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Model 4200A-SCS Parameter Analyzer

User's Manual

4200A-900-01 Rev. D April 2020

4200A-900-01D

KEITHLEY
A Tektronix Company

4200A-SCS

Parameter Analyzer

User's Manual

Document number: 4200A-SCS-900-01 Rev. D / April 2020

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 (Hg) 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 2017.

Table of contents

Section 1

Introduction

In this section:

Welcome

Thank you for choosing a Keithley Instruments product. The Model 4200A-SCS Parameter Analyzer performs laboratory-grade DC, I-V, C-V, and pulse device characterization, real-time plotting, and analysis with high precision and subfemtoamp resolution. The 4200A-SCS offers the most advanced capabilities available in a fully integrated characterization system, including a complete, embedded computer with Microsoft® Windows® operating system and mass storage. Its touchscreen interface accelerates and simplifies the process of taking data, so users can begin analyzing their results sooner. Additional features enable stress-measure capabilities suitable for a variety of reliability tests.

Introduction to this manual

This manual provides detailed applications to help you achieve success with your Keithley Instruments 4200A-SCS. In addition, information is provided about the basics of the front panel to familiarize you with the instrument. Finally, included is an overview of each application, followed by instructions to complete the application.

More information about the commands that are used in these applications is available. Refer to the *Model 4200A-SCS Reference Manual*, available from the Learning Center on your 4200A-SCS desktop.

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/contact-us.

Organization of manual sections

This manual is organized into the following sections:

- Introduction (on page 1-1): Provides an overview of the 4200A-SCS and this manual.
- Getting started (on page 2-1): Provides high-level guidance on how to install, connect, and power up the 4200A-SCS.
- Application examples (on page 3-1): Provide detailed examples of how to use the 4200A-SCS in some typical situations.
- Next steps: Provides information about additional resources that can help you use the 4200A-SCS.

This manual is also available from the Learning Center, which you can access from your 4200A-SCS desktop.

Application examples

This manual provides application examples that show you how to perform tests from the front panel and over a remote interface. The applications include:

- Create a new project and test (on page 3-1)
- Use the RPM to switch the SMU, CVU, and PMU (on page 4-1)
- Configure and use a Series 700 Switching System (on page 5-1)
- Make I-V measurements on a solar cell (on page 6-1)
- Make C-V measurements on a MOSCAP (on page 7-1)
- Use the 4200A-CVIV Multi-Switch (on page 8-1)
- PMU for pulsed I-V measurements on a MOSFET (on page 9-1)

NOTE

The default settings used for the devices, tests, and projects in Clarius are generally sufficient to produce usable data when executing a test. However, you may have additional settings you want to apply when you configure your measurements.

General ratings

The general ratings and connections of the 4200A-SCS instrument are listed in the following table.

Category	Specification
Supply voltage range	100 V_{RMS} to 240 V_{RMS}, 50 Hz or 60 Hz
Current rating	1000 VA
Input and output connections	See Front panel overview (on page 2-1) and Rear panel overview (on page 2-4).
Environmental conditions	For indoor use only **Temperature range:** Operating: 10 °C to 40 °C (50 °F to 104 °F) Storage: –15 °C to 60 °C (5 °F to 140 °F) **Humidity range:** Operating: 5% to 80% relative humidity, non-condensing Storage: 5% to 90% relative humidity, non-condensing **Altitude** Operating: 0 to 2000 m (0 to 6562 ft) Storage: 0 to 4600 m (0 to 15092 ft) **Pollution degree:** 1 or 2

Section 2

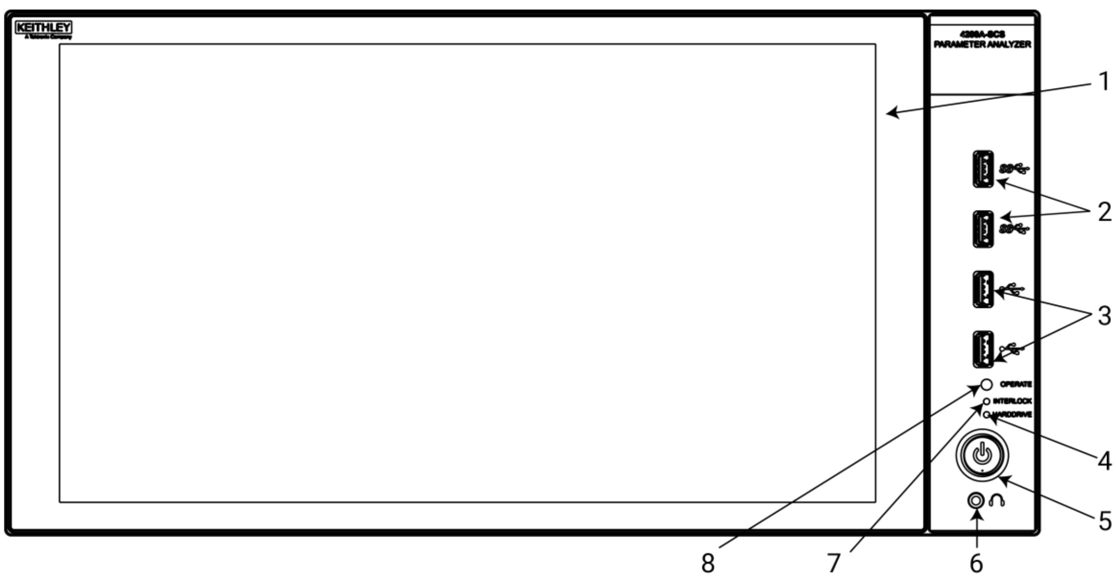
Getting started

In this section:

Front panel overview

Many controls and interfaces are on the front panel of the 4200A-SCS Parameter Analyzer. The next figure shows the front panel of the 4200A-SCS. The components are summarized following the figure.

Figure 1: 4200A-SCS front panel



1	Display	A 1920 x 1080 full HD resolution, touchscreen display.
2	Two v3.0 USB ports	Allows you to connect to peripherals such as flash drives, pointing devices, scanners, and external hard drives that are compatible with the USB v3.0 standard.
3	Two v2.0 USB ports	Allows you to connect to peripherals that are compatible with the USB v2.0 standard.
4	Hard drive indicator	Illuminates when the hard drive is being accessed.
5	Power switch	Turns the main system power on or off.
6	Headphone connector	Provides a 1/8" stereo output connection.
7	Interlock indicator	Illuminates when the 12 VDC interlock circuit is closed.
8	Operate indicator	Illuminates when any internal cards are energized.

NOTE

4200A-SCS-ND has no display and requires an external monitor.

Touchscreen basics

You can operate the 4200A-SCS using the touchscreen. You can use your fingers, clean room gloves, or any stylus manufactured for capacitive touchscreens.

To select and move on the screen:

- To scroll, swipe up or down on the screen.
- To select an item, touch it on the screen.
- To double-click an item, touch it twice.
- To right-click an item, touch and hold, then release to see the options.

To enter information, you can use the on-screen keyboard. Swipe from the left side of the display to open the keyboard.

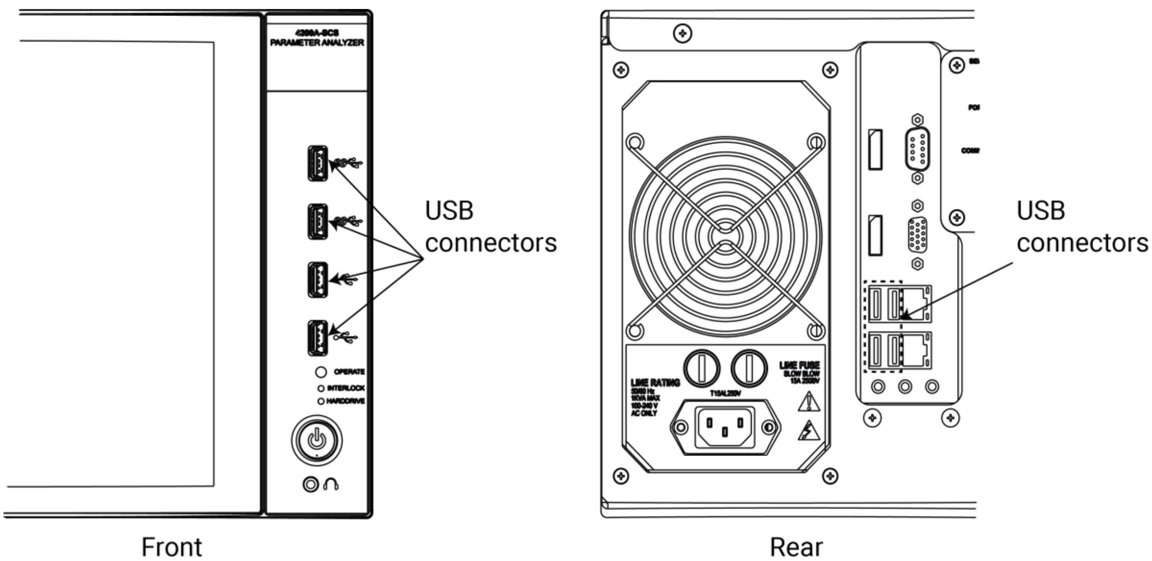
The touchscreen uses standard Microsoft® Windows® touch actions. For additional information on the actions, refer to the Microsoft help information, available from the on-screen keyboard window menu option **Tool > Help Topics**.

You can also adjust the touch settings using the Pen and Touch options in the Windows Control Panel.

Connect a keyboard and mouse

Connect the keyboard to the 4200A-SCS with a USB cable. You can plug it into any of the eight USB ports. To ensure proper operation, be sure that the keyboard is connected before power-up.

Figure 2: Keyboard and mouse connections

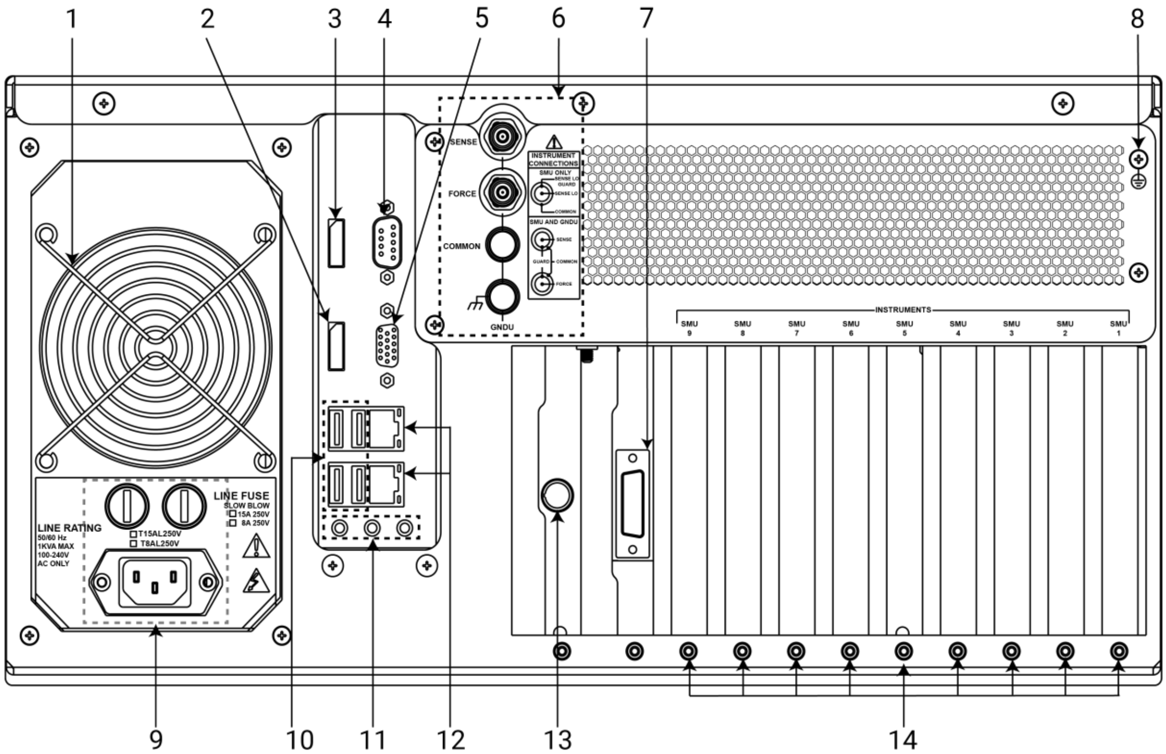


If you want to use an optional mouse, connect a USB mouse to any of the 4200A-SCS USB ports.

Rear panel overview

The following figure shows the rear panel of the 4200A-SCS. The connectors and components are summarized following the figure.

Figure 3: 4200A-SCS rear panel



1	Fan	Provides system cooling.
2	DP port	Provides a standard DisplayPort connection. Supports up to v1.2.
3	HDMI port	Provides a standard High Definition Multimedia Interface (HDMI®) connection. Supports up to v1.3.
4	Serial port	Connects to an RS-232 peripheral.
5	External monitor port	15-pin video connector.
6	Ground unit	Provides system-level SENSE, FORCE, and COMMON connections.
7	IEEE-488 connector	Connects to peripherals with a GPIB interface.
8	Grounding screw	Connects to protective earth (safety ground)
9	Power receptacle and line fuses	Connects to line power through supplied line cord. Two line fuses protect the instrument.
10	Four v3.0 USB connectors	Allows you to connect to peripherals such as keyboards, pointing devices, printers, flash drives, external hard drives, and printers that are compatible with the USB v3.0 standard.
11	Microphone and speaker connectors	Provides microphone, left speaker, and right speaker connections.
12	Two LAN connectors	Two gigabit LAN connectors interface the unit to ethernet local networks.
13	12 VDC interlock connector	Connects the instrument to a test fixture or prober interlock circuit.
14	Nine instrument slots	Support the factory-installed SMU, CVU, and PMU/PGU cards.

Connect an external monitor

You can connect an external monitor to the 4200A-SCS. For best results, use a 1920x1080p HD monitor to maintain the correct resolution when using the Clarius application.

The HDMI port on your 4200A-SCS supports up to v1.3. The DisplayPort (DP) supports up to v1.2

Installation

This section contains information about handling and installing the 4200A-SCS:

- **Locating the system:** Describes how to select the best operating environment location for your 4200A-SCS.
- **Basic system connections:** Explains how to connect the grounding cable, LAN cable, GPIB-compatible instruments, and the safety interlock to the 4200A-SCS.
- **SMU connections:** Describes how to make SMU connections to the device under test (DUT).
- **Powering the 4200A-SCS:** Describes line power requirements for the 4200A-SCS, and shows how to connect the power line cord.

CAUTION

When you start one of the Clarius+ applications for the first time, you must agree to the license agreement before continuing. If you do not respond with "Yes", your system will not function until you reinstall the software.

NOTE

The condensed installation information in this section is intended to get your 4200A-SCS set up and ready to turn on as quickly as possible. Detailed information on connections is provided in the *Model 4200A-SCS Reference Manual*.

Locating the system

Locate the 4200A-SCS so that it will operate within the following ambient temperature and humidity limits:

- Temperature: +10 °C to +40 °C
- Relative humidity: 5% to 80%, non-condensing

NOTE

SMU and preamplifier accuracy specifications are based on operation at 23 °C ±5 °C and between 5% and 60% relative humidity. See the 4200A-SCS datasheet at the Keithley Instruments website (tek.com/keithley) for derating factors outside these ranges.

CAUTION

To avoid overheating, operate the instrument only in an area with proper ventilation. Allow at least eight inches of clearance at the back of the mainframe to assure sufficient airflow and comply with the following guidelines:

- Operate the instrument in a clean, dust-free environment.
- Keep the fan vents and cooling vents from becoming blocked (sides and rear of the instrument).
- Do not position any devices adjacent to the instrument that force air (heated or unheated) into cooling vents. This additional airflow could compromise accuracy performance.
- When rack mounting the instrument, ensure adequate airflow around the sides, bottom, and back.
- Do not rack-mount high power dissipation equipment adjacent to the 4200A-SCS.
- To ensure proper cooling in rack environments with only convection cooling, place the hottest equipment (for example, power supply) at the top of the rack. Place precision equipment, such as the 4200A-SCS, as low as possible in the rack, where temperatures are the coolest. Adding spacer panels below the instrument helps to ensure adequate airflow.

Basic system connections

This section provides basic system connections to get your 4200A-SCS set up and running. More detailed connection information is in the "Connections and configuration" section of the *Model 4200A-SCS Reference Manual*.

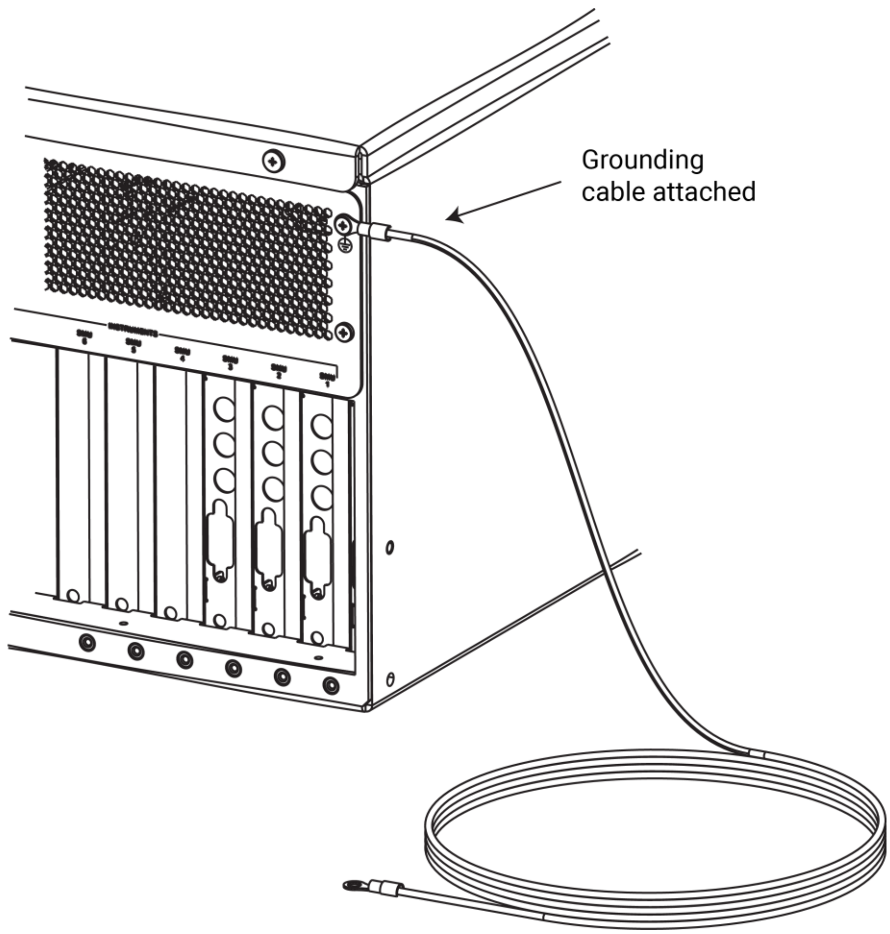
Connecting to protective earth

WARNING

The 4200A-SCS must be connected to protective earth (safety ground) using the supplied green-yellow ground cable. Failure to attach the ground wires to a known protective earth may result in electric shock.

Connect one lugged end of the supplied grounding cable to the protective earth (safety ground) screw on the rear of your 4200A-SCS. See the next figure.

Figure 4: Grounding cable connected to the rear of the 4200A-SCS

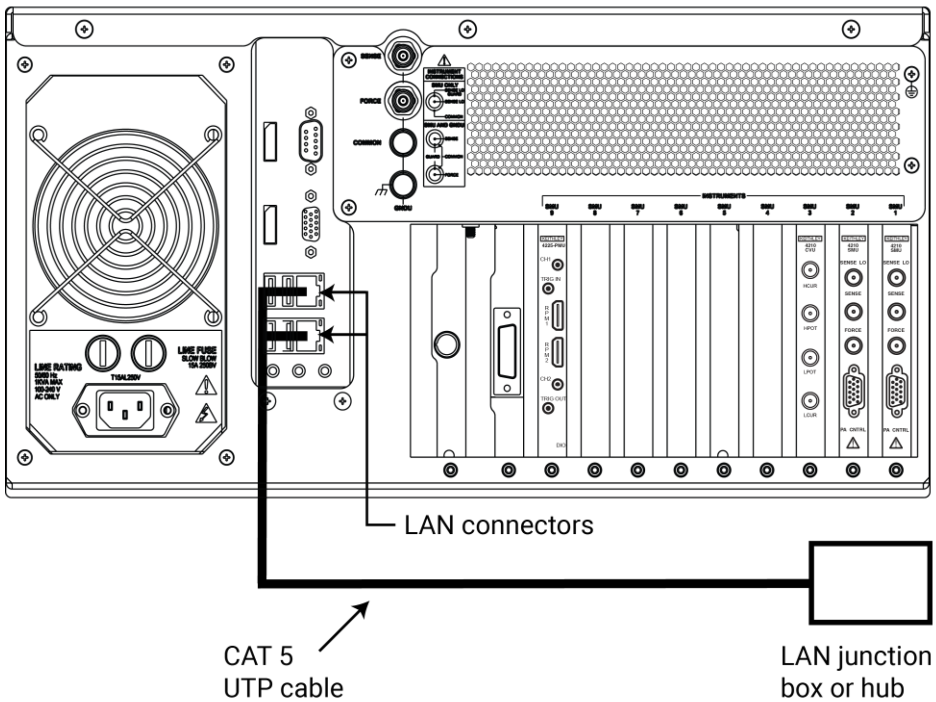


Connecting a LAN cable

The two LAN connectors on the 4200A-SCS are standard RJ-45 connectors intended for use with unshielded twisted pair (UTP) cable. For best results, use only CAT 5 UTP cables equipped with RJ-45 connectors to connect your LANs, as shown in the following figure.

If IP addresses are statically assigned, you need to assign a different IP address to each LAN port.

Figure 5: LAN connections

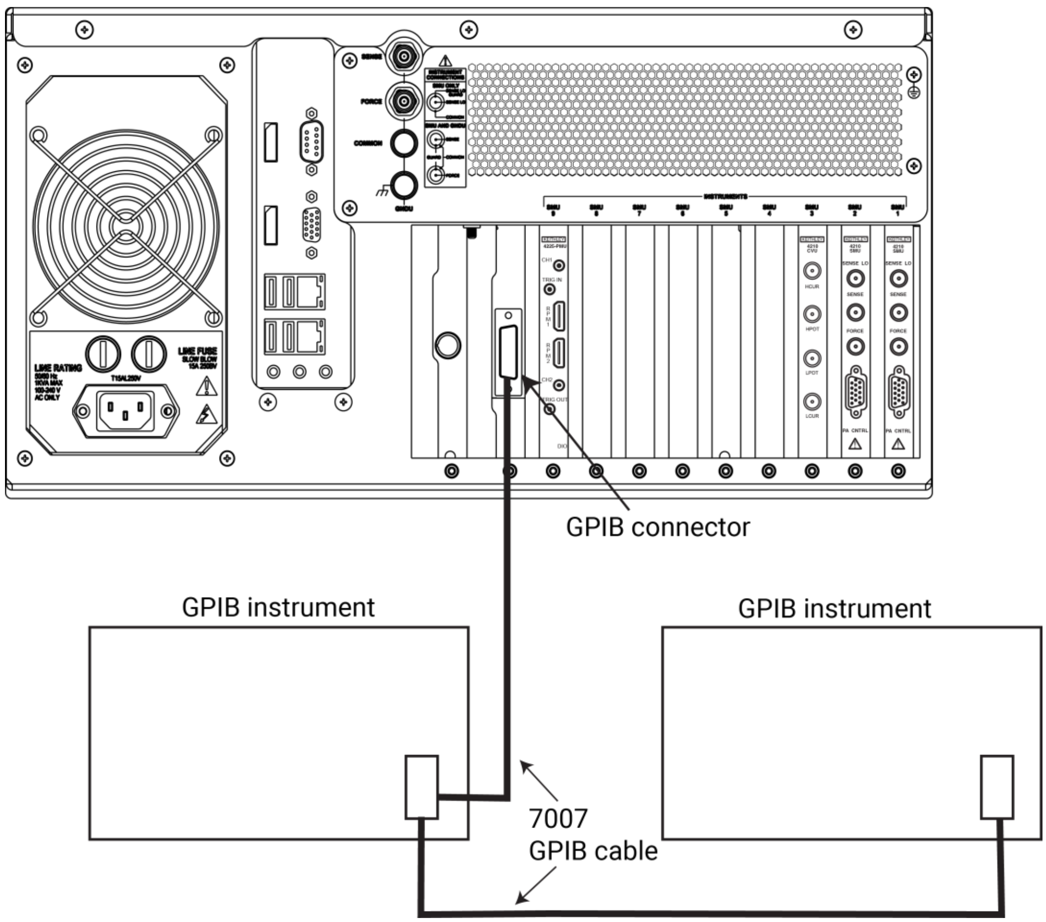


Connecting GPIB instruments

You can use the 4200A-SCS to control one or more external instruments using the IEEE-488 general purpose instrument bus (GPIB). An example of typical instruments used in a test system with the 4200A-SCS are a switching system and an external C-V meter.

