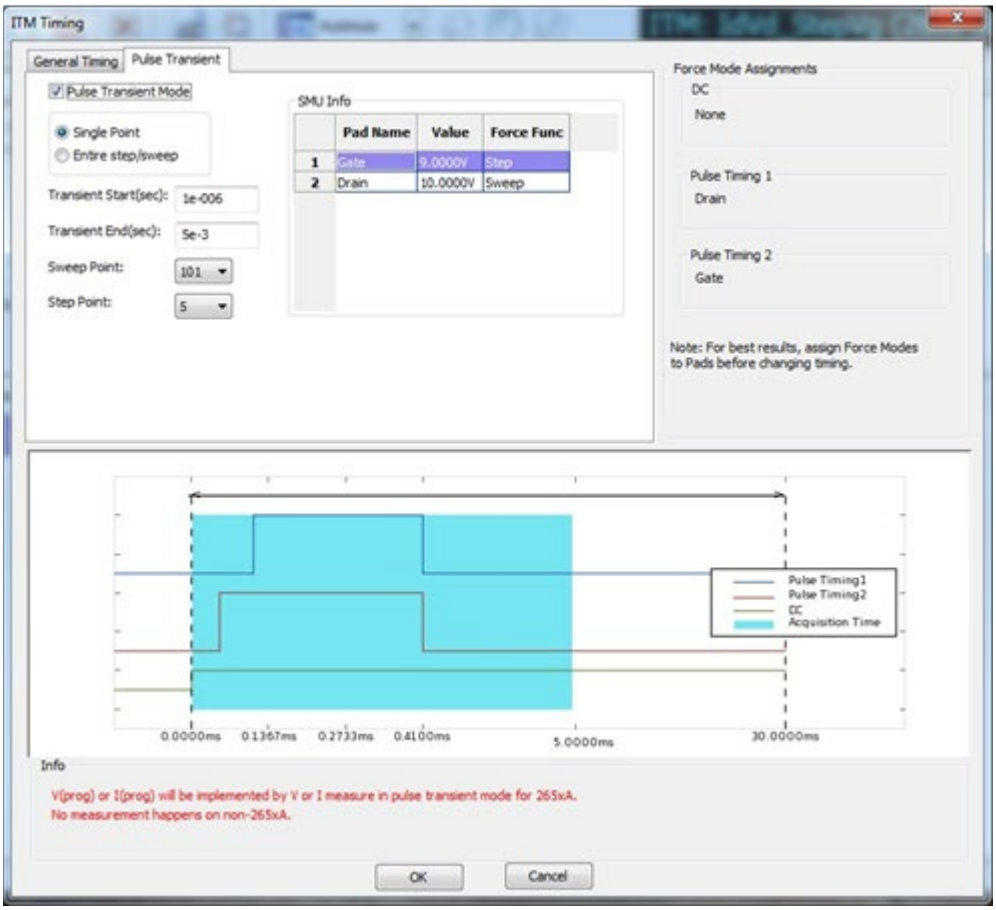
To capture digitized pulse waveforms, capture the timing data by selecting Timestamp Enabled in the General Parameters.

You will also enable and configure Pulse Transient Mode, as described in the following topic.

Configure the Pulse Transient tab settings

You enable and configure the digitize feature of the 2650A Series SMUs in the Pulse Transient tab of the ITM Timing dialog. The following table describes each of the settings.

Figure 48: ITM Timing dialog, Pulse Transient tab



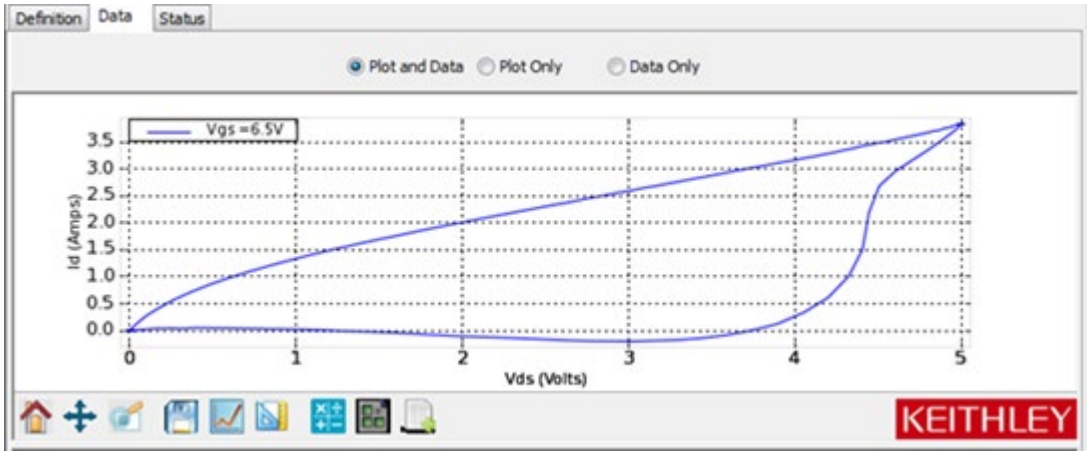
ITM Timing, Pulse Transient tab setting categories

Setting	Function
Pulse Transient Mode	Digitizes a single point of the step/sweep sequence. Selecting Pulse Transient Mode enables the mode and the controls to configure the mode.
Single Point / Entire step/sweep	Controls whether ACS Basic goes directly to the selected step/sweep point and digitizes it or if it runs through the entire step/sweep sequence to digitize the selected point. To get to results quickly, use Single Point. If the data you get when going directly to the point differs from the data you get when you run the entire sweep, select Entire step/sweep to see results that most closely match the output when the full test is run. Differences in data is most commonly due to device self-heating.
Transient Start / Transient End	Sets the start and end times of the digitizing window and are relative to the start of the period. This window is represented in the previous figure by the blue shaded area.
Sweep Point / Step Point	Selects which points in the step/sweep sequence you want to digitize.
SMU Info	Displays the programed levels for the SMUs at that step and sweep point. By default, the last point of the step/sweep sequence is selected, which corresponds to the point where there is 7 V on the Gate and 10 V on the Drain.
Force Mode Assignments	Displays which SMUs have been assigned to each of the three timing configurations.

To configure the digitize feature:

1. Select Step and Sweep points that correspond to a Gate voltage of 6.5 V and a Drain voltage of 5 V.
2. Select **Pulse Transient Mode** to enable pulse transient mode.
3. Set Transient Start to **0**.
4. Set Transient End to **1e-3**.
5. Set the Sweep Point to **51**.
6. Set the Step Point to **4**.
7. Select **OK**.
8. Select the **Data** tab.
9. Select Run (▶) to start the test. The results are displayed on the Data tab and resemble the following figure.

Figure 49: ITM Timing test results



By default, the graph for the IdVd_StepVg test is configured to show current versus voltage. To get a scope-like view, you need to plot the signals versus time. Since the default plot is already setup for displaying the IV curves of the device, it is preferable to not make any changes to its settings when trying to view the digitized data. Instead, create a new plot to graph the data.

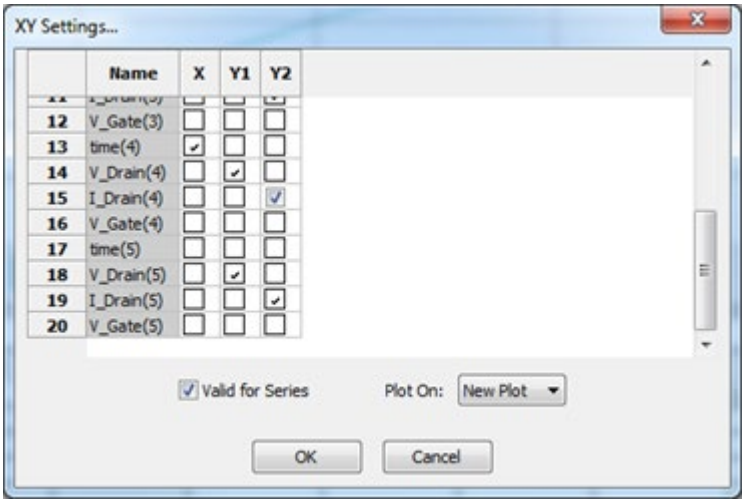
Create a new plot

1. Select the plot icon, then select **New Plot**.

Figure 50: New Plot

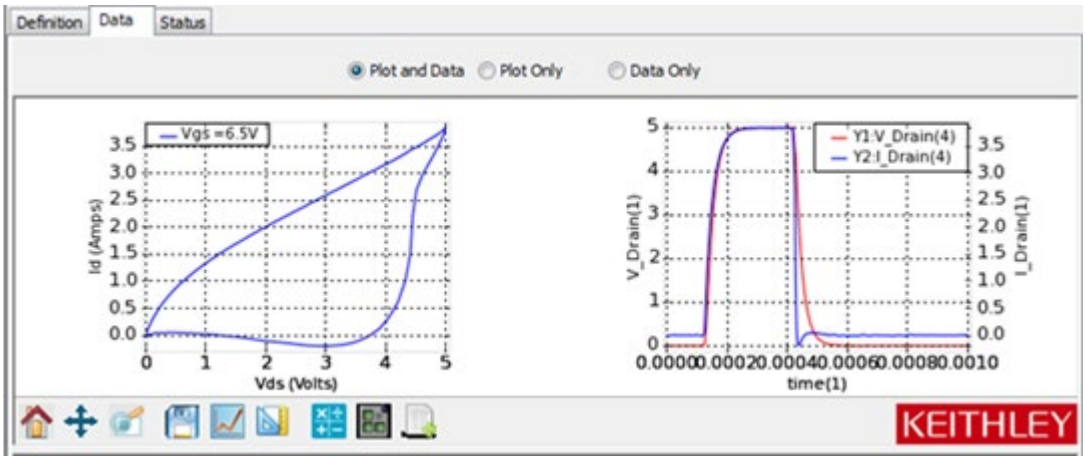
2. In the XY Settings dialog, scroll down to **time(4)**.
3. For time(4), select **X**.
4. For V_Drain(4), select **Y1**.
5. For I_Drain(4), select **Y2**.
6. Select **OK**.

Figure 51: XY Settings dialog



The digitized data now appears on a second plot to the right of the original. The voltage waveform is shown on the plot in red and the current waveform is shown on the plot in blue.

Figure 52: New digitized data



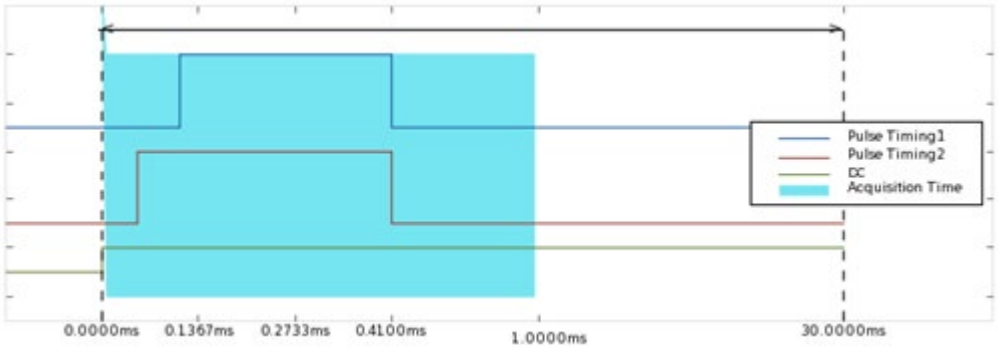
Adjust the pulse timing settings

When a waveform has been established, you can change some of the timing settings to observe differences.

To change the timing settings:

1. Select the **Definition** tab.
2. Select **Timing**.

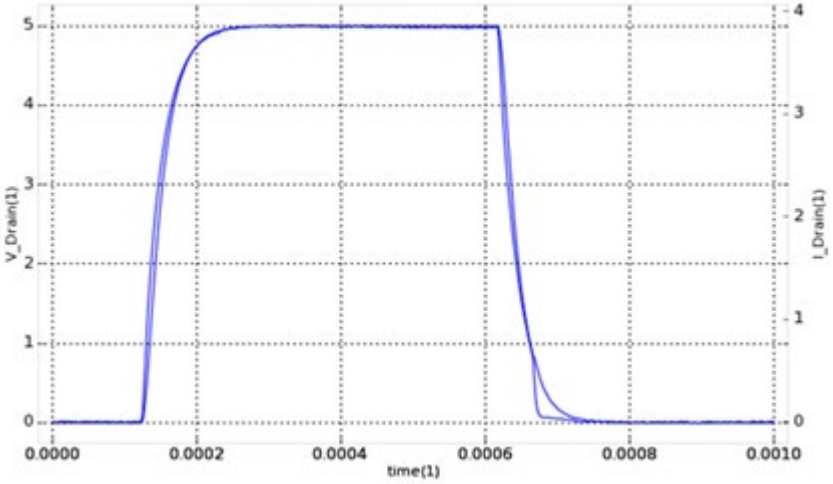
Figure 53: Timing example waveform



In this test, the Drain is configured to use Pulse Timing 1 and the Gate is configured to use Pulse Timing 2. The default settings have the rising edge of the Gate signal (Pulse Timing 2) 60 µs before the rising edge of the Drain signal and the falling edge of both signals occurring at the same time.

3. Change the Pulse Width of Pulse Timing 1 to **5e-4** (500 µs).
4. Change the Pulse Width of Pulse Timing 2 to **6e-4** (600 us).
5. Set the Measure Delay to **4e-4** (400 us).
6. Set the Period to **5e-3** (50 ms).
7. Select **OK**.
8. Select the Data tab of the Test dialog.
9. Select **Run** (▶) to start the test.

Figure 54: Graphed results



After you run the test, you should see a graph similar the one above. These results show that the signal settles quickly, so dc measurements with these timing parameters should produce repeatable measurements.

Off-state characteristics

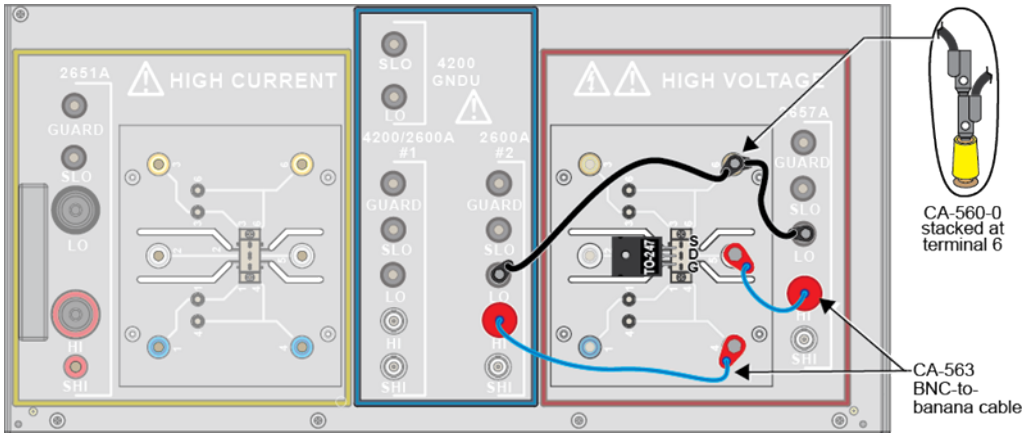
Configure the test fixture

The PCT supports either the Keithley Instruments Model 8010 or Model 8010 test fixture. Follow one of the following procedures depending on your test fixture.

To configure the Model 8010 test fixture:

1. On the High Voltage side of the Model 8010 test fixture, insert the test sample device into the test socket. Place the device with the Gate pin closest to the front of the test fixture.
2. Wire the test fixture as shown in the following figure:
   - Connect the 2657A HI signal to the Drain terminal.
   - Connect the 4200/2600 #2 signal to the Gate terminal.
   - Connect the LO terminals of the 2657A and the 4200/2600 #2 signal to the Source terminal.

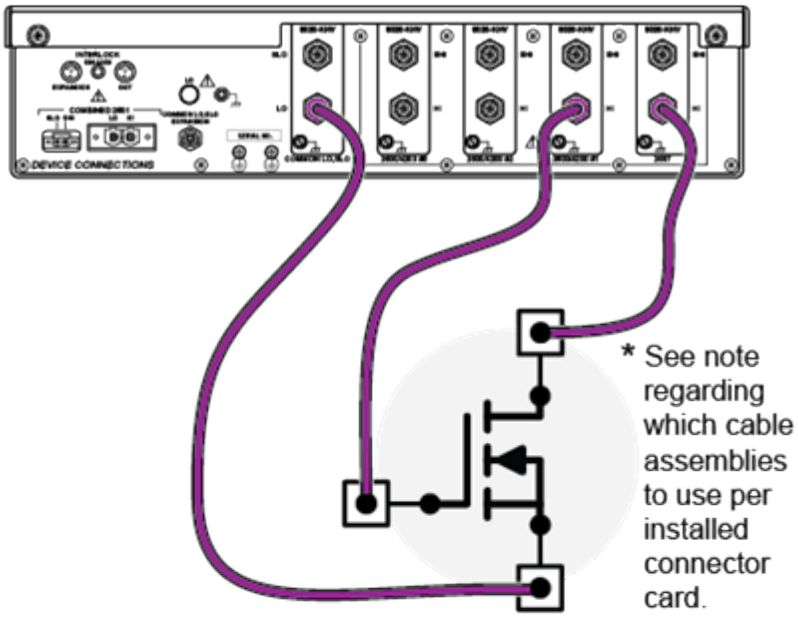
Figure 55: Leakage current measurement test fixture configuration

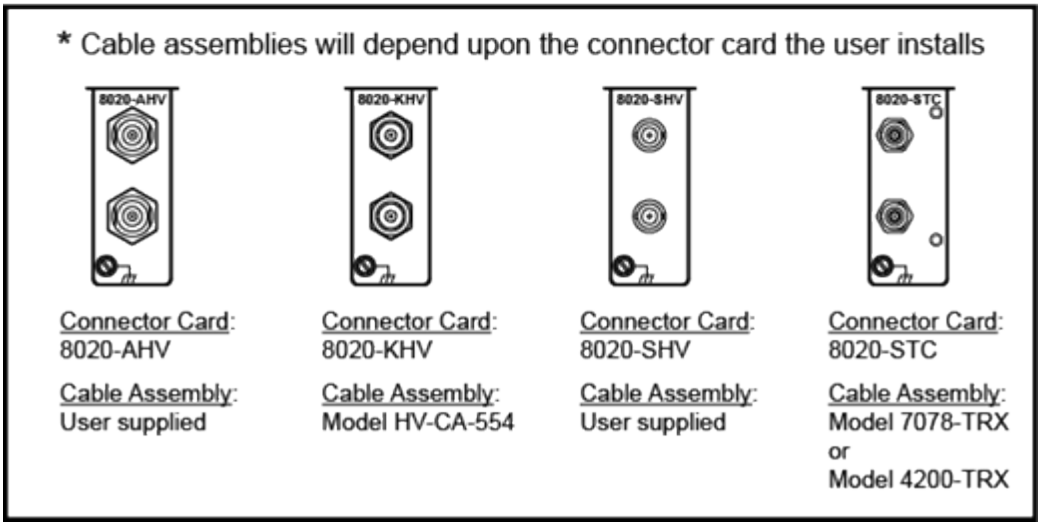


To configure the Model 8020 interface panel:

1. Wire the test fixture as shown in the following figure:
   - Connect the LO signal to the Source terminal of the device.
   - Connect the 2657 HI signal to the Drain terminal of the device.
   - Connect the 2600/4200 #1 HI signal to the Gate terminal of the device.

Figure 56: Configuring the 8020 interface panel for leakage current measurement





Measuring leakage current in MultiMode

Characterizing a semiconductor device in its off-state includes leakage current measurements, sourcing a voltage, and measuring a small current. These measurements require sensitive equipment with proper guarding and shielding.

To introduce you to measuring leakage current, this application shows you how to use MultiMode to perform an Idss test on a high-voltage MOSFET using the sample part provided in the PCT-DOC-KIT.

To do the test, you do the following steps:

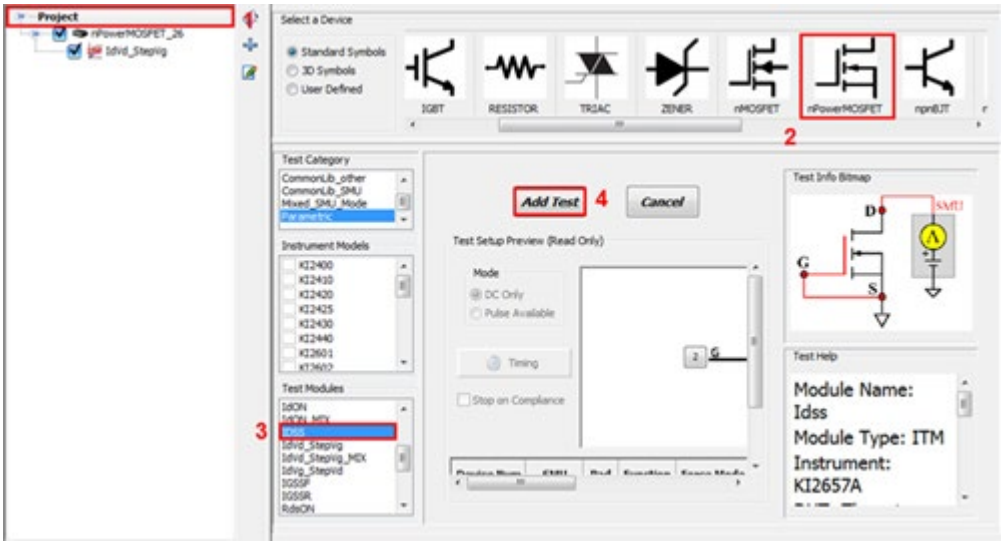
1. Configure the connections to the device
2. Add the Idss test to the project
3. Configure the test settings to suit the DUT
4. Run the test and obtain the leakage current from the device

Add and configure the Idss test

To add and configure the Idss test:

1. In the Project Navigation Tree, select **Project** to display the Test Libraries.

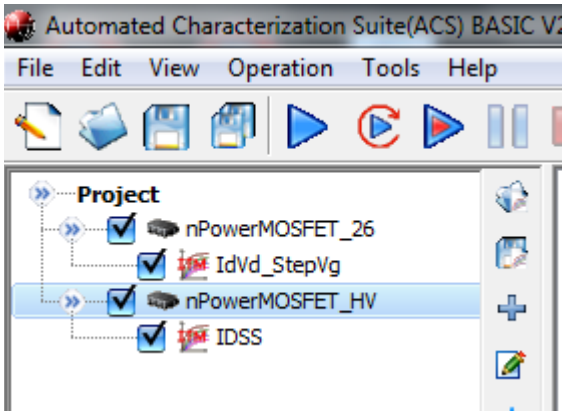
Figure 57: Test Libraries



2. Select the nPowerMOSFET device from the Select a Device pane.
3. Select the IDSS test from the Test Modules list.
4. Select **Add Test** to add the test to your project.
5. Select **New device**, then select **OK**. You now have the device nPowerMOSFET_26_1 in your project tree.

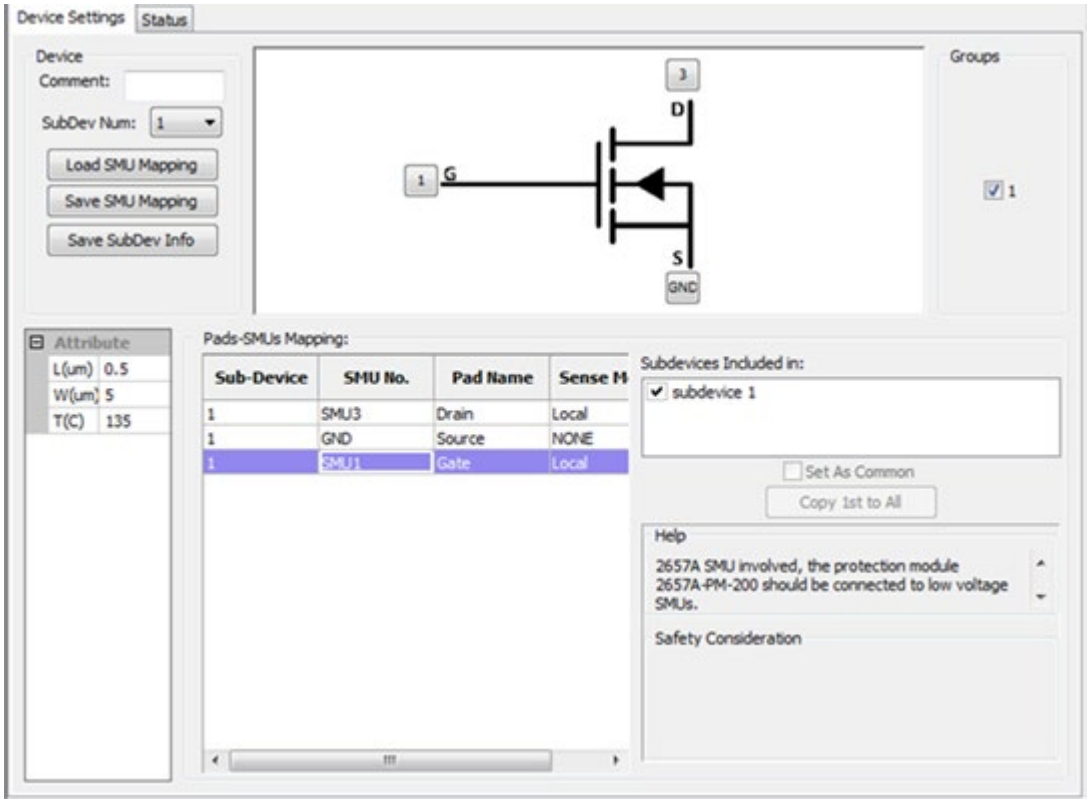
6. Right-click the device and select **Rename**.
7. Change the name to **nPowerMOSFET_HV**.
8. Press <Enter> to save the change.

Figure 58: New device in project navigation tree



9. Select the nPowerMOSFET_HV device.
10. Use Pads-SMUs mapping, then follow one of the next steps, depending on your test fixture.
    - For the Model 8010, attach SMU 3 (2657A) to the Drain and the SMU2 (2636B SMU B) to the Gate
    - For the Model 8020, configure the SMU3 (2657A) to the Drain and SMU1 (2636B SMU A) to the Gate
11. Set the Sense Mode for both SMUs to **Local**.
12. Configure the Source terminal to GND.

Figure 59: Device Settings dialog (Model 8020 connections)



13. Select the **Idss** test under the IGBT_26 device in the Project Navigation Tree.
14. Select the **Definition** tab.
15. Set the Source value to **1000 V**.

Figure 60: Setting Source value to 1000 V

Device Num	SMU	Pad	Function	Force Mode	Source	Measure	Compliance	Meas.Range	Advanced
1	SMU3	Drain	Bias V	DC	1000.0	I+V	0.001	auto	...
	SMU1	Gate	GND						

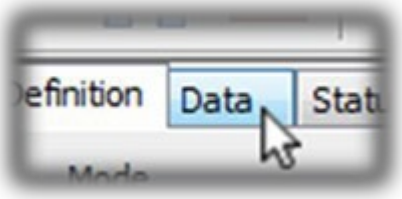
16. For the gate SMU (SMU 1 or SMU 2), set the source function to **GND**.
17. Set the compliance (current limit) of both SMUs to **1 mA**.
18. Select measurement of current and voltage for SMU 3 (2657A).

NOTE

If you want to profile the leakage current of the device as a function of voltage, set the source function to sweep V. Configure the sweep settings in the Source field.