The following figure shows how to connect GPIB instruments to the 4200A-SCS.

Figure 6: 4200A-SCS GPIB instrument connections



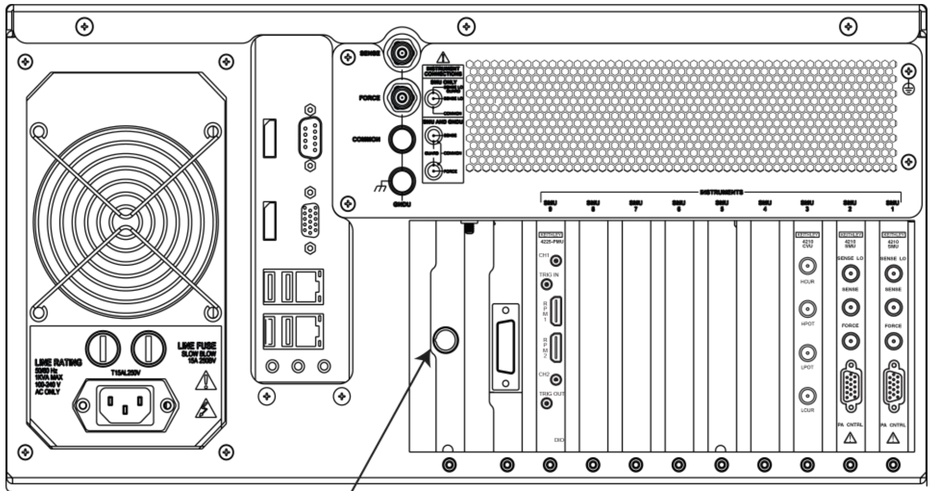
Connecting the interlock

The next figure shows the location of the interlock connector on the rear panel of the 4200A-SCS.

To connect the interlock:

1. Connect one end of the supplied 236-ILC-3 interlock cable to the interlock connector on the rear panel of the 4200A-SCS (see the next figure).

Figure 7: Interlock connector on the rear panel of the 4200A-SCS



2. Connect the other end of the interlock cable to a compatible test fixture, such as the Keithley Instruments LR:8028.

For more information, see the "Configuring the safety interlock" topic in the *4200A-SCS Reference Manual*.

SMU connections

The following topics explain how to connect the source-measure units (SMUs) to the device under test (DUT).

WARNING

Do not touch test cables or connectors when powering up the 4200A-SCS. Hazardous voltage may be output momentarily, posing a safety hazard that could result in personal injury or death.

Do not turn on the 4200A-SCS until you have reviewed the safe power-up procedure in Powering the 4200A-SCS (on page 2-16).

CAUTION

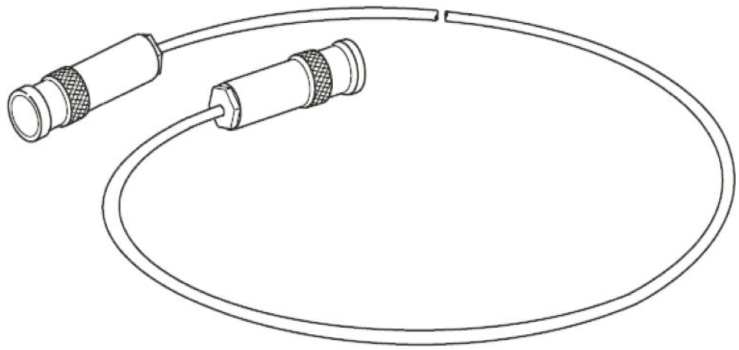
Do not connect the DUT to the 4200A-SCS before powering it up, because the hazardous voltage that may be output momentarily at power-up could damage the DUT.

If your 4200A-SCS includes preamplifiers, all tests should be performed using the preamplifiers, as the installed SMUs were optimized at the factory to use them.

Triaxial cables

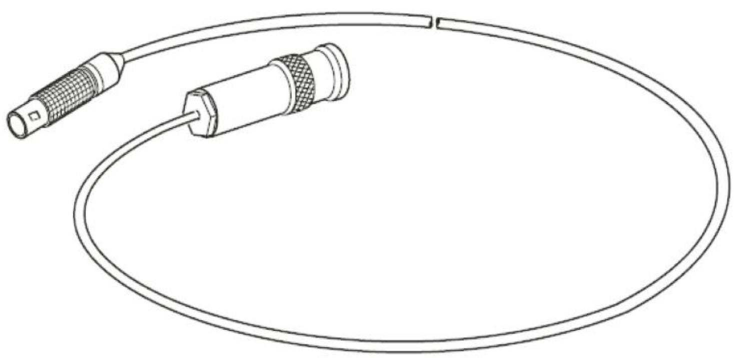
Triaxial cables are supplied to make connections to the DUT (device under test). With preamplifiers installed, use the low-noise triaxial cables, which are terminated with 3-slot triaxial connectors on both ends. One end of the cable connects to the preamplifier and the other end connects to the DUT test fixture or probe station.

Figure 8: Triaxial cable 4200-TRX-X



If your system does not have preamplifiers installed, use the cables that have a miniature triaxial connector on one end and a standard 3-slot triaxial connector on the other end. The cable end that is terminated with the miniature connector connects directly to the SMU, and the other end connects to the test fixture or probe station.

Figure 9: Triaxial cable 4200-MTRX-X



CAUTION

With preamplifiers installed, NEVER make connections directly to any of the miniature triaxial connectors on the SMU modules. This may result in damage to the SMU or DUT or may produce corrupt data.

Basic connections

The simplest method to connect SMUs to the device under test (DUT) is to use one SMU for each terminal of the device. When setting up a test, the FORCE terminal (center conductor) of the SMU is used to apply voltage or current to the device. The FORCE terminal or ground unit can also be used to connect the device terminal to the COMMON circuit.

NOTE

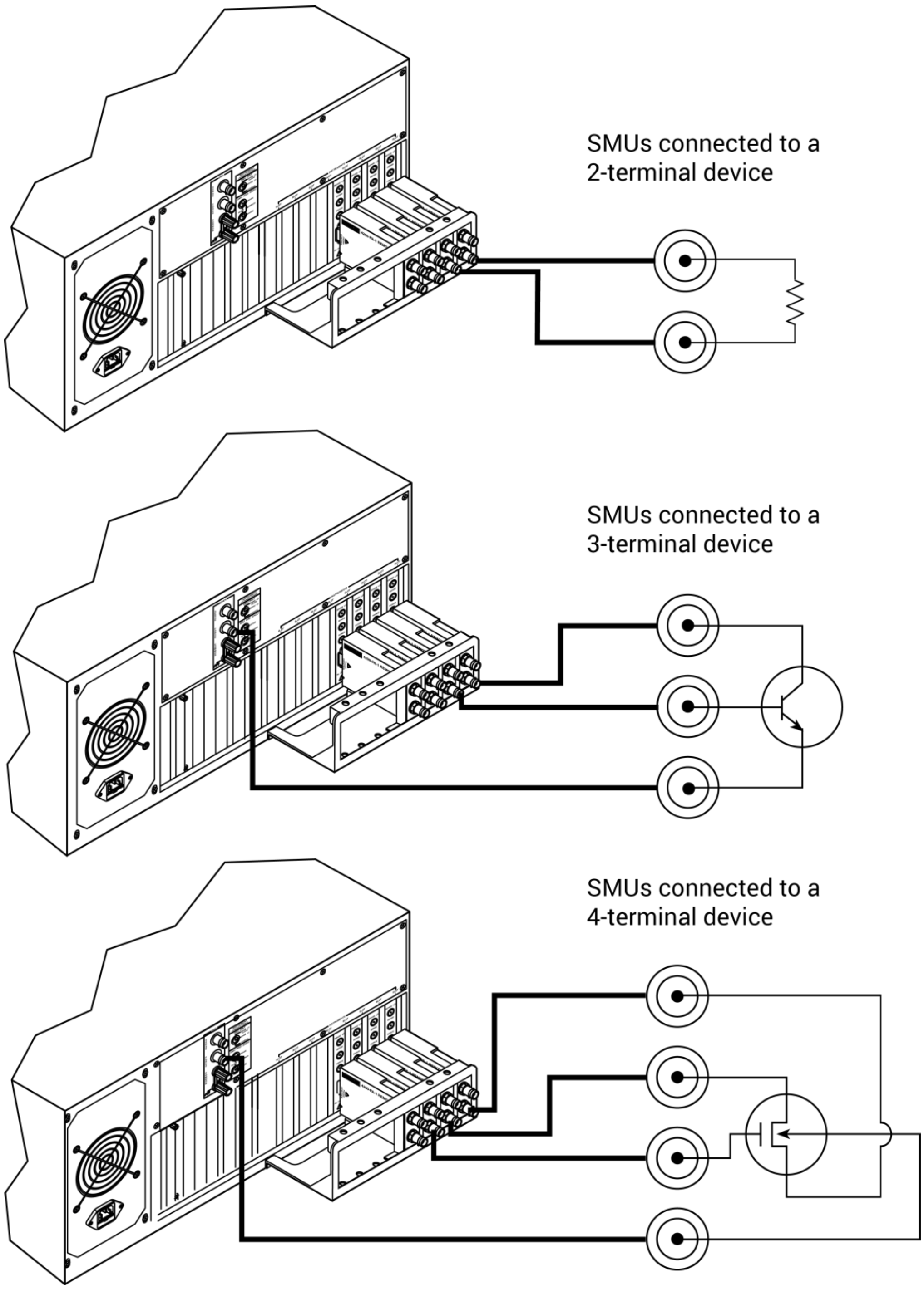
Complete details on connections (including SENSE terminal connections) are provided in the "Connections and configuration" section of the *Model 4200A-SCS Reference Manual*.

The next figure shows SMU connections to 2-terminal, 3-terminal, and 4-terminal devices. Notice that only the FORCE HI terminal of each SMU is connected to the device terminal. FORCE HI is the center conductor of the triaxial cable.

CAUTION

Connecting the SMU or ground unit SENSE terminal without the FORCE terminal may damage the instrument and return erroneous results.

Figure 10: SMU (with preamplifiers) connections to DUT



Mounting preamplifiers in a probe station

You can mount the preamplifiers remotely on a probe station using an optional mounting kit. Follow the steps below to mount and connect a remote preamplifier on a probe station. Details are provided in the documentation provided with the mounting kit.

Three remote preamplifier mounting options are available:

- **4200-MAG-BASE:** A magnetic base for mounting a preamplifier onto a probe station platen.
- **4200-VAC-BASE:** A vacuum base for mounting a preamplifier onto a probe station platen.
- **4200-TMB:** A triaxial mounting bracket for mounting a preamplifier onto a probe station or onto the triaxial mounting panel of a test fixture.

NOTE

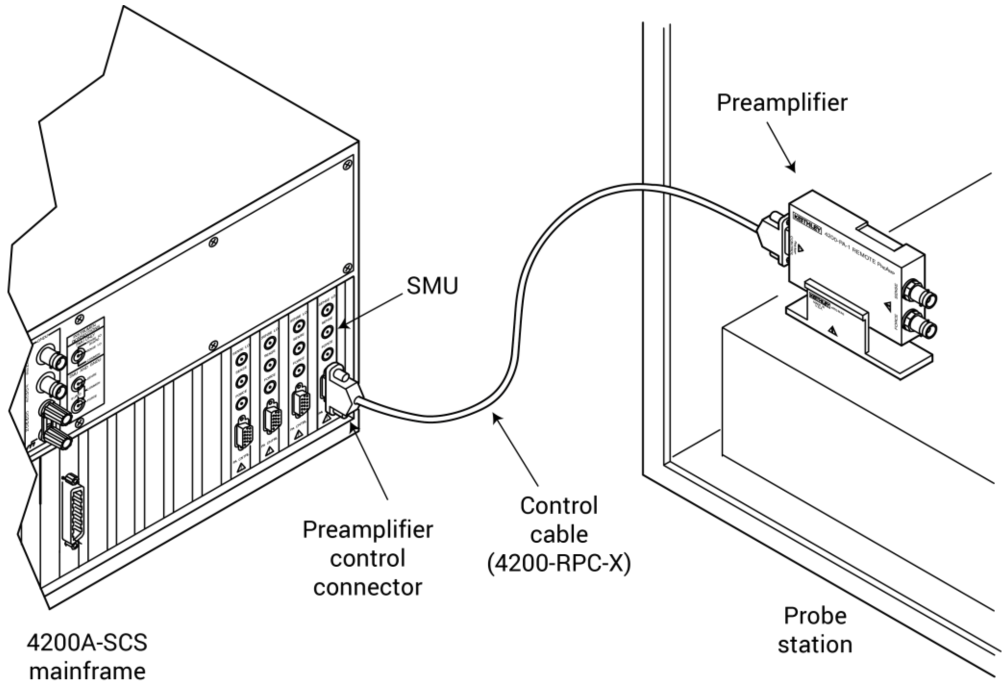
Each preamplifier is matched to the SMU it is connected to. When you disconnect the preamplifiers to mount them to a probe station, make sure to reconnect each one to its matching SMU.

To mount a preamplifier onto a probe station:

1. Turn off the system power for the 4200A-SCS from the front panel.
2. Disconnect the preamplifiers from the rear panel of the 4200A-SCS. They are secured to the rear panel by a mounting bracket.
3. Mount the preamplifier at the remote location using the appropriate mounting kit.
4. Connect the control cable between the preamplifier control connector on the preamplifier and the PA CNTRL connector on the SMU.
5. Make sure that the connecting cable is secure at both ends.

For additional preamplifier details, see the *Model 4200A-SCS Reference Manual*.

Figure 11: Installing a preamplifier on the probe station



Powering the 4200A-SCS

CAUTION

Operating the instrument on an incorrect line voltage may cause damage, possibly voiding the warranty.

WARNING

The power cord supplied with the 4200A-SCS contains a separate protective earth (safety ground) wire for use with grounded outlets. When proper connections are made, the instrument chassis is connected to power-line ground through the ground wire in the power cord. In the event of a failure, not using a properly grounded protective earth and grounded outlet may result in personal injury or death due to electric shock.

Do not replace detachable mains supply cords with inadequately rated cords. Failure to use properly rated cords may result in personal injury or death due to electric shock.

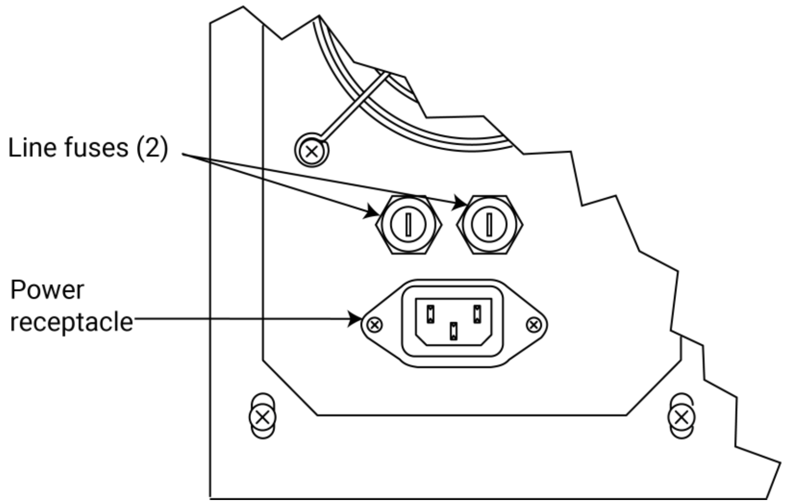
The 4200A-SCS operates from a line voltage in the range of 100 VAC to 240 VAC at a frequency of 50 Hz or 60 Hz. Line voltage is automatically sensed, but line frequency is not.

The 4200A-SCS power switch allows you to either shut down the instrument without shutting down the software, or shut down the instrument and the software. To shut down only the instruments, press the power button briefly. To shut down the instrument and the software, hold the power button down for a few seconds.

To connect and power the unit:

1. Check to be sure that the operating voltage in your area is compatible.
2. Connect the female end of the supplied power cord to the AC receptacle on the rear panel. See the Rear panel overview (on page 2-4) for details.

Figure 12: Line power receptacle



3. Connect the other end of the supplied line cord to a grounded AC line power receptacle.
4. Turn the power ON using the front-panel power switch.

NOTE

Although the instrument does not sense power line frequency at power-up, Keithley ships your 4200A-SCS with line frequency settings that match the line frequency that was specified on the order — either 50 Hz or 60 Hz. However, if necessary, you can change the line frequency setting using the KCon utility. Refer to the Keithley Configuration Utility (KCon) section in the *Model 4200A-SCS Reference Manual*.

NOTE

Operating the 4200A-SCS with the wrong line frequency setting may result in noisy readings because the line frequency setting affects SMU line frequency noise rejection.

5. Allow the instrument to warm up for at least 30 minutes to achieve rated measurement accuracy.

Section 3

Create a new project and test

In this section:

Introduction

This section provides an example of how to create a new blank project and configure a new blank test. You will create a test to be performed on a MOSFET, but the procedure is general and can be applied to different devices and applications.

NOTE

The default settings used for the devices, tests, and projects in Clarius are generally sufficient to produce usable data when executing a test. However, you may have additional settings you want to apply when you configure your measurements.

Equipment required

- One 4200A-SCS, with the following instruments:
  - Two medium power (420x-SMU) or high power (42x1-SMU) SMUs
  - Two 4200-PAs
- Three 4200-TRX-2 or 4200-MTRX-2 triaxial cables (supplied with SMU)
- One shielded, three-terminal test fixture with triaxial inputs (such as the 8101-PIV)

Device connections

Using the supplied cables, connect the output terminals of the instruments directly to the MOSFET terminals in the shielded test fixture. The triaxial terminals on the shielded test fixture allow you to connect to the device and maintain a completely shielded and guarded test setup.

WARNING

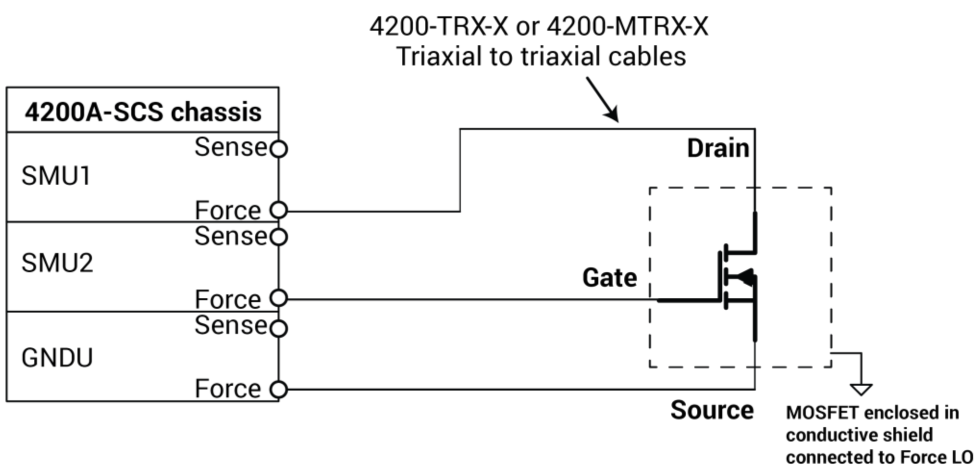
Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

Connection schematic

The hardware connections from the output of the instruments in the 4200A-SCS chassis to the test fixture that contains the MOSFET are shown in the following figure. All of the connections are 2-wire and only the Force terminal of each SMU is used. The SMUs and GNDU are each connected to a different terminal of the 3-terminal MOSFET.

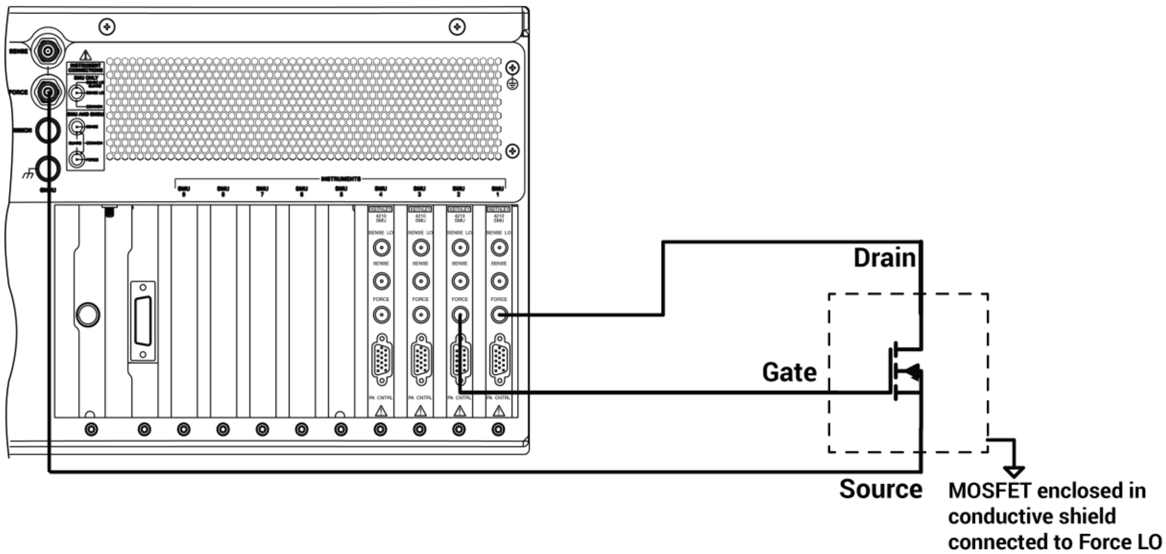
Figure 13: Connections from the 4200A-SCS to a MOSFET



Connect the 4200A-SCS to the DUT

The hardware connections from the output of the instruments in the 4200A-SCS chassis to the test fixture that contains the MOSFET are shown in the next figure.

Figure 14: Rear panel connections from the 4200A-SCS to a MOSFET



Set up the measurements in Clarius

This section describes how to set up the 4200A-SCS to generate a V_{ds}-I_d family of curves for a 3-terminal n-type MOSFET. This general procedure can also be used to create tests for other devices and other applications.

For this example, you will use the Clarius application to:

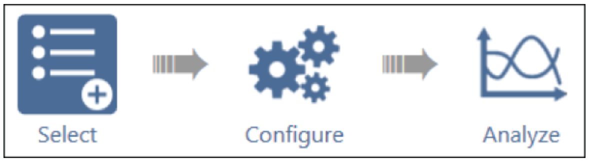
- Select and rename a new project
- Add a device
- Select a custom test
- Configure the test
- Execute the test
- View and analyze the test results

Select and rename a new project

To select and rename a new project:

1. Choose **Select**.

Figure 15: Select highlighted



2. In the Library, select **Projects**.
3. Select **New Project**.
4. Select **Create**.

Figure 16: Select a New Project from the Project Library

5. Select **Yes** when prompted to replace the existing project.
6. Assign a title to the project by selecting **Rename** above the project tree.
7. Enter a project name into the text box, then select **Enter**. `MOSFET_TEST` has been chosen for this example.

Figure 17: Toolbar with Rename function

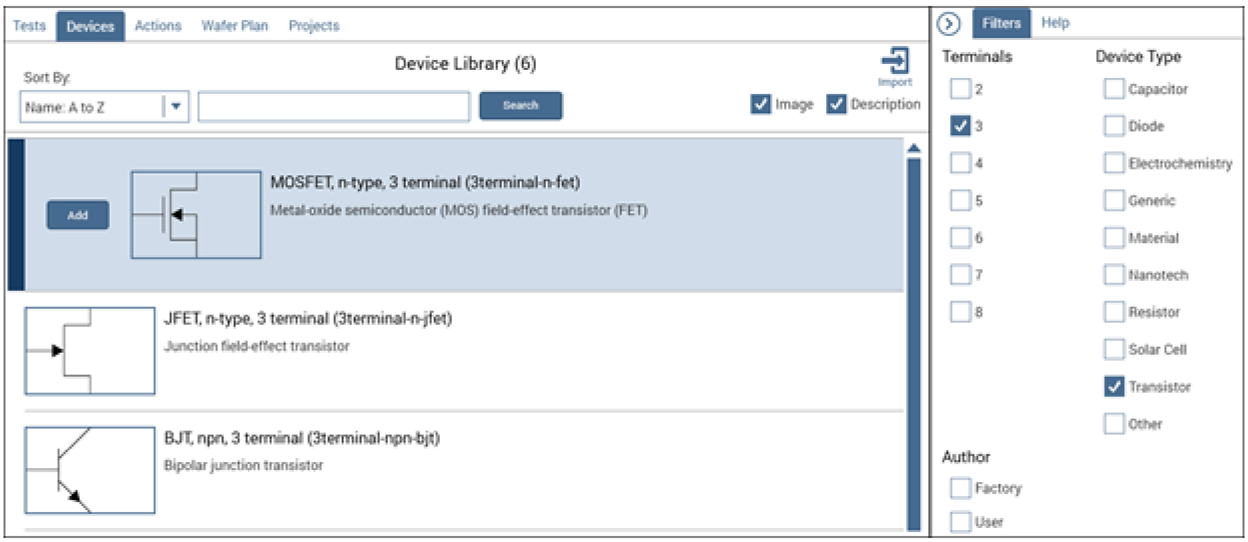
Add a device

Tests must be placed in the project under a device.