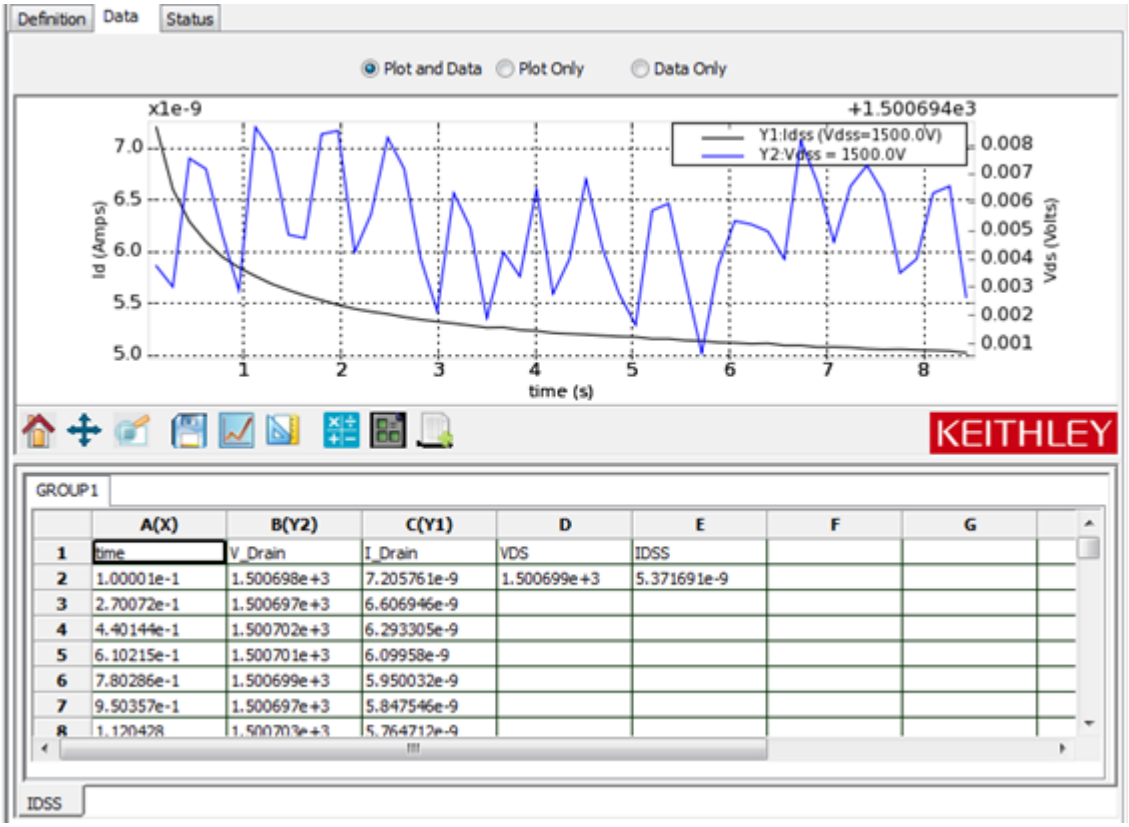
19. Select the **Data** tab.

Figure 61: Data tab



Sample data for the DSS test is displayed.

Figure 62: Data tab with sample DSS test data

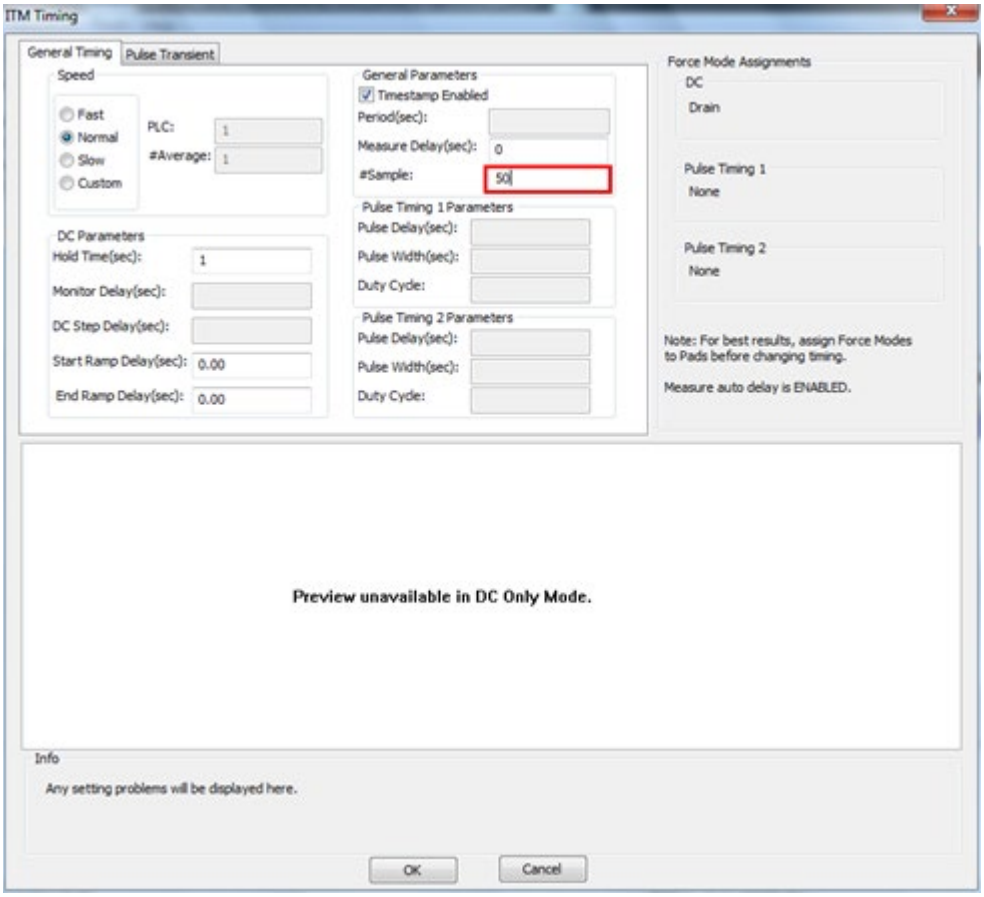


	A(X)	B(Y2)	C(Y1)	D	E	F	G
1	time	V_Drain	I_Drain	VDS	IDSS		
2	1.00001e-1	1.500698e+3	7.205761e-9	1.500699e+3	5.371691e-9		
3	2.70072e-1	1.500697e+3	6.606946e-9				
4	4.40144e-1	1.500702e+3	6.293305e-9				
5	6.10215e-1	1.500701e+3	6.09958e-9				
6	7.80286e-1	1.500699e+3	5.950032e-9				
7	9.50357e-1	1.500697e+3	5.847546e-9				
8	1.120428	1.500703e+3	5.764712e-9				

The current through the device and the voltage across the device are plotted versus time on the graph. This test works by sourcing the test voltage and taking many readings. The readings are then averaged to give you a final value.

You can adjust the number of samples taken and averaged in the Timing dialog of the test. Under General Parameters, enter the number of readings for #Sample. See the following figure.

Figure 63: Sample quantity adjustment

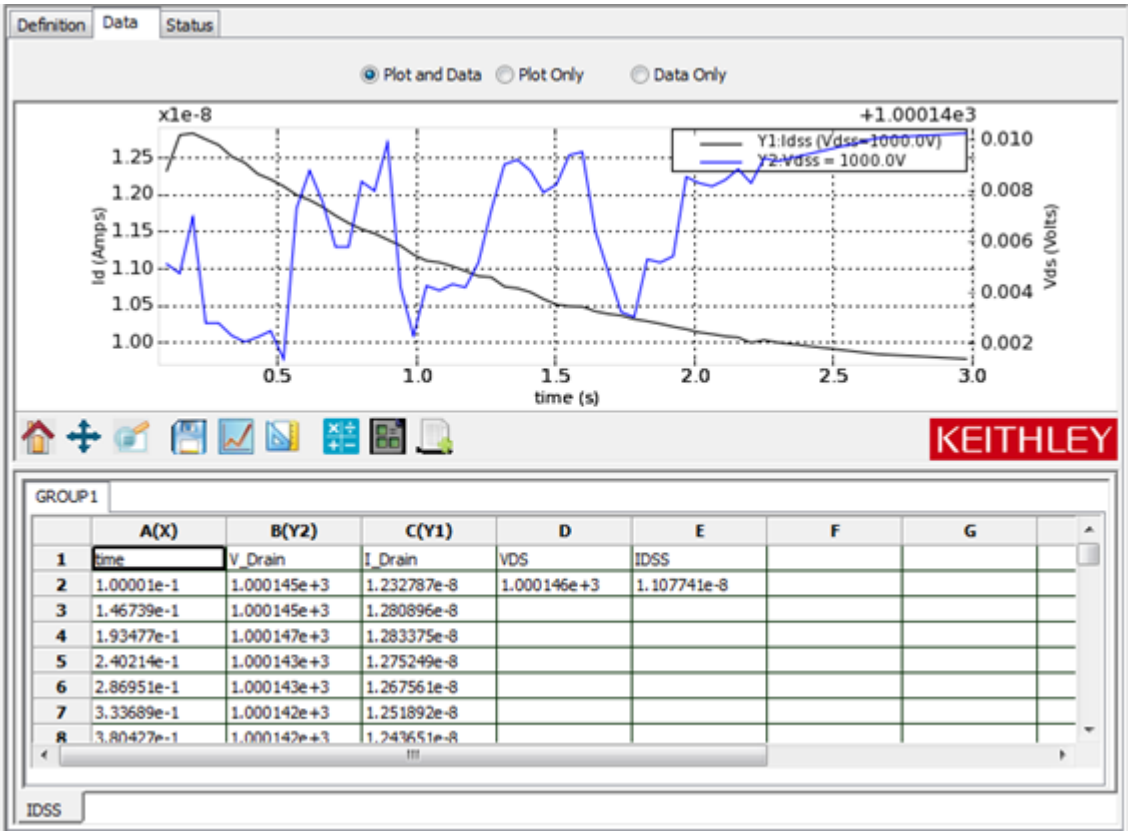


You can also configure the test to stop if the compliance (current limit) is reached. Select **Stop on Compliance** to have the test automatically stop if any SMU reaches current limit.

Run the test

Select **Run** (▶) to start the test.

Figure 64: Data and results of IDSS test



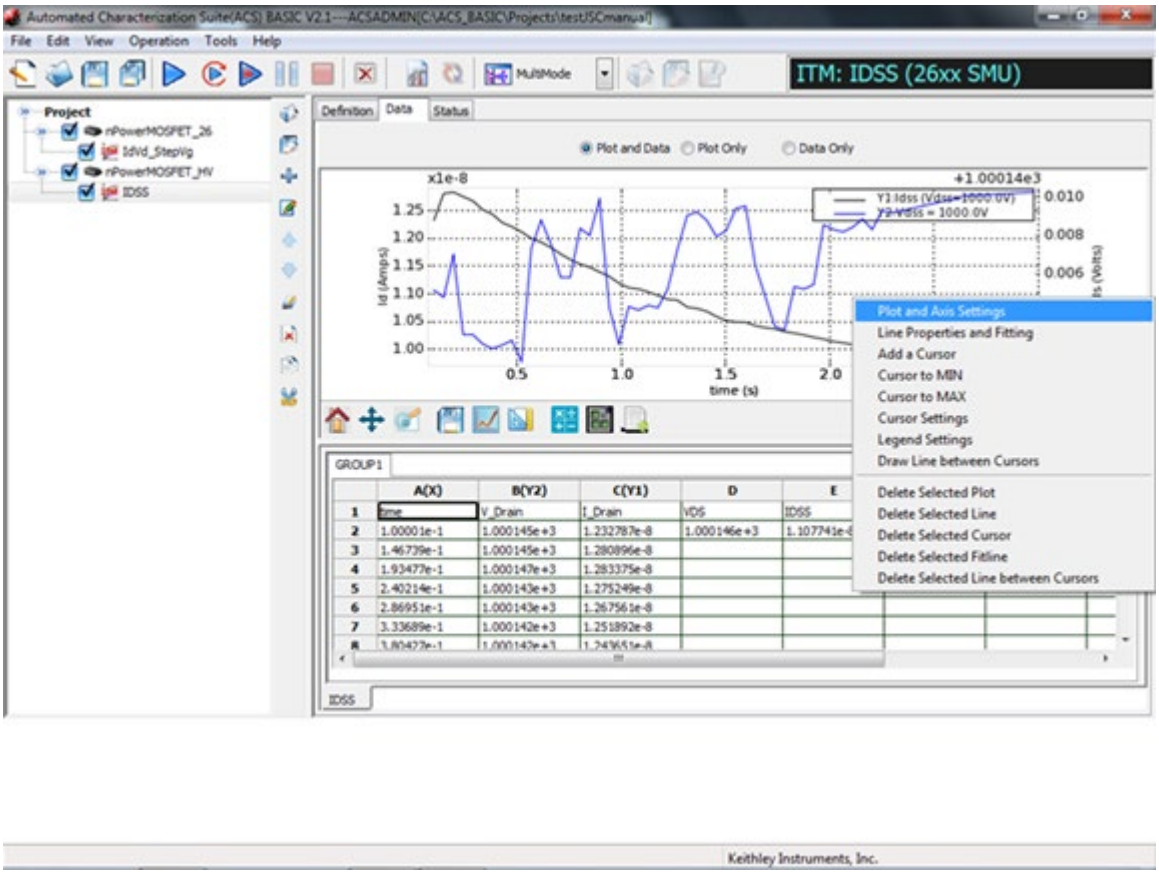
	A(X)	B(Y2)	C(Y1)	D	E	F	G
1	time	V_Drain	I_Drain	VDS	IDSS		
2	1.00001e-1	1.000145e+3	1.232787e-8	1.000146e+3	1.107741e-8		
3	1.46739e-1	1.000145e+3	1.280896e-8				
4	1.93477e-1	1.000147e+3	1.283375e-8				
5	2.40214e-1	1.000143e+3	1.275249e-8				
6	2.86951e-1	1.000143e+3	1.267561e-8				
7	3.33689e-1	1.000142e+3	1.251892e-8				
8	3.80427e-1	1.000142e+3	1.243651e-8				

The data you collect should look similar to the data seen here. While the voltage data may appear noisy at first, take note of the scale of the plot. You can simplify the plot by adjusting the scale for the voltage readings in the Data tab.

To simplify the plot:

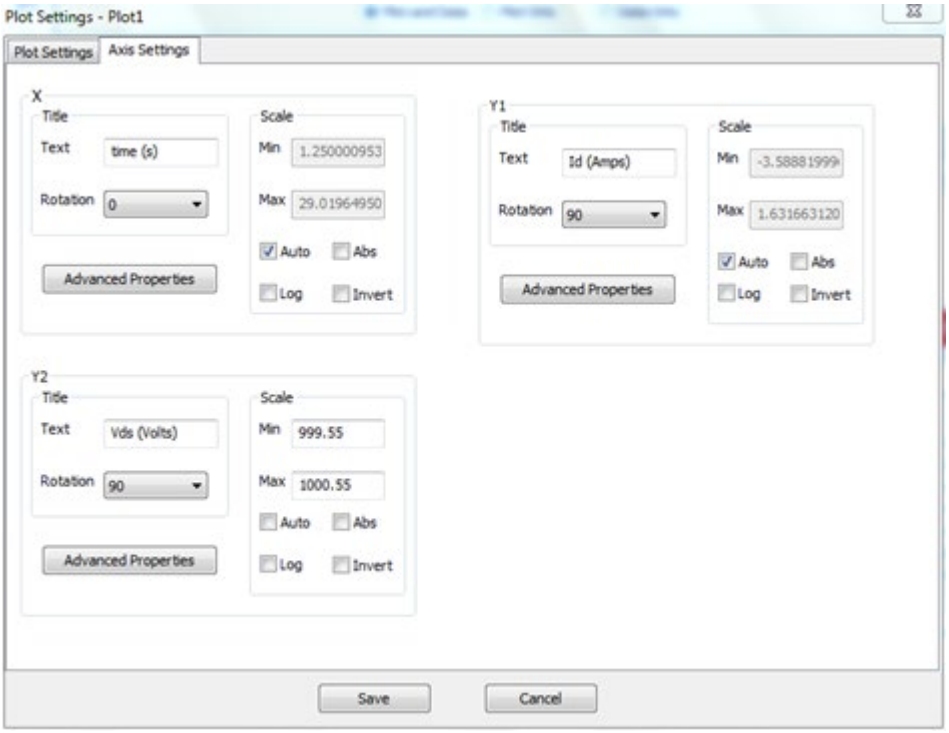
1. Right-click the graph and select **Plot and Axis Settings**.

Figure 65: Plot and Axis Settings



2. Select the **Axis Settings** tab.
3. For Y2, clear **Auto**.
4. Set the Min value to **999.55**.
5. Set the Max value to **1000.55**.

Figure 66: Plot Settings dialog



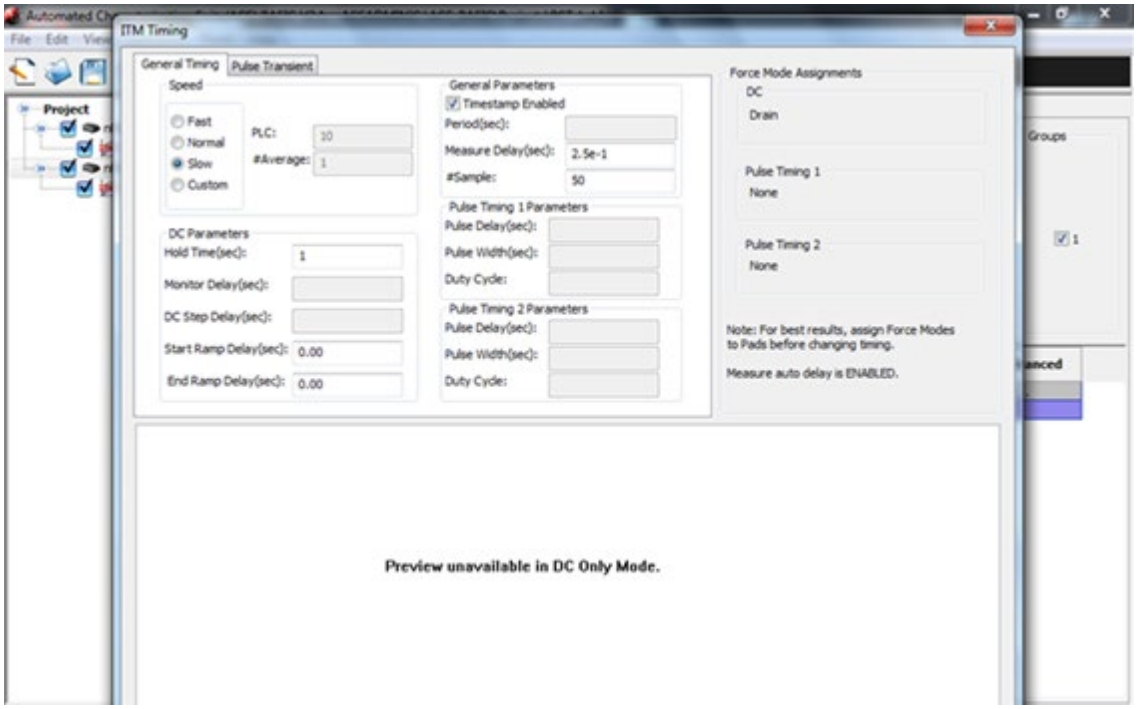
6. Select **Save**.

You can improve the stability of the current measurements by adjusting the timing. Accurate low current measurements typically involve significant settling time and longer integration times.

To refine the Idss results:

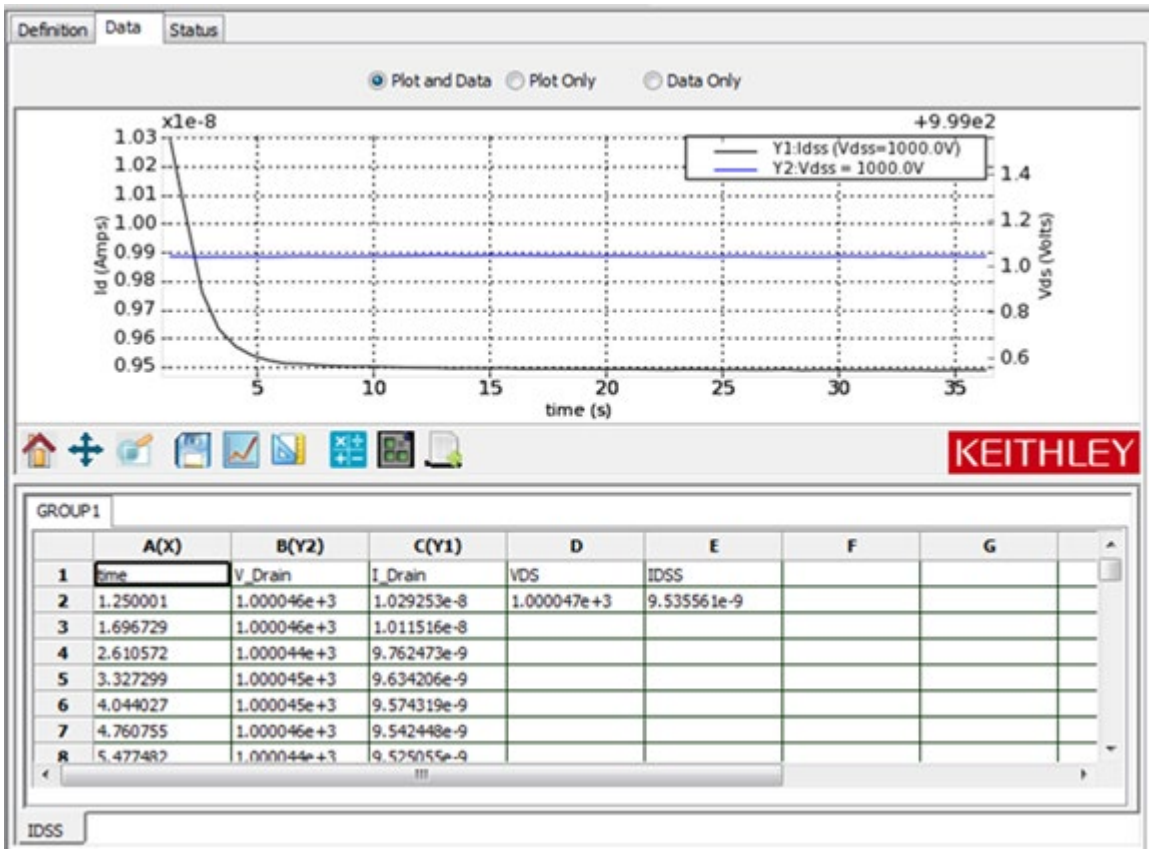
1. Open the ITM Timing dialog by selecting **Timing**.
2. Set the Hold Time to **1 s**.
3. Set the speed to **Slow**.
4. By default, auto delay is enabled, but you can add delay time. Set the Measure Delay to **0.25 s**, which sets the SMU to delay 250 ms beyond the auto delay time for increased settling. See the following figure for an example.

Figure 67: ITM Timing dialog with settings



5. Select **OK**.
6. Select **Run** (▶).
7. Note the improved Idss results. Your refined results should be similar to those in the following figure.

Figure 68: Refined Idss results



	A(X)	B(Y2)	C(Y1)	D	E	F	G
1	Time	V_Drain	I_Drain	VDS	IDSS		
2	1.250001	1.000046e+3	1.029253e-8	1.000047e+3	9.535561e-9		
3	1.696729	1.000046e+3	1.011516e-8				
4	2.610572	1.000044e+3	9.762473e-9				
5	3.327299	1.000045e+3	9.634206e-9				
6	4.044027	1.000045e+3	9.574319e-9				
7	4.760755	1.000046e+3	9.542448e-9				
8	5.477482	1.000044e+3	9.525055e-9				

The datasheet for the sample device specifies a 10 µA maximum value for Idss. The measured leakage current should be much smaller than the specification. Such specifications are typically created using traditional curve tracers, which have limited current measurement resolution and are generally unable to measure currents less than 10 µA. If the measured value exceeds the specification, the device is likely damaged. Verify connections and then re-test.

Section 5

C-V applications on power MOSFETs

In this section:

Overview and requirements 5-1
Background of MOSFET capacitance measurements 5-1
Safety precautions and discharge procedures 5-4
Model 8010 connections 5-10
Model 8020 connections 5-15
Perform connection compensations on C-V measurements ...5-20
Make a Ciss measurement 5-38
Make a Coss measurement 5-46
Make a Crss measurement 5-57
Optimizing Crss measurement connections for difficult measurements 5-64

Overview and requirements

This section describes circuit-level power MOSFET capacitance measurements on a device up to 3 kV using a Keithley Instruments Model 8020 with the optional 8020-CVU installed or the Model 8010 with the CVU-3K-KIT option and a 2600-PCT-3B with the PCT-CVU accessory unit.

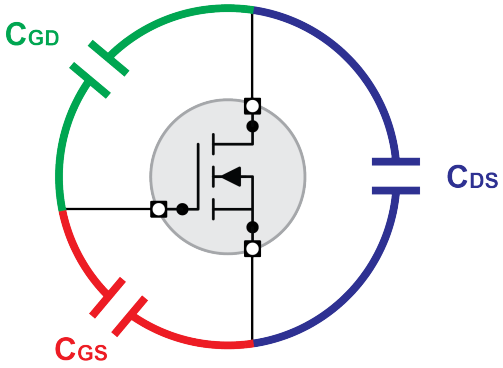
See the Model 8010 and Model 8020 User Guides, available at tek.com/keithley, for connection information on 2-terminal devices and for component-level capacitance measurements of power MOSFETs.

Background of MOSFET capacitance measurements

There are two different ways to look at the capacitance of three-terminal power semiconductor devices such as MOSFETs, BJTs, and IGBTs: At the component level and at the circuit level. Looking at the capacitances at the component level involves a characterization of capacitance between every device terminal. Looking at the capacitance at the circuit-level involves a characterization of the combination of component level capacitances.

As an example, the following figure illustrates the component level capacitances of a power MOSFET.

Figure 69: Component-level capacitances for power MOSFET



The following three figures illustrate the relationship between the component level and circuit-level capacitances for a power MOSFET. Similar capacitance measurements can also be made for BJT and IGBT devices.

Figure 70: Diagram of input capacitance for a power MOSFET

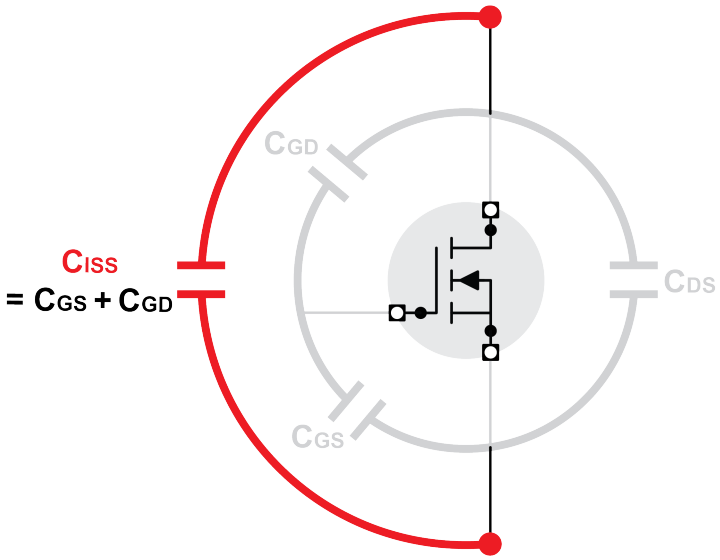


Figure 71: Diagram of output capacitance for a power MOSFET

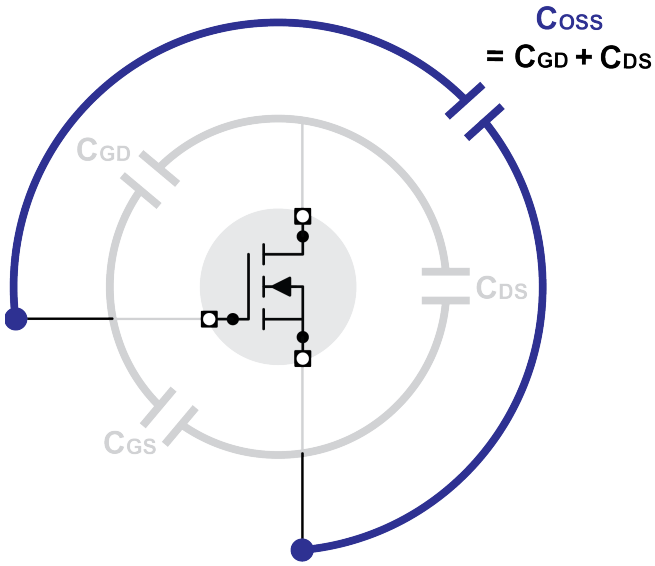
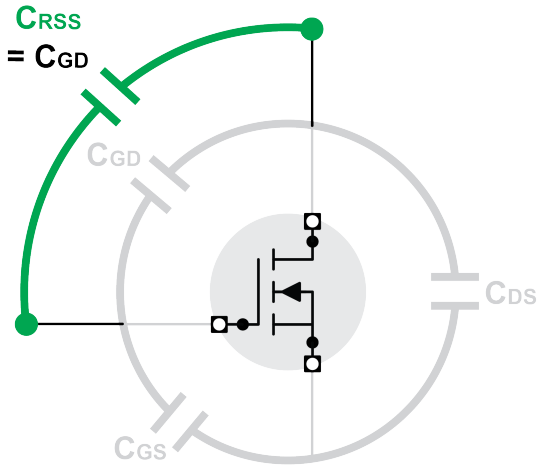


Figure 72: Diagram of reverse transfer capacitance for a power MOSFET



Device capacitance typically varies with applied voltage. Complete characterization of the DUT requires knowledge of the capacitance at the maximum rated voltage. The remainder of this section reviews the safety precautions, connection diagrams between the instrumentation, the test fixtures, and the DUT for high-voltage capacitance measurements.