To add a device:

1. Select **Devices**.
2. From the Filters pane, select the **3** under the Terminals heading and **Transistor** under the Device Type option.

Figure 18: Searching for a device using Filters



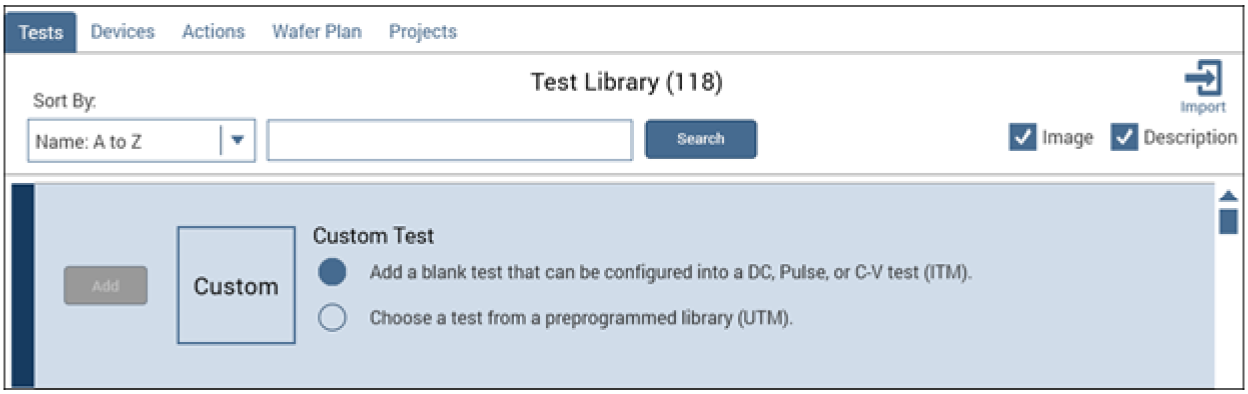
3. Select the `MOSFET, n-type, 3 terminal (3terminal-n-fet)` device.
4. Select **Add** to copy it to the project tree.

Select a custom test

To select a custom test:

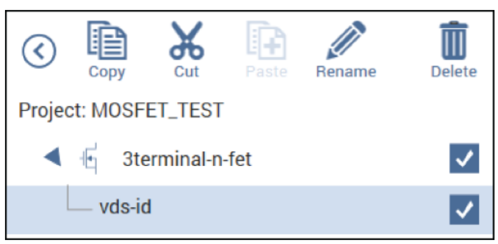
1. Select **Tests**.
2. Select **Custom Test**, then select **Add** to create a new 3-terminal, n-type MOSFET test in the project tree.

Figure 19: Custom Test option



3. Select **Rename** from the toolbar. Enter a test name in the text box, then select **Enter**. `vds-id` was chosen for this example.

Figure 20: MOSFET_TEST project tree with one device and one test

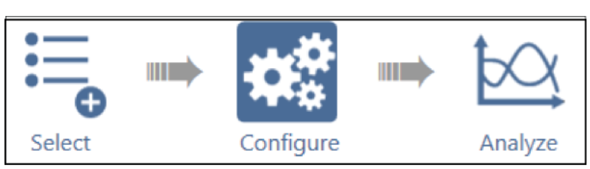


Configure the test

To configure the test:

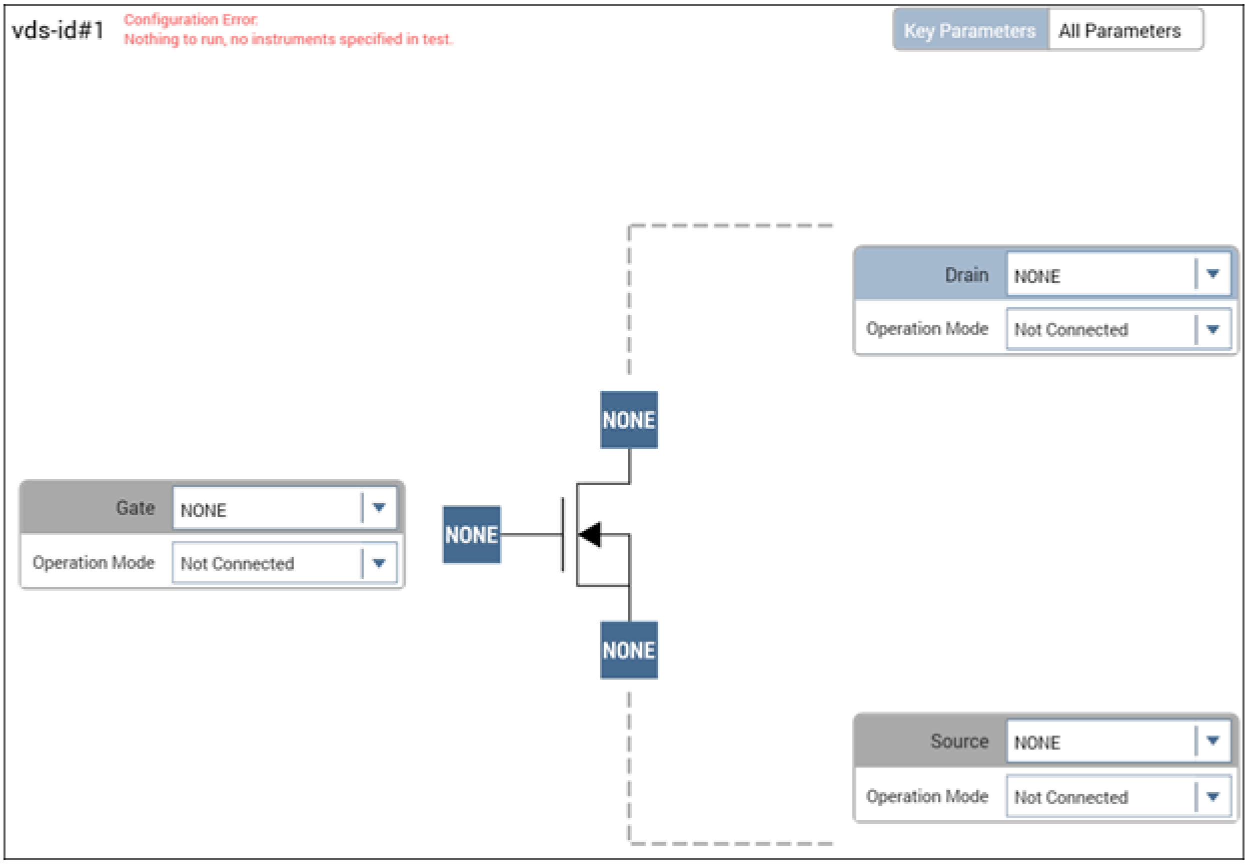
1. Select **Configure**.

Figure 21: Configure highlighted



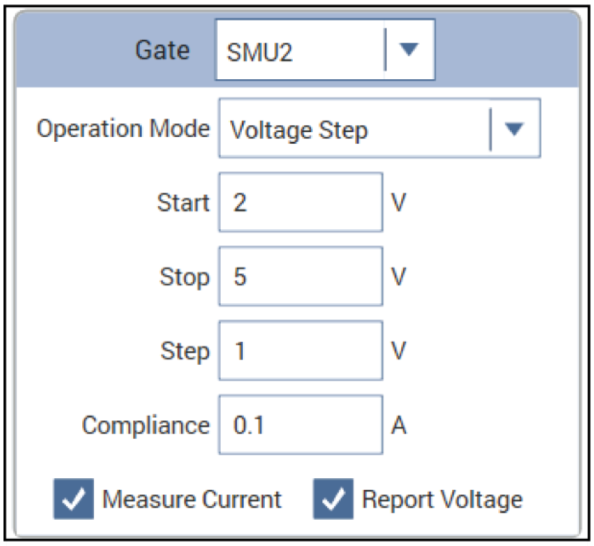
2. In the project tree, select `vds-id`. Because this test is custom, you must assign functions to all terminals connected to the MOSFET before you can run the test.

Figure 22: All MOSFET terminals unassigned in a custom test



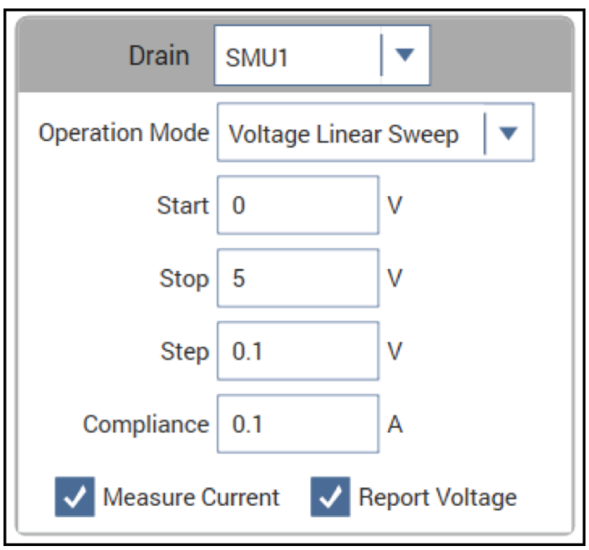
3. Set the Gate terminal connection to **SMU2**.
4. Set the Operation Mode to **Voltage Step**.
5. Change the Start, Stop, Step, and Compliance settings to match the next figure or to the gate settings appropriate for your device.

Figure 23: SMU2 steps from 2 V to 5 V, connected to MOSFET Gate terminal



6. Set the Drain terminal connection to **SMU1**.
7. Set the Operation Mode to **Voltage Linear Sweep**.
8. Change the Start, Stop, Step, and Compliance settings to match the next figure.

Figure 24: SMU1 sweeps from 0 V to 5 V, connected to MOSFET Drain terminal



9. Set the Operation Mode of the Source terminal to **GNDU**.

Execute the test

Select **Run** to execute the test.

Figure 25: Run

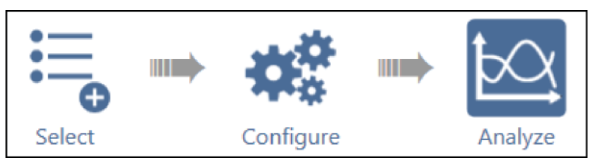
View and analyze the test results

While the test is running, you can view the data in the spreadsheet of the Analyze pane. Because you created a new test, the data must be assigned to the axes of the graph before you can view graphical results.

To view and analyze the test results:

1. Select **Analyze**. The Analyze screen displays data as it is gathered in the spreadsheet and a blank graph with unassigned axes.

Figure 26: Analyze highlighted



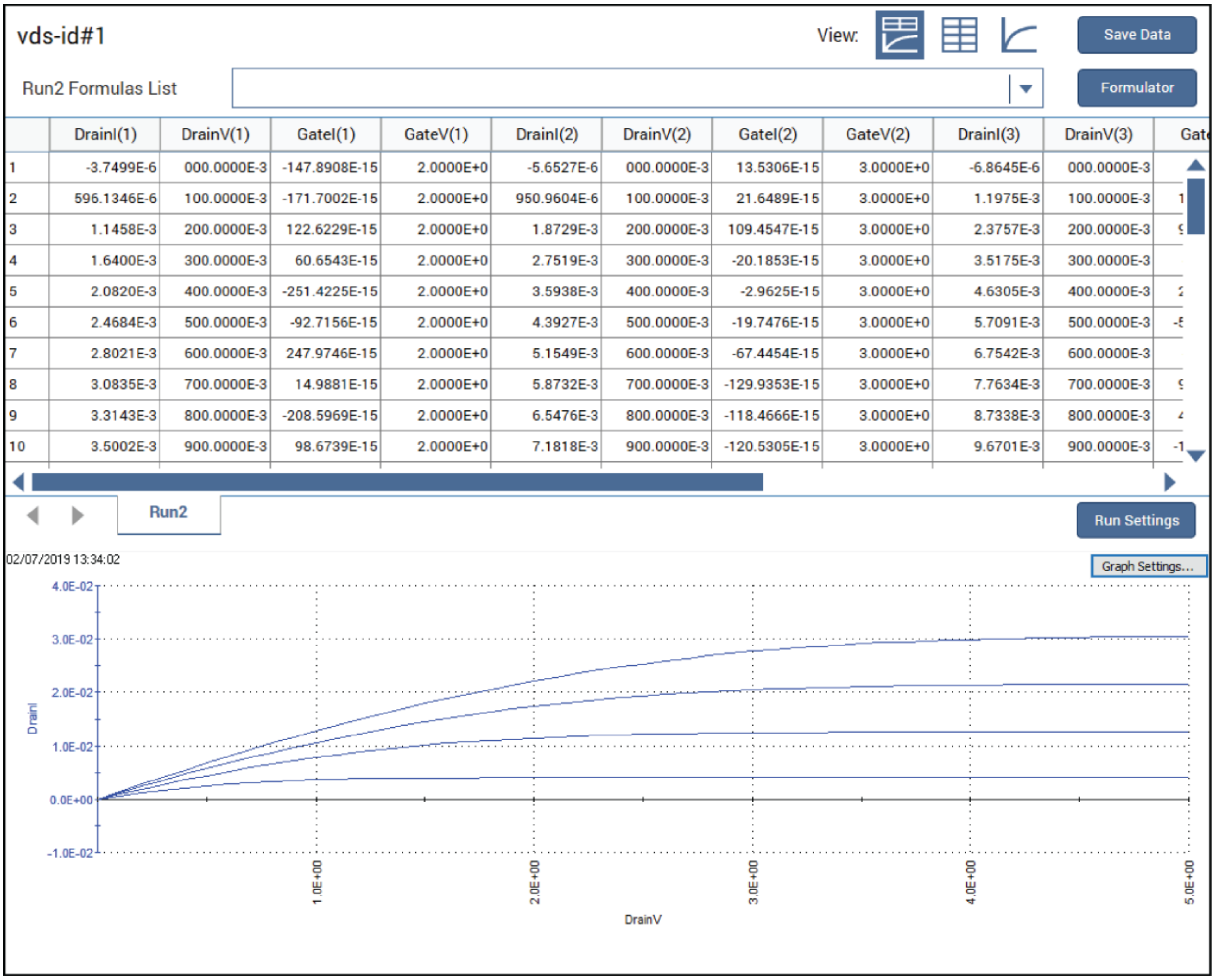
2. Select **Graph Settings**.
3. Select **Define Graph**.
4. In the Graph Definition screen, assign X to **DrainV** and Y1 to **DrainI**.

Figure 27: Define the graph

Data Series	Sheet	Column	X	Y1	Y2
DrainI*	Data	1		*	
DrainV*	Data	2	*		
GateI*	Data	3			
GateV*	Data	4			

5. Select **OK**.
6. The graph displays the `vds-Id` family of curves.

Figure 28: Analyze Pane showing test results



	DrainI(1)	DrainV(1)	GateI(1)	GateV(1)	DrainI(2)	DrainV(2)	GateI(2)	GateV(2)	DrainI(3)	DrainV(3)
1	-3.7499E-6	000.0000E-3	-147.8908E-15	2.0000E+0	-5.6527E-6	000.0000E-3	13.5306E-15	3.0000E+0	-6.8645E-6	000.0000E-3
2	596.1346E-6	100.0000E-3	-171.7002E-15	2.0000E+0	950.9604E-6	100.0000E-3	21.6489E-15	3.0000E+0	1.1975E-3	100.0000E-3
3	1.1458E-3	200.0000E-3	122.6229E-15	2.0000E+0	1.8729E-3	200.0000E-3	109.4547E-15	3.0000E+0	2.3757E-3	200.0000E-3
4	1.6400E-3	300.0000E-3	60.6543E-15	2.0000E+0	2.7519E-3	300.0000E-3	-20.1853E-15	3.0000E+0	3.5175E-3	300.0000E-3
5	2.0820E-3	400.0000E-3	-251.4225E-15	2.0000E+0	3.5938E-3	400.0000E-3	-2.9625E-15	3.0000E+0	4.6305E-3	400.0000E-3
6	2.4684E-3	500.0000E-3	-92.7156E-15	2.0000E+0	4.3927E-3	500.0000E-3	-19.7476E-15	3.0000E+0	5.7091E-3	500.0000E-3
7	2.8021E-3	600.0000E-3	247.9746E-15	2.0000E+0	5.1549E-3	600.0000E-3	-67.4454E-15	3.0000E+0	6.7542E-3	600.0000E-3
8	3.0835E-3	700.0000E-3	14.9881E-15	2.0000E+0	5.8732E-3	700.0000E-3	-129.9353E-15	3.0000E+0	7.7634E-3	700.0000E-3
9	3.3143E-3	800.0000E-3	-208.5969E-15	2.0000E+0	6.5476E-3	800.0000E-3	-118.4666E-15	3.0000E+0	8.7338E-3	800.0000E-3
10	3.5002E-3	900.0000E-3	98.6739E-15	2.0000E+0	7.1818E-3	900.0000E-3	-120.5305E-15	3.0000E+0	9.6701E-3	900.0000E-3

Use the RPM to switch the SMU, CVU, and PMU

In this section:

Introduction

The 4225-RPM Remote Amplifier/Switch Module is an accessory for the 4225-PMU 2-Channel UltraFast I-V Module. The 4225-RPM has two purposes:

- To extend the current measurement ranges of the PMU to the 100 nA range.
- To enable the user to switch between the instruments without changing cables.

This section provides an example of how to use the 4225-RPM to switch the 420x-SMU or 421x-SMU, 421x-CVU, and 4225-PMU and make DC I-V, C-V, and pulsed I-V measurements to a single device without having to reconnect the device between measurements.

For this example, you will:

- Make connections from two SMUs, one CVU, and the two-channel PMU to the inputs of two 4225-RPMs.
- Make connections from the outputs of the two 4225-RPMs to a diode.
- Generate DC I-V, C-V, and pulsed I-V measurements.

Equipment required

- One 4200A-SCS with the following instruments:
  - Two 420x-SMUs or 421x-SMUs
  - Two 4200-PAs
  - One 421x-CVU
  - One 4225-PMU
  - Two 4225-RPMs
- Four 4200-TRX-2 or 4200-MTRX-2 triaxial cables (supplied with SMU)
- Four CA-447A SMA cables (supplied with CVU)
- Two CA-547-2A RPM interconnect cables (supplied with RPM)
- Four CA-534-24A triaxial cables
- Two 237-TRX-T triaxial tees
- One shielded test fixture with connection to GNDU (Force LO)

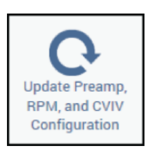
Update the RPM configuration in KCon

The KCon application is used to manage the configuration of the 4200A-SCS, including the 4225-RPM. Before using an RPM for automatic switching, you must update the RPM configuration in KCon. This associates the instruments connected to each RPM and enables automatic switching between tests.

To update the RPM configuration in KCon:

1. Make sure your device under test is disconnected from the RPM output terminals.
2. Close the Clarius application.
3. Open the KCon application.
4. Select **Update Preamp, RPM, and CVIV Configuration**.

Figure 29: Update the RPM configuration in KCon



5. Select **Save**.
6. Close **KCon**.
7. Open **Clarius**.

Device connections

Using the supplied cables, make connections from the output terminals of the instruments to the input terminals of the two RPMs. Connect the output terminals of the RPMs to the diode in a 4-wire configuration to provide the best measurement accuracy and eliminate the lead resistance effects on I-V and C-V measurements.

⚠ WARNING

Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

Connection schematic

The hardware connections from the output terminals of the instruments in the 4200A-SCS are connected to the input terminals of the two 4225-RPMs and then from the output terminals of the two RPMs to the diode under test, as shown in the next figure.

The Sense and Force output terminals of 4200-SMU Channel 1 are connected to the SMU Sense and SMU Force connections of 4225-RPM Channel 1 using 4200-TRX-2 or 4200-MTRX-2 triaxial to triaxial cables. The same connection is made between 4200-SMU Channel 2 and 4225-RPM Channel 2, using the same cable model.

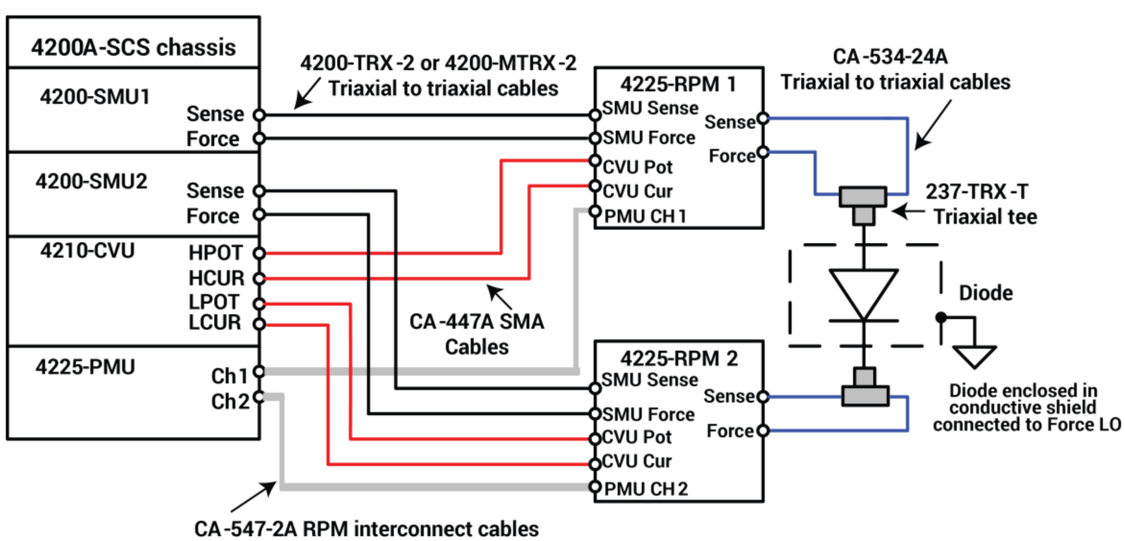
The HPOT and HCUR output terminals of the 4210-CVU are connected to the CVU Pot and CVU Cur inputs of 4225-RPM Channel 1 using CA-447A SMA cables. The LPOT and LCUR output terminals of the 4210-CVU are connected to the CVU Pot and CVU Cur inputs of 4225-RPM Channel 2 using CA-447A SMA cables.

The output terminals of the 4225-PMUs are connected to the RPM Control inputs of their respective channels on the 4225-RPMs.

The Force and Sense output terminals from 4225-RPM Channel 1 are connected to the anode of the diode using two triaxial cables (part number CA-534-24A) and a triaxial tee (237-TRX-T). These triaxial cables are rated for accurate low current (I-V) and high frequency (C-V and pulsed I-V) measurements.

The output terminals of 4225-RPM Channel 2 are connected to the cathode of the diode using the same cables and triaxial tee as those for Channel 1. To prevent noisy measurements, enclose the diode in a conductive shield connected to the Force LO terminal of the 4200A-SCS.

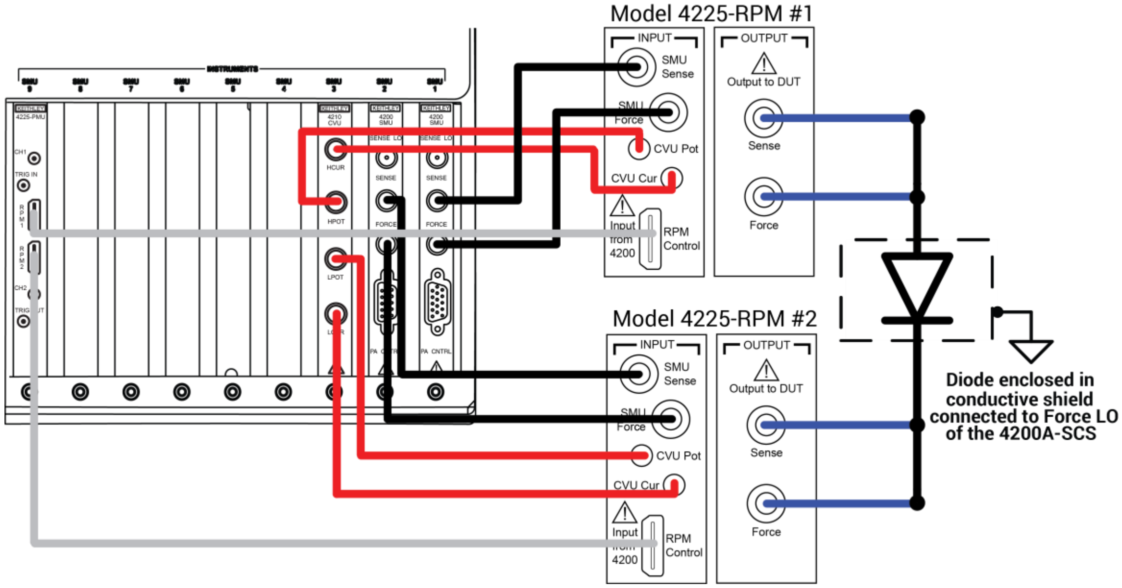
Figure 30: Connections from the 4200A-SCS and 4225-RPMs to the diode



Connect the 4200A-SCS to the DUT

The next figure shows the 4200A-SCS rear panel connections to the input terminals of two 4225-RPMs and from the outputs of the 4225-RPMs to the diode.

Figure 31: Rear panel connections to the inputs of the 4225-RPM units and from the units to the device



Set up the measurements in Clarius

This section describes how to set up the 4200A-SCS to make I-V, C-V, and pulsed I-V measurements on a diode. You will create a new project and add a test to the project tree for each measurement type.

For this example, you will use the Clarius application to:

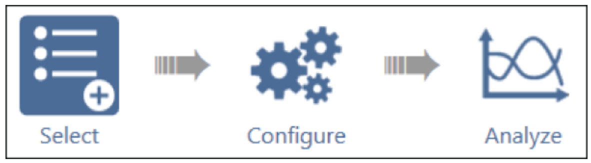
- Create a new project
- Add a device
- Search for and select existing tests in the Test Library
- Configure the tests
- Run the tests
- View and analyze the test results

Create a new project

To create a new project:

1. Choose **Select**.

Figure 32: Select highlighted



2. In the Library, select **Projects**.
3. Select **New Project**.
4. Select **Create**.

Figure 33: Select a New Project from the Project Library

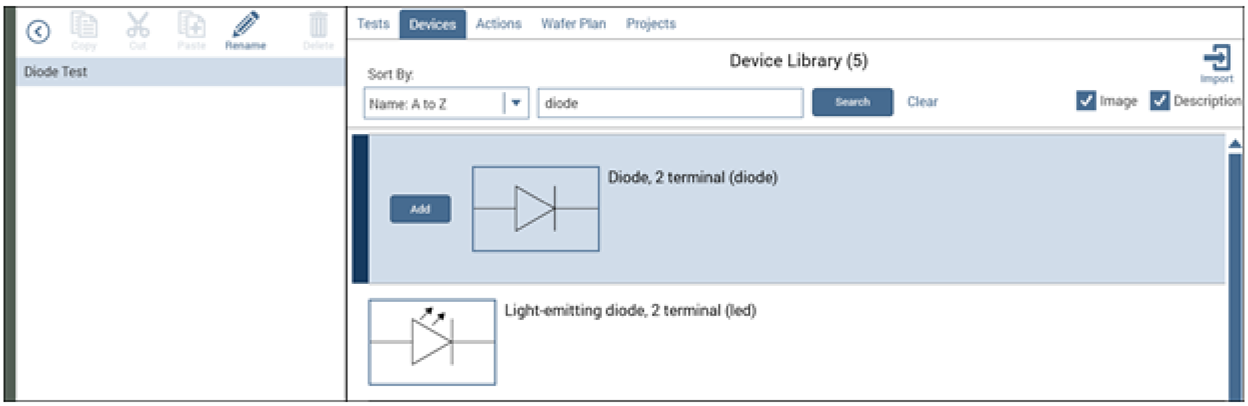
5. Select **Yes** when prompted to replace the existing project.
6. Select **Rename** to assign a new title to the project.
7. Enter `Diode Test`.
8. Select **Enter**.

Add a device

To add a device:

1. Select **Devices**.
2. Type `diode` into the search box.
3. Select **Search**.
4. Select the **Diode, 2 terminal** device.
5. Select **Add** to add it to the project tree.

Figure 34: Select and add a diode device to the project tree

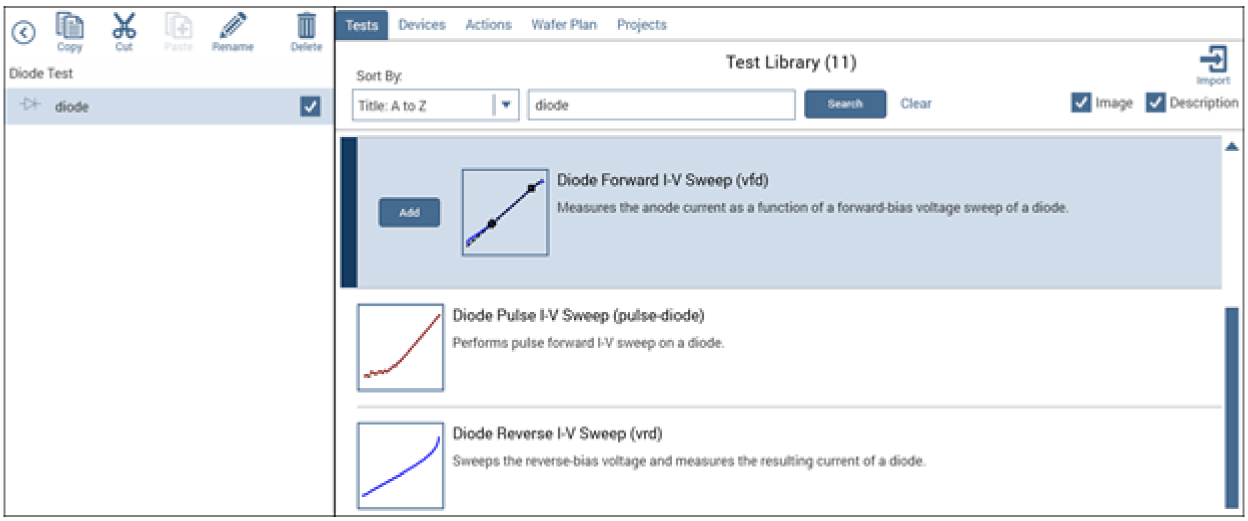


Search for and select existing tests in the Test Library

To search for and select an existing test:

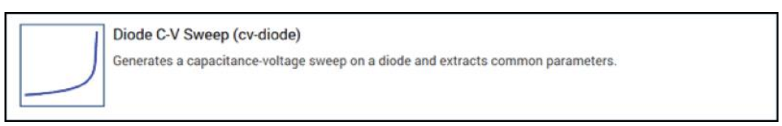
1. Select **Tests**.
2. To find a diode test in the Test Library, type the word `diode` in the search box, then select **Search**.
3. Scroll to find the `Diode Forward I-V Sweep (vfd)` test.
4. Select **Add** to add the test to the project tree.

Figure 35: Add the Diode Forward I-V Sweep (vfd) test to the project tree



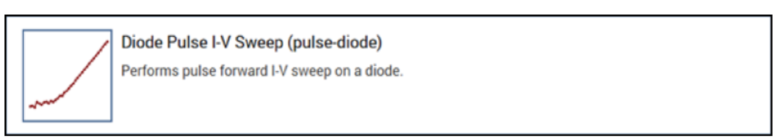
5. Scroll to find the `Diode C-V Sweep (cv-diode)` test.
6. Select **Add** to add this test to the project tree.

Figure 36: Diode C-V Sweep (cv-diode) test



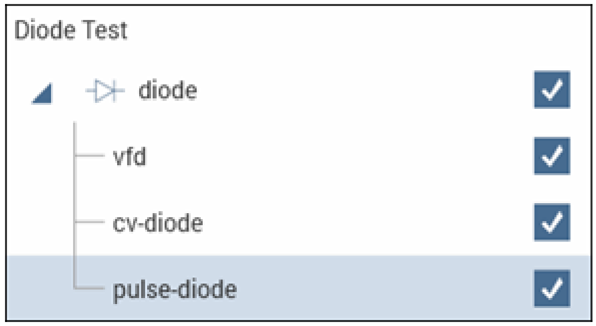
7. Scroll to find the `Diode Pulse I-V Sweep (pulse-diode)` test.
8. Select **Add** to add this test to the project tree.

Figure 37: Diode Pulse I-V Sweep (pulse-diode) test



Your project tree now has three tests.

Figure 38: Three tests added to project tree

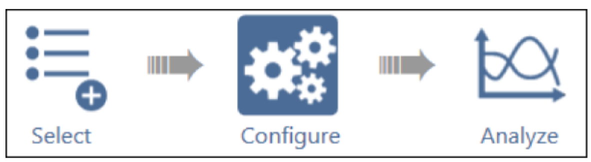


Configure the vfd test

To configure the vfd test:

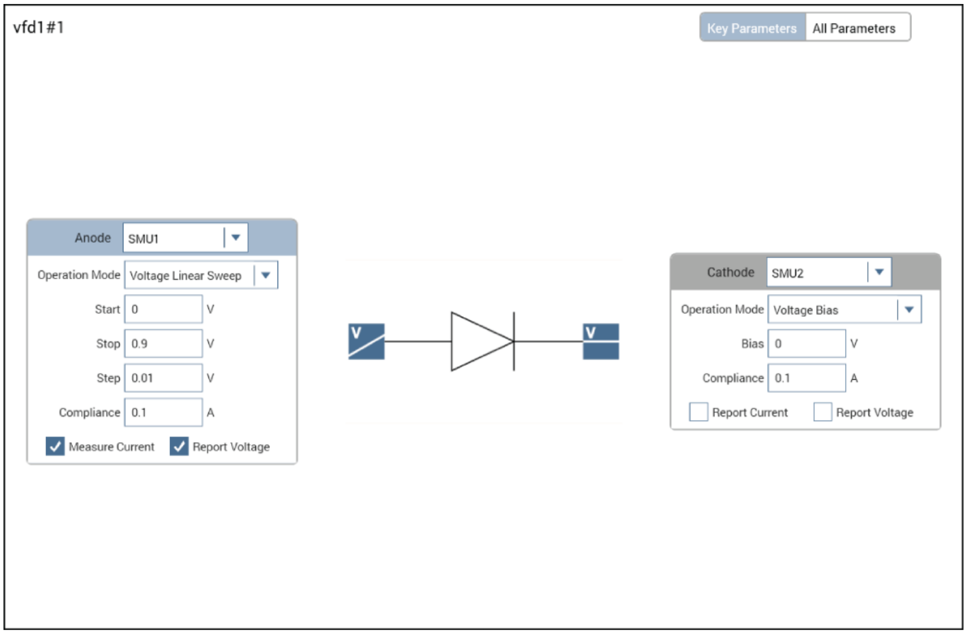
1. Choose **Configure.**

Figure 39: Configure highlighted



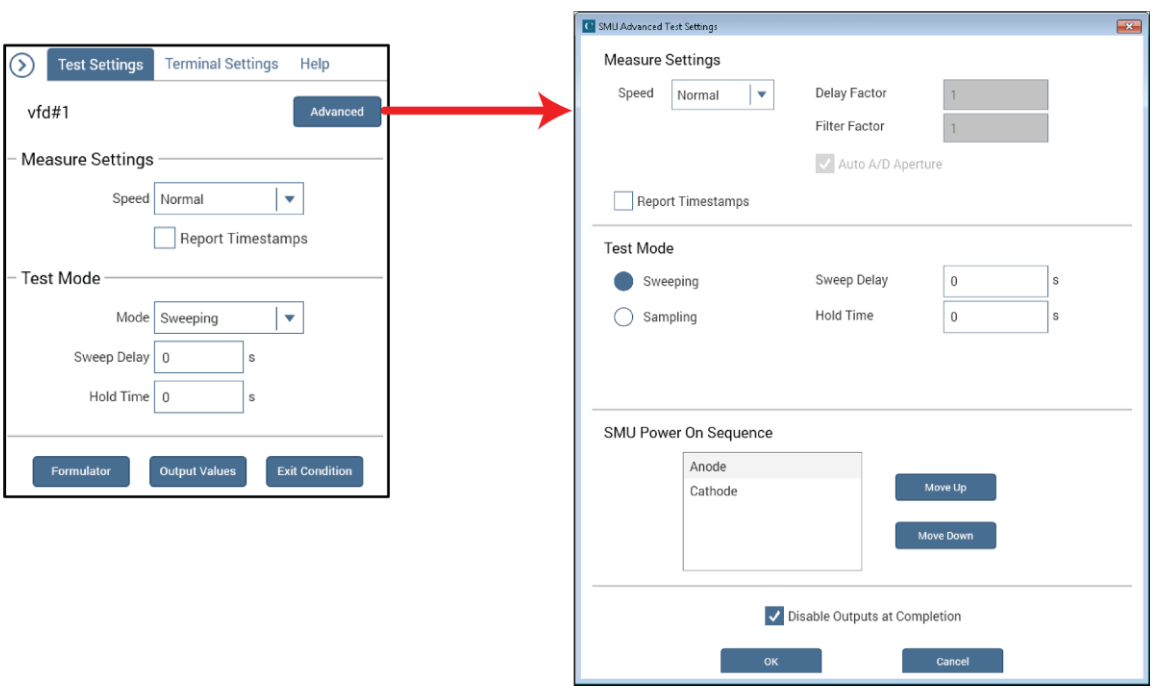
2. In the project tree, select the `vfd` test.
3. Adjust the Anode settings in the Key Parameters pane as needed.

Figure 40: Forward I-V sweep, vfd terminal settings



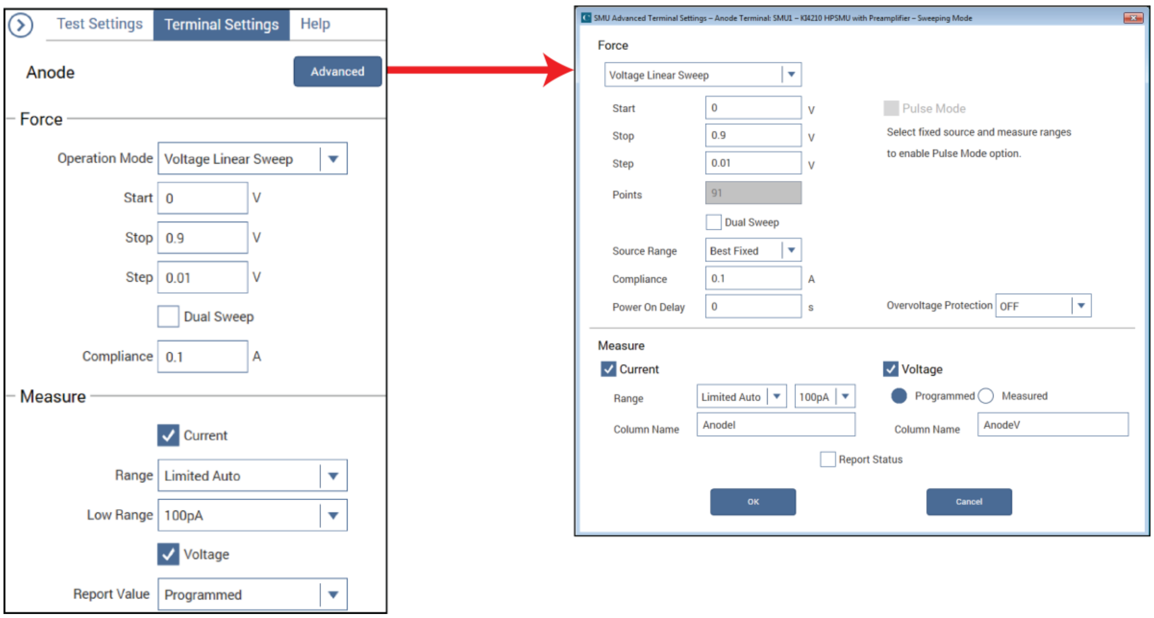
4. In the Test Settings pane, select **Advanced**.
5. Adjust the parameters as needed. Be sure to include the delay between sweep steps.

Figure 41: Test Settings pane and Test Settings Advanced dialog box



6. Select **OK** to accept the settings.
7. Select **Terminal Settings**.
8. Select **Advanced**.
9. Adjust the voltage source and current measurement parameters as needed.

Figure 42: Terminal Settings pane and Terminal Settings Advanced dialog box



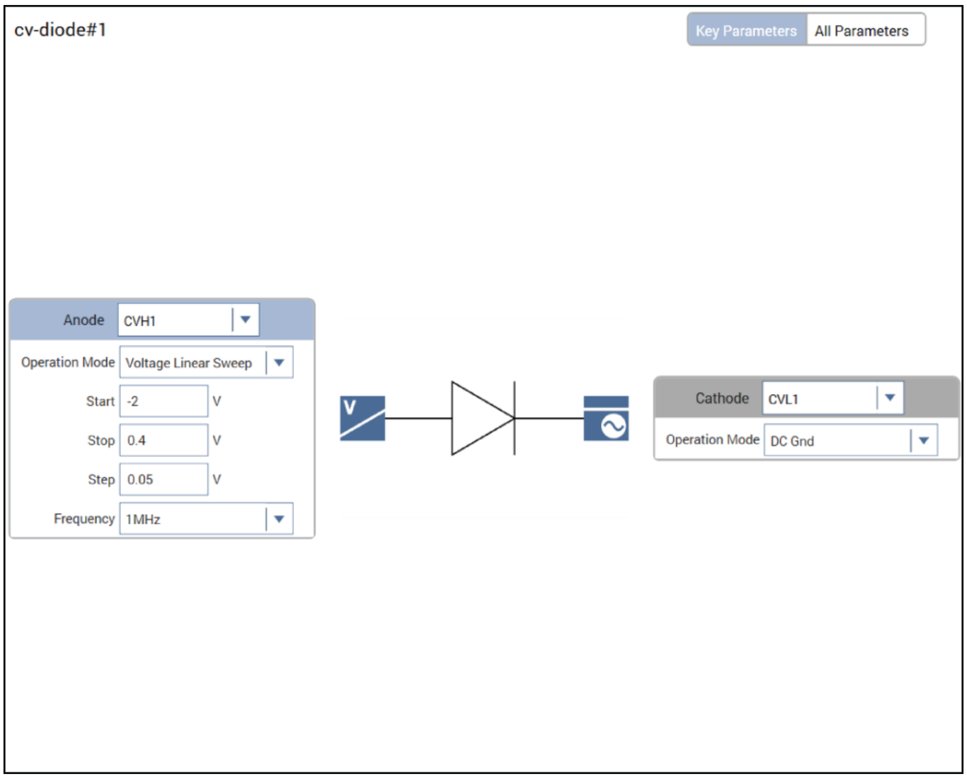
10. Select **OK** to accept the changes.

Configure the cv-diode test

To configure the cv-diode test:

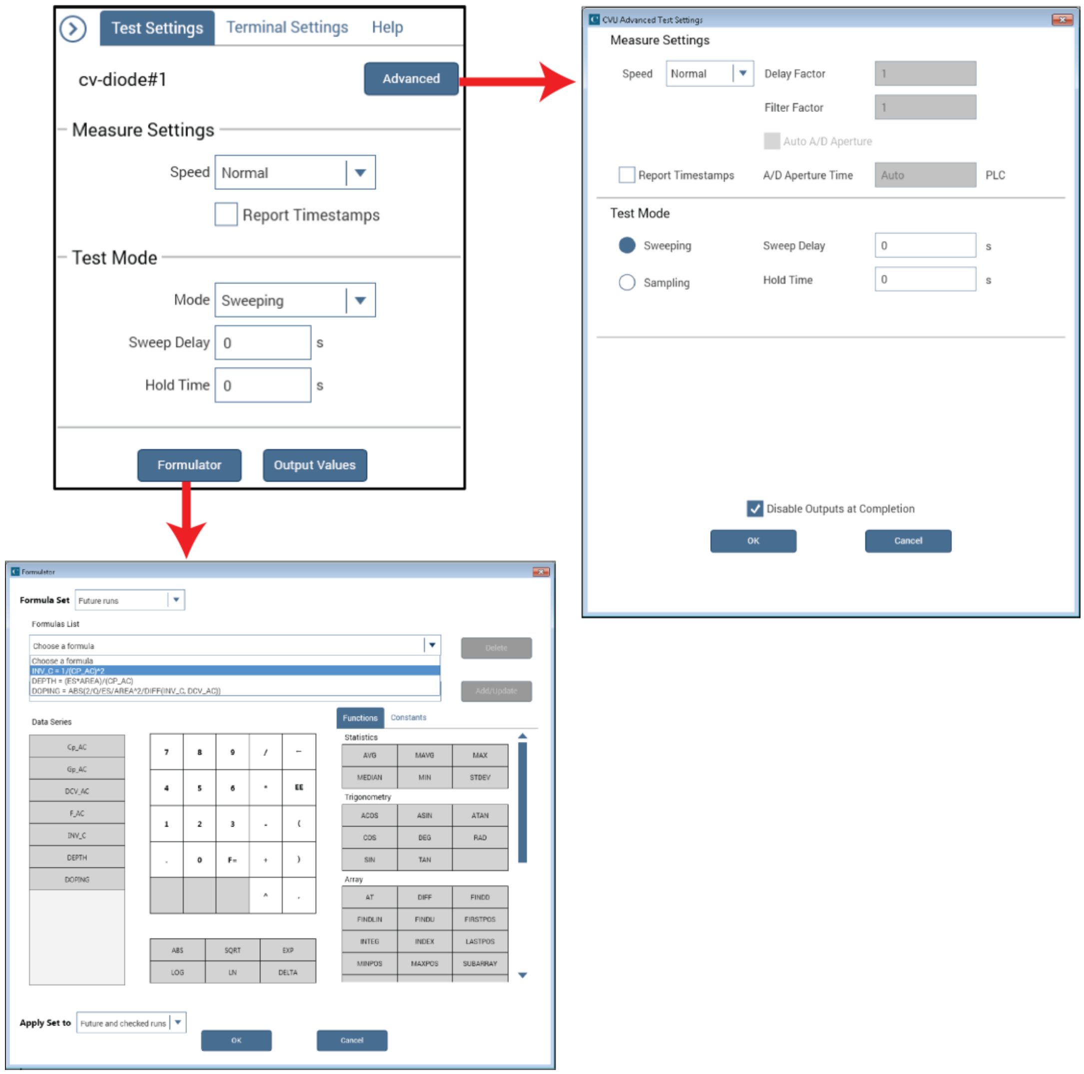
1. Select the `cv-diode` test from the project tree.
2. Select the **Anode** terminal of the diode in the Key Parameters pane
3. Adjust the voltage source and test frequency settings as needed.

Figure 43: Key Parameters pane for the cv-diode sweep test



4. On the Test Settings pane, select **Advanced**. Adjust the timing parameters as needed. Be sure to include the sweep delay time in your adjustments.

Figure 44: Test Settings pane and the Test Settings Advanced and Formulator dialog boxes for the cv-diode sweep test

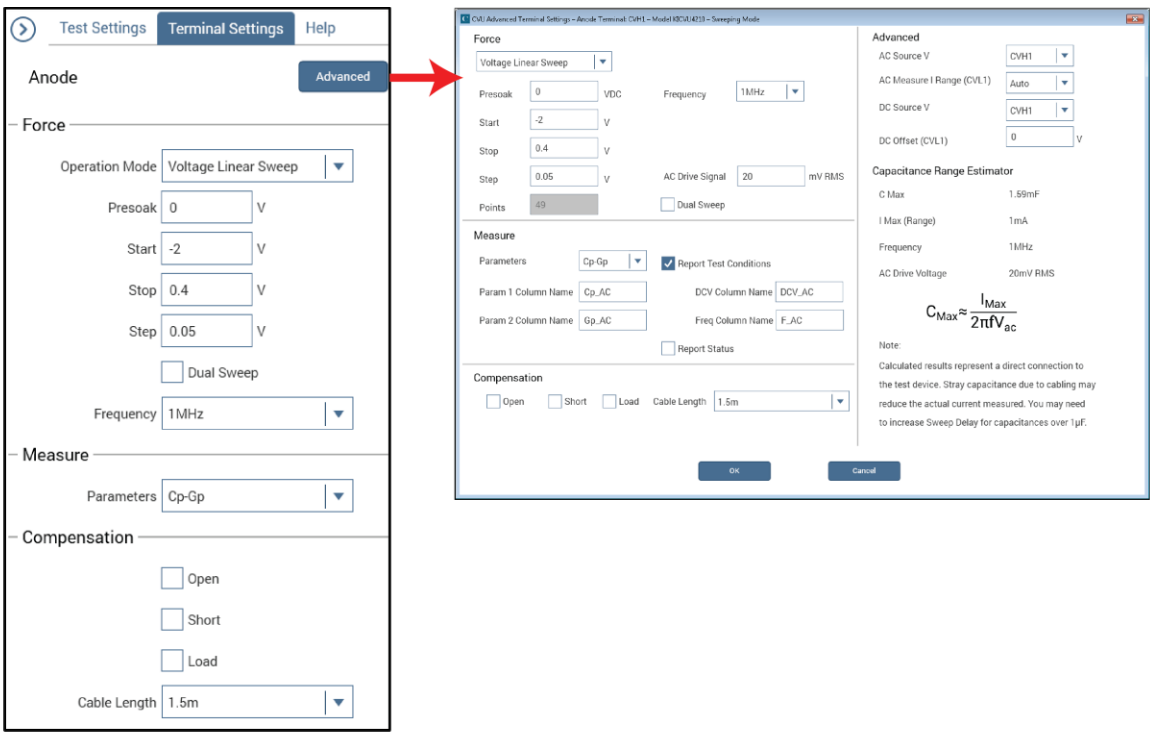


5. On the Terminal Settings pane and the Terminal Settings Advanced dialog box of the Anode terminal, adjust the parameters.