Safety precautions and discharge procedures

WARNING

Hazardous voltages may be present in the test system. To prevent electrical shock that could cause injury or death, never make or break connections to the instruments in the system while the output is on. Power off the equipment from the front panel or disconnect the main power cord from the rear of the Series 2600-PCT-xB and discharge any energy storage components (for example, capacitors or cables) before handling cables connected to the outputs. Putting the equipment in standby mode does not guarantee that the outputs are not powered if a hardware or software fault occurs.

Discharging bias tee capacitance in the Model 8010

The capacitance of the bias tees in the Model CVU-200-KIT and CVU-3K-KIT can hold charge. Devices with sufficient capacitance can also hold charge. A shock hazard exists if a proper discharge is not performed and you open the Model 8010 cover and touch one of the instrument or device terminals in the fixture. Never assume that the safety interlock discharges the system.

The Model 2657A SMU is programmed in ACS Basic to safely discharge the bias tee and device capacitance after completing a high-voltage C-V test. However, an operator error, a power outage, or an unforeseen event can leave a dangerous charge in the system. Therefore, the Model CVU-3K-KIT includes the 8020-DP High-Voltage Discharge Probe. Use this discharge probe to manually discharge the bias tee capacitance and system capacitance within the Model 8010 by touching the banana jacks and BNC connectors inside of the fixture.

See the following figure for an overview of the Model 8020-DP High Voltage Discharge Probe.

Figure 73: Model 8020-DP High Voltage Discharge Probe

Perform system capacitance discharge with the Model 8020-DP High Voltage Discharge Probe:

1. Connect the Model 8020-DP ground connection cable to an unused protective earth screw on one of the bias tees.

Figure 74: 8020-DP connected to bias tee protective earth screw

CAUTION

Do not stack cable connectors on the protective ground screw. Connect only to an unused screw.

2. Open the lid of the Model 8010 test fixture.
3. While holding the 8020-DP by the handgrip only, use the probe tip to contact the terminals on the device test board that connect the HI and SHI terminals of the 2657A, as shown the following two figures.

Figure 75: Contacting the HI terminal of the Model 8010 test board

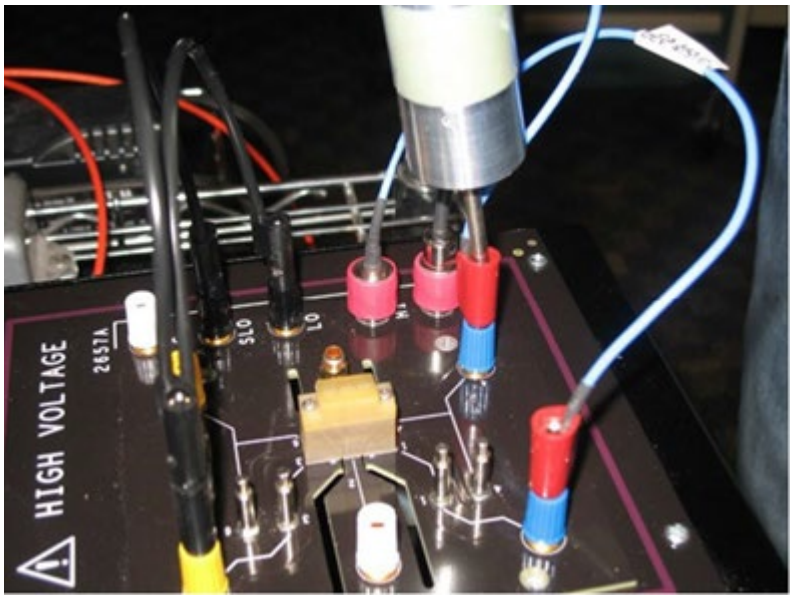
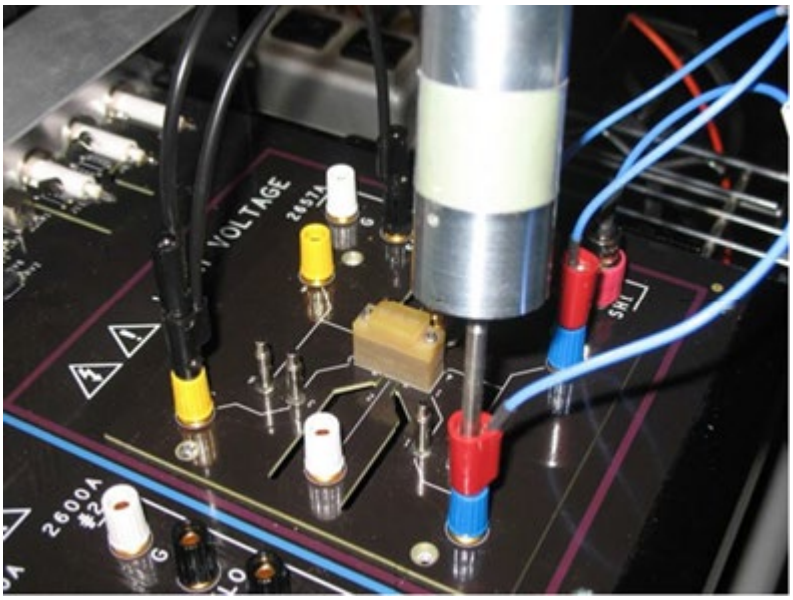
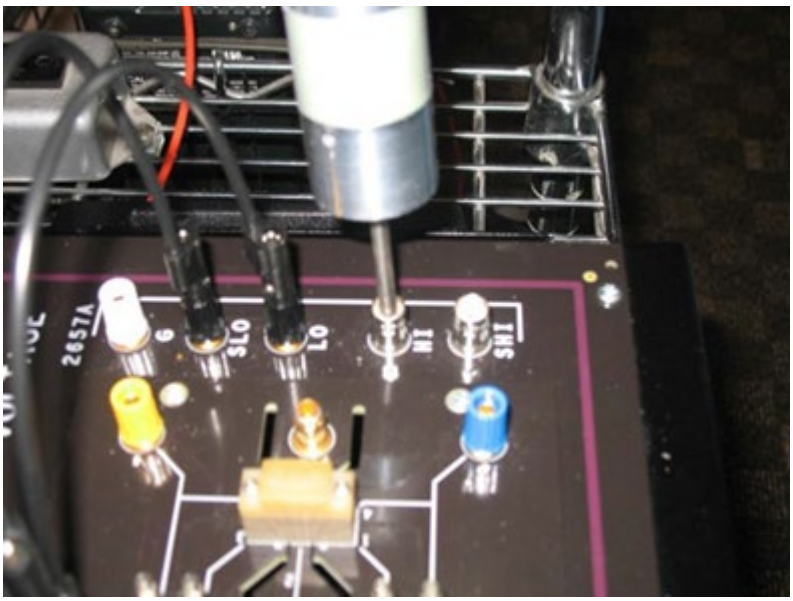


Figure 76: Contacting the SHI terminal of the Model 8010 test board



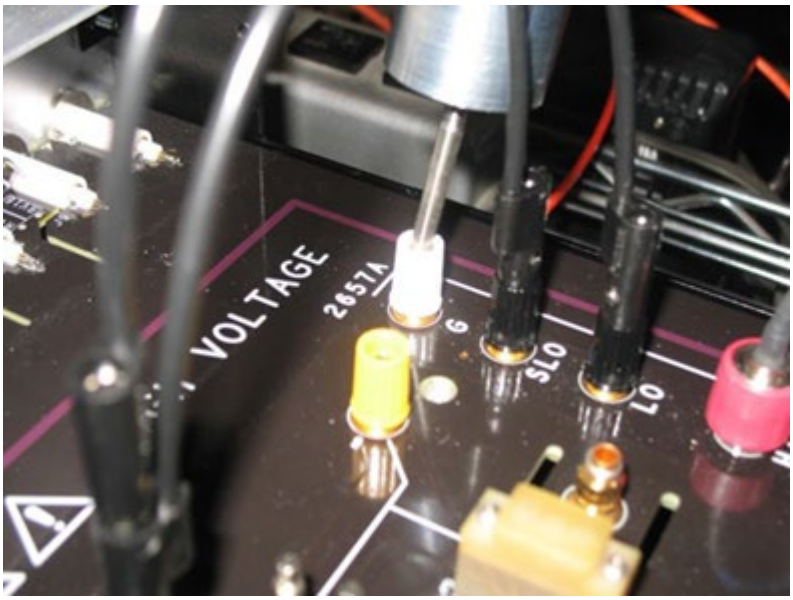
4. If there is no cable connected to the HI and SHI connections of the 2657A, use the discharge probe to contact the center conductors of the HI and SHI BNC connectors.

Figure 77: Contacting the HI BNC connector of the Model 8010 test fixture



5. Maintain contact for at least 1 second to safely discharge system capacitance.
6. Contact the GUARD banana jack of the Model 2657A.

Figure 78: Contacting the GUARD banana connector of the Model 8010 test board



7. Maintain contact for at least 1 second.
8. Repeat discharge procedure on the HI and SHI terminals of the Model 2600B or 4200A within the Model 8010 fixture.

Discharging bias tee capacitance within the Model 8020

The 8020-CVU option for the Model 8020 has internal capacitance that can hold charge. A shock hazard exists if a proper discharge is not performed and the user removes the 8020 top cover or in other ways accesses a live terminal in the system. Never assume the safety interlock discharges the system.

Be sure to use the SMU to discharge the capacitance properly after each test and before removing the top cover of the 8020 or accessing live terminals in the system. The Model 2657A SMU is programmed in ACS Basic to safely discharge the bias tee and device capacitance after completing a high-voltage CV test. A user error or another unforeseen event, such as a power outage, can leave a dangerous charge in the system. Therefore, the Model 8020 with the 8020-CVU option includes a high voltage discharge probe, Model 8020-DP. Use this discharge probe to manually discharge the bias tee capacitance and system capacitance before making adjustments on the 8020 main board or at the device interface.

See the following figure for an overview of the Model 8020-DP High Voltage Discharge Probe.

Figure 79: Model 8020-DP High Voltage Discharge Probe

Perform system capacitance discharge with the Model 8020-DP High Voltage Discharge Probe:

1. Connect the Model 8020-DP High Voltage Discharge Probe ground connection cable to an unused protective earth screw on the Model 8020. Examples are shown in the following figure.

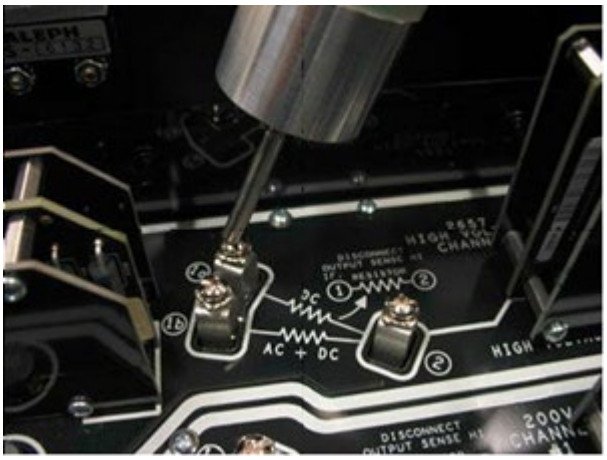
Figure 80: Protective earth (safety ground) screw locations on the Model 8020

CAUTION

Do not stack cable connectors on the protective ground screw. Connect only to an unused screw.

2. Remove the top cover of the Model 8020 High Power Interface Panel.
3. While holding the 8020-DP by the handgrip only, use the probe tip to contact each of the posts at notes 1a, 1b, and 2 on the Model 8020 main board for the high-voltage channel and each of the 200 V channels. See the following figure.

Figure 81: Contacting nodes on the Model 8020 main board



4. Maintain contact for at least 1 second to safely discharge system capacitance.

Discharge system capacitance from SMU front panel interface

If you are controlling the SMUs from the front-panel interface, a best practice is to discharge system capacitance with the SMU output on. Configure the SMU to force 0 V and measure current with a current limit of at least 1 mA. A current measurement of approximately 0 mA indicates a proper discharge. The Keithley Instruments ACS Basic software executes this discharge procedure after completing a high-voltage CV test. ACS Basic sets the Model 2657A output to 0 V with a current limit of 1 mA and holds for 1 second before turning off the output. See the following figure for an illustration.

Figure 82: Model 2657A executing discharge

Model 8010 connections

Refer to the following figures to connect your SMUs, PCT-CVU, and CVU-3K-KIT to the Model 8010. You need to reference these drawings for both the connection compensation and capacitance measurement procedures.

⚠ WARNING

The ground wires must be attached to a known protective earth (safety ground) before turning on the instruments. Failure to attach the ground wires to a known protective earth (safety ground) may result in electric shock.

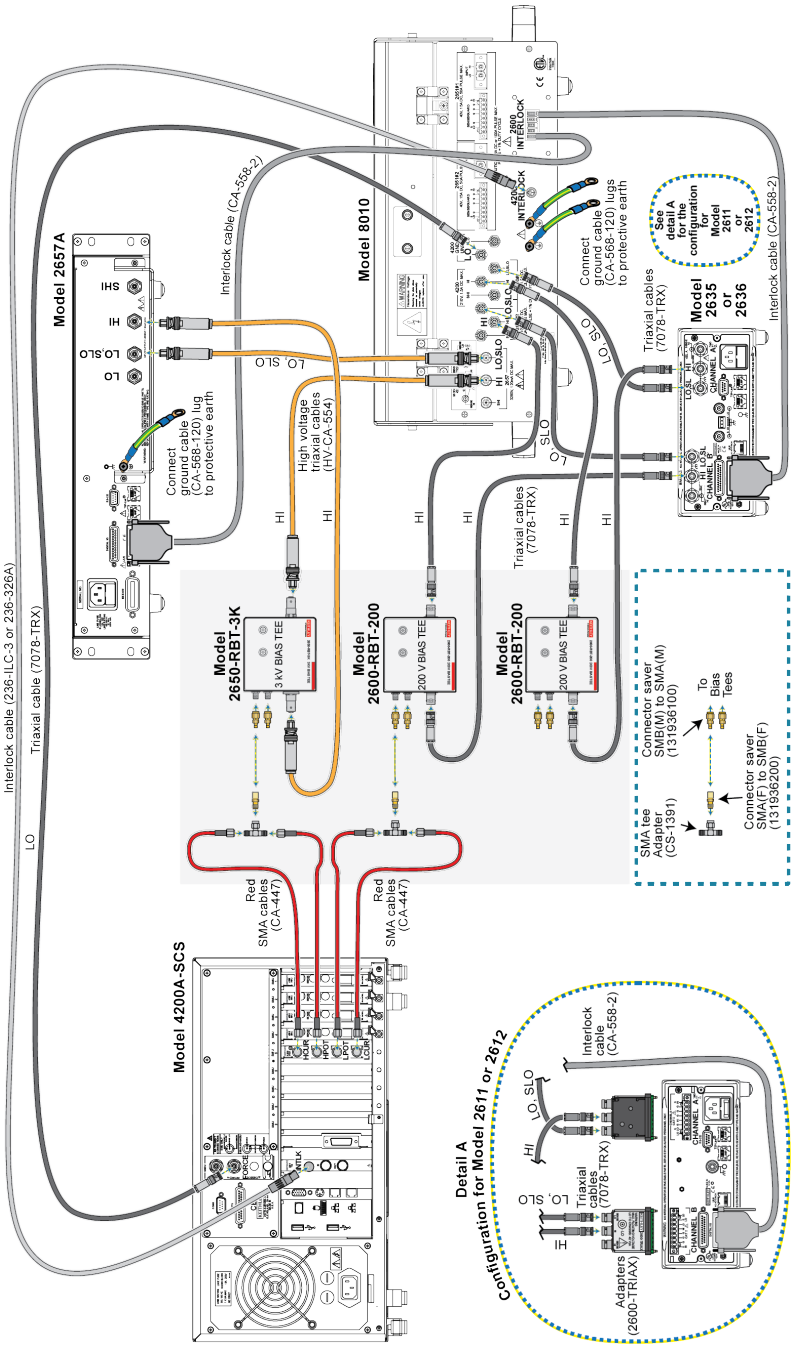
NOTE

The following figures rely on a SMU per bias tee. With the Model 2600-PCT-1B and 2600-PCT-2B, there are not enough appropriate SMUs to connect to bias tees. For these configurations, connect the force terminal of the GNDU of the PCT-CVU to the bias tee that connects to the Source terminal of the FET or the Emitter terminal of the BJT or IGBT.

Model 8010 Crss test connections

The following figure shows the Model 8010 SMU, PCT-CVU, and CVU-3K-KIT connections for the Crss test.

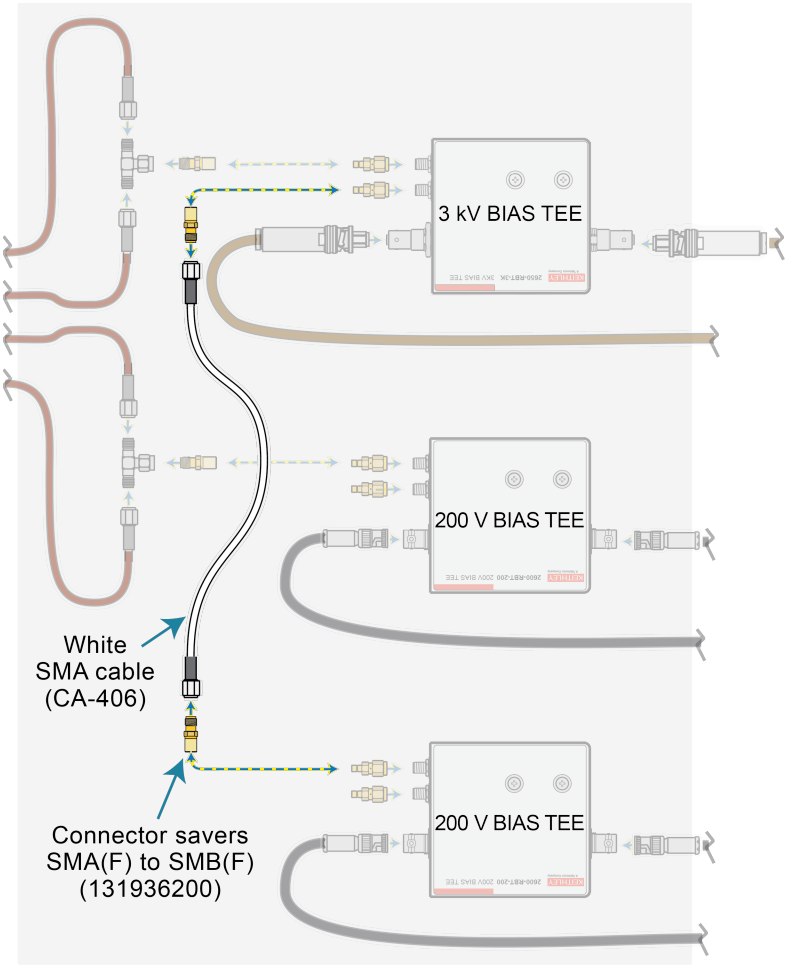
Figure 83: Model 8010 connections for the Crss and Cgd tests



Model 8010 Ciss test connections

The following figure shows the Model 8010 SMU, PCT-CVU, and CVU-3K-KIT connections for the Ciss test.

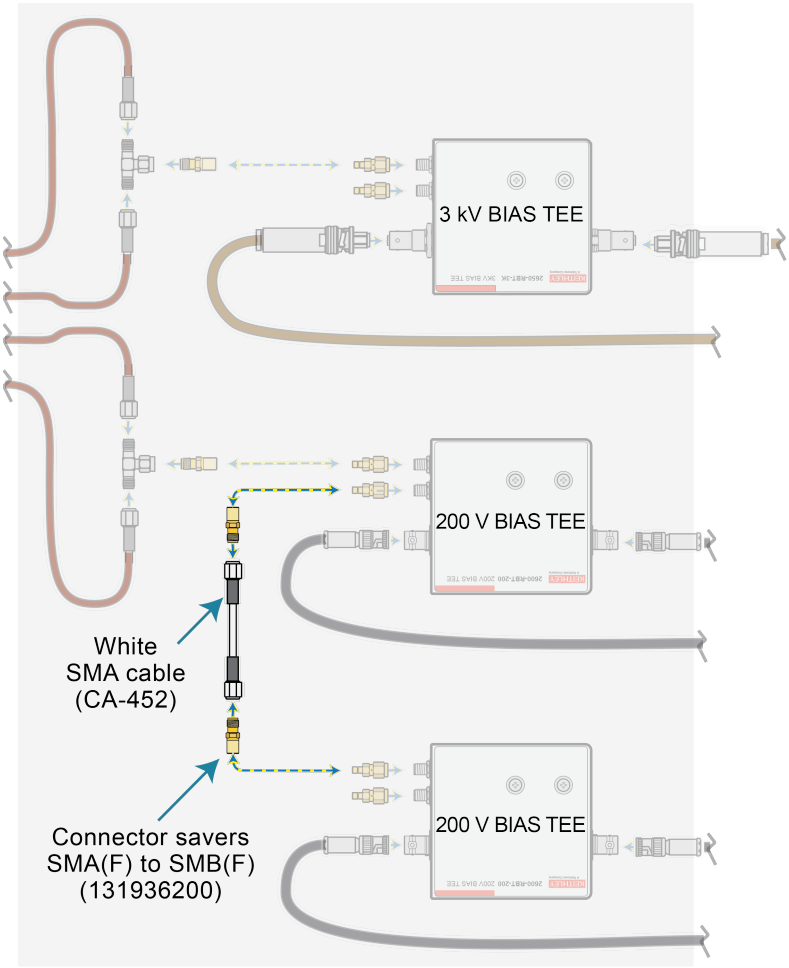
Figure 84: Instrument connections to the Model 8010 for the Ciss test



Model 8010 Coss test connections

The following figure shows the Model 8010 SMU, PCT-CVU, and CVU-3K-KIT connections for the Coss test.

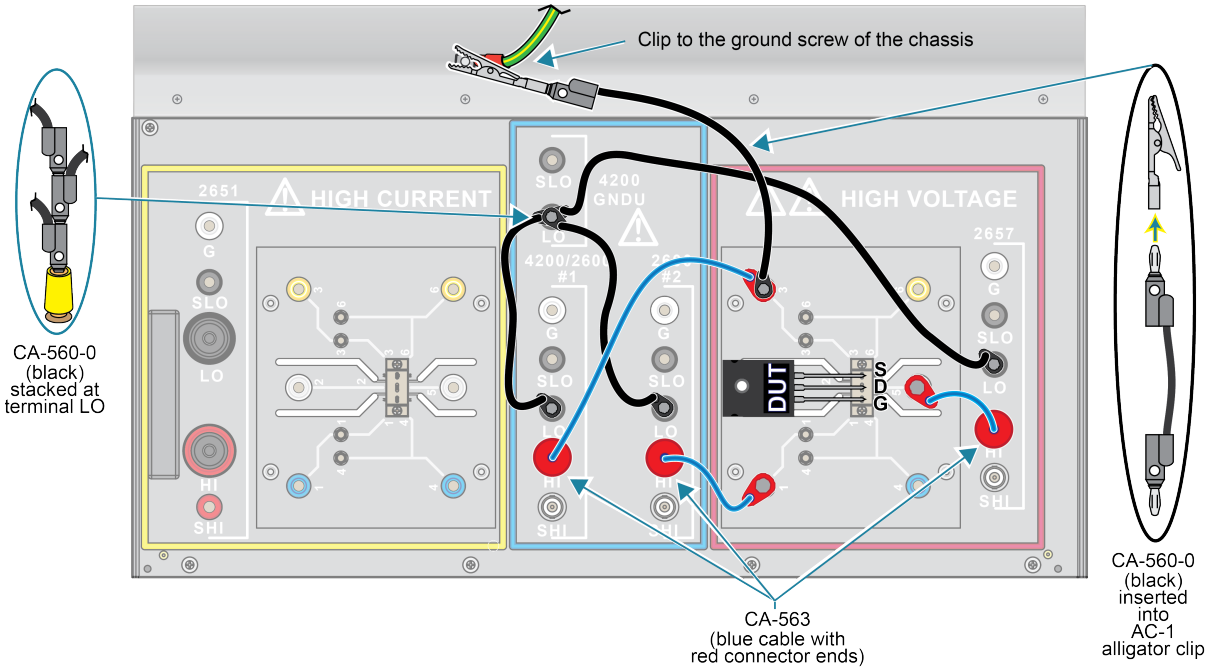
Figure 85: Instrument connections to the Model 8010 for the Coss test



Model 8010 connections to the device for Crss

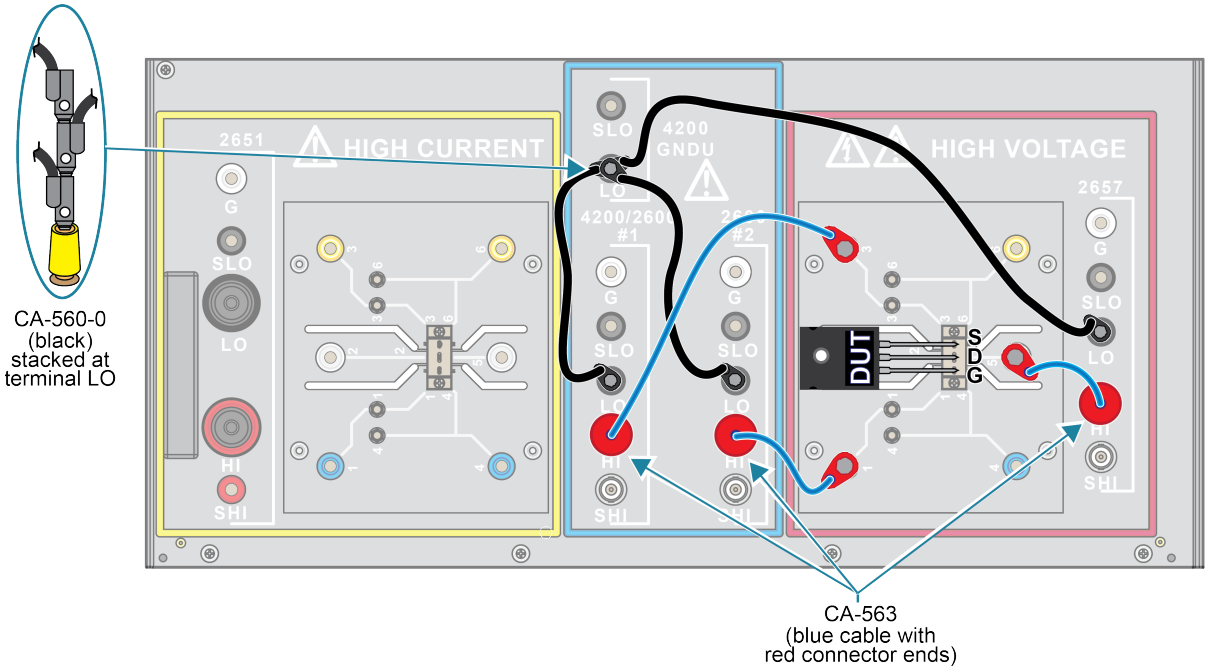
The following figure shows the Model 8010 connections to a power MOSFET for the Crss test.

Figure 86: Model 8010 device connections for Crss test



Model 8010 connections to the device for Ciss and Coss

Figure 87: Model 8010 device connections for Ciss and Coss tests



Model 8020 connections

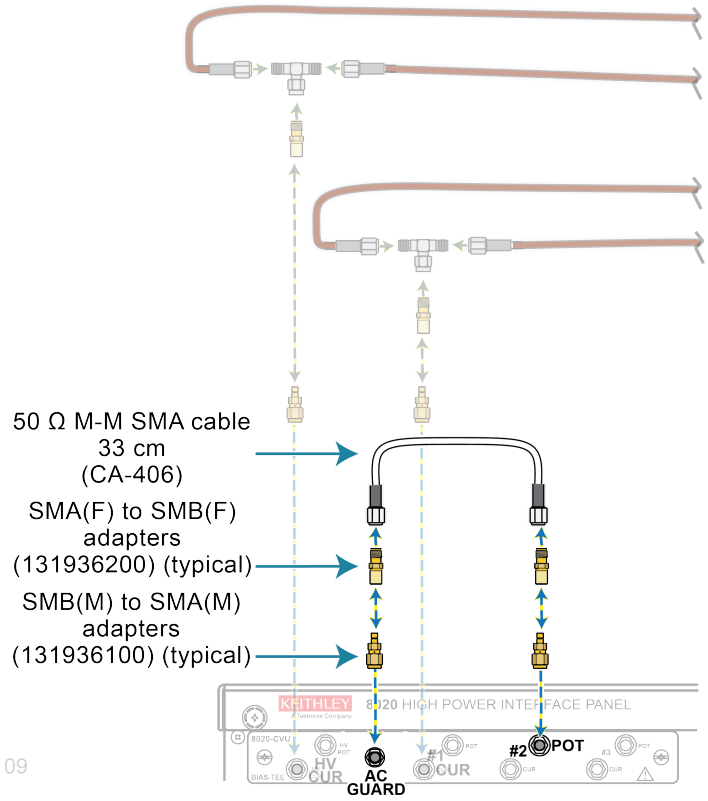
NOTE

The following figures rely upon a SMU per bias tee. With the Model 2600-PCT-1B and 2600-PCT-2B, there are not enough appropriate SMUs to connect to bias tees. For these configurations, connect the force terminal of the GNDU of the PCT-CVU to the bias tee that connects to the Source terminal of the FET or the Emitter terminal of the BJT or IGBT.