NOTE

If you are including cable compensation values, run the Tools menu option **CVU Connection Compensation.** Refer to Perform offset compensation (on page 7-10) for more detail.

Figure 45: Terminal Settings pane and the Terminal Settings Advanced dialog box for the cv-diode sweep test

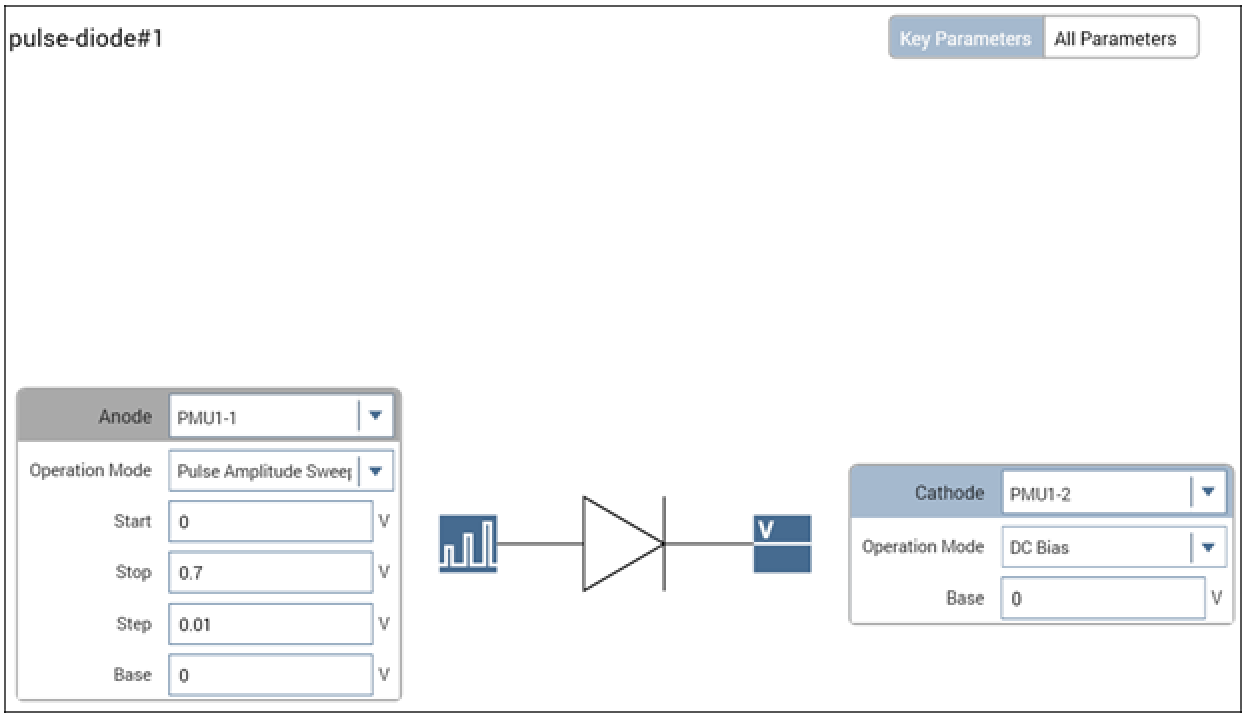


Configure the pulse-diode test

To configure the pulse-diode test:

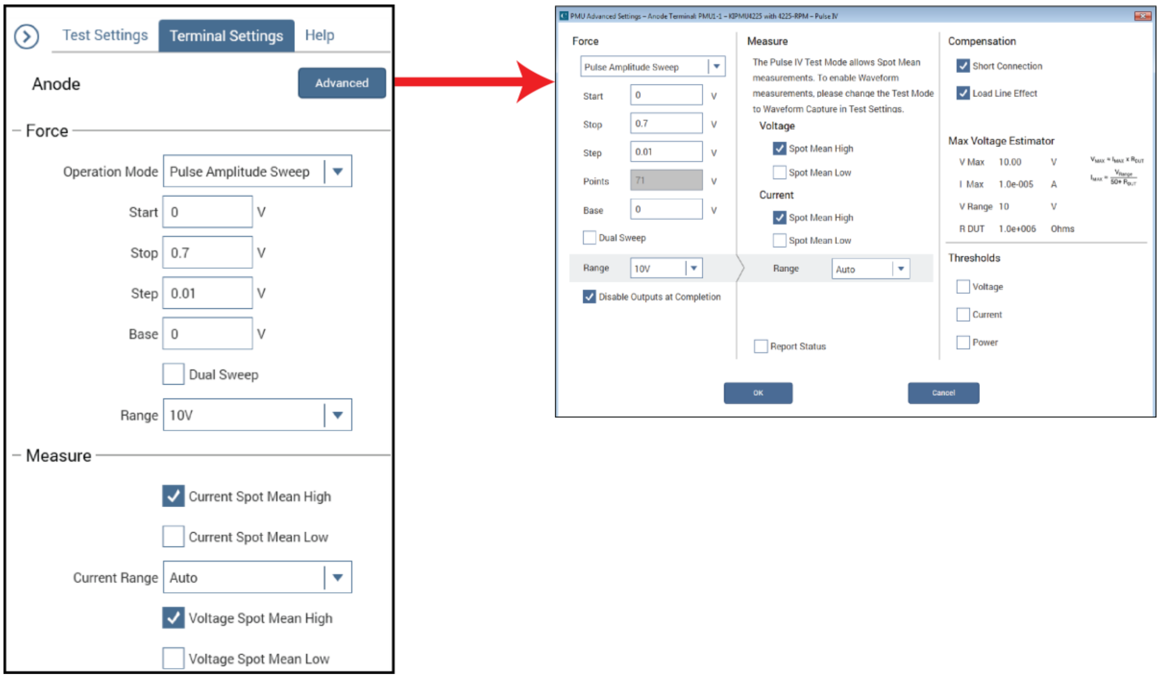
1. In the project tree, select the `pulse-diode` test.
2. From the Key Parameters pane, change the Cathode terminal setting from **PMU1-GND** to **PMU1-2**, as shown in the following figure.
3. Adjust the pulse operation as needed.

Figure 46: Key Parameters pane for the pulse-diode test



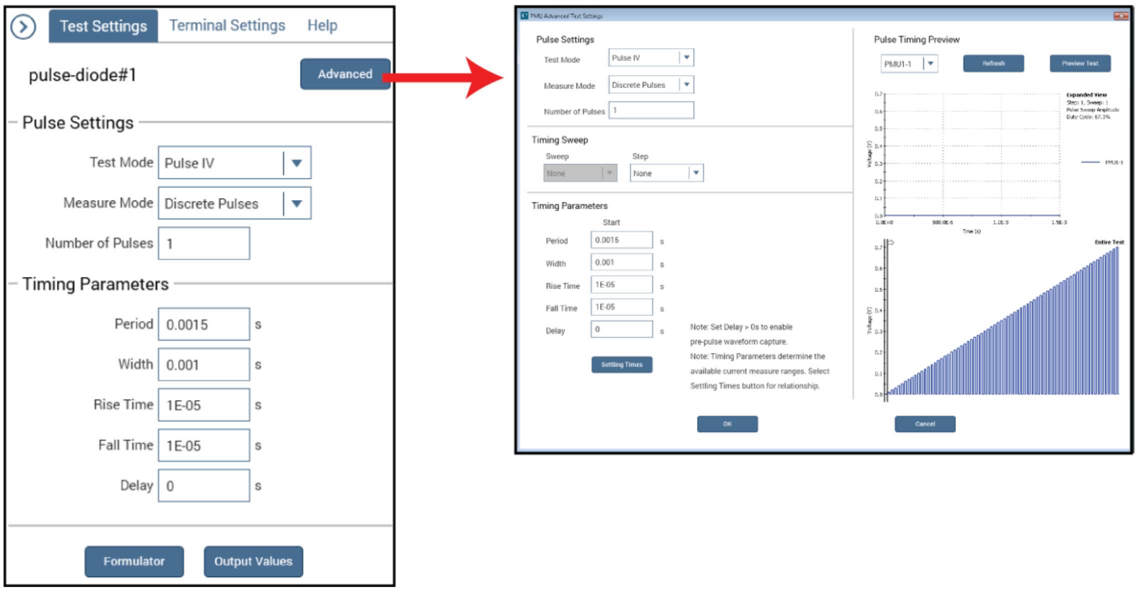
4. Select the **Anode** terminal.
5. Select **Terminal Settings**.
6. Select **Advanced** to configure the measurements as needed, including spot mean, PMU compensation, and PMU threshold levels.

Figure 47: Terminal Settings pane and the Terminal Settings Advanced dialog box for Pulse-Diode test



7. Select **OK**.
8. Select the Cathode terminal.
9. Select **Test Settings**.
10. Select **Advanced** to adjust the test mode and pulse timing settings, as needed.

Figure 48: Test Settings pane and the Test Settings Advanced dialog box for the Pulse-Diode test



11. Select **OK** to accept the changes.

Run the test

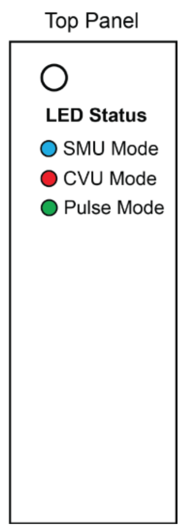
Once the tests have been configured, you can execute every test under the device.

To run the tests for the device:

1. Select the diode device in the project tree.
2. Verify that the check boxes for the tests and the device are selected.
3. Select **Run**. The three tests run sequentially and the RPM automatically switches the outputs between the SMU, CVU, and PMU.
4. Select the **Analyze** pane to see the results.

As the instruments switch between tests, the LEDs at the top of the RPMs change color. When the output is connected to the SMU, the LED is blue. When the output is connected to the CVU, the LED is red. When the output is connected to the PMU, the LED is green, which is also the default state.

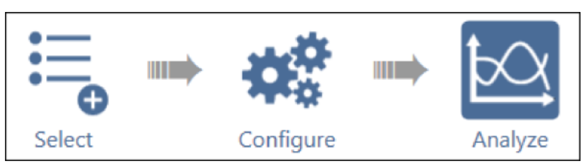
Figure 49: Top of the 4225-RPM indicating the LED status



View and analyze the test results

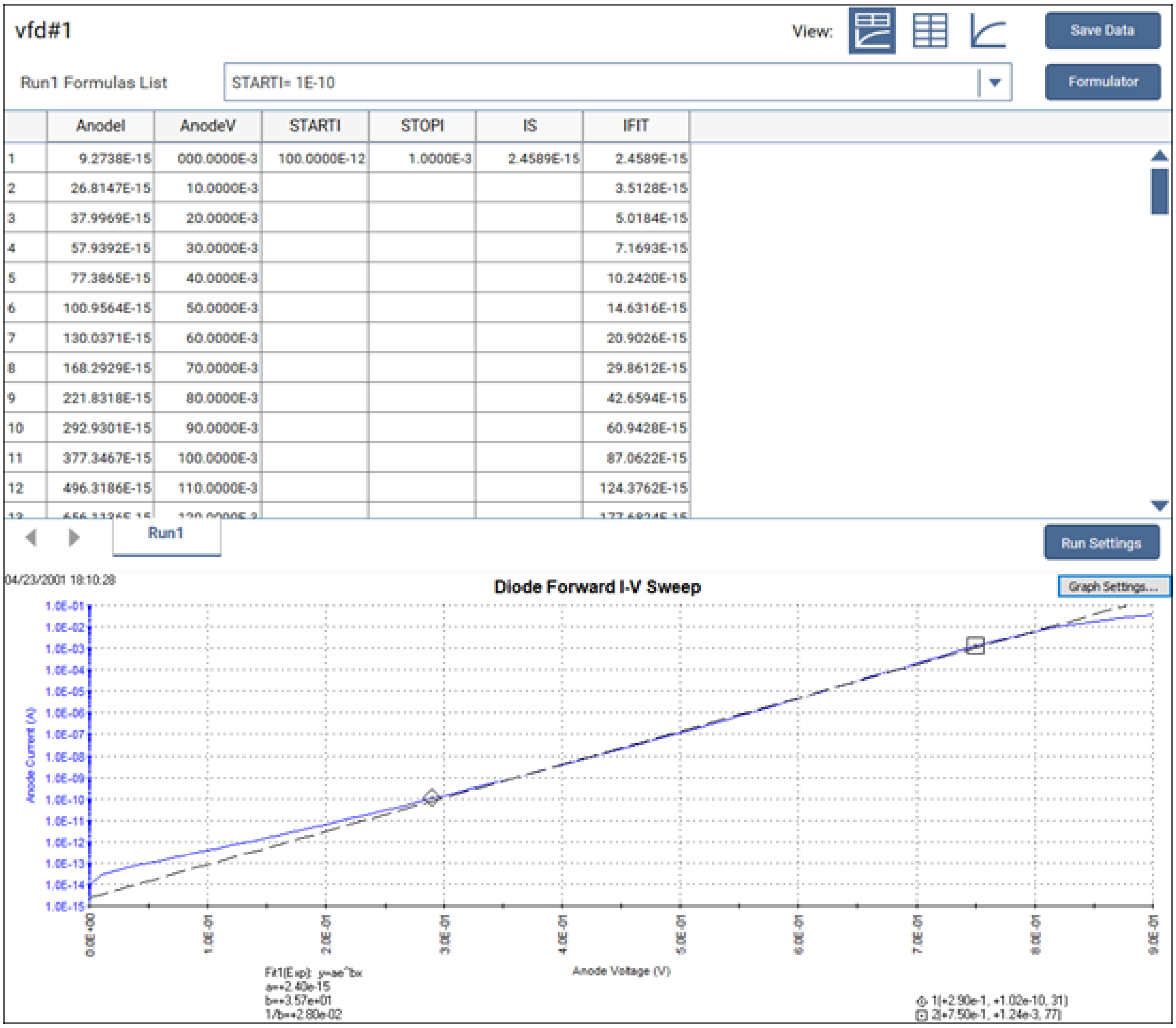
You can select **Analyze** when you run the project to view test results in real-time.

Figure 50: Analyze highlighted



Select a test from the project tree to display its results. The data for the `vfd` test is displayed in the next figure. Both the data and the graph are displayed in this view.

Figure 51: Analyze pane for the vfd test



Configure and use a Series 700 Switching System

In this section:

Introduction

In this tutorial, you will configure a Keithley Instruments Series 700 Switching System (707, 707A, 707B, 708, 708A, or 708B) in the Keithley Configuration Utility (KCon). You will then use the system to connect any instrument terminal to any test system pin without changing connections. You will also create a new project for an n-channel MOSFET transistor and use the project to make both I-V and C-V measurements using the switching system.

Switching systems are controlled by the 4200A-SCS using the GPIB bus. Use a 7007-1 or 7007-2 GPIB cable to connect your switching system to the 4200A-SCS. Once the switching system and test fixture have been defined in KCon, you use Clarius to set up the connections and automatically connect the instruments to the test system pins using the switching system.

In Clarius, the `connectpins` action from the Action Library is used to control switching systems. This action controls the opening and closing of crosspoints in a switching system so that you can connect any row of the matrix card to any (or multiple) columns of the matrix card. The `connectpins` action is added to the project and runs twice in this example. Each run establishes new connection settings.

For more details about switching system connections and the Action Library, refer to the *Model 4200A-SCS Reference Manual.*

Equipment required

- One 4200A-SCS with the following instruments:
  - Three 420x-SMUs or 421x-SMUs
  - One 421x-CVU
- Eight 4200-MTRX-X triaxial cables or 4200-TRX-X cables if using preamplifiers
- Four CA-447A SMA cables (supplied with the CVU)
- Four CS-1247 SMA female to BNC male adapters (supplied with the CVU)
- Two CS-701A BNC Tee adapters (female, male, female)
- Two 7078-TRX-BNC BNC female to triaxial male adapters
- One Series 700 Switching System with a 7072 8x12 Matrix Card
- One shielded four-terminal test fixture with triaxial inputs
- One n-channel MOSFET transistor

Device connections

The next topics detail the connections from the 7072 to the n-channel MOSFET and the connections from the SMUs or CVU, and GNDU to the 7072 Matrix Card in the Series 700 Switching System.

WARNING

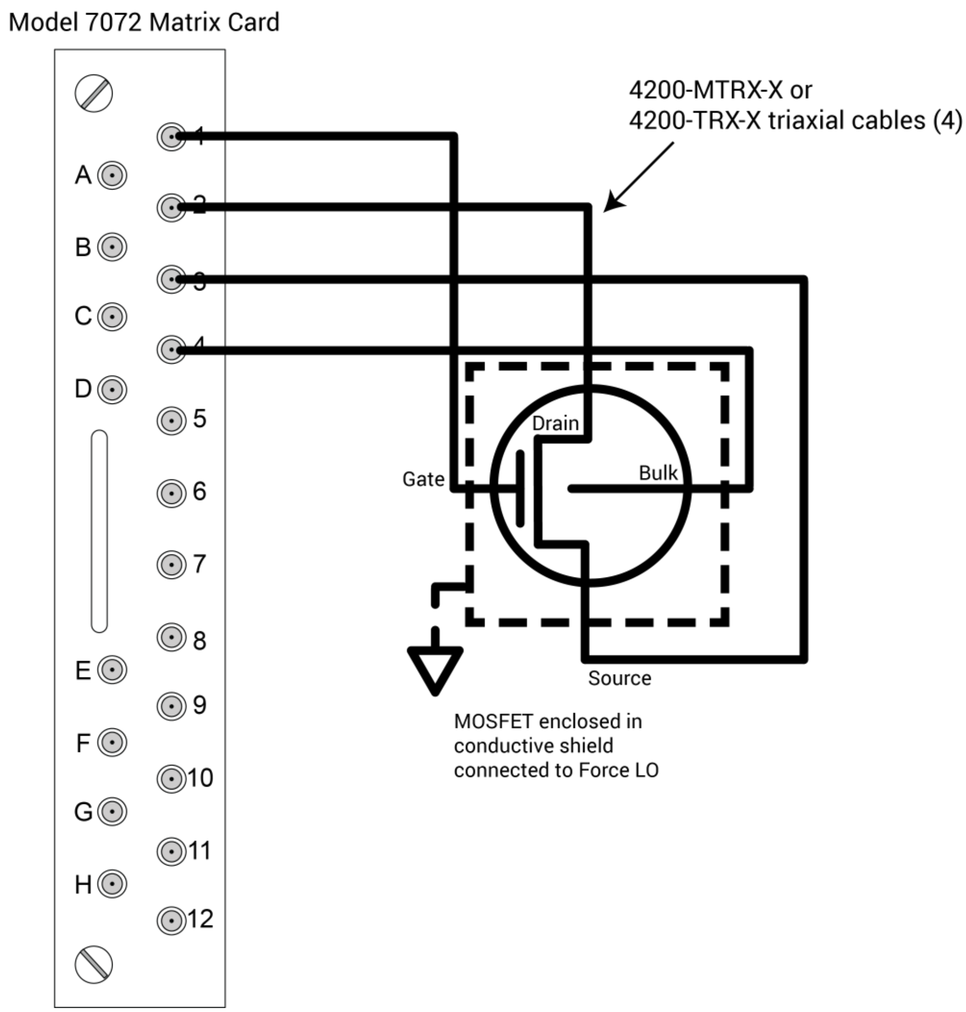
Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

Connect the 7072 to the DUT

The hardware connections from the 7072 Matrix Card to the 4-terminal MOSFET DUT are shown in the following figure. Use four triaxial cables to connect to the input terminals of your test fixture. For systems without a preamplifier, use 4200-MTRX-X triaxial cables. For system with preamplifiers, use 4200-TRX-X triaxial cables.

Figure 52: Connections from the 7072 Matrix Card to the MOSFET DUT



Connect the 4200A-SCS to the 7072

This section describes connections to the 7072.

To connect the 4200A-SCS and SMUs to the 7072:

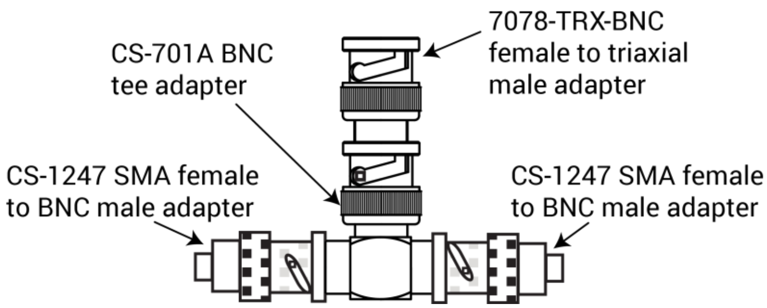
Using four 4200-MTRX-X or 4200-TRX-X triaxial cables, make the following connections:

- 4200A-SCS GNDU FORCE to 7072 input terminal E
- 42x0 SMU channel 1 Force to 7072 input terminal A
- 42x0 SMU channel 2 Force to 7072 input terminal B
- 42x0 SMU channel 3 Force to 7072 input terminal C

To connect the 4210-CVU to the 7072:

1. Using the parts in the following figure, assemble a tee adapter to connect the 4210-CVU to the 7072.

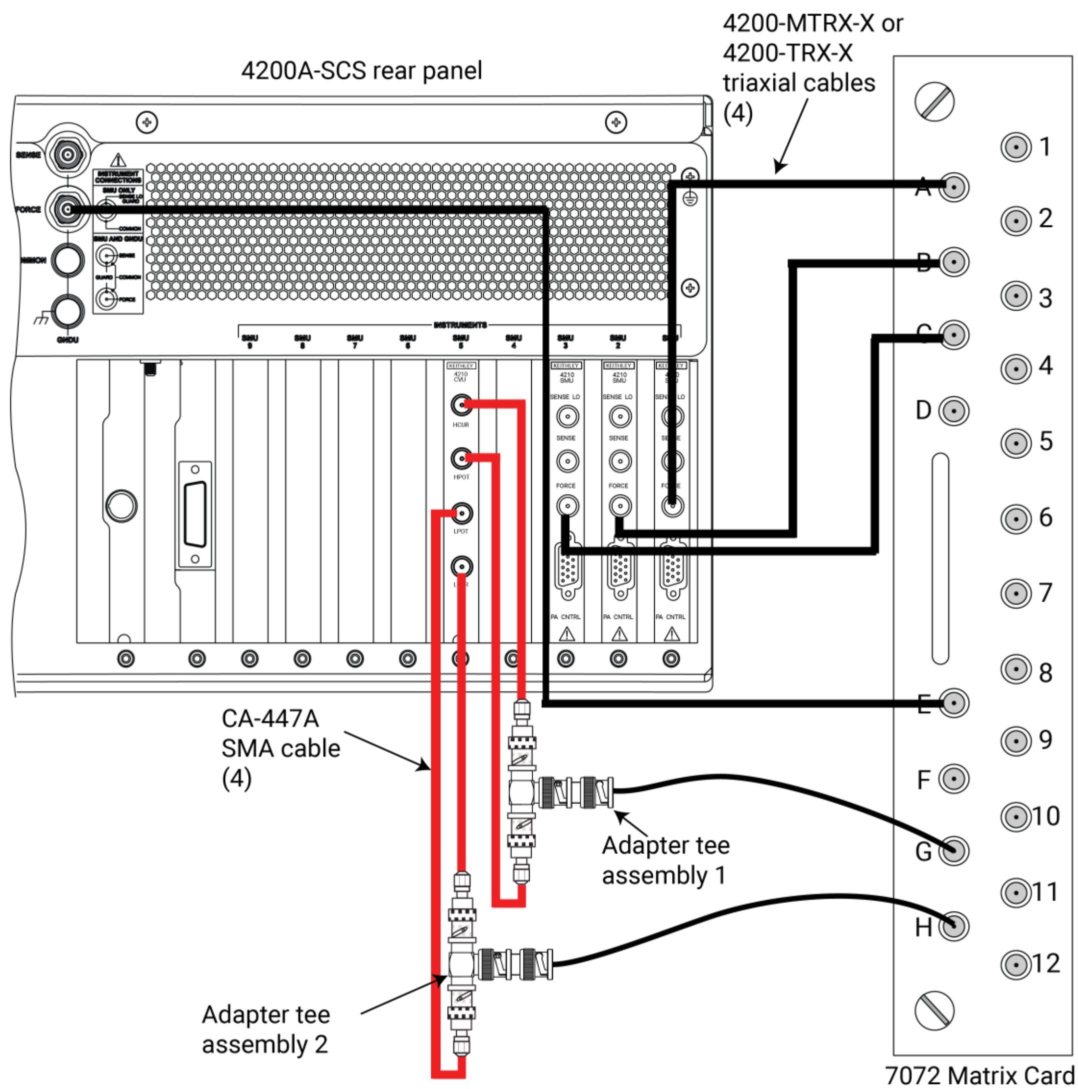
Figure 53: 4210-CVU to 7072 adapter tee assembly



2. Using four CA-447A SMA cables, make the following connections:
   - 4210-CVU HCUR to adapter tee assembly 1
   - 4210-CVU HPOT to adapter tee assembly 1
   - 4210-CVU LPOT to adapter tee assembly 2
   - 4210-CVU LCUR to adapter tee assembly 2
3. Connect adapter tee assembly 1 to input terminal G of the 7072.
4. Connect adapter tee assembly 2 to input terminal H of the 7072.