Model 8020 Crss test connections

The following figure shows the Model 8020 connections for the Crss test.

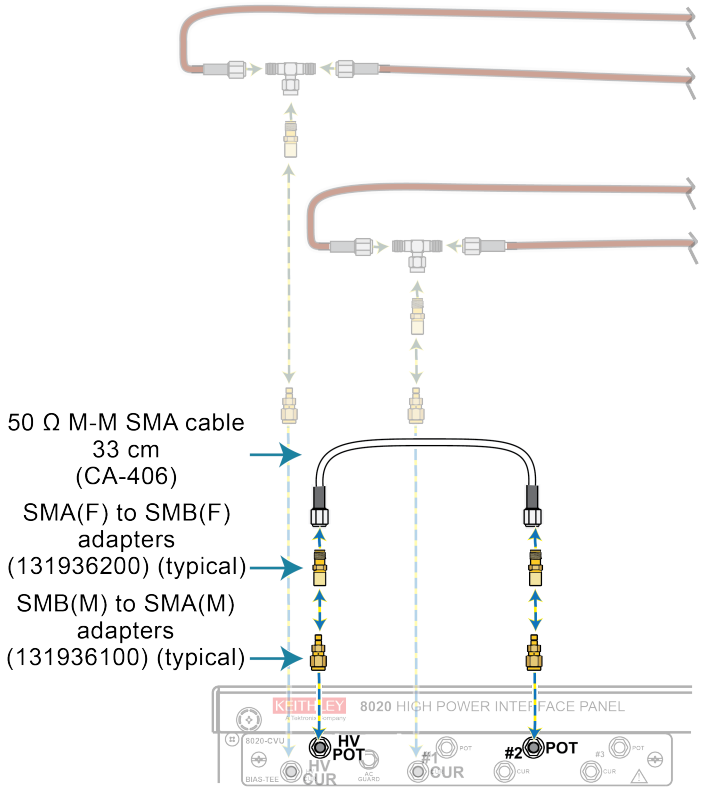
Figure 88: Instrument connections to the Model 8020 for the Crss test



Model 8020 Ciss test connections

The following figure shows the Model 8020 connections for the Ciss test.

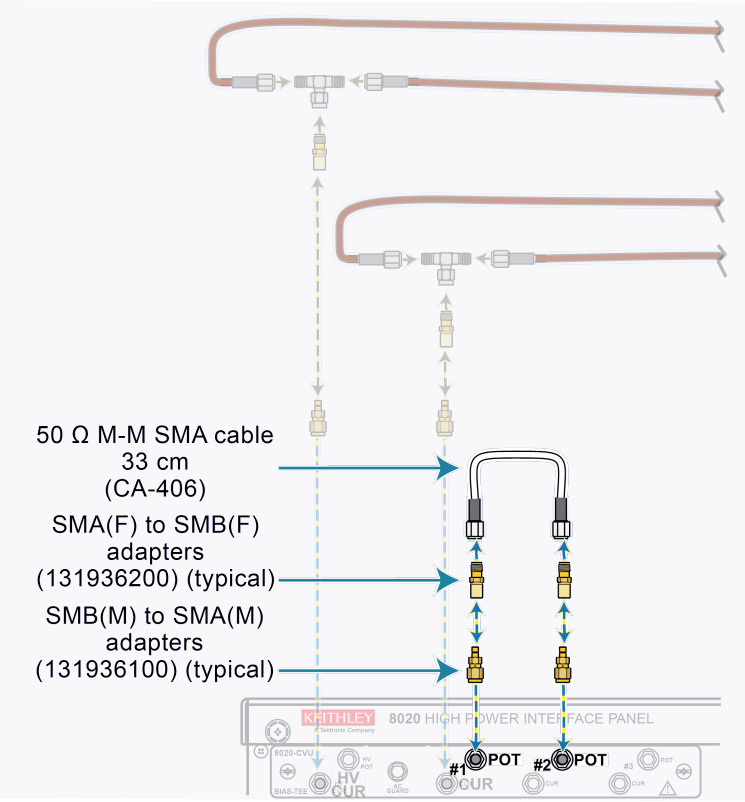
Figure 89: Instrument connections to the Model 8020 for the Ciss test



Model 8020 Coss connections

The following figure shows the Model 8020 connections for the Coss test.

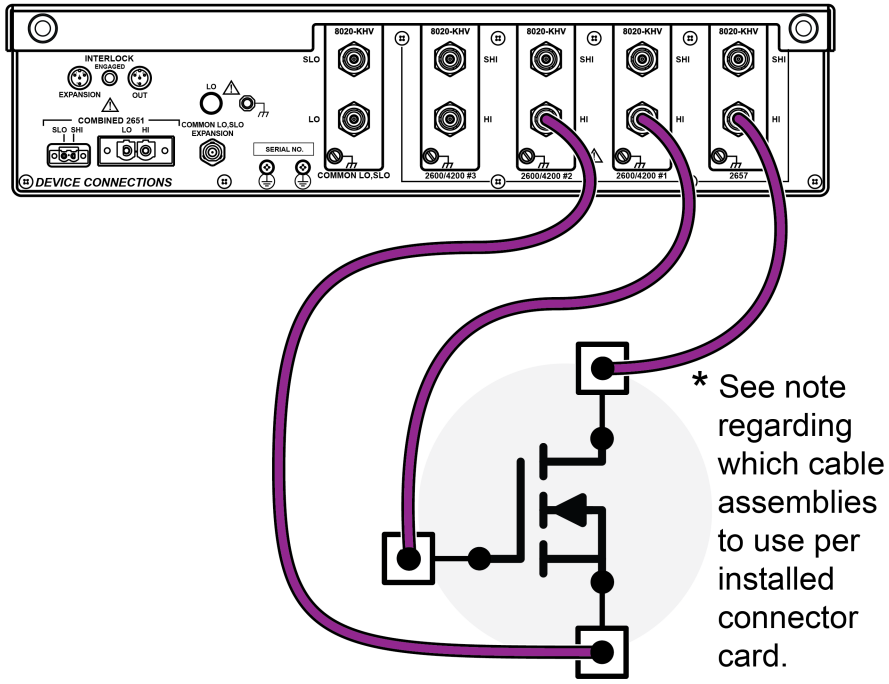
Figure 90: Instrument connections to the Model 8020 for the Coss test



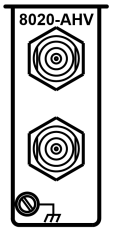
Model 8020 test connections to the device

The following figure shows the Model 8020 connections to the device under test for Ciss, Coss, and Crss measurements.

Figure 91: Model 8020 connections to the device

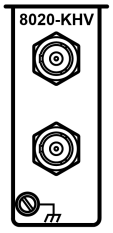


* Cable assemblies will depend upon the connector card the user installs



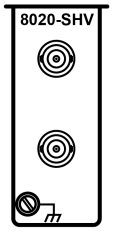
Connector Card:
8020-AHV

Cable Assembly:
User supplied



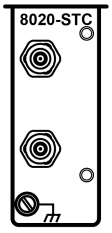
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



Connector Card:
8020-STC

Cable Assembly:
Model 7078-TRX
or
Model 4200-TRX

Perform connection compensations on C-V measurements

Stray capacitance, resistance, and inductance in the test setup can cause measurement errors. These errors vary with setup and their impact varies with frequency. To remove these errors from the measurement, perform connection compensation. Because there are connection changes between capacitance measurements of a power MOSFET, each capacitance measurement requires a separate open and short compensation. ACS Basic stores correction data for each capacitance measurement. This section describes how to perform compensation for the three circuit-level capacitance measurements: Ciss, Coss, and Crss.

Perform open and short compensation whenever the test configuration changes. This includes cabling and adapter changes and changes to the bias tee configurations.

Though compensation can be performed individually for each capacitance measurement, this section steps you through the open and short compensations for all the circuit-level capacitance parameters (Ciss, Coss, and Crss).

Ciss compensation

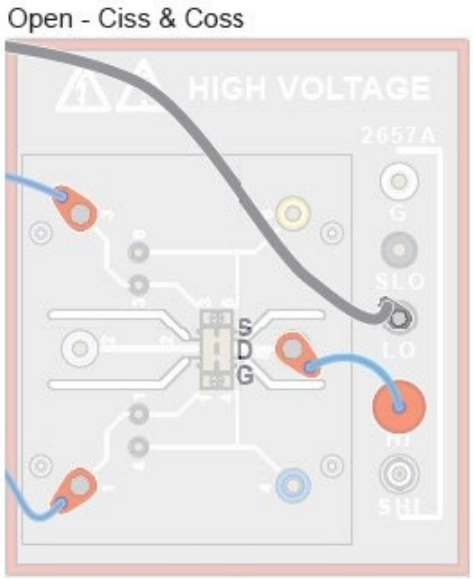
NOTE

Before you begin connection compensations, make sure that you have connected your instruments correctly. See Model 8010 Ciss test connections (on page 5-12) or Model 8020 Ciss test connections (on page 5-17).

Perform open compensation for the Ciss measurement:

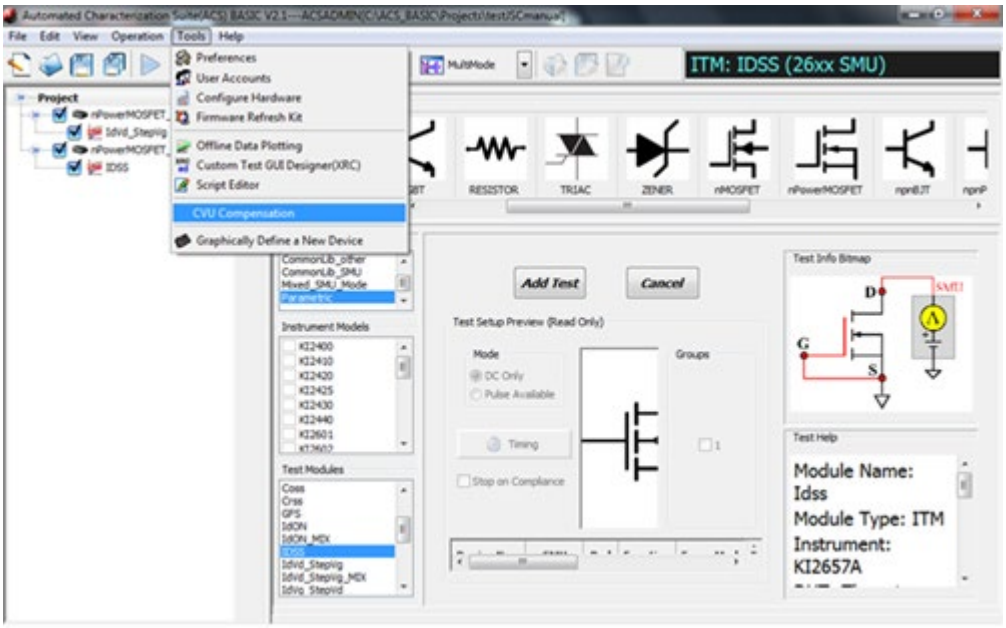
1. If you are using the Model 8010, make sure that no device is inserted in the device socket in the test fixture (see the following figure), then close the lid of the test fixture.

Figure 92: Internal 8010 connections for Ciss open compensation



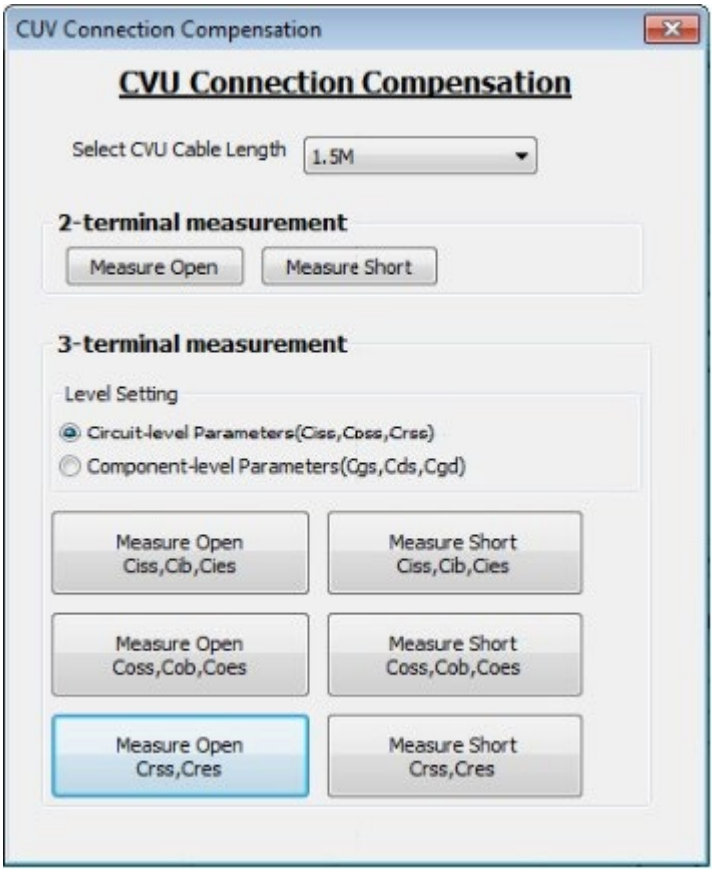
2. If you are using the Model 8020, remove the DUT or lift the probes on a probe station to disconnect from the device.
3. In ACS Basic, open MultiMode if it is not already open. To set up a MultiMode project, refer to Set up a new MultiMode project (on page 4-16).
4. Select **Tools** and select **CVU Compensation**, as shown in the following figure.

Figure 93: Tools > CVU Compensation



5. The CVU Connection Compensation dialog is displayed, as shown in the following figure.

Figure 94: CVU Connection Compensation dialog

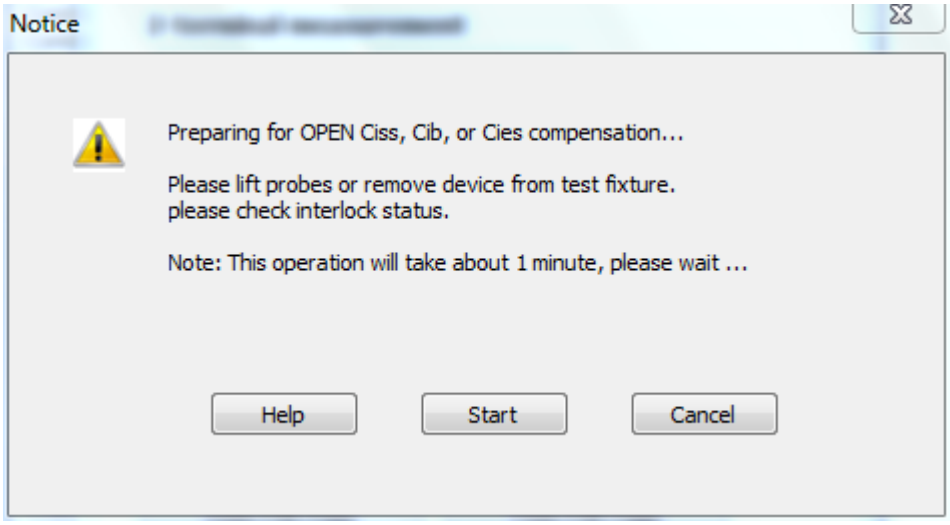


NOTE

If this CV connection compensation dialog does not appear, make sure that your device interface settings are correct in the hardware configurator. The bias tee checkbox must be selected. Refer to Getting started with ACS Basic (on page 3-1) for more details.

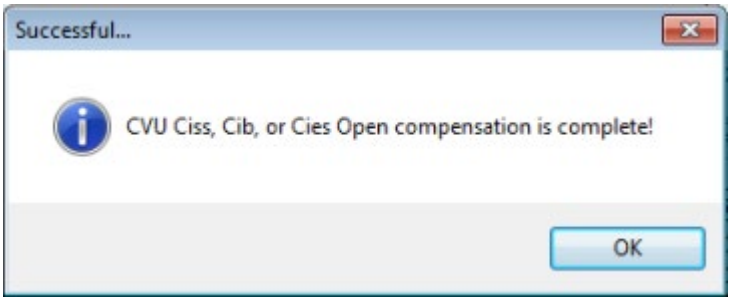
6. Select the appropriate CVU Cable Length according to the cables that you have. 1.5 m cables are supplied with the PCT-CVU.
7. Under 3-terminal measurement, for Level Setting, select **Circuit-level Parameters**.
8. Select **Measure Open Ciss, Cib, Cies**. The Measure Open for Ciss, Cib, Cies dialog is displayed, as shown in the following figure. Select **Help** to display detailed information for compensation connections and device terminal terminology.

Figure 95: Measure Open dialog



9. Select **Start** to begin the open compensation measurement. A progress dialog is displayed. Open compensation may take up to 90 seconds to complete.
10. When the measurement is complete, the following dialog is displayed. Select **OK** to confirm.

Figure 96: Compensation complete dialog

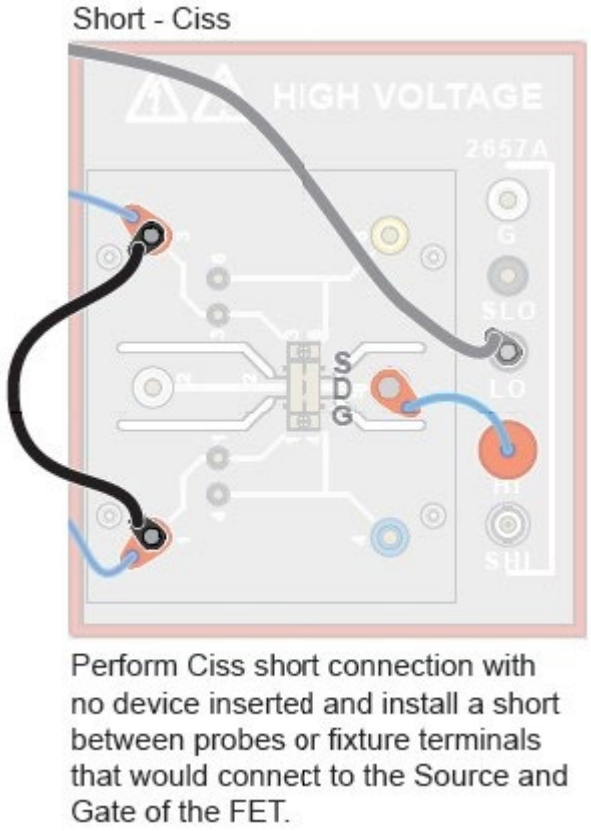


11. Leave the CVU Connection dialog open for the remaining compensation procedures.

Perform short compensation for Ciss measurement:

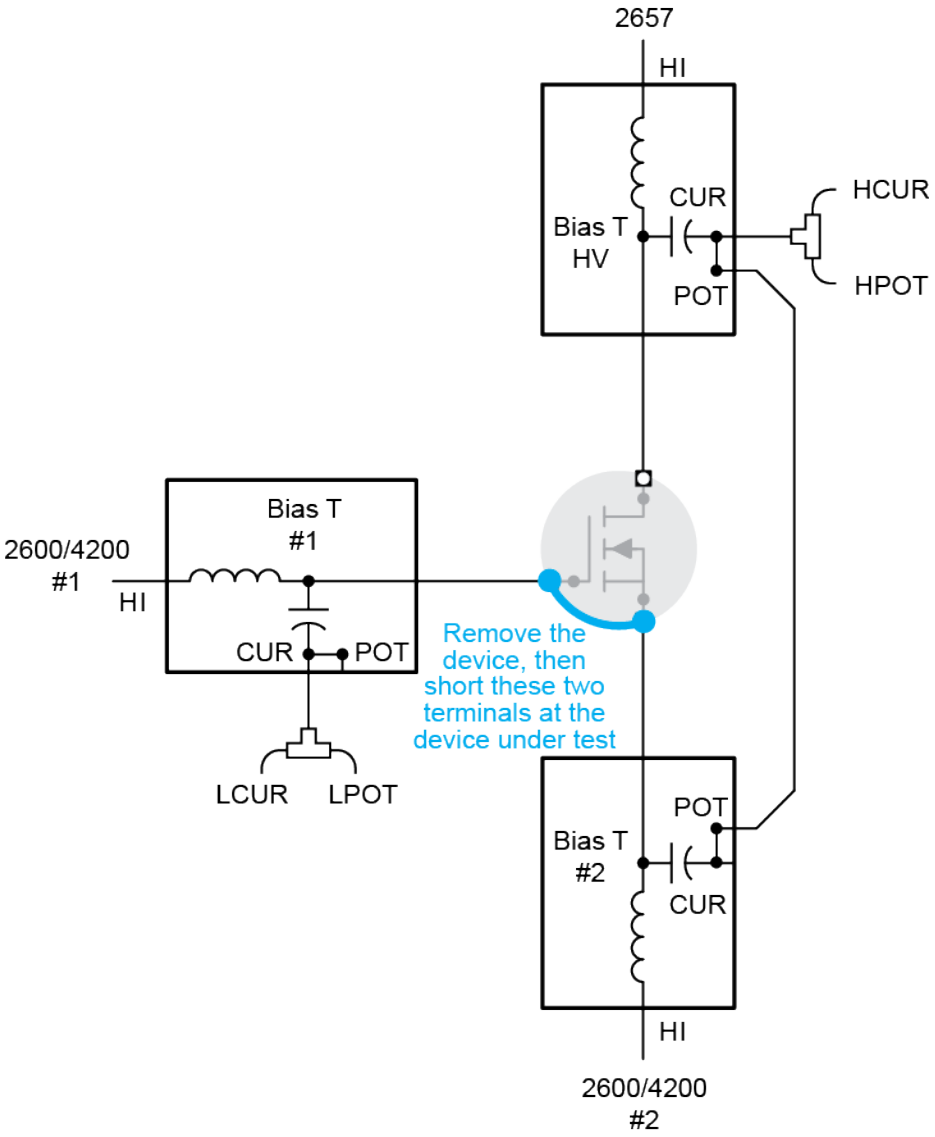
1. If you are using the Model 8010, make sure that no device is inserted in the device socket in the test fixture.
2. Use a banana jumper to short the gate and source terminals, as shown in the following figure, then close the lid of the test fixture.

Figure 97: Internal 8010 connections for Ciss short compensation



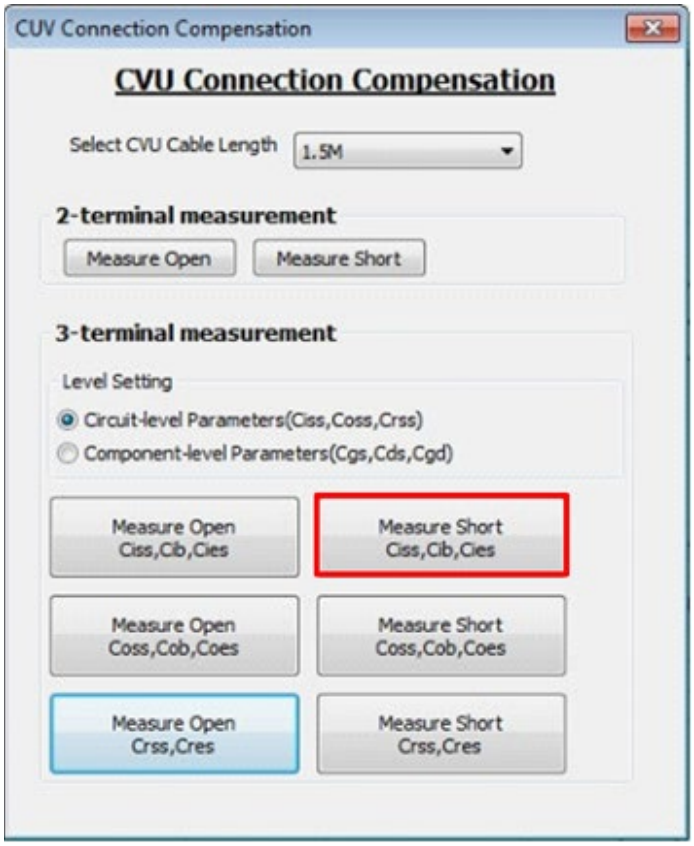
3. If you are using the Model 8020, remove or disconnect from the device and place a short between the connections to the gate and source terminals. Note the location of the short in the following figure.

Figure 98: Ciss measurement, short compensation

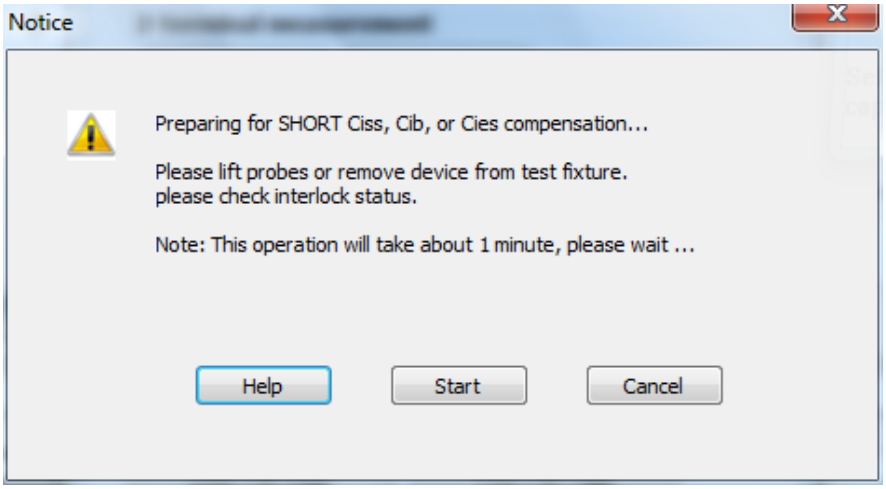


4. Select **Measure Short Ciss, Cib, Cies**.

Figure 99: CVU Connection Compensation dialog



5. The Measure Short for Ciss, Cib, Cies dialog is displayed, as shown in the following figure. Select **Help** to display detailed information for short compensation connections and device terminal terminology.



6. Select **Start** to begin the short compensation measurement. A progress dialog is displayed. Short compensation may take up to 90 seconds to complete.
7. When the measurement is complete, select **OK** to confirm.
8. Leave the CVU Connection dialog open for the remaining compensation procedures.
9. Remove the shorting wire to proceed to the next connection compensation measurement.

Coss compensation

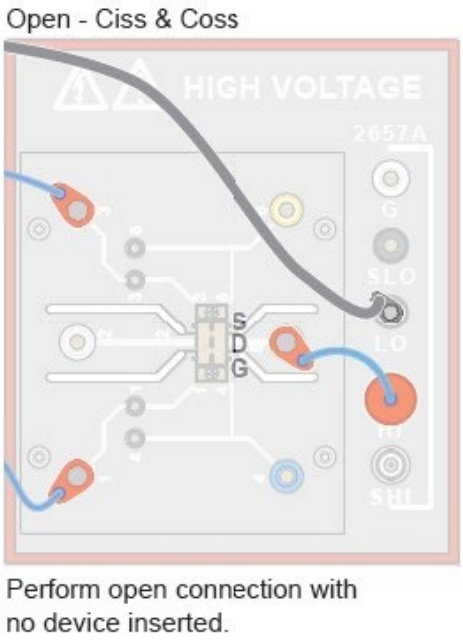
NOTE

Before you begin connection compensations, make sure that you have connected your instruments correctly. See Model 8010 Coss test connections (on page 5-13) and Model 8020 Coss test connections (on page 5-18).

Perform open compensation for Coss measurement:

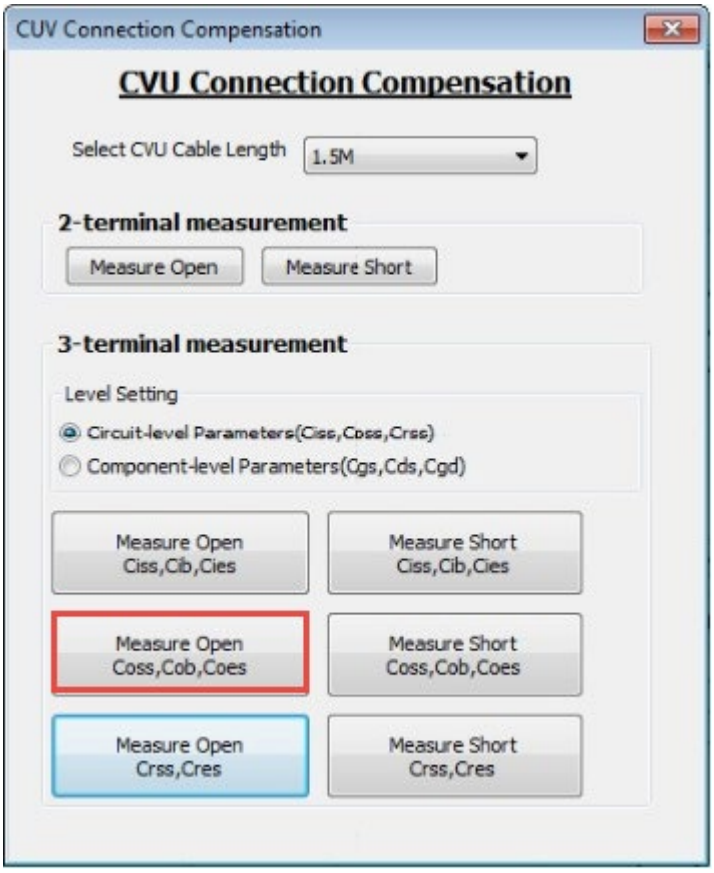
1. If you are using the Model 8010, make sure that no device is inserted in the device socket in the test fixture, as shown in the following figure, then close the lid of the test fixture.

Figure 100: Internal 8010 connections for Coss open compensation



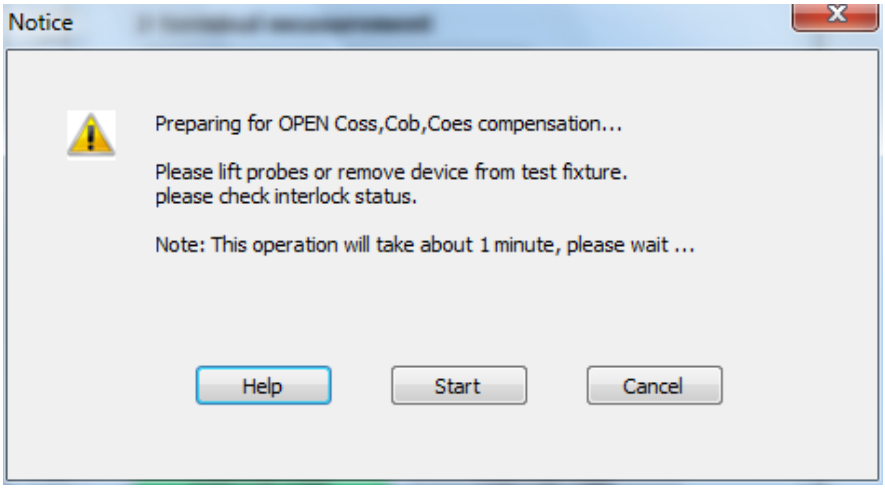
2. If you are using the Model 8020, remove the DUT or lift the probes on a probe station to disconnect from the device.
3. In the CVU Connection Compensation dialog of the ACS Basic software, select **Measure Open Coss, Cob, Coes**, shown in the following figure.

Figure 101: CVU Connection Compensation dialog



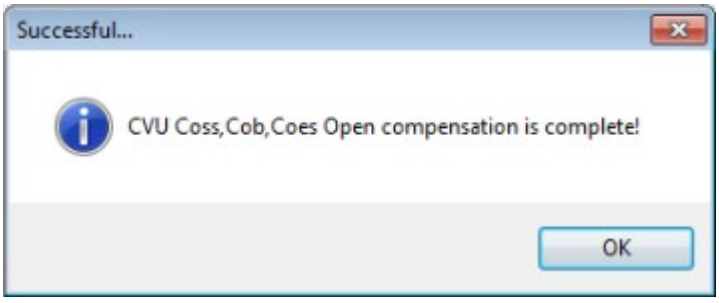
4. The Measure Open for Coss, Cob, Coes dialog is displayed. Select **Help** to display detailed information for compensation connections and device terminal terminology.

Figure 102: Measure Open dialog



5. Select **Start** to begin the open compensation measurement.
6. A progress dialog is displayed. Open compensation may take up to 90 seconds to complete. When the measurement is complete, the following dialog is displayed.

Figure 103: Compensation complete dialog

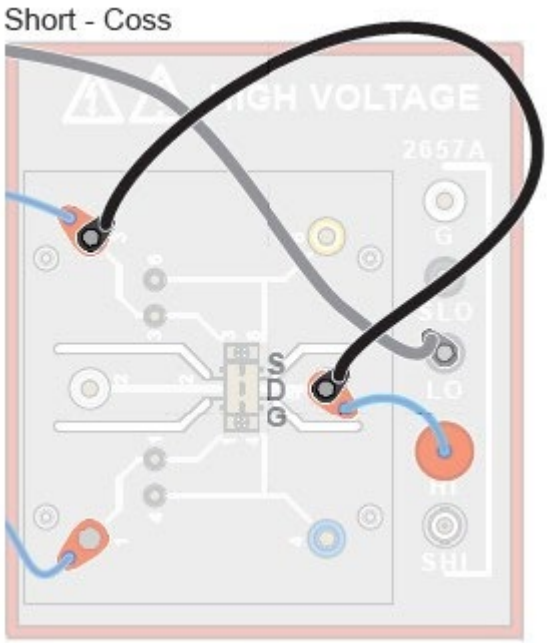


7. Select **OK**. Leave the CVU Connections Compensation dialog open for the remaining compensation procedures.

Perform short compensation for Coss measurement:

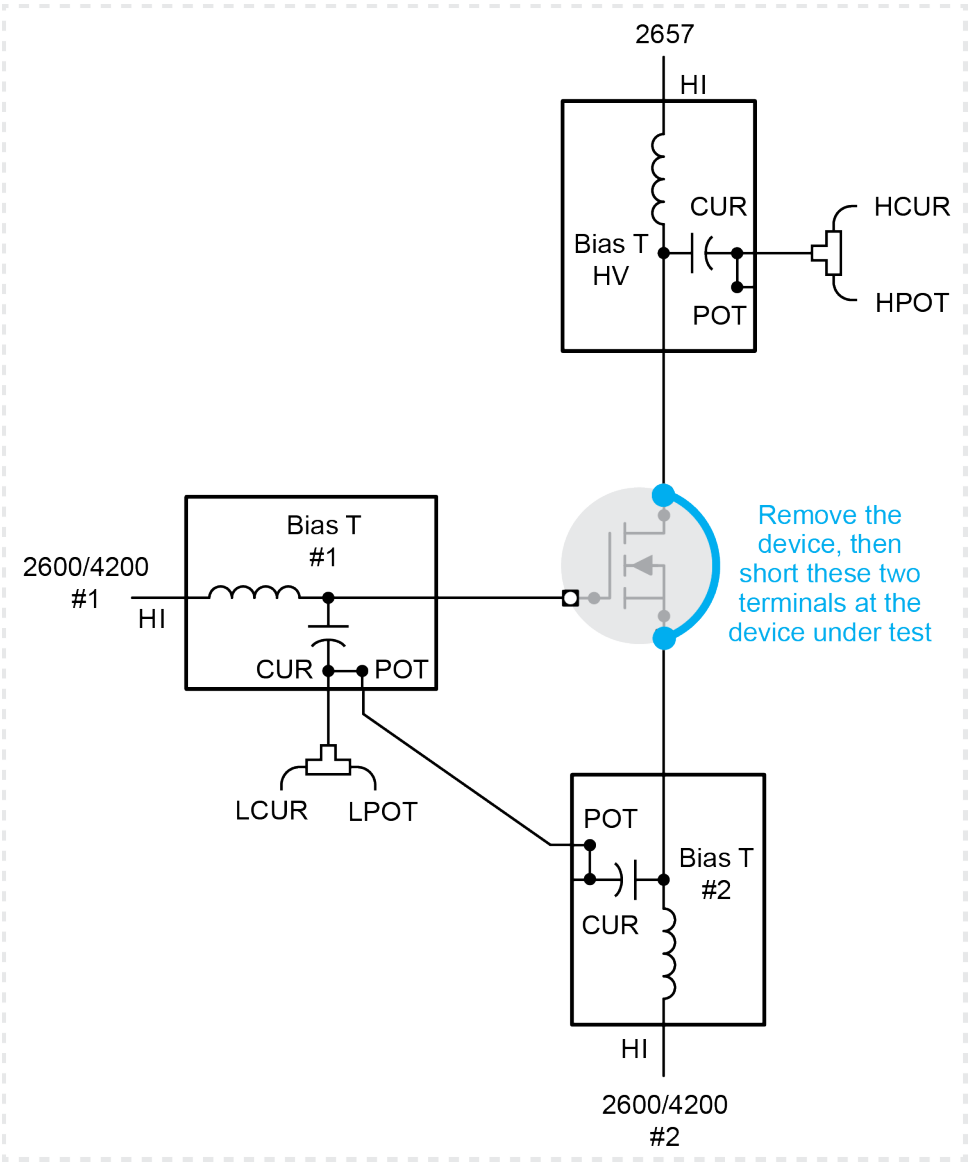
1. If you are using the Model 8010, make sure that no device is inserted in the device socket in the test fixture.
2. Short the Source and Drain terminals using a banana jumper, as shown in the following figure, then close the lid of the Model 8010.

Figure 104: Internal 8010 connections for Coss short compensation



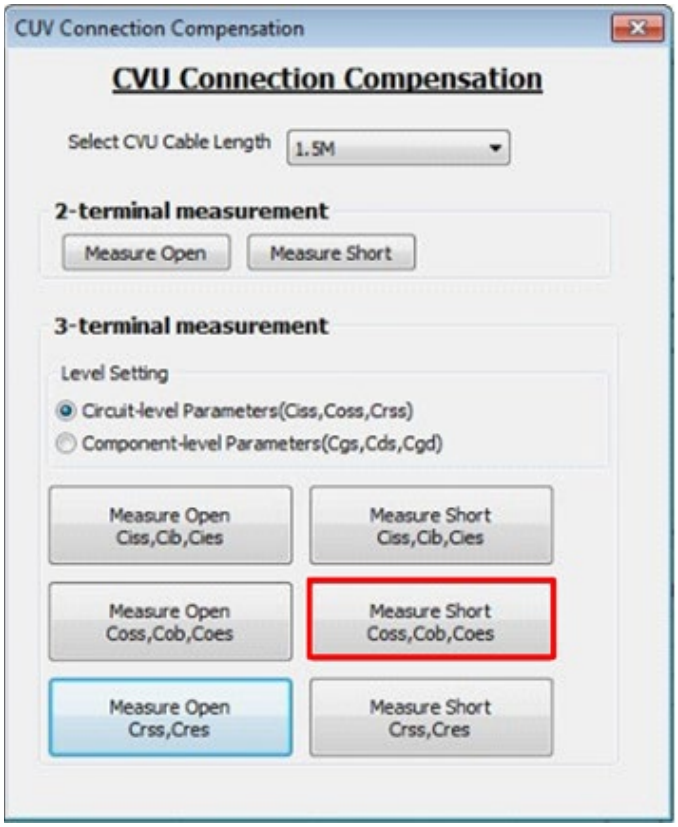
3. If you are using the Model 8020, remove or disconnect from the device and place a short between the connections to the drain and source terminals. In this compensation, compensation is made for the larger of Cgd or Cds (typically Cds). Refer to the following figure for the location of the short.

Figure 105: Coss measurement, short compensation



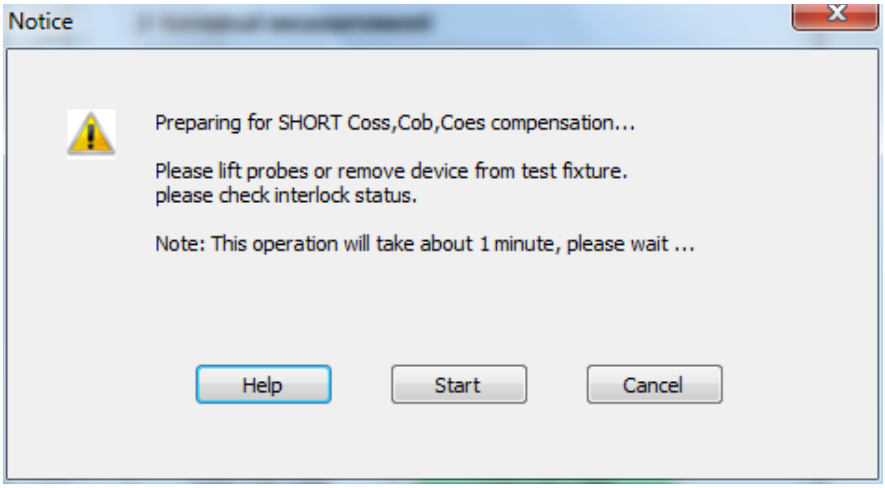
4. In the CVU Connections Compensation dialog, select **Measure Short Coss, Cob, Coes**.

Figure 106: CVU Connection Compensation dialog



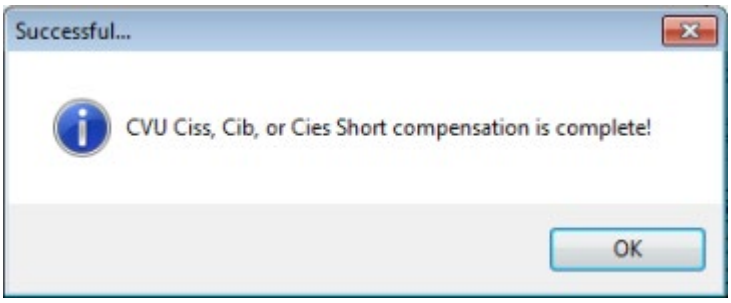
5. The Measure Short for Coss, Cob, Coes dialog is displayed, as shown in the following figure. Select **Help** to display detailed information for the short compensation connections and for device terminal terminology.

Figure 107: Measure Short for Coss, Cob, Coes dialog



6. Select **Start** to start the short compensation measurement.
7. While running the short compensation measurement, a progress dialog is displayed. The short compensation takes less than 90 seconds to complete. The following dialog is displayed.

Figure 108: Compensation successful dialog



8. Select **OK**.
9. Remove the shorting wire to proceed to the next connection compensation measurement. Leave the CVU Connection Compensation dialog open to complete the remaining compensation procedures.

Crss compensation

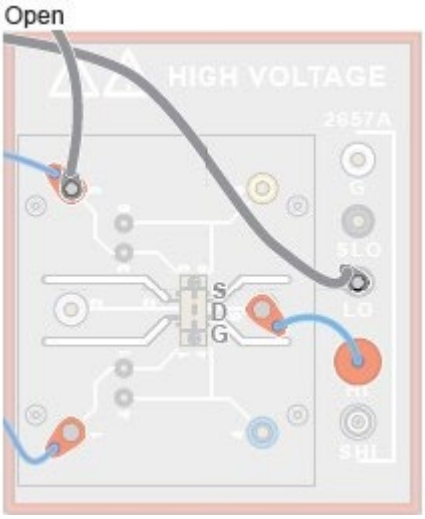
NOTE

Before you begin connection compensation, make sure that you have connected your instruments correctly. See Model 8010 Crss test connections (on page 5-10) and Model 8020 Crss test connections (on page 5-18).

Perform an open compensation for Crss measurement:

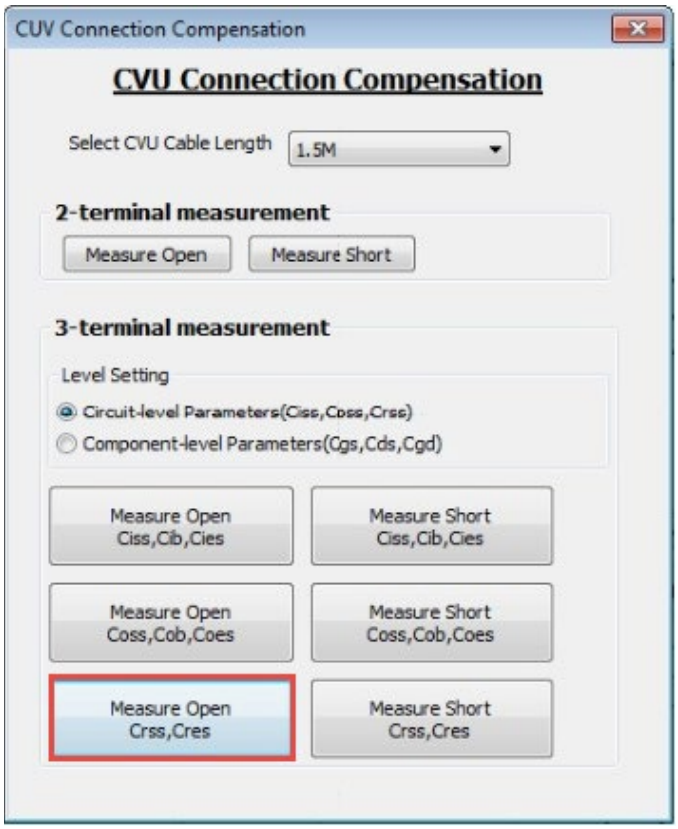
1. If you are using the Model 8010, make sure that no device is inserted in the device socket in the test fixture, as shown in the following figure, then close the lid of the test fixture.

Figure 109: Internal 8010 connections for Crss short compensation



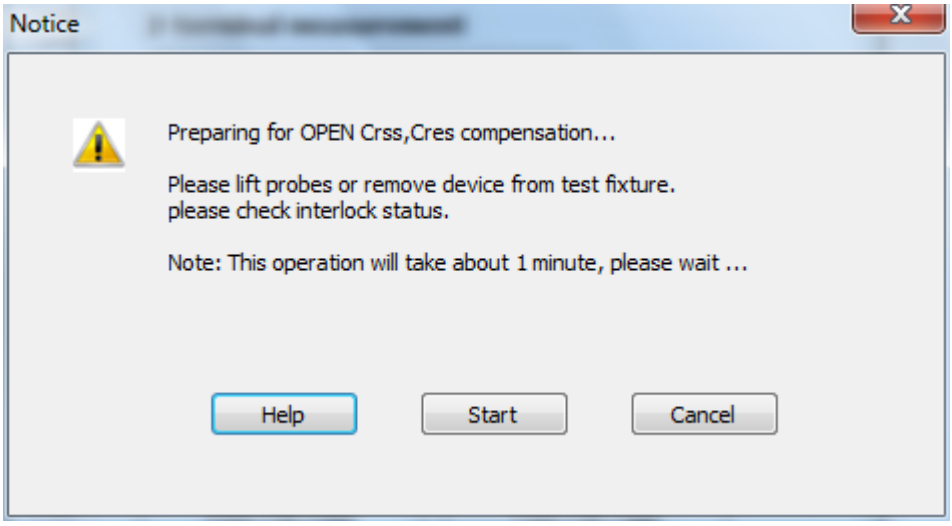
2. If using the Model 8020, remove the DUT or lift the probes on the probe station to disconnect from the device.
3. In the CVU Connection Compensation dialog, select **Measure Open Crss, Cres**.

Figure 110: CVU Connection Compensation dialog



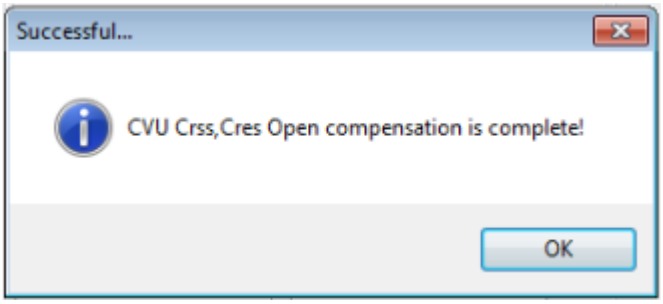
4. The Measure Open for Crss, Cres dialog is displayed, as shown in the following figure. Select **Help** to display detailed information for compensation connections and device terminal terminology.

Figure 111: Measure Open dialog



5. Select **Start**. A progress dialog is displayed. Open compensation takes up to 90 seconds to complete.
6. When the measurement is complete, the dialog shown in the following figure is displayed.

Figure 112: Compensation Successful dialog

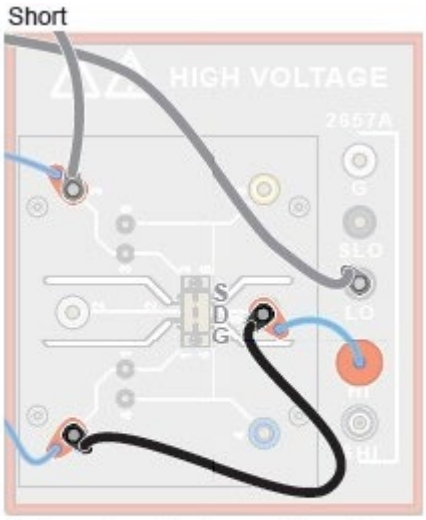


7. Select **OK**. Leave the CVU Connection Compensations dialog open for the remaining compensation procedures.

Perform short compensation for Crss measurement:

1. If you are using the Model 8010, make sure that no device is inserted in the device socket in the test fixture, then install a shorting wire between the drain and gate using a banana jumper, as shown in the following figure. Close the lid of the test fixture.

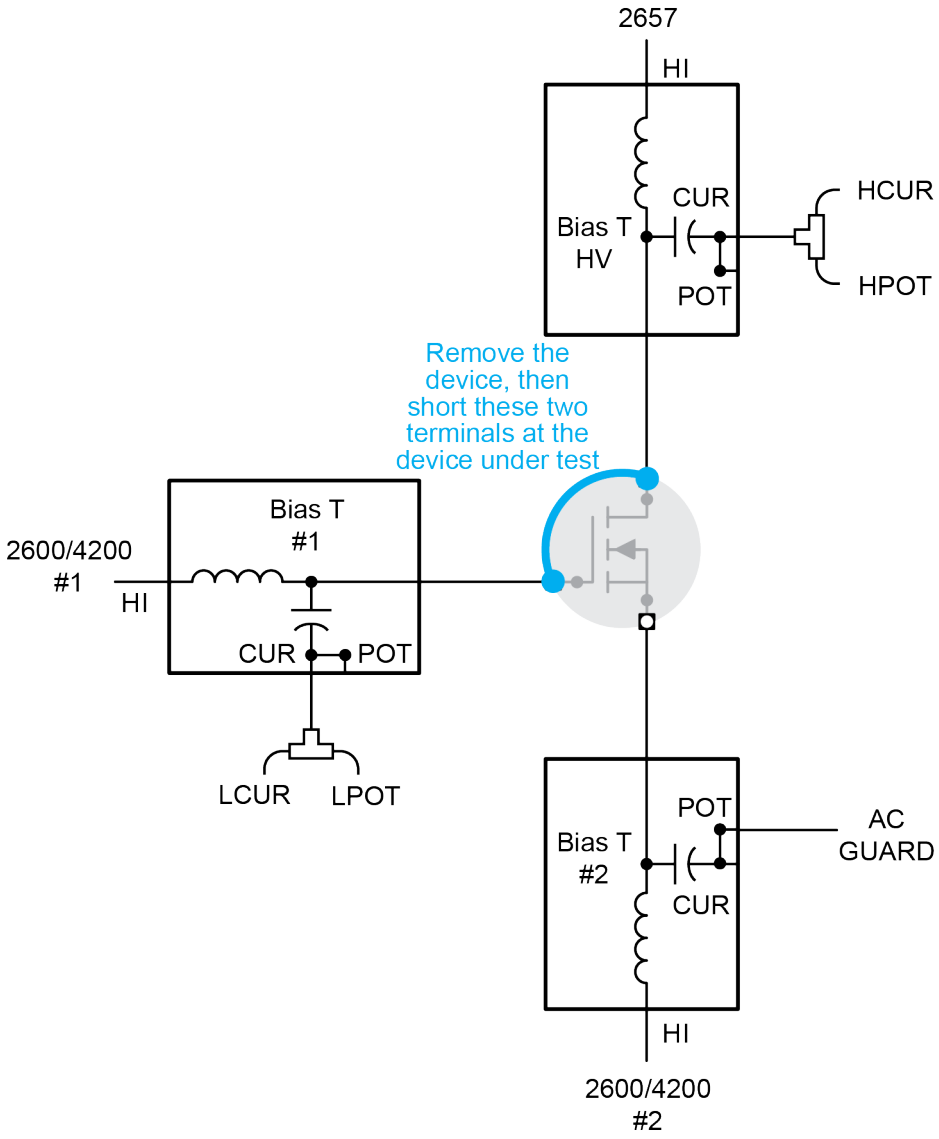
Figure 113: Internal 8010 connections for Crss short compensation



Perform C_{GD} short connection with no device inserted and install a short between probes or fixture terminals that would connect to the Gate and Drain of the FET.

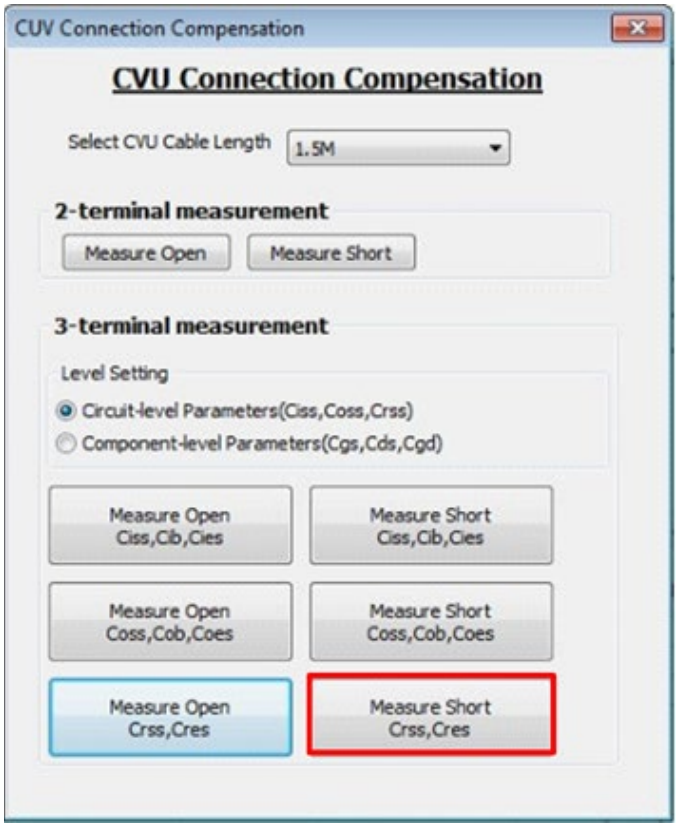
2. If you are using the Model 8020, remove or disconnect from the device and place a short between the connections to the gate and drain terminals, as shown in the following figure.

Figure 114: Cgd / Crss measurement, short compensation



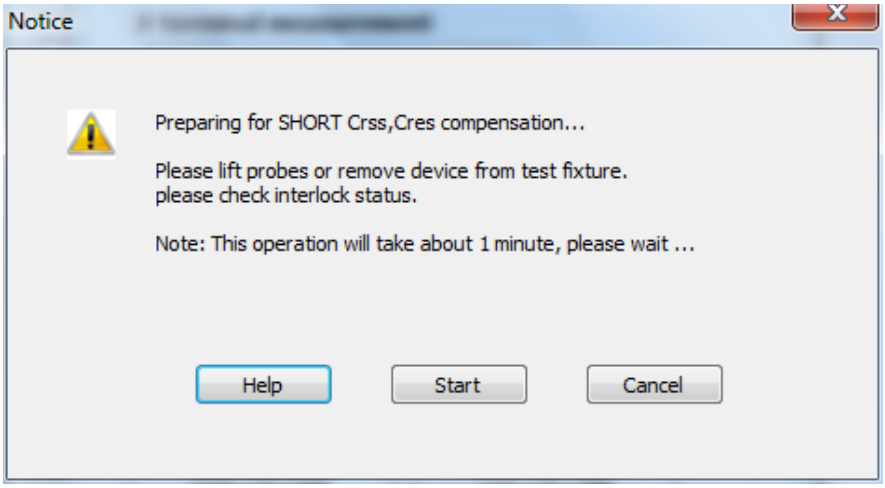
3. Select **Measure Short Crss, Cres**.