The connections are shown in the following figure.

Figure 54: 4200A-SCS to 7072 Matrix Card connections



Update the switch configuration in KCon

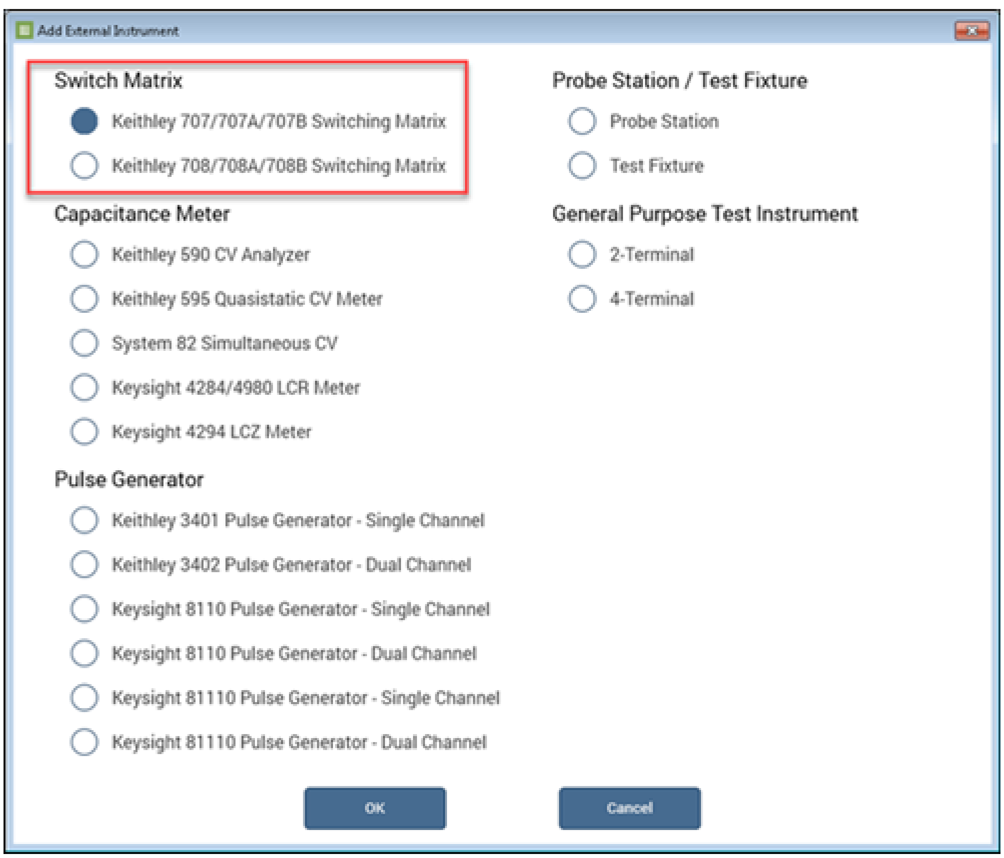
After completing the switch and device connections, use KCon to manage the configuration of all instrumentation controlled by the 4200A-SCS software. You use KCon to:

- Add the switching system to the 4200A-SCS configuration
- Add the test fixture to the system configuration
- Configure the test fixture
- Add a matrix card to the switching system
- Configure the matrix card connections

To add a switching system to the 4200A-SCS configuration:

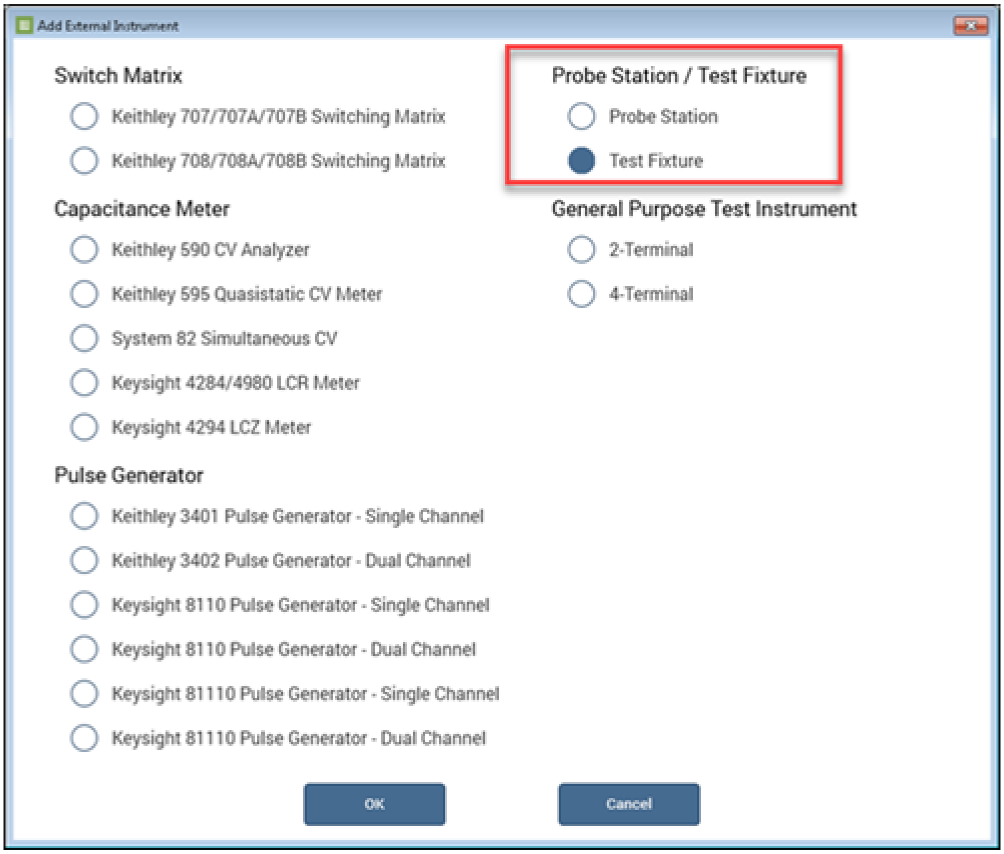
1. From the desktop, open the KCon application.
2. In the bottom left of the KCon window, select **Add External Instrument**.
3. Select your switching system. The Series 700 Switching Systems are highlighted in the next figure.

Figure 55: Add External Instrument box, Series 700 Switching Systems highlighted



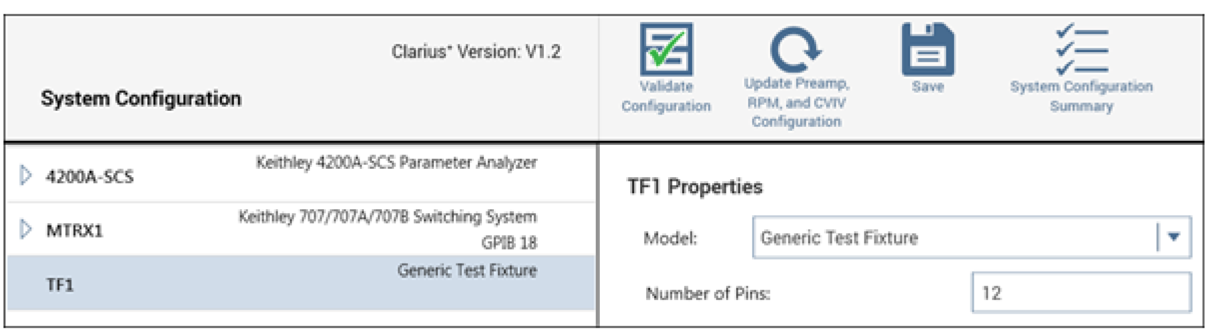
4. Select **OK**.
5. Select **Add External Instrument** again.
6. Select **Test Fixture**.

Figure 56: Add External Instrument dialog box, Test Fixture highlighted



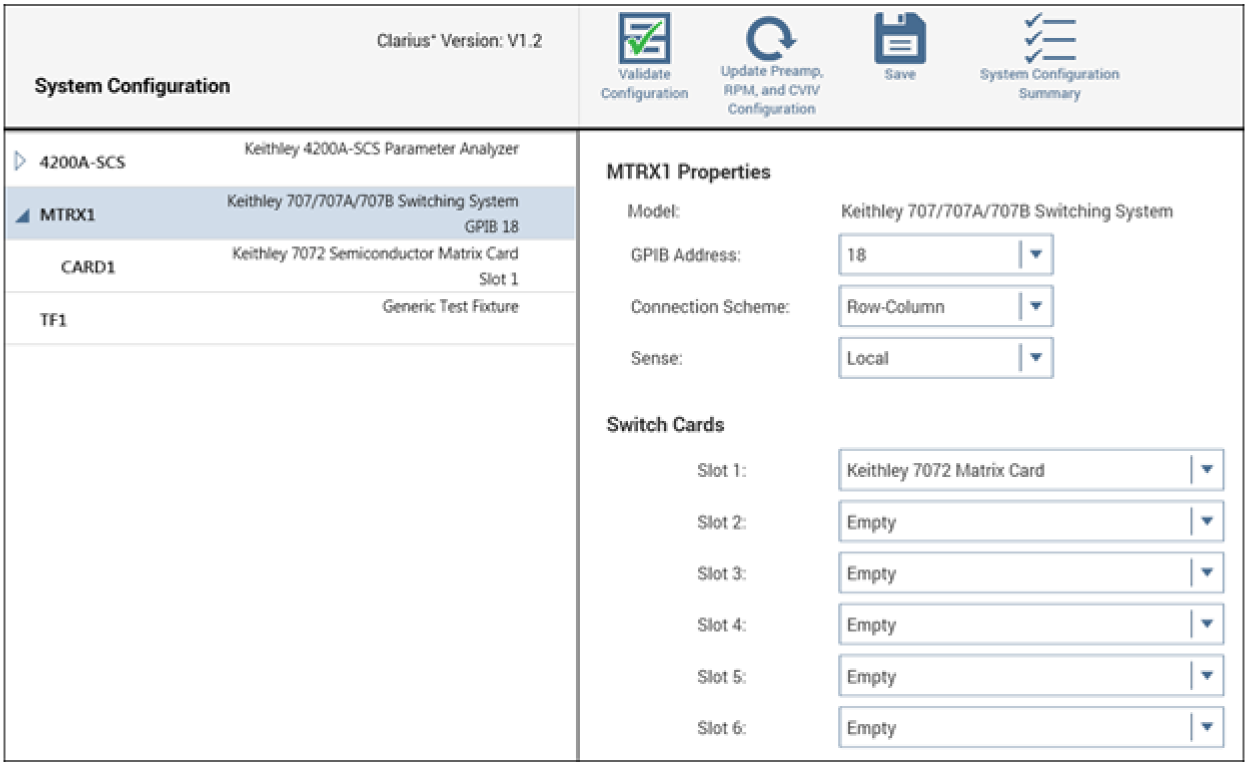
7. Select **OK**.
8. From the configuration navigator, select the test fixture you just added (**TF1**).
9. Set the number of pins equal to the number of output pins in your switching system (**12** for this example, using one 7072 matrix card).

Figure 57: Properties for a Generic Test Fixture



10. From the configuration navigator, select the switching system you just added (**MTRX1**).
11. In the Properties pane, add the 7072 Matrix Card to the correct slot of the switching system.
12. Confirm that the GPIB Channel of your device (0 to 30) matches the channel shown in the Properties. The next figure shows a Keithley Instruments 707/707A/707B Switching System with the matrix card installed in slot 1.

Figure 58: Properties pane of Keithley 708/708A/708B Switching System with one 7072 Matrix Card



NOTE

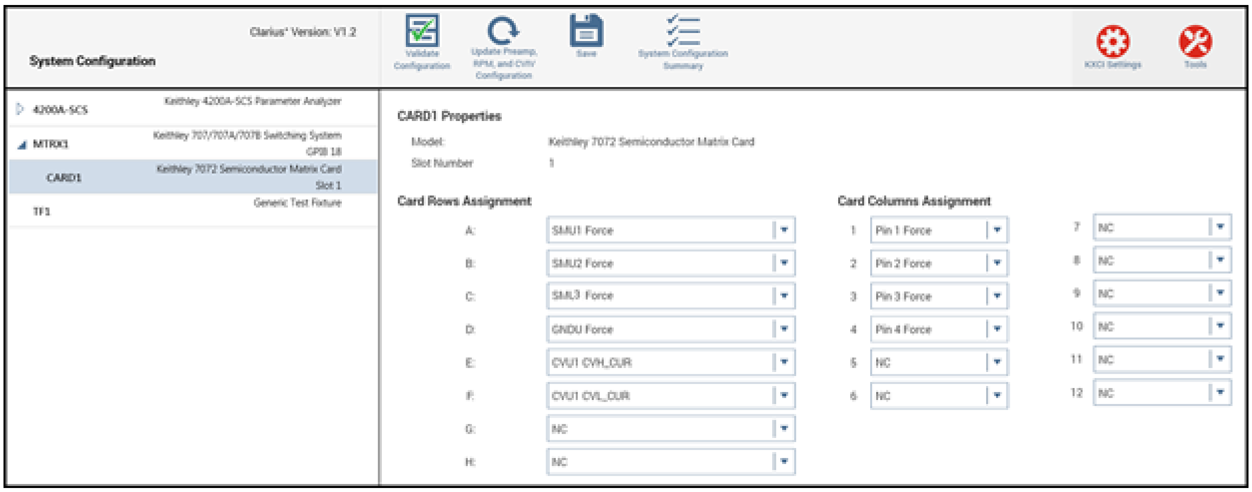
If you are using a 707B or 708B Switching System, you must use the control panel on the front of your switching system to enable DDC and change the command set to 70XA by following these steps:

1. Select **Menu**.
2. Select **DDC**.
3. Select **Enable**.
4. Select **70XB-VERSION**.

This allows the switching system to be controlled by the 4200A-SCS.

13. Select the arrow next to MTRX1 to see the settings for the 7072 Matrix Card.
14. Select **CARD1**.
15. Complete the Card Rows Assignments according to how you connected the instruments to the 7072. For this example, the assignments are:
    - **Row A - SMU1 Force**
    - **Row B - SMU2 Force**
    - **Row C - SMU3 Force**
    - **Row E - GNDU Force**
    - **Row G - CVU1 CVH_CUR**
    - **Row H - CVU1 CVL_CUR**
16. Under the Card Columns Assignment heading, designate at least the first four columns with pin assignments that match their column number. For example, Pin 1 Force to column 1.

Figure 59: Completed Properties pane for the 7072 Matrix Card

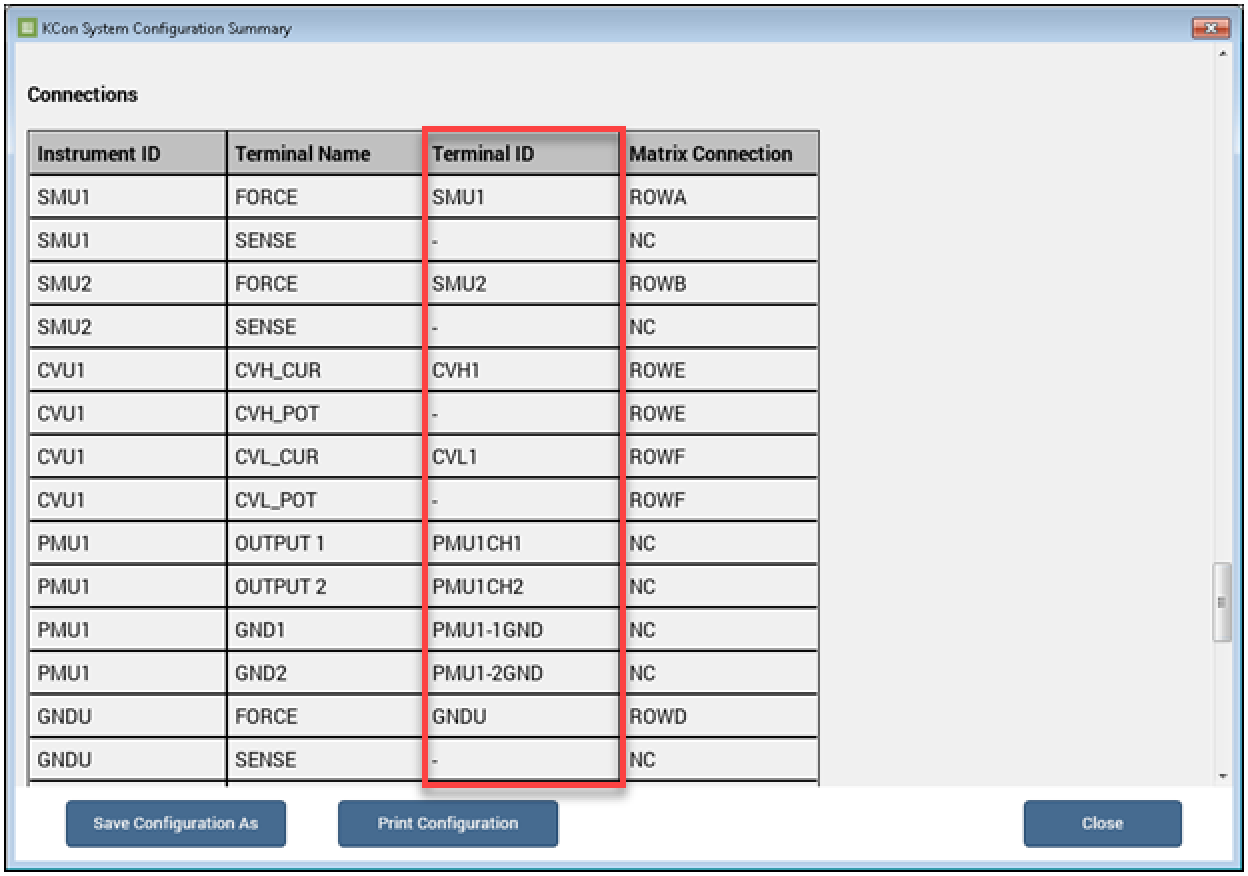


17. From the KCon toolbar, select **Validate Configuration** to ensure that the switching system is connected properly.

Figure 60: Validate Configuration icon

18. Select **Save** to save the system configuration.
19. Select **System Configuration Summary**, then scroll down to the Connections section. You need the names from the Terminal ID column when setting the switching system connections in Clarius. You can select **Save Configuration As** or **Print Configuration** to record the terminal IDs. The default values for the most common instruments are shown in the next figure.

Figure 61: System Configuration Summary: Default Terminal ID Connections



Instrument ID	Terminal Name	Terminal ID	Matrix Connection
SMU1	FORCE	SMU1	ROWA
SMU1	SENSE	-	NC
SMU2	FORCE	SMU2	ROWB
SMU2	SENSE	-	NC
CVU1	CVH_CUR	CVH1	ROWE
CVU1	CVH_POT	-	ROWE
CVU1	CVL_CUR	CVL1	ROWF
CVU1	CVL_POT	-	ROWF
PMU1	OUTPUT 1	PMU1CH1	NC
PMU1	OUTPUT 2	PMU1CH2	NC
PMU1	GND1	PMU1-1GND	NC
PMU1	GND2	PMU1-2GND	NC
GNDU	FORCE	GNDU	ROWD
GNDU	SENSE	-	NC

20. Close the window when you are finished.
21. Close the KCon application.

Set up the measurements in Clarius

After closing KCon, open the Clarius application from the desktop. In this section, you use the Clarius application to configure and run two tests on an n-channel MOSFET transistor: A plot of drain current versus drain voltage using the SMUs and a C-V sweep. By using the Series 700 Switching System, you do not need to rearrange cables between the tests.

For this example, you use the Clarius application to:

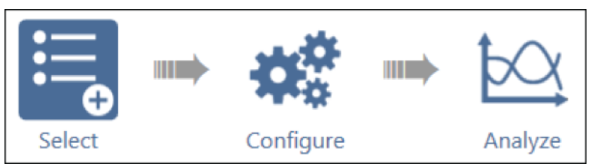
- Create a new project
- Add a device
- Add an action
- Configure the action
- Search for and add two tests
- Run the project and view the tests

Create a new project

To create a new project:

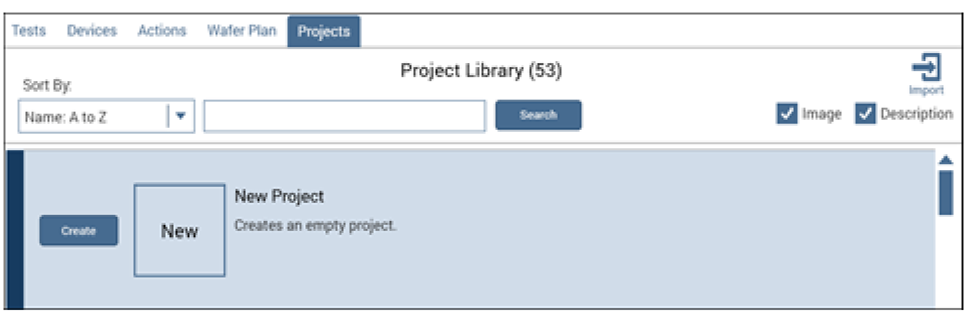
1. Choose **Select**.

Figure 62: Select highlighted



2. In the Library, select **Projects**.
3. Select **New Project**.
4. Select **Create**.

Figure 63: Select a New Project from the Project Library



5. Select **Yes** when prompted to replace the existing project.

Add a device

To add a device:

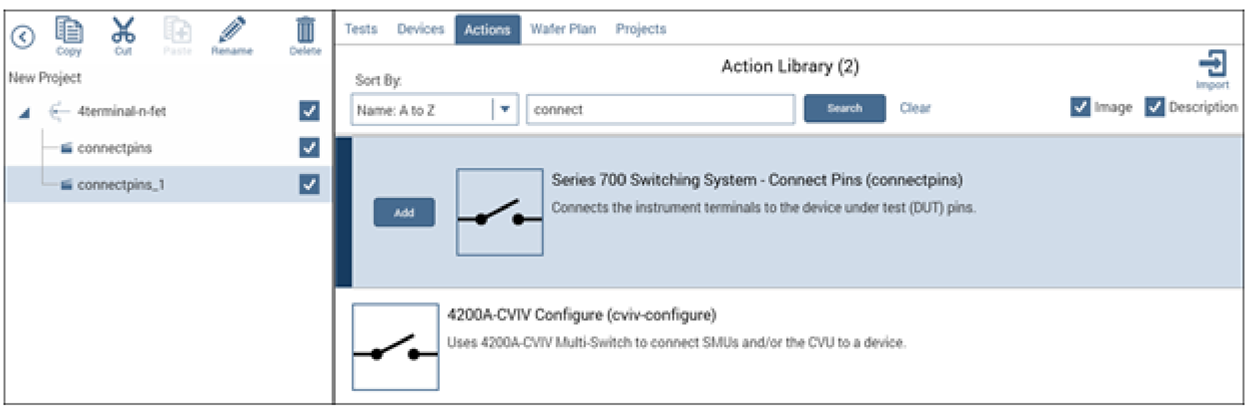
1. Select **Devices**.
2. Enter **MOSFET** in the search box.
3. Select **Search**.
4. Scroll to the **MOSFET, n-type, 4 terminal** (`4terminal-n-fet`) device.
5. Select **Add** to add it to the project tree.

Add the connectpins action

To add the connectpins action:

1. Select **Actions**.
2. Type **connect** in the search box.
3. Select **Search**.
4. Scroll to the `connectpins` action, then **Add** it to the project tree twice.