Figure 115: CVU Connection Compensation dialog



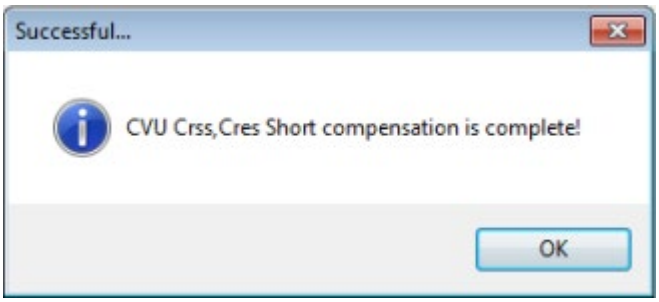
4. The Measure Short for Crss, Cres dialog is displayed, as shown in the following figure. Select **Help** to display detailed information for compensation connections and device terminal terminology.

Figure 116: Measure Short for Crss, Cres dialog



5. Select **Start**. A progress dialog is displayed. The open compensation takes less than 90 seconds to complete. When the measurement is complete, the dialog shown in the following figure is displayed.

Figure 117: Compensation complete dialog



6. Select **OK**.
7. Remove the shorting wire between the source and drain terminals. For the Model 8010, also remove the connection between the source terminal and the 8010 chassis.

All connection compensations are now complete. Close the CVU Connections Compensations dialog in ACS Basic by selecting the X in the upper right of the dialog.

Make a Ciss measurement

NOTE

Before you make measurements, make sure that you have connected your instruments correctly. See Model 8010 Ciss test connections (on page 5-12) or Model 8020 Ciss test connections (on page 5-17).

Connect to the device:

If you are using the Model 8010, insert the device into the 8010 test fixture. If you are using the Model 8020, make contact with the device at the probe station.

Software procedure:

Ensure that MultiMode is open in the ACS Basic software. See Collecting I-V curves in MultiMode (on page 4-4) for software configuration.

Make a Ciss measurement:

NOTE

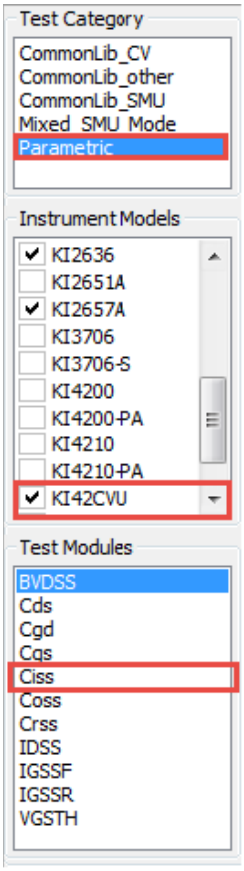
Make sure that you have performed open and short connection compensations before making a measurement. See Perform connection compensations on C-V measurements (on page 5-20) for more information and instructions.

1. From Select a Device, select **nPowerMOSFET**, as shown in the following figure.

Figure 118: Selecting the nPowerMOSFET device

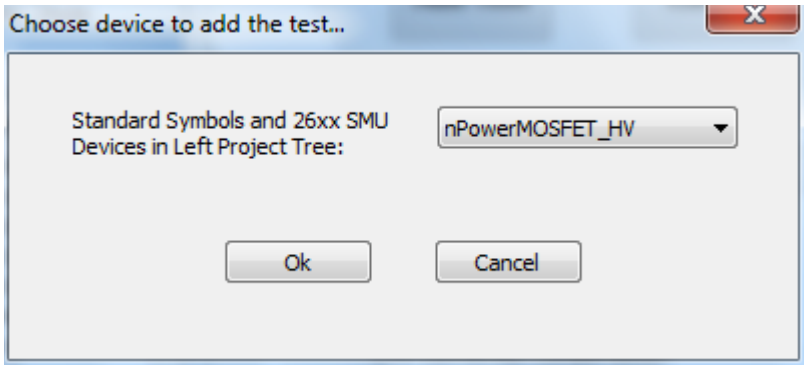
2. From Test Category, select **Parametric**, as shown in the following figure.

Figure 119: Test options



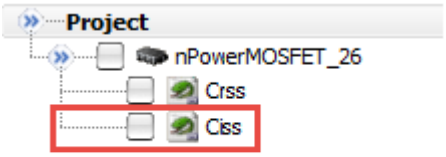
3. From Instrument Models, select **KI42CVU**.
4. From Test Modules, select **Ciss**.
5. Select **Add Test** to add the Ciss test to the project tree.
6. If prompted with Choose Device to Add the Test, select the device from the list and select **OK**, as shown in the following figure.

Figure 120: Choosing device



7. In the project tree, double-click the Ciss test, shown in the following figure, to open the Ciss test module.

Figure 121: Ciss test in project tree

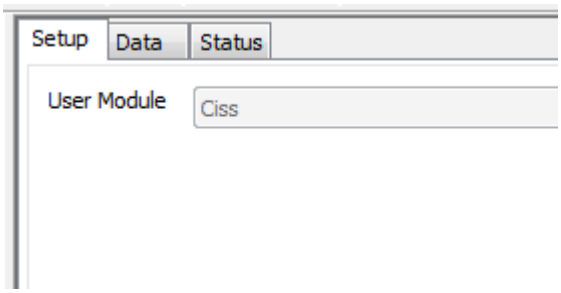


NOTE

The Ciss module is a Python Test Module (PTM). As such, it references global SMU numbers. If you are using a Model 4200A-SCS and you have SMU cards installed in its chassis, the SMU identification numbers will differ from those previously used for I-V tests. Refer to “Hardware Configuration” in the *ACS Basic Reference Manual* for details.

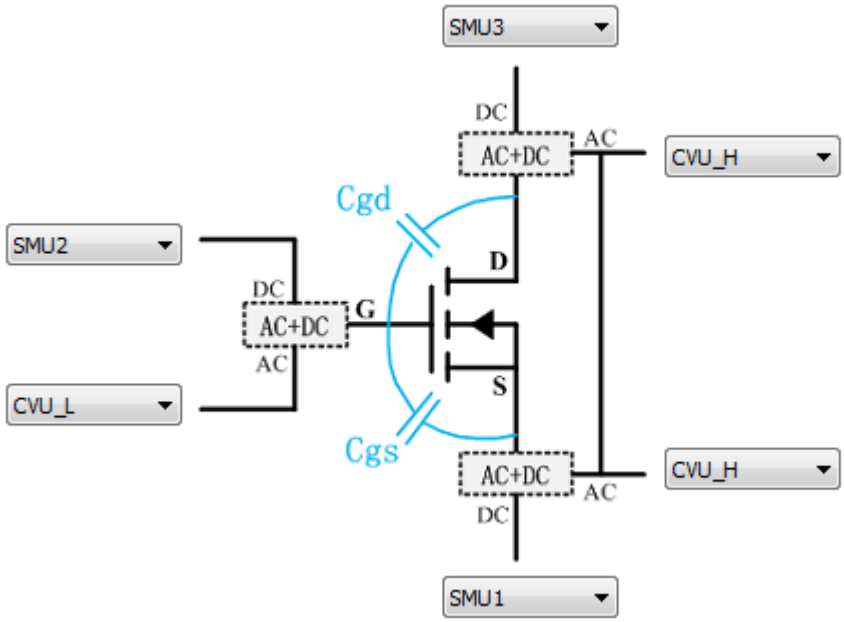
8. Select the **Setup** tab.

Figure 122: Ciss Setup tab



9. Assign the SMUs as shown in the following figure. These settings assume the use of a 2600-PCT-3B or 2600-PCT-4B, as configured in Getting started with ACS Basic (on page 3-1). Use the actual SMU number for your configuration.

Figure 123: Ciss SMU assignments and block diagram (Model 8010 connections)



If you are using the Model 8010, use these configuration settings

- **Drain DC:** SMU3 (2657), **AC:** CVU_H
- **Gate DC:** SMU2 (2600B, ch B), **AC:** CVU_L
- **Source DC:** SMU1 (2600B, ch A), **AC:** CVU_H

If using the Model 8020, use these configuration settings

- **Drain DC:** SMU3 (2657), **AC:** CVU_H
- **Gate DC:** SMU1 (2600B, ch A), **AC:** CVU_L
- **Source DC:** SMU2 (2600B, ch B), **AC:** CVU_H

NOTE

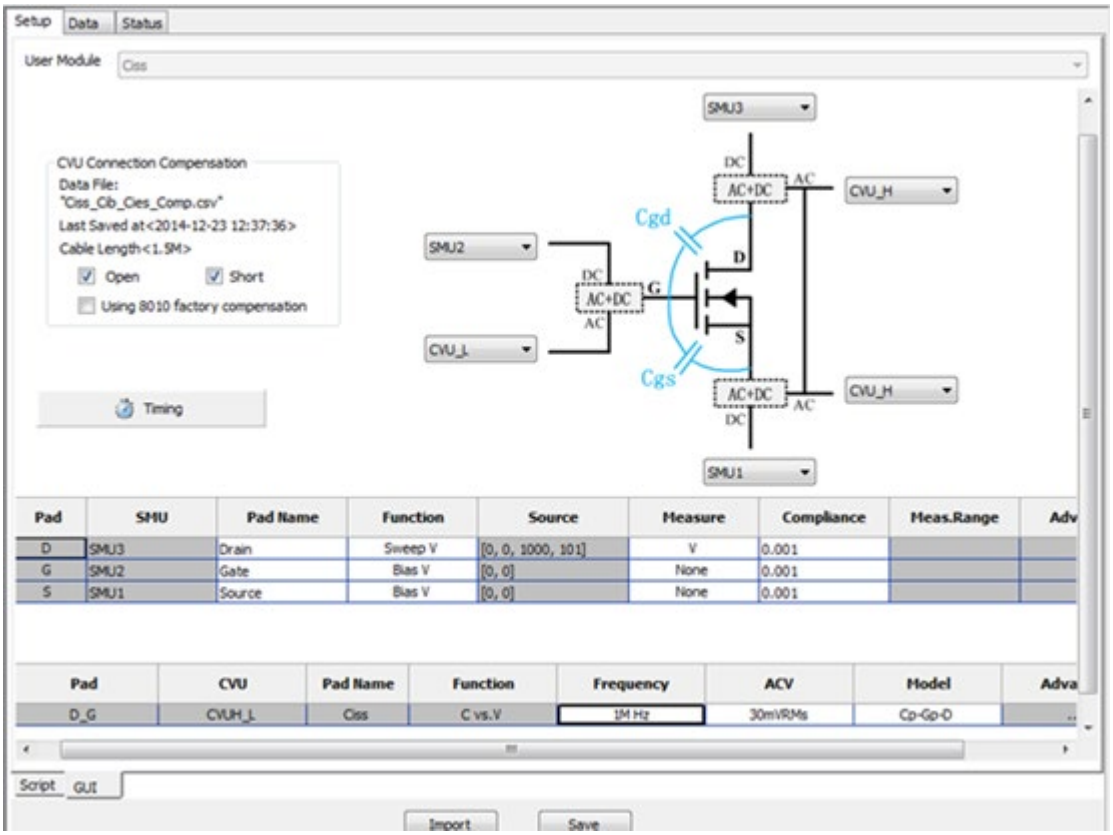
The Gate AC and Source AC instruments are linked automatically. This represents the hardware connection of the white SMA cable (CA-406) shorting the two 200 V bias tees.

NOTE

Hover the cursor over the SMU pad to display the corresponding instrument model number.

1. Enter your values in the test settings table.
2. For the included sample device, sweep voltage at the drain from 0 to 1000 V in 10 V steps.
3. Adjust the sweep values by selecting the **Source** field for the drain SMU.
4. Configure the drain SMU to measure voltage.
5. Configure the gate and source SMUs to have a source function of bias V with a source value of 0 V.
6. For the CVU, set the measurement frequency to 1 MHz by selecting Frequency and then selecting 1 MHz from the list.
7. Use the default ACV of 30 mVrms.
8. Use the Cp-Gp-D model.

Figure 124: Test settings table

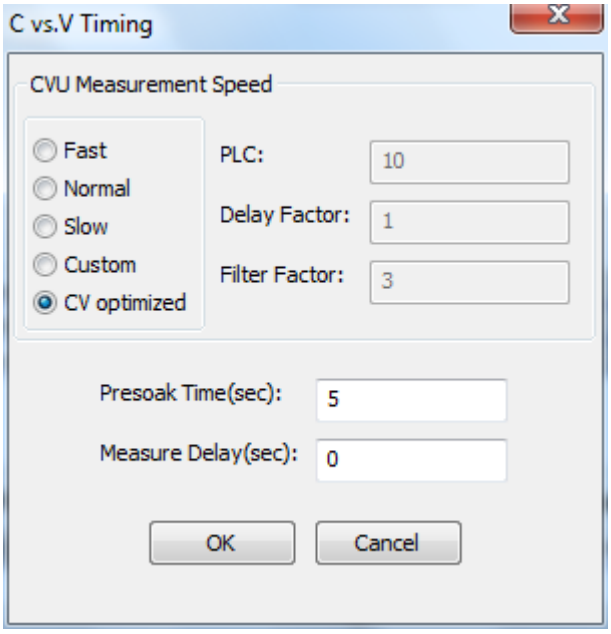


NOTE

For the Ciss test module, the capacitance measurement function is fixed to capacitance vs. voltage. To view capacitance as a function of frequency, use the Generic HV C-V Test under the CommonLib_CV test category. Refer to the ACS Basic software user's manual for information on using this test module.

9. Select **Timing**.
10. Ensure that CV optimized is selected and the Presoak Time is 5 seconds, as shown in the following figure. Select **OK**.

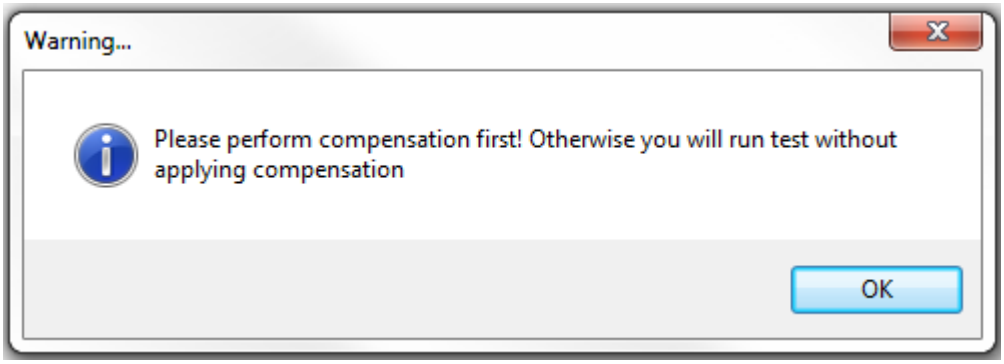
Figure 125: C vs. V Timing dialog



11. Select the Open and Short boxes in the CVU Connection Compensation area to apply the compensation to the measured data.

    The latest compensation is loaded automatically. If no compensation has been performed, you may receive the error message shown in the following figure. To perform compensation, refer to Perform connection compensation on C-V measurements (on page 5-20).

Figure 126: Warning that compensation was not performed

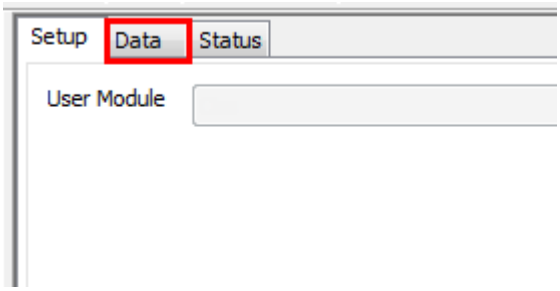


NOTE

If you have the Model 8010 and are using the CVU-3K-KIT, you can also use built-in compensation data by selecting "Using 8010 factory compensation." This allows you to make a quick validation on the device capacitance without performing the complete compensation for your specific environment.

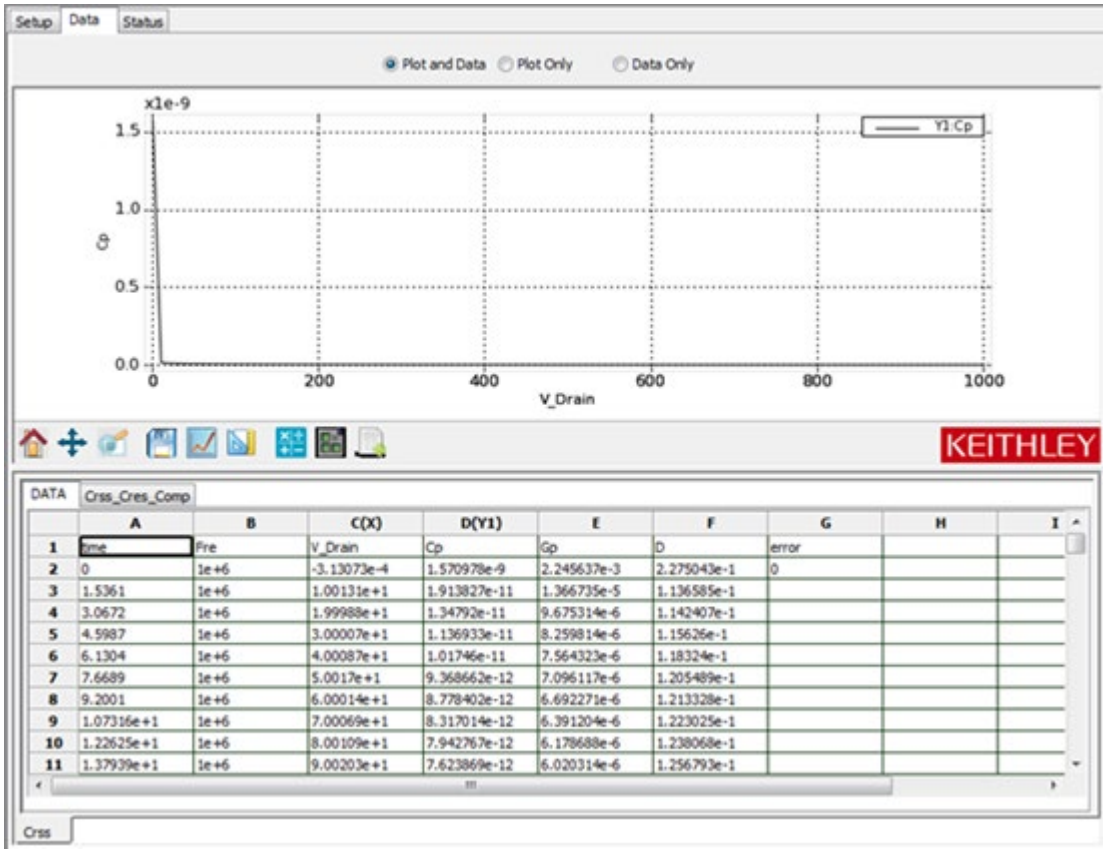
12. Sample data and pilots are included with the test. Select the Data tab, as shown in the following figure.

Figure 127: Data tab



13. Select Run (▶) to start the test. The results should appear similar to those in the following figure.

Figure 128: Run icon



	A	B	C(X)	D(Y1)	E	F	G	H	I
1	Time	Fre	V_Drain	Cp	Gp	D	error		
2	0	1e+6	-3.13073e-4	1.570978e-9	2.245637e-3	2.275043e-1	0		
3	1.5361	1e+6	1.00131e+1	1.913827e-11	1.366735e-5	1.136585e-1			
4	3.0672	1e+6	1.99988e+1	1.34792e-11	9.675314e-6	1.142407e-1			
5	4.5987	1e+6	3.00007e+1	1.136933e-11	8.259814e-6	1.15626e-1			
6	6.1304	1e+6	4.00087e+1	1.01746e-11	7.564323e-6	1.18324e-1			
7	7.6689	1e+6	5.0017e+1	9.368662e-12	7.096117e-6	1.205489e-1			
8	9.2001	1e+6	6.00014e+1	8.778402e-12	6.692271e-6	1.213328e-1			
9	1.07316e+1	1e+6	7.00069e+1	8.317014e-12	6.391204e-6	1.223025e-1			
10	1.22625e+1	1e+6	8.00109e+1	7.942767e-12	6.178688e-6	1.238068e-1			
11	1.37939e+1	1e+6	9.00203e+1	7.623869e-12	6.020314e-6	1.256793e-1			

⚠ WARNING

If high voltage is used during the test, make sure a proper discharge procedure is performed before removing the top cover of the Model 8020 or making connection changes inside of the Applications Test Fixture.

Make a Coss measurement

NOTE

Before you make measurements, make sure that you have connected your instruments correctly. See Model 8010 Coss test connections (on page 5-13) or Model 8020 Coss test connections (on page 5-18).

Connect to the device:

Connections to the device in the Model 8010 or at the device connections panel of the Model 8020 are the same as for the Ciss test. Therefore, the connections are not changed.

Make a Coss measurement:

NOTE

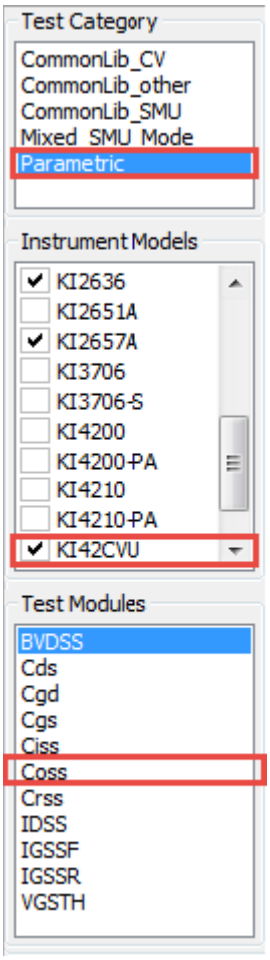
Make sure that you have performed open and short connection compensations before making a measurement. See Perform connection compensations on C-V measurements (on page 5-20) for more information and instructions.

1. From Select a Device, select **nPowerMOSFET**, as shown in the following figure.

Figure 129: Selecting the nPowerMOSFET device

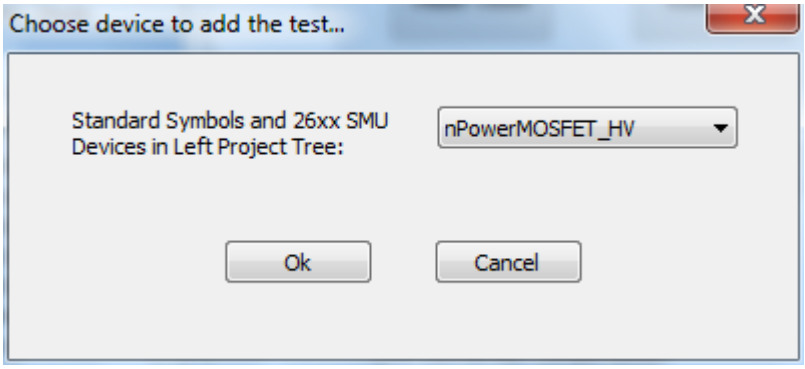
2. From Test Category, select **Parametric**, as shown in the following figure.

Figure 130: Test options



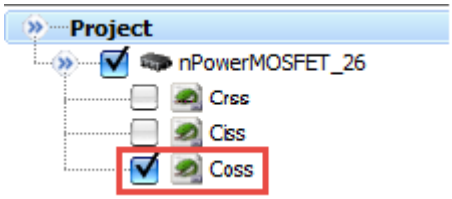
3. From Instrument Models, select **KI42CVU**.
4. From Test Modules, select **Coss**.
5. Select **Add Test** to add the Coss test to the project tree.
6. If prompted with Choose Device to Add the Test, select the device from the list and select **OK**, as shown in the following figure.

Figure 131: Choosing device



7. In the project tree, double-click the Coss test, shown in the following figure, to open the Coss test module.

Figure 132: Coss test in project tree

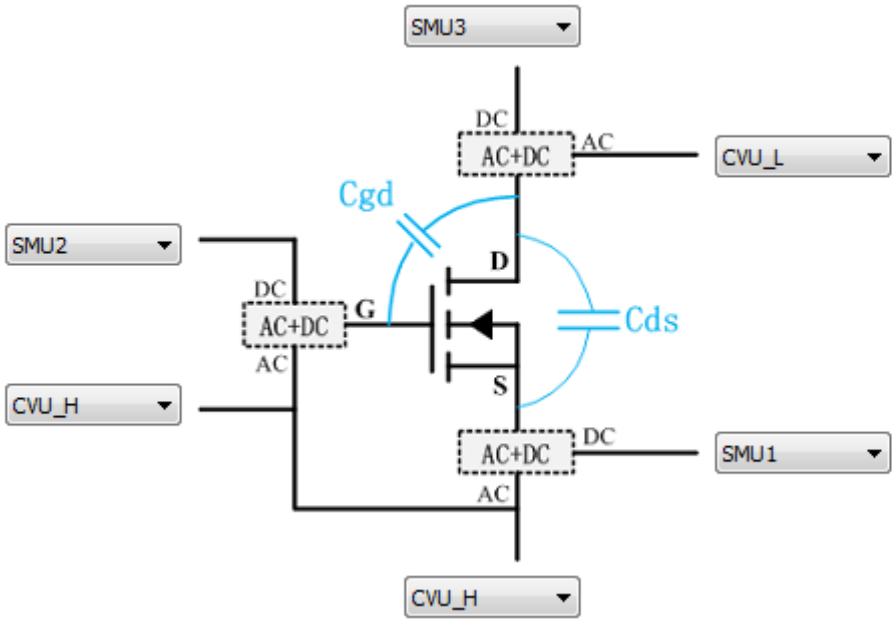


NOTE

The Ciss module is a Python Test Module (PTM). As such, it references global SMU numbers. If you are using a Model 4200A-SCS and you have SMU cards installed in its chassis, the SMU identification numbers will differ from those previously used for I-V tests. Refer to “Hardware Configuration” in the *ACS Basic Reference Manual* for details.

8. Select the **Setup** tab.
9. Assign the SMUs as shown in the following figure. Use the actual SMU number for your configuration.

Figure 133: Coss SMU assignments and block diagram (Model 8010 connections)



If you are using the Model 8010, use these configuration settings:

- **Drain DC:** SMU3 (2657A), **AC:** CVU_L
- **Gate DC:** SMU2 (2600B, ch B), **AC:** CVU_H
- **Source DC:** SMU1 (2600B, ch A), **AC:** CVU_H

If you are using the Model 8020, use these configuration settings:

- **Drain DC:** SMU3 (2657A), **AC:** CVU_L
- **Gate DC:** SMU1 (2600B, ch A), **AC:** CVU_H
- **Source DC:** SMU2 (2600B, ch B), **AC:** CVU_H

NOTE

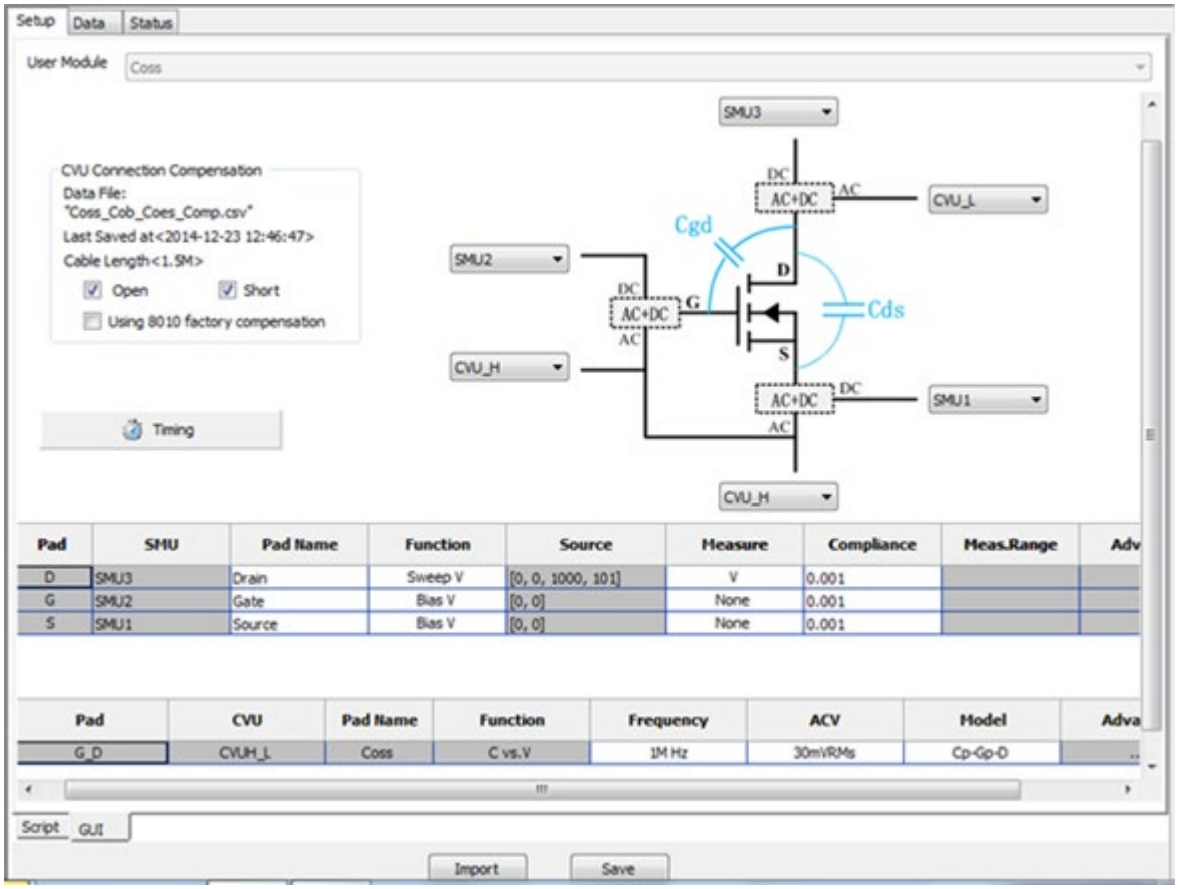
The Gate AC and Source AC instruments are linked automatically in the software. This represents the hardware connection of the white SMA cable (CA-406) shorting the two 200 V bias tees.