Figure 64: connectpins added twice

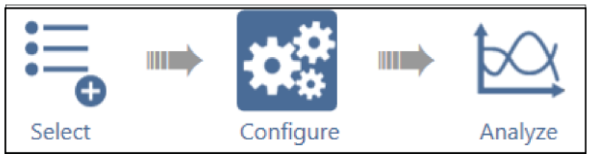


Configure the connectpins action

To configure the connectpins action:

1. Select the first `connectpins` action you added to the project tree.
2. Select **Configure**.

Figure 65: Configure highlighted

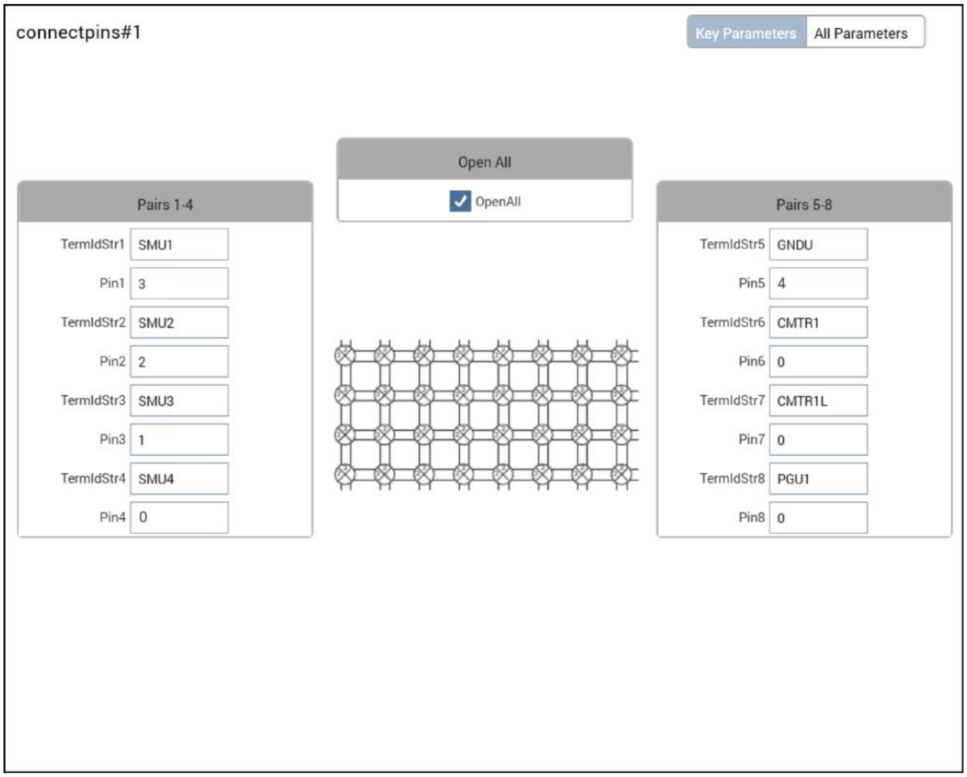


3. Make the following connections using the pairs of TermIdStr# and Pin# fields in the action:
   - **SMU1 – Pin 3**
   - **SMU2 – Pin 2**
   - **SMU3 – Pin 1**
   - **GNDU – Pin 4**

When you are finished, the Key Parameters view of the action should look like the next graphic. The order of the instruments does not matter if each instrument is paired with the correct pin number.

In this example, assigning TermIdStr1 to **SMU1** and Pin 1 to **3** connects SMU1 to Pin 3 on the matrix.

Figure 66: connectpins device connections



NOTE

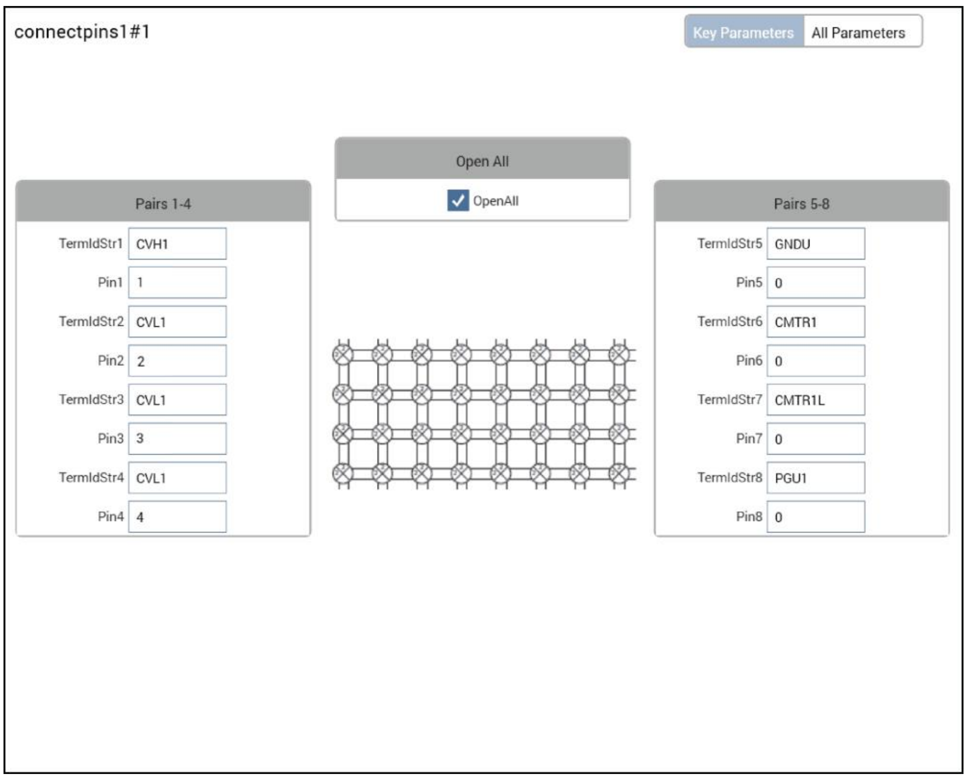
If the OpenAll check box is selected, the `connectpins` action opens all crosspoints before closing the specified pairs. This is the default and is usually the preferred behavior. However, since `connectpins` only has eight field pairs, the action can only close eight crosspoints during each run. To close more crosspoints, use multiple `connectpins` actions.

4. Select **Save**.
5. Select the second `connectpins` action you added to the project tree.
6. Make the following connections using the pairs of TermIdStr# and Pin# text fields in the action:

   - **CVH1 – Pin 1**
   - **CVL1 – Pin 2**
   - **CVL1 – Pin 3**
   - **CVL1 – Pin 4**

When you are finished, the Key Parameters for the action look like the next figure.

Figure 67: Second connectpins connections



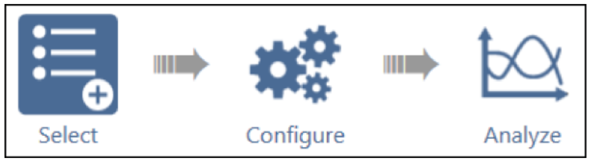
7. Select **Save**.

Search for and add existing tests from the Test Library

To search for and add existing tests from the Test Library:

1. Choose **Select**.

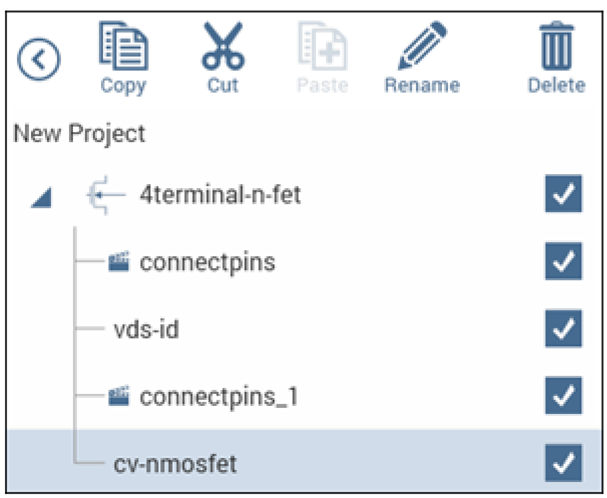
Figure 68: Select highlighted



2. Select **Tests**.
3. Type **vds** into the search box.
4. Select **Search**.
5. Scroll to the `vds-id` test.
6. Select **Add** to add it to the project tree.
7. Drag the `vds-id` test to between the two `connectpins` actions.
8. Clear the search box.
9. Type **cv** into the search box.
10. Select **Search**.
11. Scroll to the **cv-nmosfet** test. Select **Add** to add it to the project tree.
12. Drag the `cv-nmosfet` test after the second `connectpins` action.

Your project tree looks like the next figure.

Figure 69: Project tree showing tests and actions in the proper order



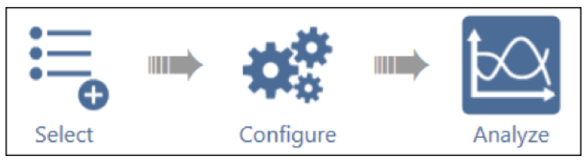
Run the project and view the tests

To run the project and view the tests:

1. In the project tree, select `New Project`.
2. Make sure the items in the project tree are checked.
3. Select **Run** to start the test. The two actions and tests run sequentially. The `connectpins` actions set the crosspoints before the tests are executed.

You can select **Analyze** when you run the project to view test results in real-time.

Figure 70: Analyze highlighted



To view the results of a test either as it runs or after it has completed, select the test in the project tree.

Section 6

Make I-V measurements on a solar cell

In this section:

Introduction

This example shows how to use a 420x-SMU or 421x-SMU instrument to perform a forward-biased voltage sweep on a solar cell in a 4-wire configuration. Current is measured on each step of the sweep and an I-V graph is generated from the collected data. The Formulator calculates common electrical characteristics of the cell.

These instructions show you how to make connections from the SMU to the solar cell and how to add the forward bias I-V test into a new project and automate the measurements.

From the I-V characteristics measured by the 4200A-SCS, you can determine important parameters about the solar cell, including:

- Maximum current (I_{max}) and voltage (V_{max})
- Maximum power (P_{max})
- Open-circuit voltage (V_{oc})
- Short-circuit current (I_{sc})

Equipment required

- One 4200A-SCS with one 420x-SMU or one 421x-SMU
- Four triaxial cables (4200-TRX-2 or 4200-MTRX-2)
- One solar cell
- One light source

Device connections

Connect your preamplifier or SMU output terminals to the solar cell in a 4-wire configuration. This provides the best measurement accuracy and eliminates the effects of the resistance of the test leads and unwanted voltage drops.

WARNING

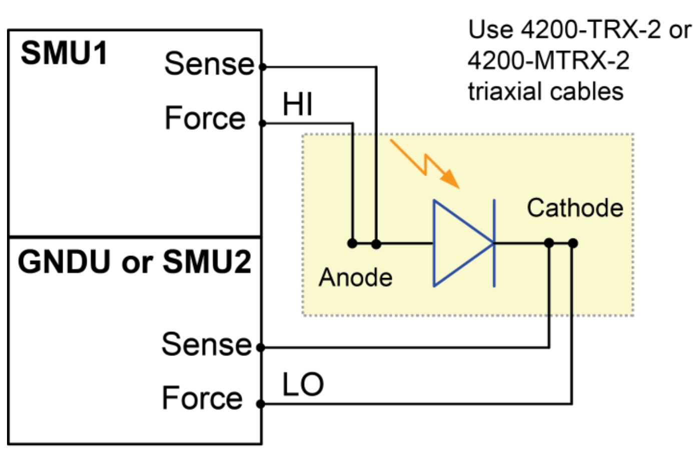
Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

Device connection schematic

Connections to the solar cell can be made using two SMUs or one SMU and the Ground Unit (GNDU). The next figure shows the connection schematic for the application.

Figure 71: Solar cell device connection schematic



Connect the 4200A-SCS to the DUT

The following two figures show the 4200A-SCS rear panel connections for the two methods mentioned in the Device connection schematic (on page 6-2) topic. You can make the connections shown in the following figures using four 4200-TRX-2 or 4200-MTRX-2 triaxial cables.

Figure 72: Rear panel connections using two SMUs

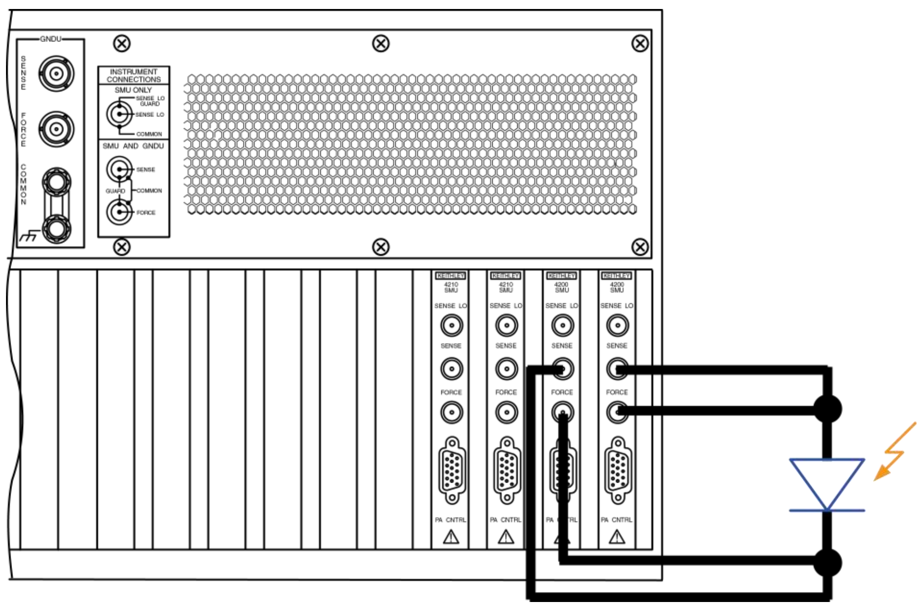
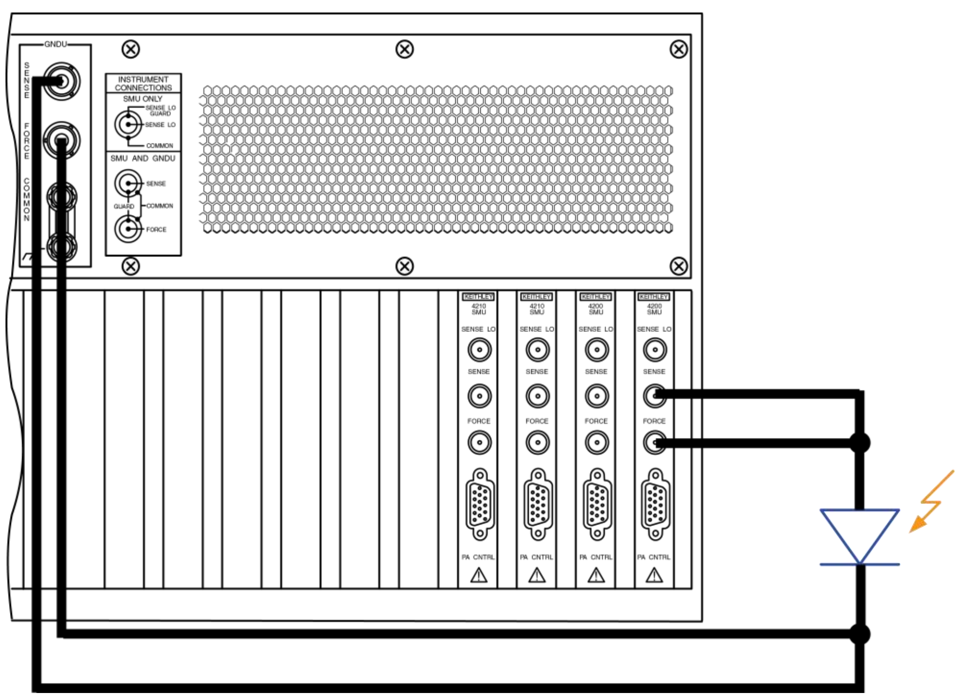


Figure 73: Rear panel connections using one SMU and GNDU



Setting up measurements in the Clarius software

This section demonstrates how to set up the 4200A-SCS to perform an I-V sweep on a solar cell. The `fwd-ivsweep` test measures current at each step of a user-configured voltage sweep. An I-V curve is generated from the acquired data and device parameters are calculated in the Formulator.

For this example, use the Clarius application to:

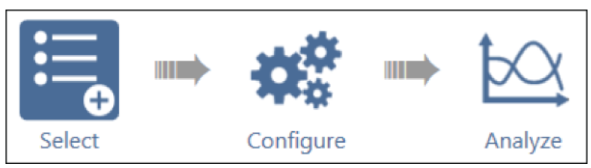
- Create a new project
- Search for and select a test
- Configure the test
- Run the test
- View and analyze the test results

Create a new project

To create a new project:

1. Choose **Select**.

Figure 74: Select highlighted



2. In the Library, select **Projects**.
3. Select **New Project**.
4. Select **Create**.

Figure 75: Select a New Project from the Project Library

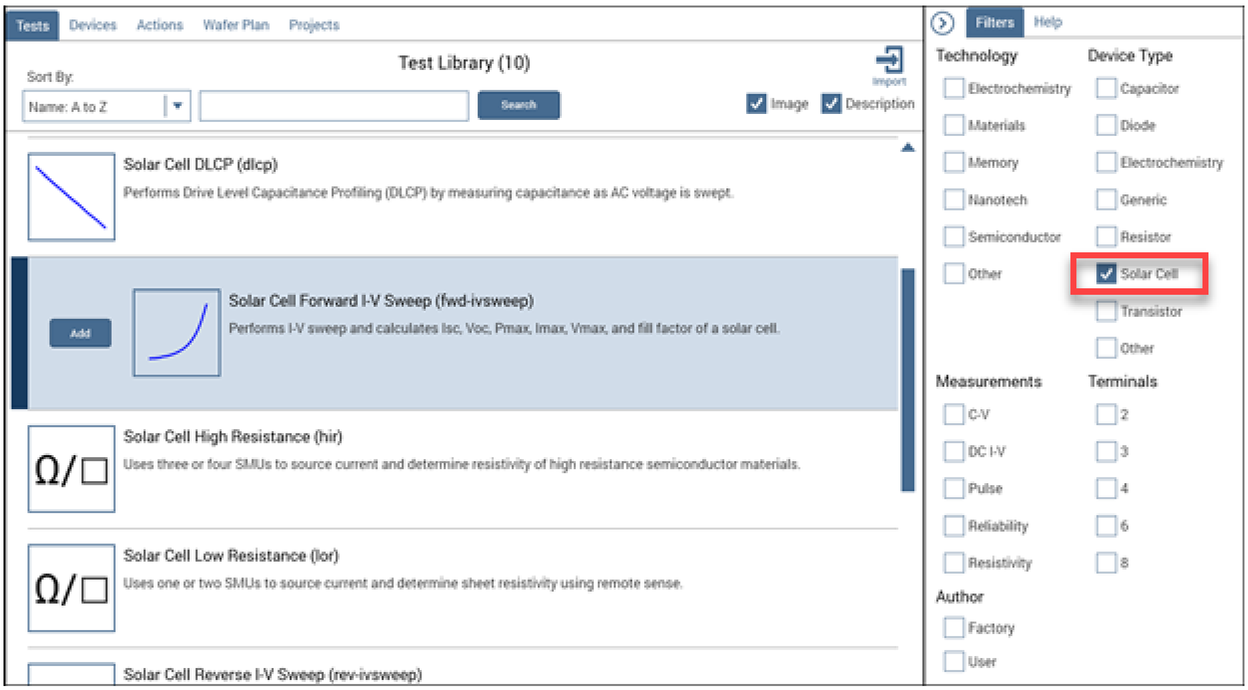
5. Select **Yes** when prompted to replace the existing project.

Search for and select a test

To search for and select the test:

1. Select **Tests**.
2. In the Filters pane, select **Solar Cell**.

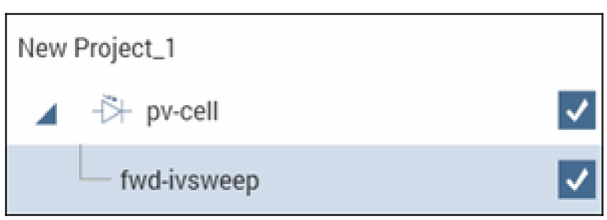
Figure 76: Use filters to select the fwd-ivsweep test



3. Select the **Solar Cell Forward I-V Sweep (fwd-ivsweep)** test.
4. Select **Add**.

The test is displayed in the project tree.

Figure 77: Test added to the project tree

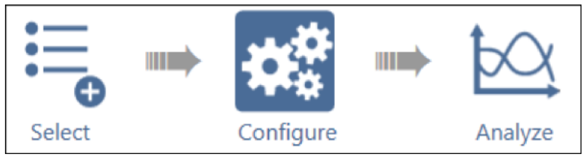


Configure the test

To configure the test:

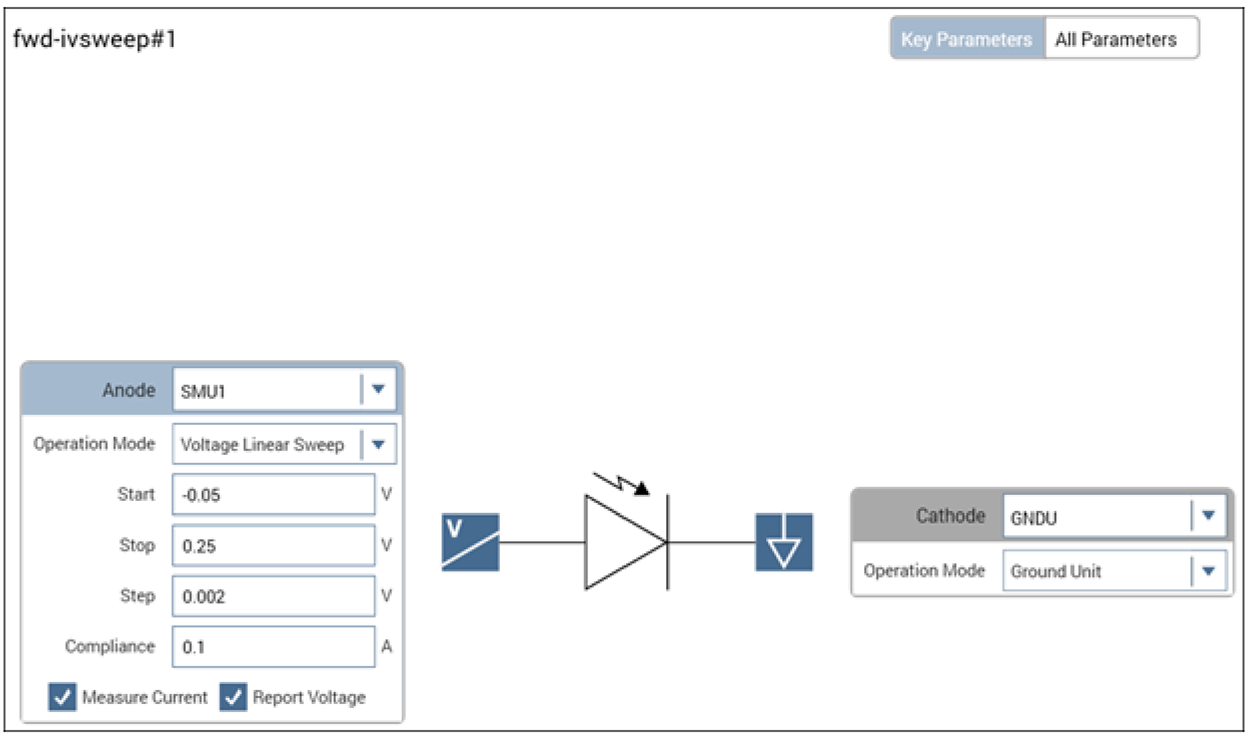
1. Select the `fwd-ivsweep` solar cell I-V test in the project tree.
2. Select **Configure**.

Figure 78: Configure highlighted



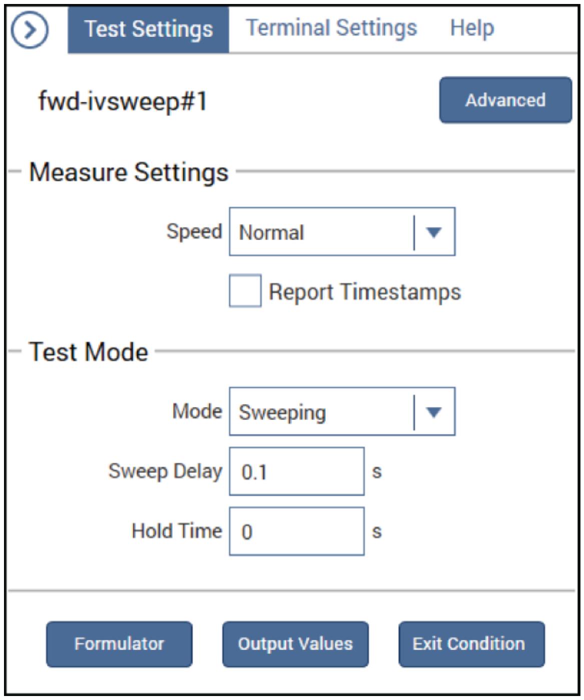
3. Adjust the Anode settings as needed.