NOTE

Hover the cursor over the SMU pad to display the corresponding instrument model number.

10. For the included sample device, sweep voltage at the drain from 0 to 1000 V in 10 V steps.
11. Adjust the sweep values by selecting the **Source** field for the drain SMU.
12. Configure the drain SMU to measure voltage.
13. Configure the gate and source SMUs to have a source function of bias V with a source value of 0 V.
14. For the CVU, set the measurement frequency to 1 MHz by selecting Frequency and then selecting 1 MHz from the list.
15. Use the default ACV of 30 mVrms.
16. Use the CP-G-D model.

Figure 134: Test settings table

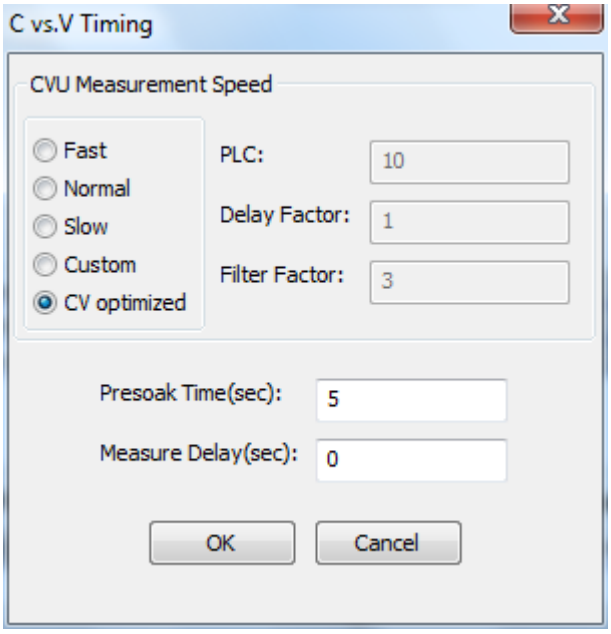


NOTE

For the Coss test module, the capacitance measurement function is fixed to capacitance vs. voltage. To view capacitance as a function of frequency, use the Generic HV C-V Test under the CommonLib_CV test category. Refer to the *ACS Basic Software Reference Manual* for information on using this test module.

17. Select **Timing**.
18. Ensure that CV optimized is selected and the Presoak Time is 5 seconds, as shown in the following figure. Select **OK**.

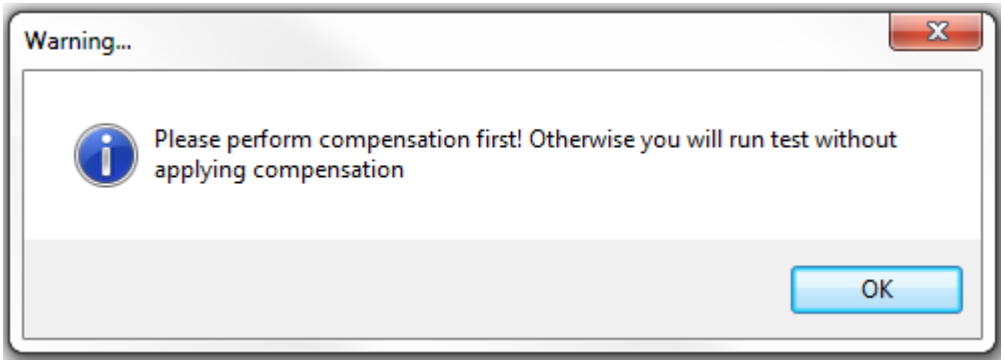
Figure 135: C vs. V Timing dialog



19. Select the Open and Short boxes in the CVU Connection Compensation area to apply the compensation to the measured data.

    The latest compensation is loaded automatically. If no compensation has been performed, you may receive the error message shown in the following figure. To perform compensation, refer to Perform connection compensation on C-V measurements (on page 5-20).

Figure 136: Warning that compensation was not performed

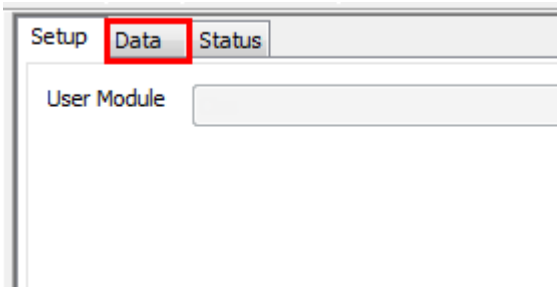


NOTE

If you have the Model 8010 and are using the CVU-3K-KIT, you can also use built-in compensation data by selecting "Using 8010 factory compensation." This allows you to make a quick validation on the device capacitance without performing the complete compensation for your specific environment.

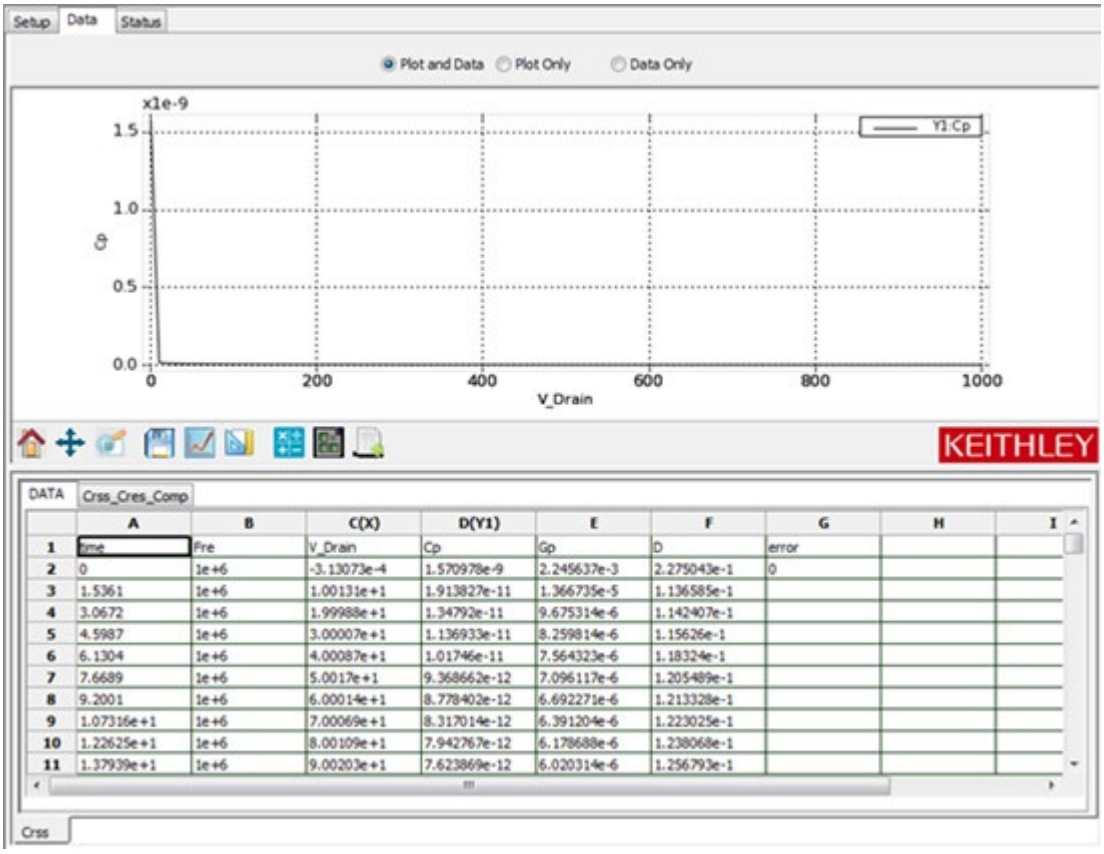
20. Sample data and pilots are included with the test. Select the Data tab, as shown in the following figure.

Figure 137: Data tab



21. Select Run (▶) to start the test. The results should appear similar to those in the following figure.

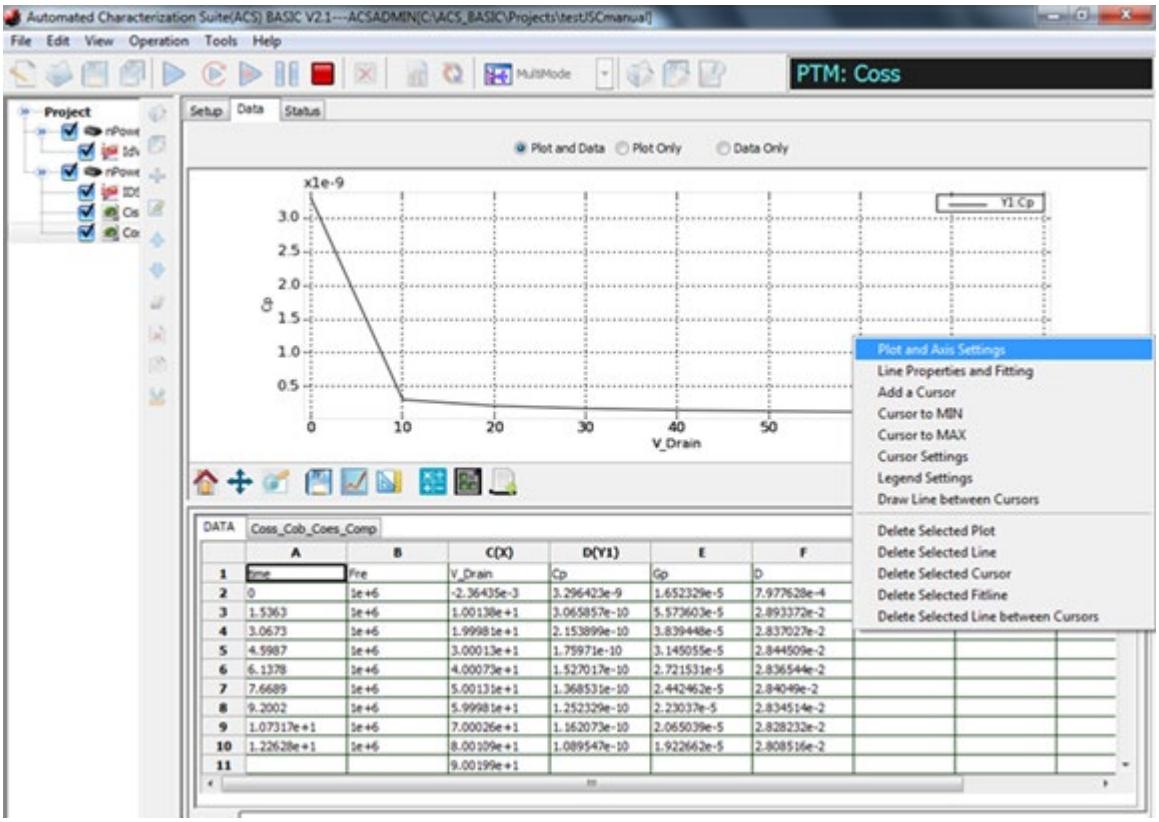
Figure 138: Run icon



	A	B	C(X)	D(Y1)	E	F	G	H	I
1	Time	Fre	V_Drain	Cp	Gp	D	error		
2	0	1e+6	-3.13073e-4	1.570978e-9	2.245637e-3	2.275043e-1	0		
3	1.5361	1e+6	1.00131e+1	1.913827e-11	1.366735e-5	1.136585e-1			
4	3.0672	1e+6	1.99988e+1	1.34792e-11	9.675314e-6	1.142407e-1			
5	4.5987	1e+6	3.00007e+1	1.136933e-11	8.259814e-6	1.15626e-1			
6	6.1304	1e+6	4.00087e+1	1.01746e-11	7.564323e-6	1.18324e-1			
7	7.6689	1e+6	5.0017e+1	9.368662e-12	7.096117e-6	1.205489e-1			
8	9.2001	1e+6	6.00014e+1	8.778402e-12	6.692271e-6	1.213328e-1			
9	1.07316e+1	1e+6	7.00069e+1	8.317014e-12	6.391204e-6	1.223025e-1			
10	1.22625e+1	1e+6	8.00109e+1	7.942767e-12	6.178688e-6	1.238068e-1			
11	1.37939e+1	1e+6	9.00203e+1	7.623869e-12	6.020314e-6	1.256793e-1			

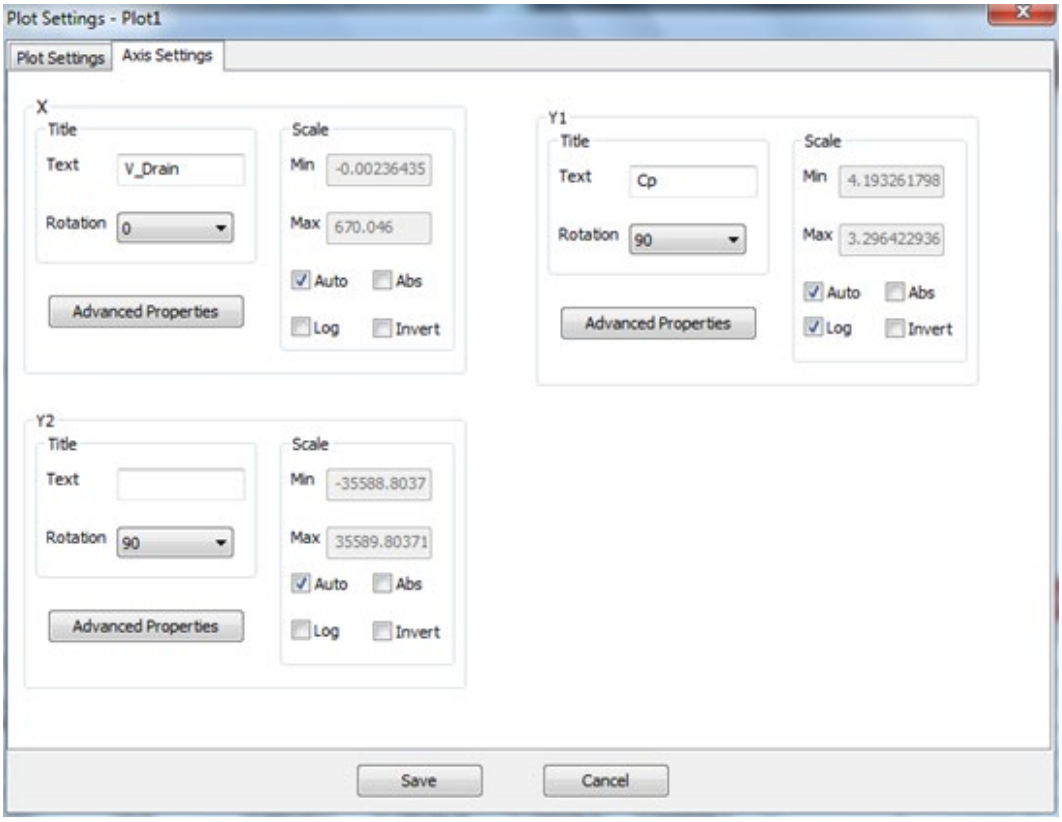
22. When the test runs, note that this device has a large change in Coss data. Changing to a log scale on the y-axis may be appropriate. To change the scale, right-click the plot area and select **Plot and Axis Settings**.

Figure 139: C-V Coss test plot axis settings



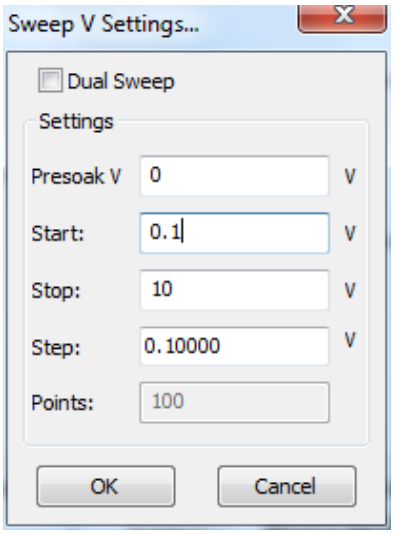
23. Select the **Axis Settings** tab.
24. Under Y1, select **Log**, as shown in the following figure.

Figure 140: Coss Axis Settings tab



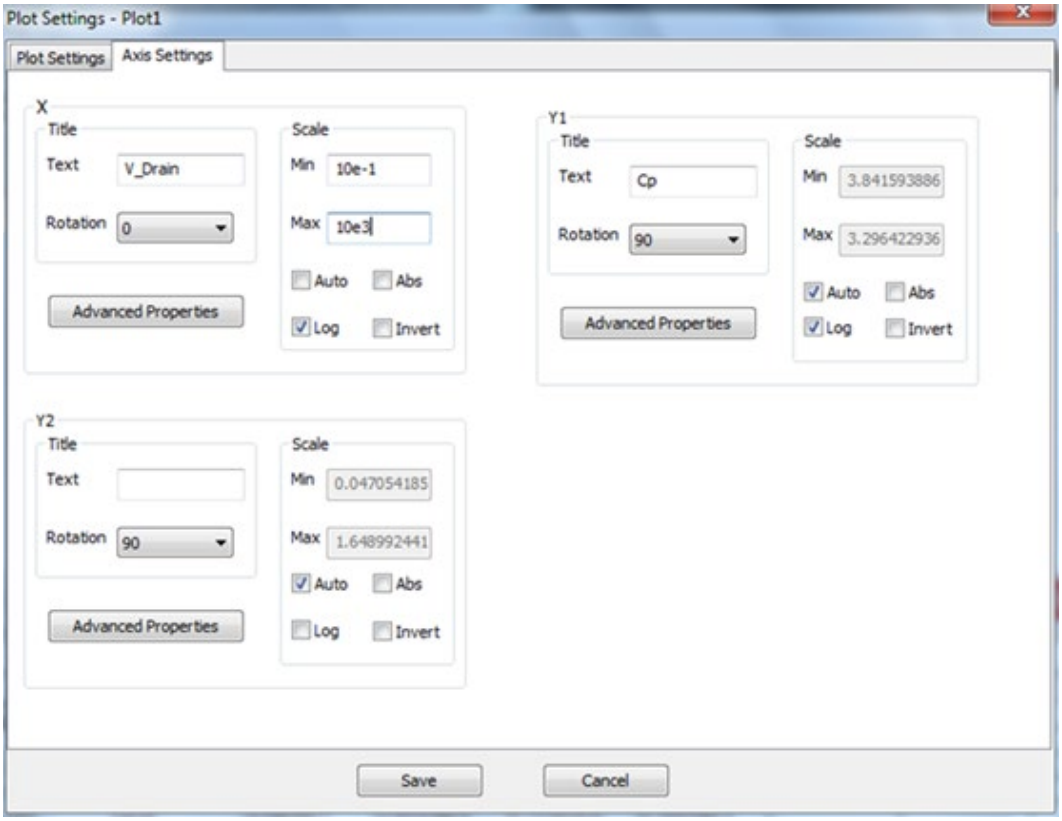
25. Select **Save**. Note that there is a large change in the data between 0.1 and 10 V. You can take a closer look at this change by running a second sweep and appending the data.
26. Select the **Setup** tab.
27. Double-click the source field for the Drain SMU to adjust the SweepV settings to sweep from 0.1 V to 10 V in 0.1 V steps.

Figure 141: Coss SweepV settings



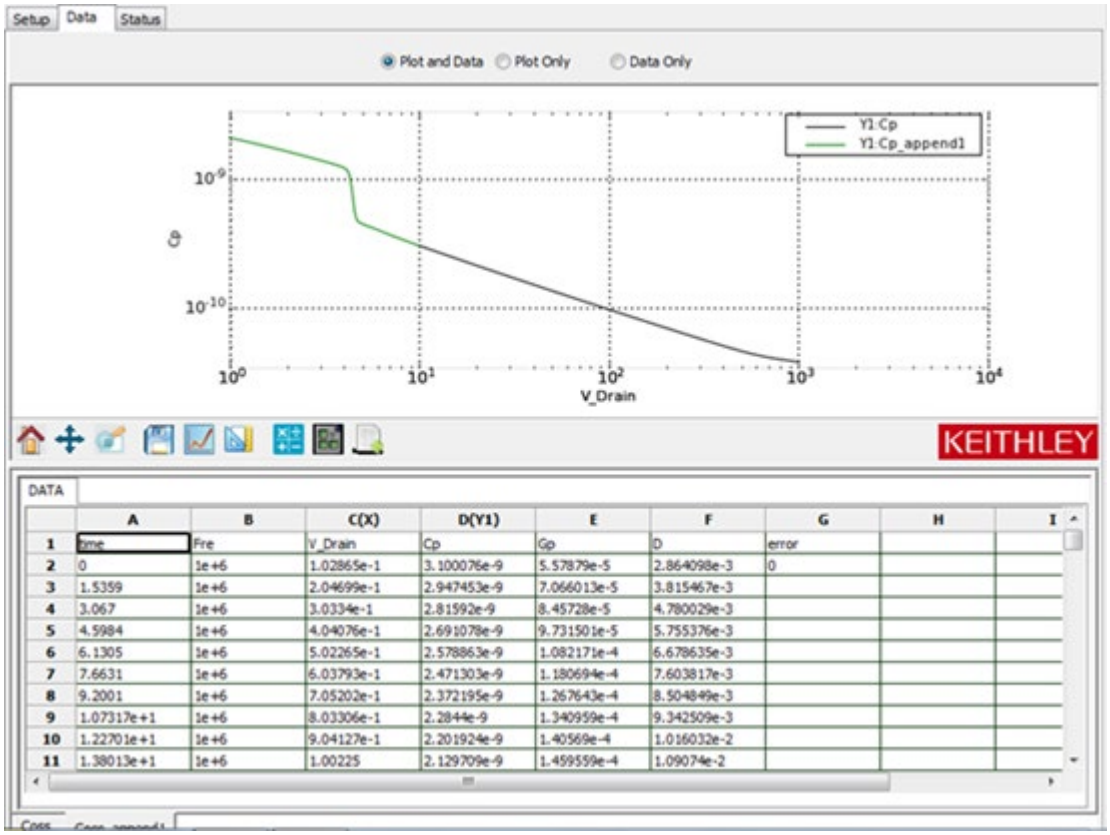
28. Select the **Data** tab, then select the **Append Run** icon in the toolbar.
29. You can also set the X-axis to a log scale. Right-click the graph and select **Plot and Axis Settings**. Select the **Axis Settings** tab and then select **Log** under X. Clear **Auto** and set the Scale Min to 10e-1 and the Max to 10e3.

Figure 142: Coss plot axis settings Log X



30. Select **Save**.
31. When the test completes, the data should appear similar to the following figure.

Figure 143: Coss results from both sweeps



	A	B	C(X)	D(Y1)	E	F	G	H	I
1	Time	Fre	V_Drain	Cp	Gp	D	error		
2	0	1e+6	1.02865e-1	3.100076e-9	5.57879e-5	2.864098e-3	0		
3	1.5359	1e+6	2.04699e-1	2.947453e-9	7.066013e-5	3.815467e-3			
4	3.067	1e+6	3.0334e-1	2.81592e-9	8.45728e-5	4.780029e-3			
5	4.5984	1e+6	4.04076e-1	2.691078e-9	9.731501e-5	5.755376e-3			
6	6.1305	1e+6	5.02265e-1	2.578863e-9	1.082171e-4	6.678635e-3			
7	7.6631	1e+6	6.03793e-1	2.471303e-9	1.180694e-4	7.603817e-3			
8	9.2001	1e+6	7.05202e-1	2.372195e-9	1.267643e-4	8.504849e-3			
9	1.07317e+1	1e+6	8.03306e-1	2.2844e-9	1.340959e-4	9.342509e-3			
10	1.22701e+1	1e+6	9.04127e-1	2.201924e-9	1.40569e-4	1.016032e-2			
11	1.38013e+1	1e+6	1.00225	2.129709e-9	1.459559e-4	1.09074e-2			

⚠ WARNING

If high voltage is used during the test, make sure a proper discharge procedure is performed before removing the top cover of the Model 8020 or making connection changes inside of the applications test fixture.

Make a Crss measurement

Crss measurement connection verification:

NOTE

Before you make measurements, make sure that you have connected your instruments correctly. See Model 8010 Crss test connections (on page 5-10) or Model 8020 Crss test connections (on page 5-16).

There is one change within the Model 8010 test fixture, but no changes at the device connections panel of the Model 8020 for this test.

Make a Crss measurement:

NOTE

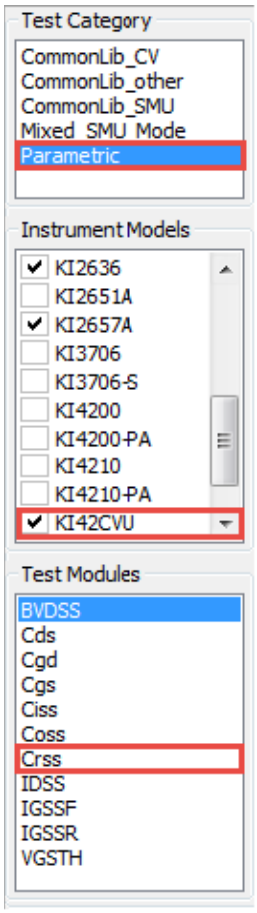
Make sure that you have performed open and short connection compensations before making a measurement. See Perform connection compensations on C-V measurements (on page 5-20) for more information and instructions.

1. From Select a Device, select **nPowerMOSFET**, as shown in the following figure.

Figure 144: Selecting the nPowerMOSFET device

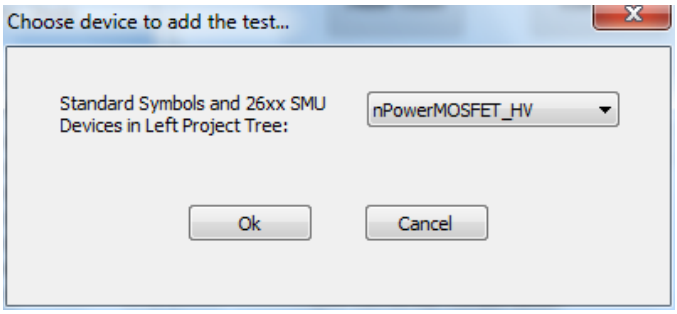
2. From Test Category, select **Parametric**, as shown in the following figure.

Figure 145: Test options



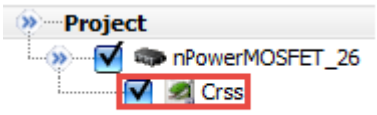
3. From Instrument Models, select **KI42CVU**.
4. From Test Modules, select **Crss**.
5. Select **Add Test** to add the Crss test to the project tree.
6. If prompted with Choose Device to Add the Test, select the device from the list and select **OK**, as shown in the following figure.

Figure 146: Choosing device



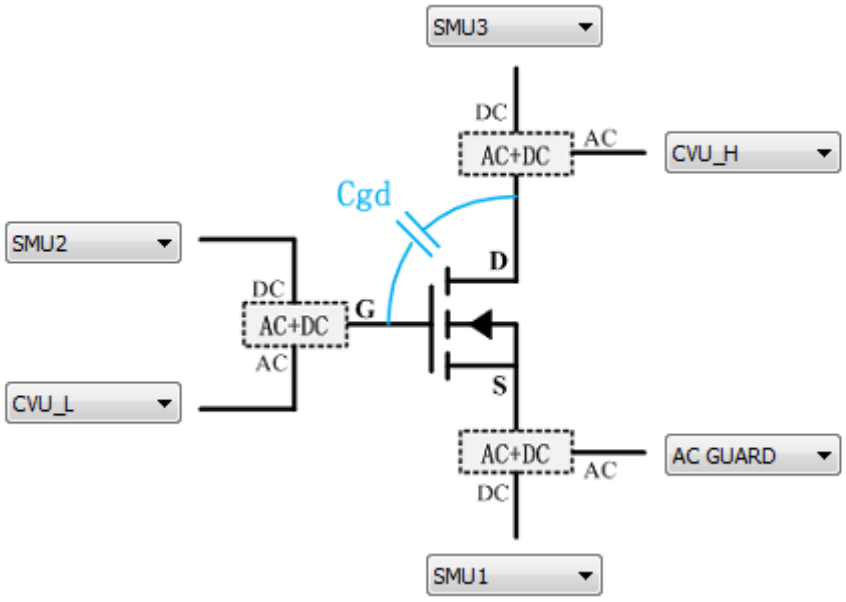
7. In the project tree, double-click the Crss test, shown in the following figure, to open the test to display the Crss test module.

Figure 147: Crss test in project tree



8. Select the **Setup** tab.
9. Assign the SMUs as shown in the following figure. Use the actual SMU number for your configuration.

Figure 148: Crss SMU assignments and block diagram (Model 8010 connections)



If you are using the Model 8010, use these configuration settings

- **Drain DC:** SMU3 (2657A), **AC:** CVU_H
- **Gate DC:** SMU2 (2600A, ch B), **AC:** CVU_L
- **Source DC:** SMU1 (2600A, ch A), **AC:** AC GUARD

If you are using the Model 8020, use these configuration settings

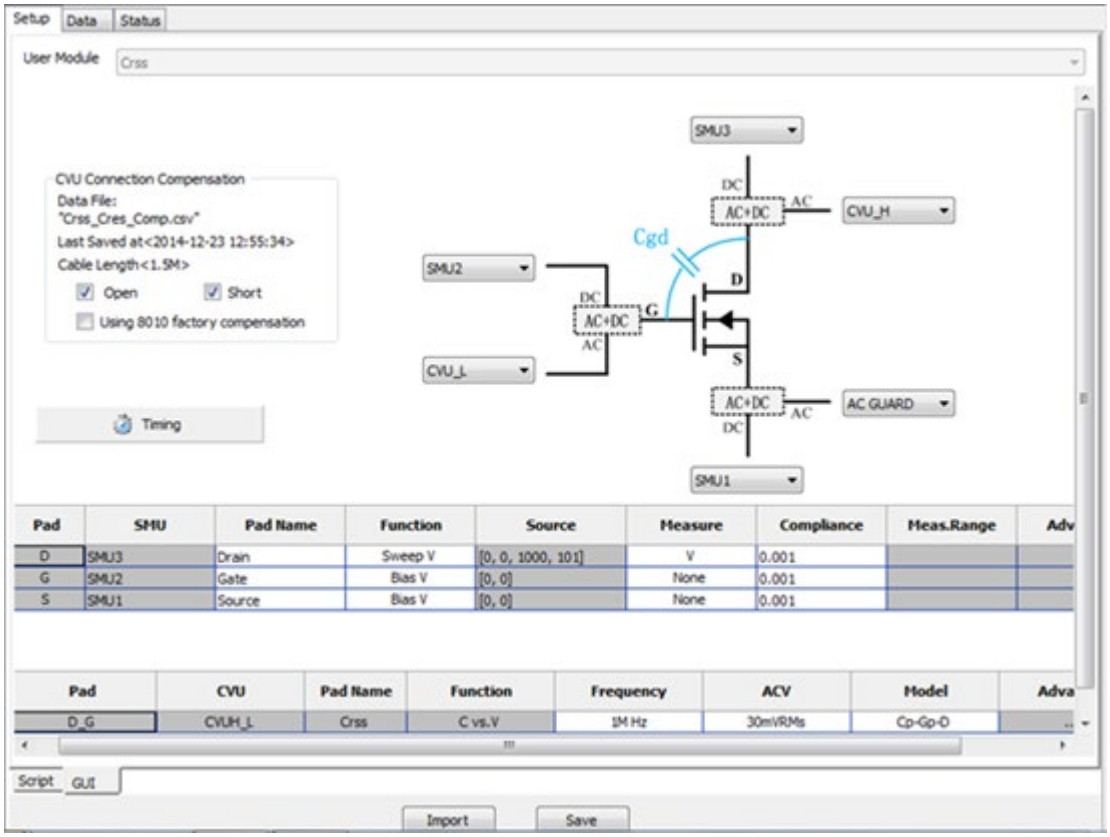
- **Drain DC:** SMU3 (2657A), **AC:** CVU_H
- **Gate DC:** SMU1 (2600B, ch A), **AC:** CVU_\L
- **Source DC:** SMU2 (2600B, ch B), **AC:** AC GUARD

NOTE

Hover the cursor over the SMU pad to display the corresponding instrument model number.

10. For the included sample device, sweep voltage at the drain from 0 to 1000 V in 10 V steps.
11. Adjust the sweep values by selecting the **Source** field for the drain SMU.
12. Configure the drain SMU to measure voltage.
13. Configure the gate and source SMUs for a source function of bias V with a source value of 0 V.
14. For the CVU, set the measurement frequency to 1 MHz by selecting Frequency and then selecting 1 MHz from the list.
15. Use the default ACV of 30 mVrms.
16. Use the CP-G-D model.

Figure 149: Test settings table

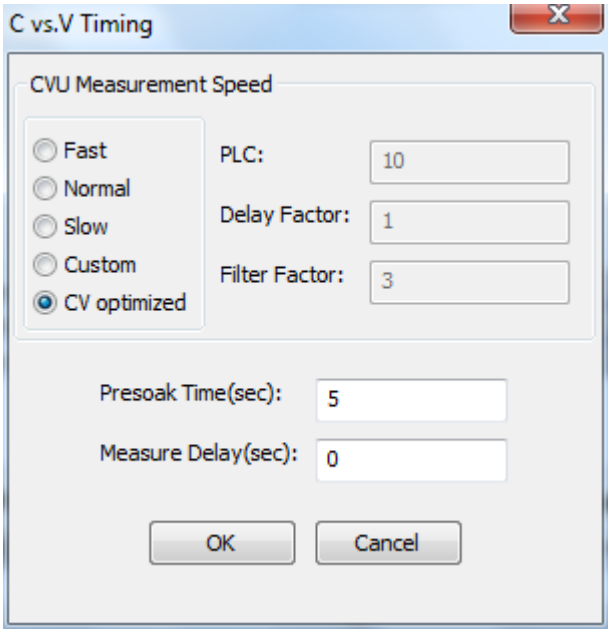


NOTE

For the Crss test module, the capacitance measurement function is fixed to capacitance vs. voltage. To view capacitance as a function of frequency, use the Generic HV C-V Test under the CommonLib_CV test category. Refer to the *ACS Basic Reference Manual* for information on using this test module.

17. Select **Timing**.
18. Ensure that CV optimized is selected and the Presoak Time is 5 seconds, as shown in the following figure. Select **OK**.

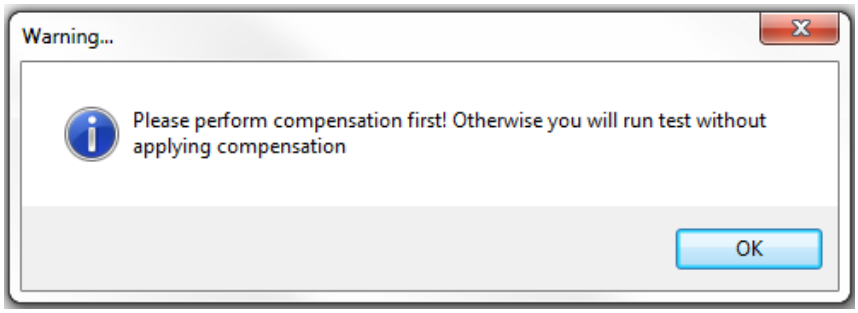
Figure 150: C vs. V Timing dialog



19. Select the Open and Short boxes in the CVU Connection Compensation area to apply the compensation to the measured data.

    The latest compensation is loaded automatically. If no compensation has been performed, you may receive the error message shown in the following figure. To perform compensation, refer to Perform connection compensation on C-V measurements (on page 5-20).

Figure 151: Warning that compensation was not performed

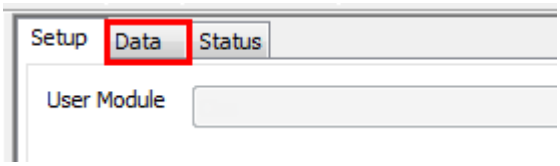


NOTE

If you have the Model 8010 and are using the CVU-3K-KIT, you can also use built-in compensation data by selecting "Using 8010 factory compensation." This allows you to make a quick validation on the device capacitance without performing the complete compensation for your specific environment.

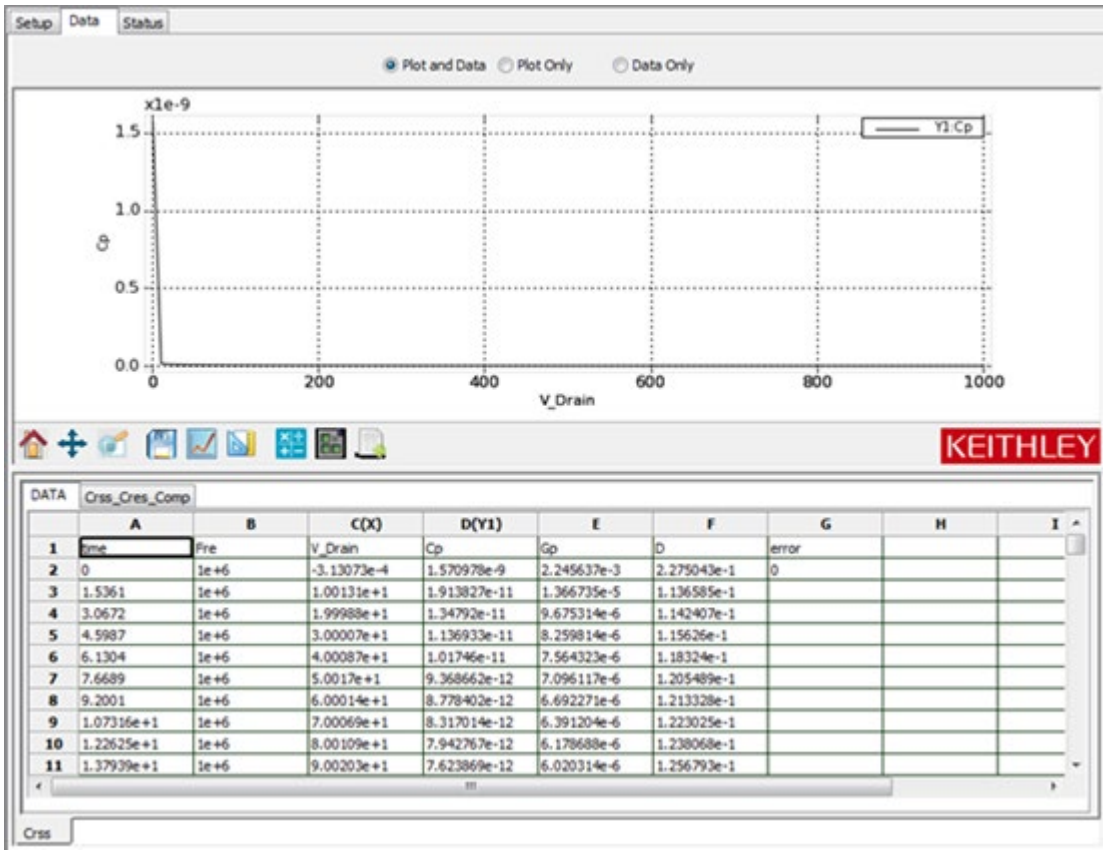
20. Sample data and pilots are included with the test. Select the Data tab, as shown in the following figure.

Figure 152: Data tab



21. Select Run (▶) to start the test. The results should appear similar to those in the following figure.

Figure 153: Run icon

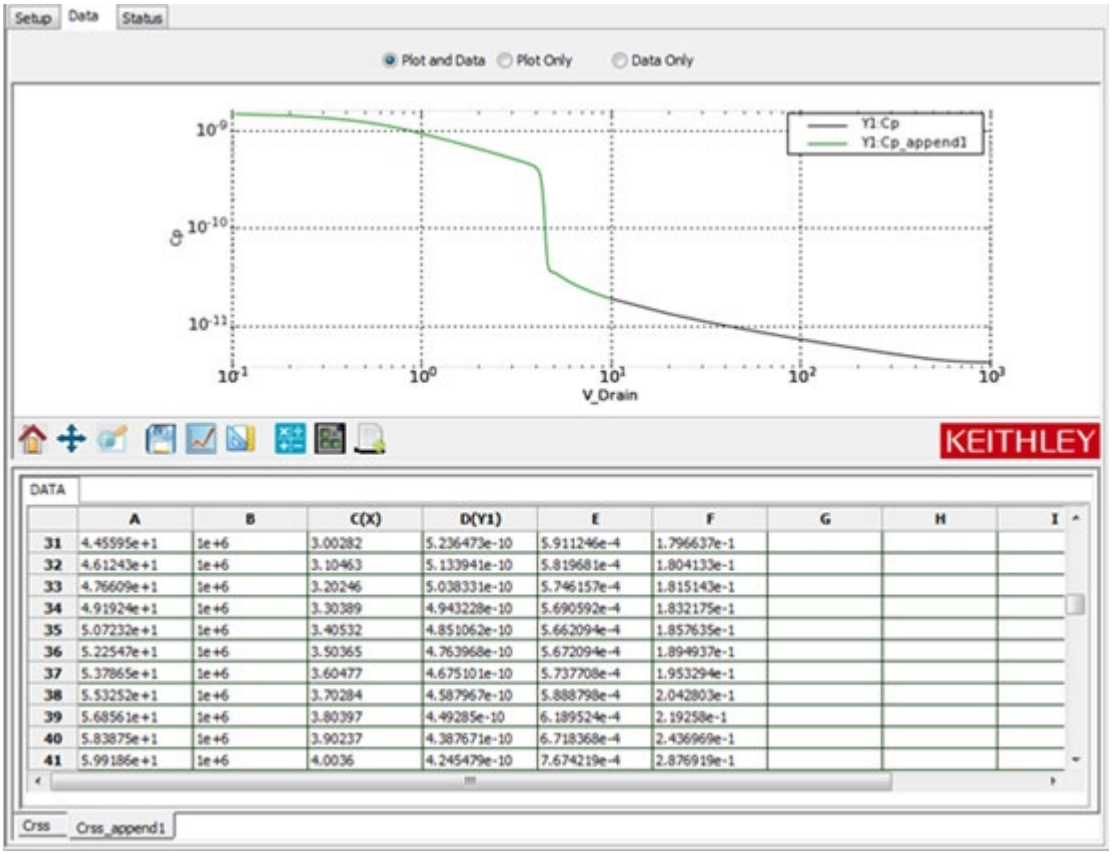


	A	B	C(X)	D(Y1)	E	F	G	H	I
1	time	Fre	V_Drain	Cp	Gp	D	error		
2	0	1e+6	-3.13073e-4	1.570978e-9	2.245637e-3	2.275043e-1	0		
3	1.5361	1e+6	1.00131e+1	1.913827e-11	1.366735e-5	1.136585e-1			
4	3.0672	1e+6	1.99988e+1	1.34792e-11	9.675314e-6	1.142407e-1			
5	4.5987	1e+6	3.00007e+1	1.136933e-11	8.259814e-6	1.15626e-1			
6	6.1304	1e+6	4.00087e+1	1.01746e-11	7.564323e-6	1.18324e-1			
7	7.6689	1e+6	5.0017e+1	9.368662e-12	7.096117e-6	1.205489e-1			
8	9.2001	1e+6	6.00014e+1	8.778402e-12	6.692271e-6	1.213328e-1			
9	1.07316e+1	1e+6	7.00069e+1	8.317014e-12	6.391204e-6	1.223025e-1			
10	1.22625e+1	1e+6	8.00109e+1	7.942767e-12	6.178688e-6	1.238068e-1			
11	1.37939e+1	1e+6	9.00203e+1	7.623869e-12	6.020314e-6	1.256793e-1			

22. Similar to the Coss data for this device, there is a large change in the measured data for Crss. Changing to a log scale on the y-axis may be appropriate. To change the scale, right-click the plot area and select **Plot and Axis Settings**.
23. Select **Log** for Y1.
24. Take a closer look at the data between 0.1 V and 10 V by running a second sweep and appending the data.

25. Return to the Setup tab and change the sweep settings by double-clicking the Source field for the Drain SMU.
26. Append the data from the second sweep to the original data by selecting the **AppendRun** button in the toolbar.
27. You can also set the X-axis to a log scale. Right-click the graph and select **Plot and Axis Settings**. Select the **Axis Settings** tab and then select **Log** under X. Clear **Auto** and set the Scale Min to 10e-1 and the Max to 10e3.
28. Select **Save**. The results should be similar to the following figure.

Figure 154: Crss data run 2



	A	B	C(X)	D(Y1)	E	F	G	H	I
31	4.45595e+1	1e+6	3.00282	5.236473e-10	5.911246e-4	1.796637e-1			
32	4.61243e+1	1e+6	3.10463	5.133941e-10	5.819681e-4	1.804133e-1			
33	4.76609e+1	1e+6	3.20246	5.038331e-10	5.746157e-4	1.815143e-1			
34	4.91924e+1	1e+6	3.30389	4.943228e-10	5.690592e-4	1.832175e-1			
35	5.07232e+1	1e+6	3.40532	4.851062e-10	5.662094e-4	1.857635e-1			
36	5.22547e+1	1e+6	3.50365	4.763968e-10	5.672094e-4	1.894937e-1			
37	5.37865e+1	1e+6	3.60477	4.675101e-10	5.737708e-4	1.953294e-1			
38	5.53252e+1	1e+6	3.70284	4.587967e-10	5.888798e-4	2.042803e-1			
39	5.68561e+1	1e+6	3.80397	4.49285e-10	6.189524e-4	2.19258e-1			
40	5.83875e+1	1e+6	3.90237	4.387671e-10	6.718368e-4	2.436969e-1			
41	5.99186e+1	1e+6	4.0036	4.245479e-10	7.674219e-4	2.876919e-1			

⚠ WARNING

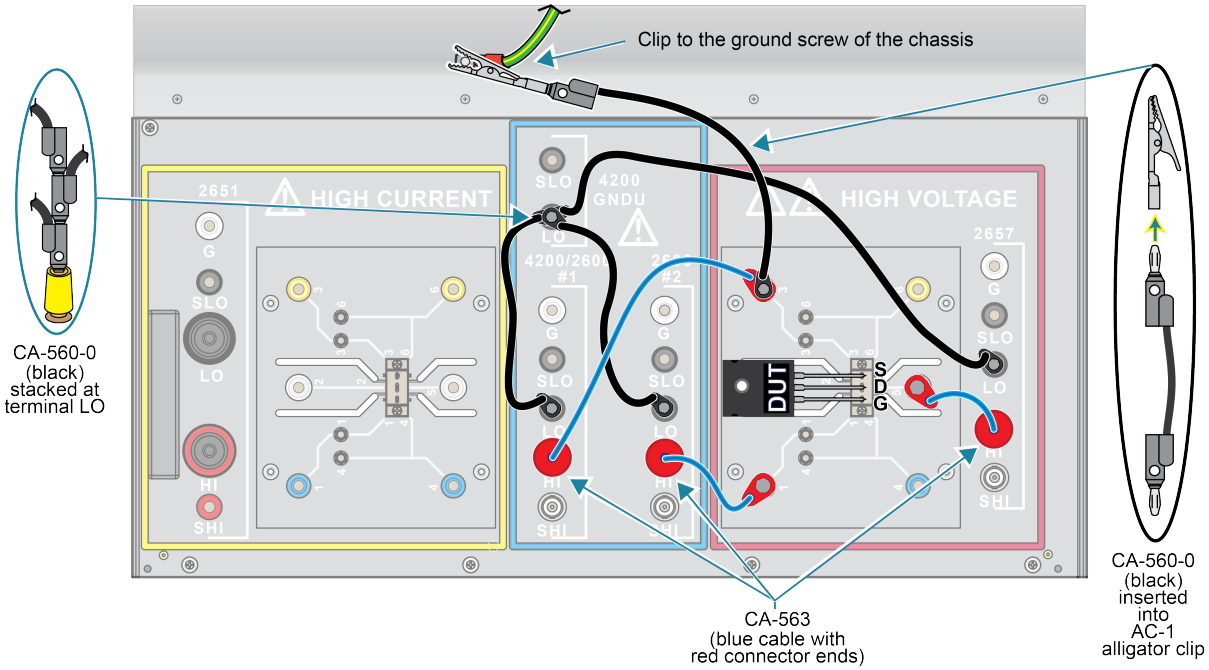
If high voltage is used during the test, make sure a proper discharge procedure is performed before removing the top cover of the Model 8020 or making connection changes inside of the applications test fixture.

Optimizing Crss measurement connections for difficult measurements

Crss measurement accuracy is affected by the size of the Cds and Cgs capacitors. The proximity of ac guard to the device under test also impacts Crss accuracy. The ac guard should be very near the virtual ground of the C-V meter, which is the return shield for the C-V measurements (the outer shell of the triaxial cable).

If the ac guard differs widely from virtual ground, then it is not an effective guard terminal. In some cases, you need to adjust connections to get a better ac guard voltage and thus a better Crss measurement. Evidence of a need to change connections is when Crss differs from the expected value or is very unstable across frequencies. To improve measurements, you can also connect the FET Source Terminal to ground close to the device under test. The Model 8010 uses these optimized connections by using a banana jumper and alligator clip to connect the FET source terminal to the chassis of the Model 8010. See the following figure for details.

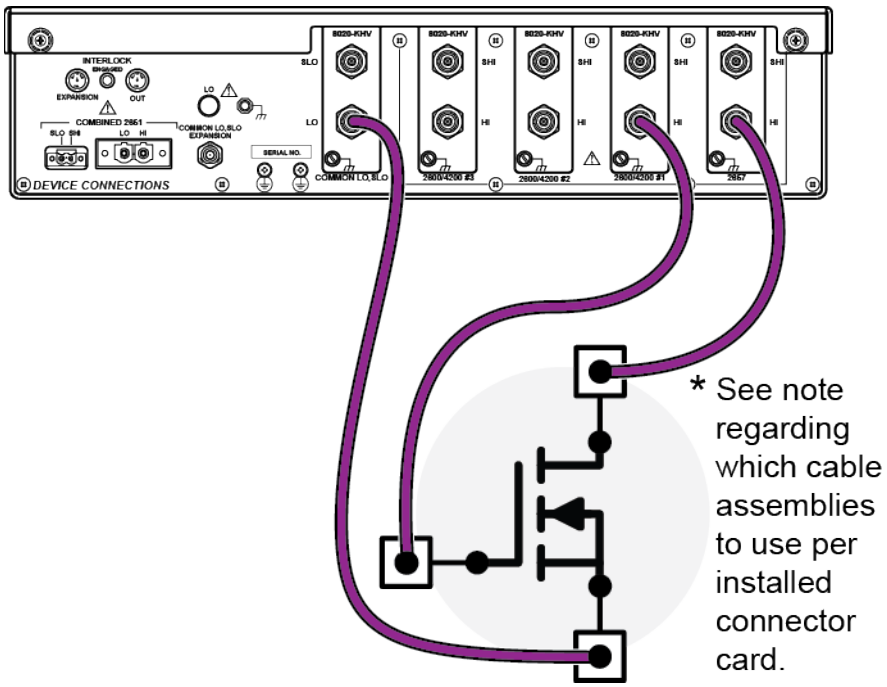
Figure 155: Model 8010 test board improved connection setup



When using the Model 8020 with a probe station, you may find that connecting to the Common LO terminal or using a shorting plug at the connector nearest the probe improves measurements. See the following figures for details.

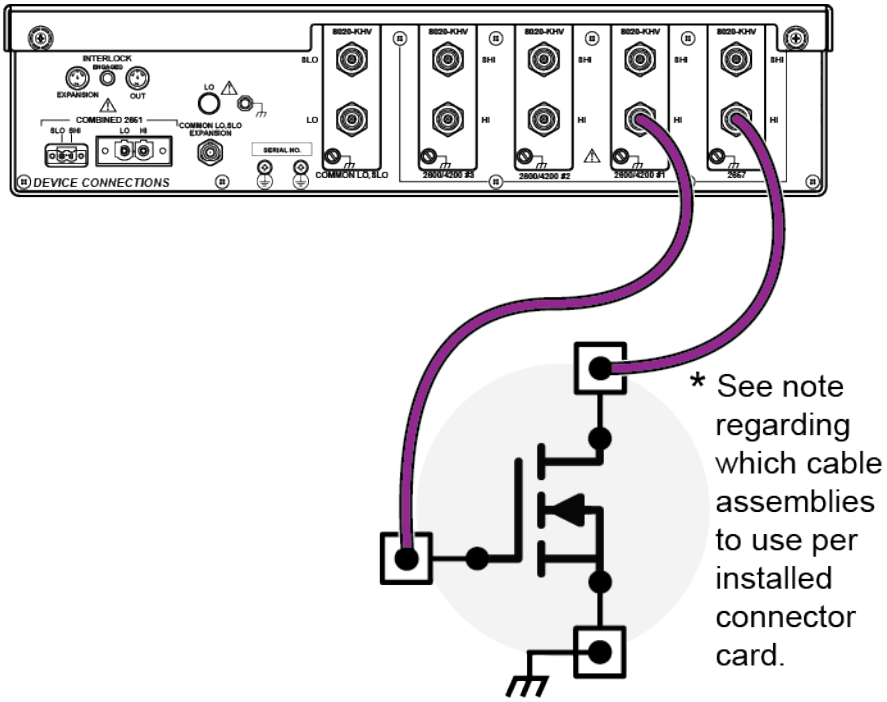
The following figure details connections to Common LO.

Figure 156: Crss measurement optimization, method 1

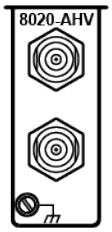


The following figure shows how to make a short at the device under test, perhaps at the probe station positioner. It may be possible to do this using an adapter that shorts the center conductor to the outer shell if the outer shell connects to chassis ground.

Figure 157: Crss measurement optimization, method 2

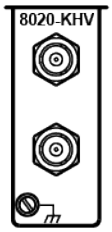


* Cable assemblies will depend upon the connector card the user installs



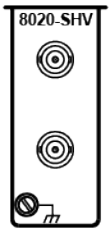
Connector Card:
8020-AHV

Cable Assembly:
User supplied



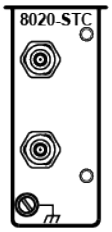
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



Connector Card:
8020-STC

Cable Assembly:
Model 7078-TRX
or
Model 4200-TRX

Section 6

Troubleshooting FAQs

In this section:

Missing cables 6-1
2600-PCT-1B and C-V measurements 6-1
2600-PCT-2B and C-V measurements 6-1
Custom tests in ACS Basic 6-2

Missing cables

Q: I opened my instrument box and did not find any cables to connect to the test fixture or interface panel.

A: All cables required to connect instrument to 8010 or 8020 are individually packaged and are included in the "Open Me First" box.

2600-PCT-1B and C-V measurements

Q: I have a 2600-PCT-1B and I want to use C-V, but I do not have a third SMU. How do I connect to the dc input of the third bias tee?

A: Connect the force terminal of the GNDU of the PCT-CVU to the third bias tee. In this configuration, there is no bias possible at the third bias tee. Detailed drawings of this connection this using the 2636B and the CVU-200-KIT Bias Tee Kit are provided in the *Model 8010 User's Manual*. See tek.com/keithley for more information.

2600-PCT-2B and C-V measurements

Q: I have a 2600-PCT-2B and I want to use C-V. Can I connect the Model 2651A to the third bias tee? How can I do this?

A: Do not connect the Model 2651A to a bias tee, because the bias tee cannot support the current capability of the instrument. Connect the force terminal of the GNDU of the PCT-CVU to the third bias tee. In this configuration, there is no bias possible at the output of the third bias tee.

Custom tests in ACS Basic

Q: Can I use ACS Basic to create tests not included in the device library?

A: Yes. You can use ITMs to configure specific settings for each SMU connected to the device or you can write custom code using Script Test Modules (STMs) or Python Test Modules (PTMs) to control other instruments. See the *ACS Basic Software Reference Manual* for more information on creating custom tests.

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