Figure 79: Key Parameters pane for the I-V sweep of a solar cell



4. In the Test Settings pane, adjust the Measure Settings and Test Mode as needed.

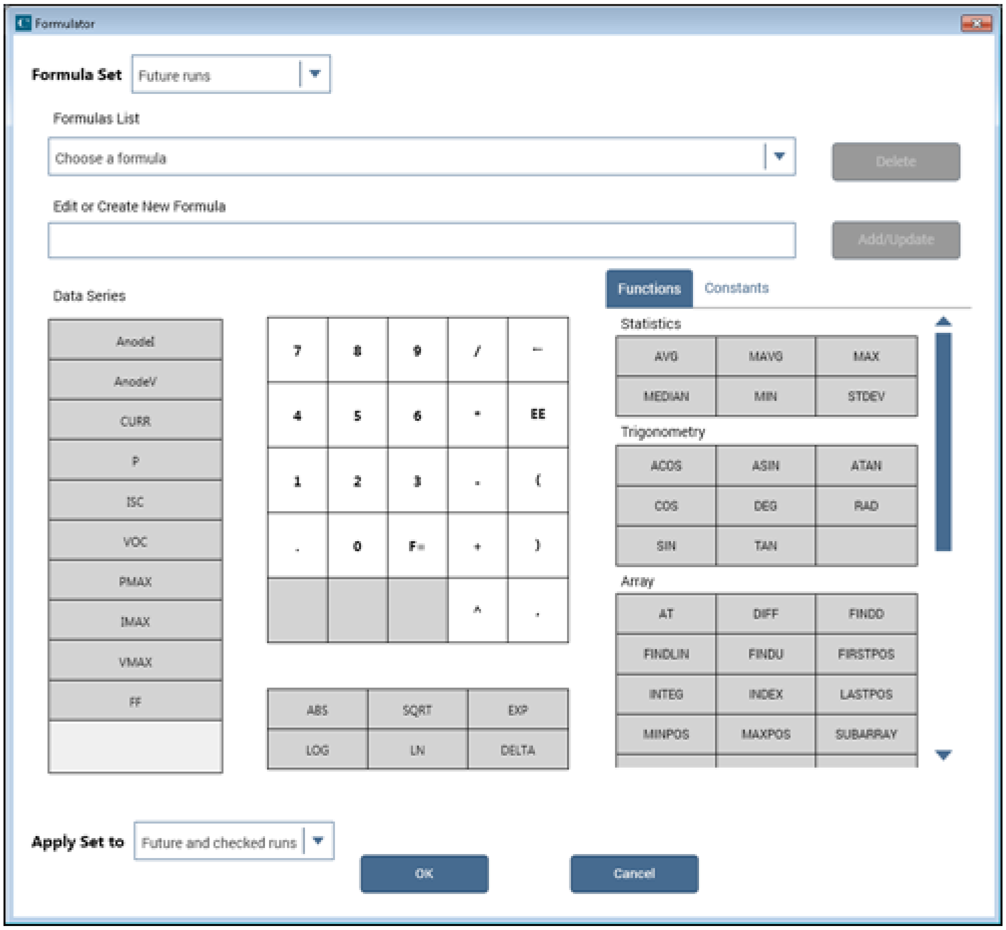
Figure 80: Test Settings pane



NOTE

The Formulator is also in the Test Settings pane. If you select the Formulator in the Test Settings pane, the Formulator dialog box appears as shown in the figure below.

Figure 81: Formulator dialog box



This test calculates V_{oc}, I_{sc}, P_{max}, and other device parameters. See the *Electrical Characterization of Photovoltaic Materials and Solar Cells with the 4200A-SCS Parameter Analyzer* application note for details on Formulator calculations. You can also add new formulas or edit existing formulas. See the "Formulator" topic in the *Model 4200A-SCS Reference Manual* for more information.

Run the test

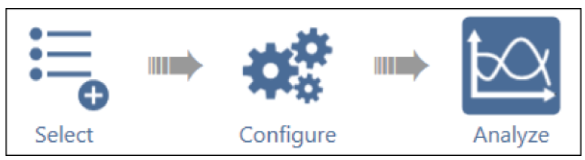
1. Highlight the `fwd-ivsweep` test in the project tree.
2. Select **Run** to execute the test.

Figure 82: Run

Analyze the test results

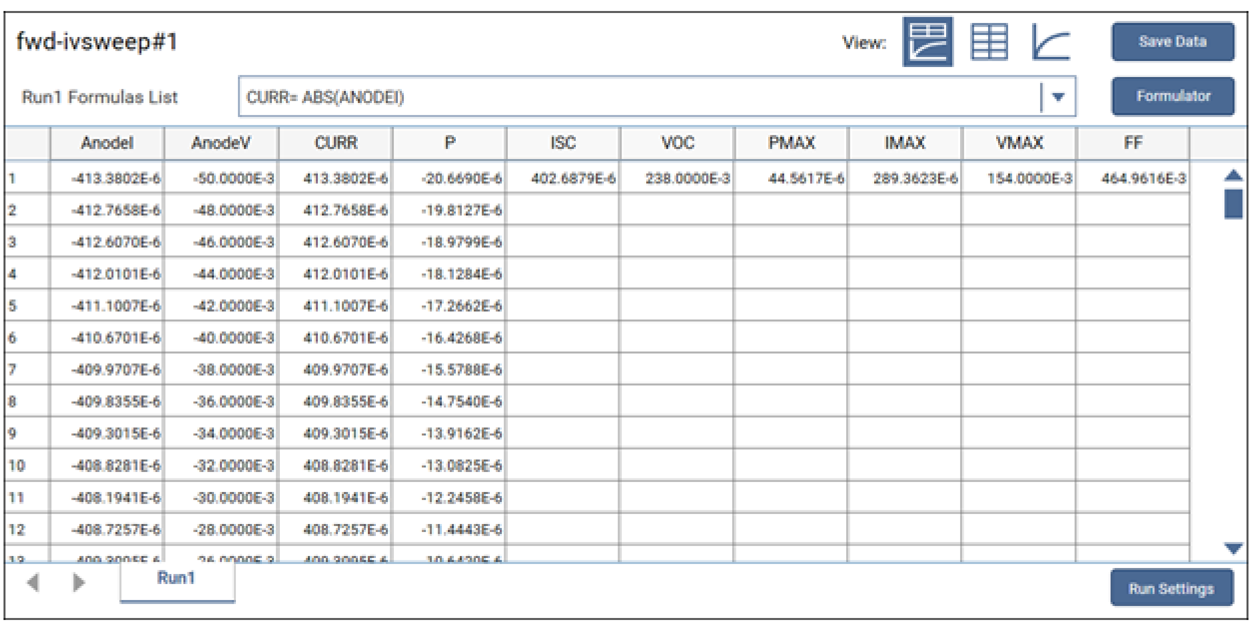
You can select **Analyze** when you run the project to view test results in real-time.

Figure 83: Analyze highlighted



You can also use the View icons in the upper-right of the center pane to display the sheet, graph, or sheet and graph. The sheet only view is shown in the next figure.

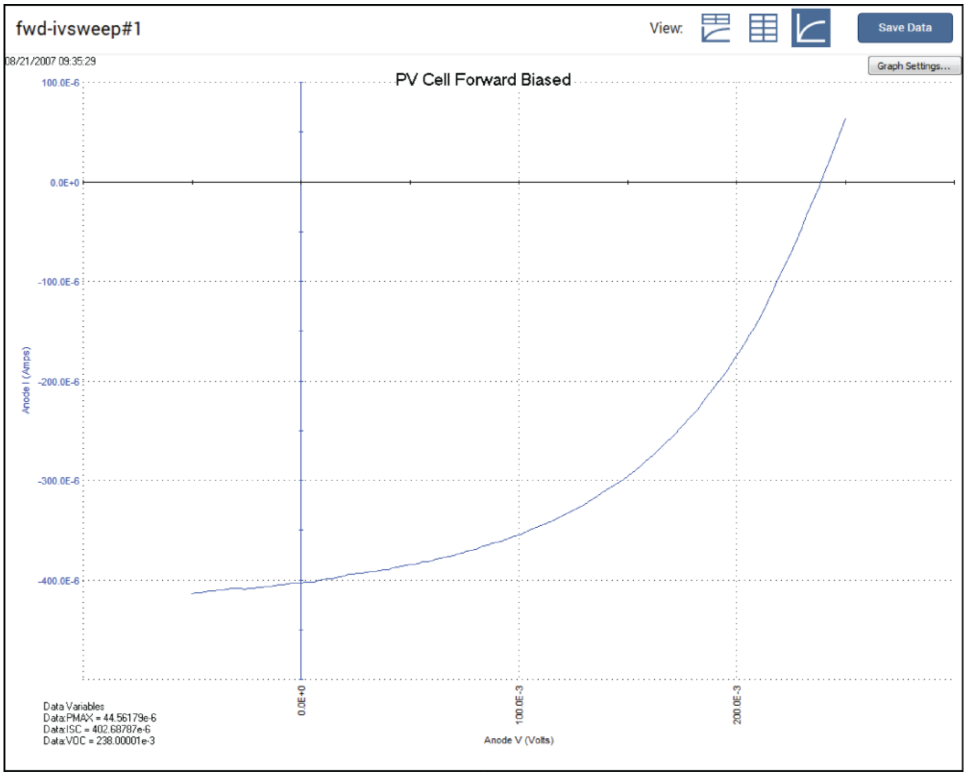
Figure 84: Sheet only view selected, View icons highlighted



The sheet displays the results with the voltage and current data labeled Anode V and Anode I, respectively. The formulas calculated in the Formulator are shown in the right-most columns. They include the maximum power (PMAX), open circuit voltage (VOC), short circuit current (ISC), and fill factor (FF). More information about the sheet and Formulator can be found in the *Model 4200A-SCS Reference Manual*.

To see an expanded view of the graphed test results, select the graph view. The following graph shows the sweep of an illuminated silicon photovoltaic (PV) cell generated by the SMU.

Figure 85: Test results showing I-V graph of an illuminated solar cell



Because the system SMUs can sink current, the curve can pass through the fourth quadrant and allow power to be extracted from the device (I–, V+). If you want to have the data displayed in the first quadrant, use the Formulator to multiply the current by -1 and plot this calculated result instead.

You can also show previous test runs in the graph window by selecting them under the Run History tab. Select the check box next to the test you want to display, and the test curves are displayed in the graph window. If you select multiple run histories, the graphs are overlaid.

Additional tests

You can add other solar cell tests to the project. Search for **solar cell** in the Tests library to find additional tests.

Section 7

Make C-V measurements on a MOSCAP

In this section:

Introduction

Capacitance-voltage (C-V) measurements are commonly used to study gate-oxide quality in detail. These measurements are made on two-terminal devices called MOS capacitors, which are MOSFETs without a source and drain. C-V test results offer device and process information, including bulk and interface charges. Many MOS device parameters, such as oxide thickness, flat band voltage, and threshold voltage, can also be extracted from the C-V test data.

This section provides an example of how to use the 4210-CVU C-V Analyzer to make a C-V sweep on a MOS capacitor and derive common parameter extractions from the C-V data using the Formulator.

Equipment required

One 4200A-SCS with the following instruments and accessories:

- One 421x-CVU
- Four CA-447A SMA cables
- Four CS-1247 SMA female to BNC male adapters
- Two CS-701 BNC tee adapters

Device connections

Using the supplied cables, make connections from the output terminals of the CVU to the MOS capacitor.

⚠ WARNING

Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

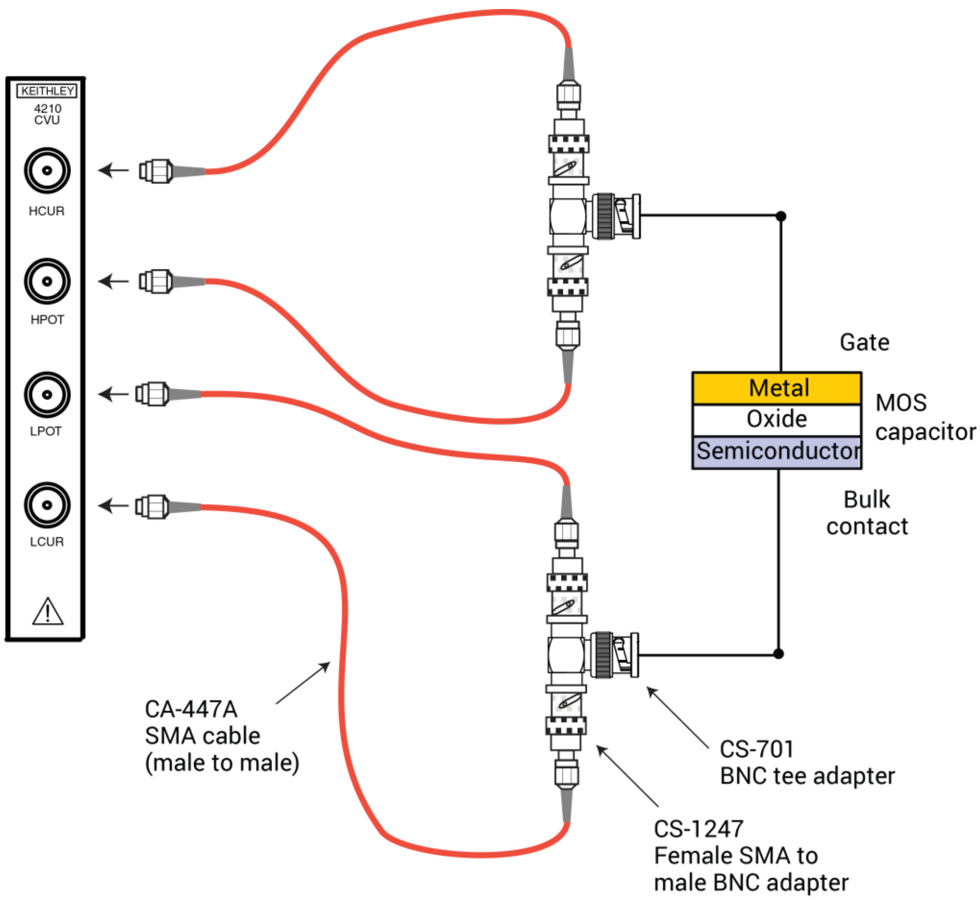
Connect the 4200A-SCS to the DUT

The hardware connections from the output terminals of the CVU to the MOS capacitor are shown in the following figure. Connect one cable to each of the CVU terminals, then connect one SMA female to BNC male adapter to the end of each cable.

The cables from the HCUR and HPOT terminals are coupled with the BNC tee adapter and are then connected to the gate of the MOS capacitor. The cables from the LCUR and LPOT terminals are also connected together with the BNC tee adapter and then are connected to the bulk of the MOS capacitor.

In the Clarius application, you will configure HCUR to be the high terminal of the AC ammeter and HPOT to be the high of the DC voltage source.

Figure 86: Connections from the 4210-CVU to the MOS capacitor



Set up the measurements in Clarius

This section describes how to set up the Clarius application to make a C-V sweep on a MOS capacitor. You select an existing project from the project library and configure a C-V sweep test.

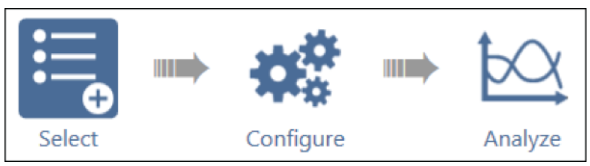
For this example, you will use Clarius to:

- Search for and select a project in the Project Library
- Configure the test
- Perform offset compensation
- Run the test
- View and analyze the test results

Search for and select a project

1. Choose **Select**.

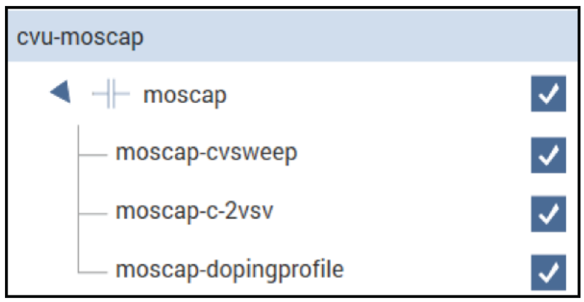
Figure 87: Select highlighted



2. Select **Projects**.
3. Type **MOScap** into the search bar.
4. Select **Search**.
5. Select **MOS Capacitor C-V** project (`cvu-moscap`).
6. Select **Create**.
7. Select **Yes** when prompted to replace the existing project.

The project is displayed. This project has three C-V tests for a MOS capacitor, as shown in the next figure.

Figure 88: MOS capacitor C-V project tree with three tests



Configure the test

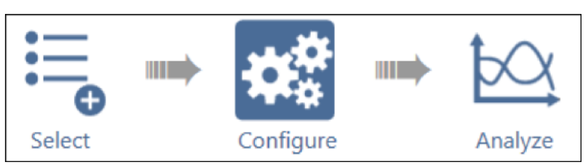
To configure the C-V sweep test, you set the source and measure parameters, define the timing parameters, and adjust the constants and formulas for extracting parameters from the C-V data.

This test makes a capacitance measurement at each step of a user-configured voltage sweep. A C-V graph is generated from the acquired data and several device parameters are calculated in the Formulator.

To configure the test:

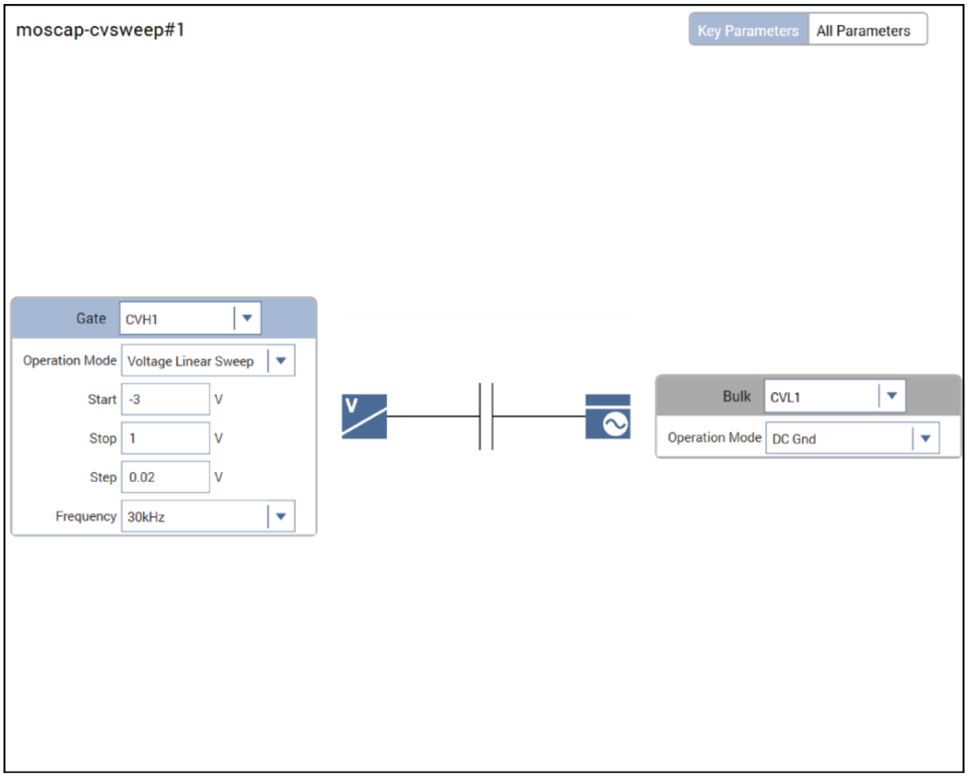
1. Select **Configure**.

Figure 89: Configure highlighted



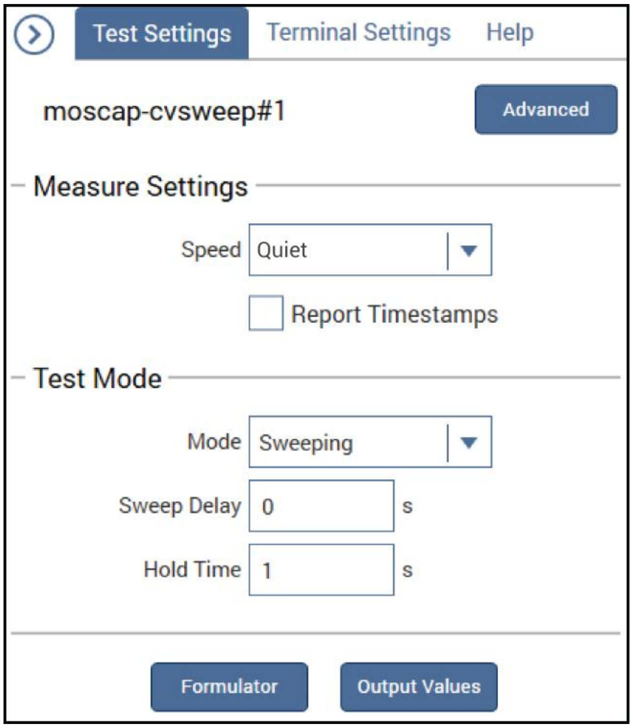
2. In the project tree, select the **moscap-cvsweep** test.
3. In the Key Parameters pane, adjust the voltage sweep and test frequency values as needed.

Figure 90: Key parameters for the C-V sweep of a MOS capacitor



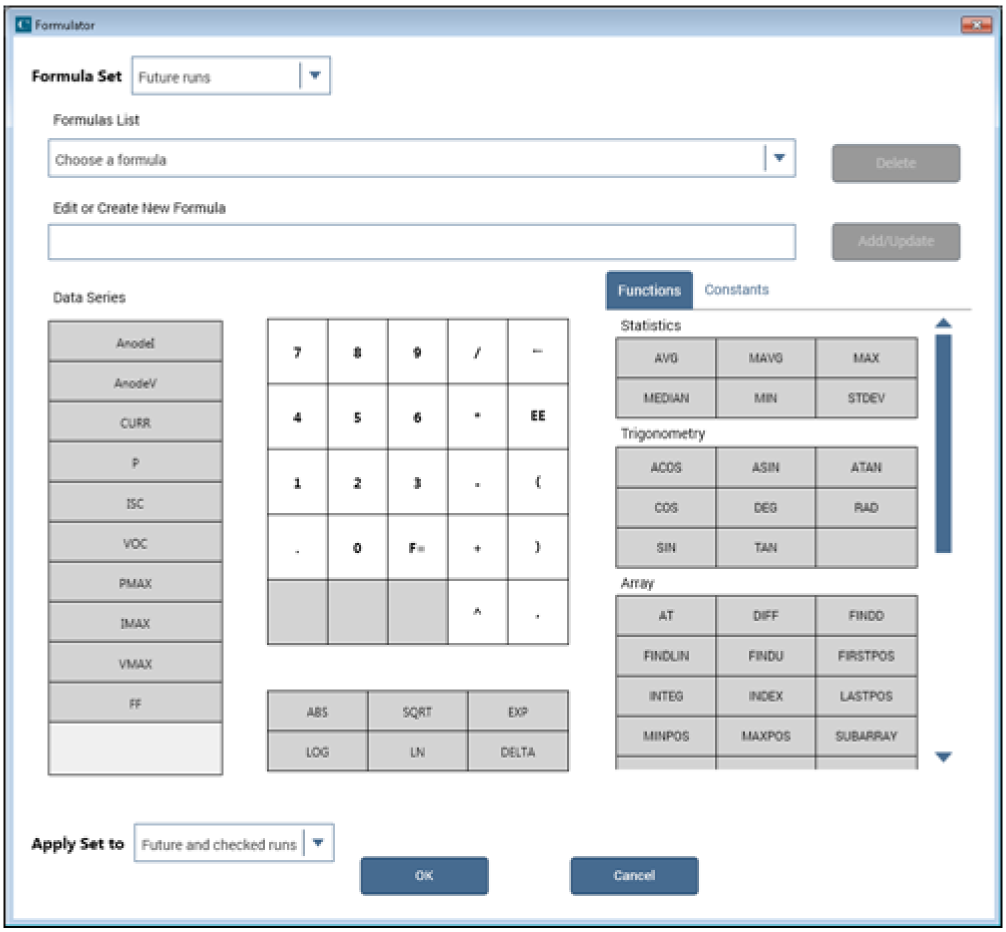
4. In the Test Settings pane, set the Speed to **Quiet** for sensitive capacitance measurements.

Figure 91: Test Settings pane



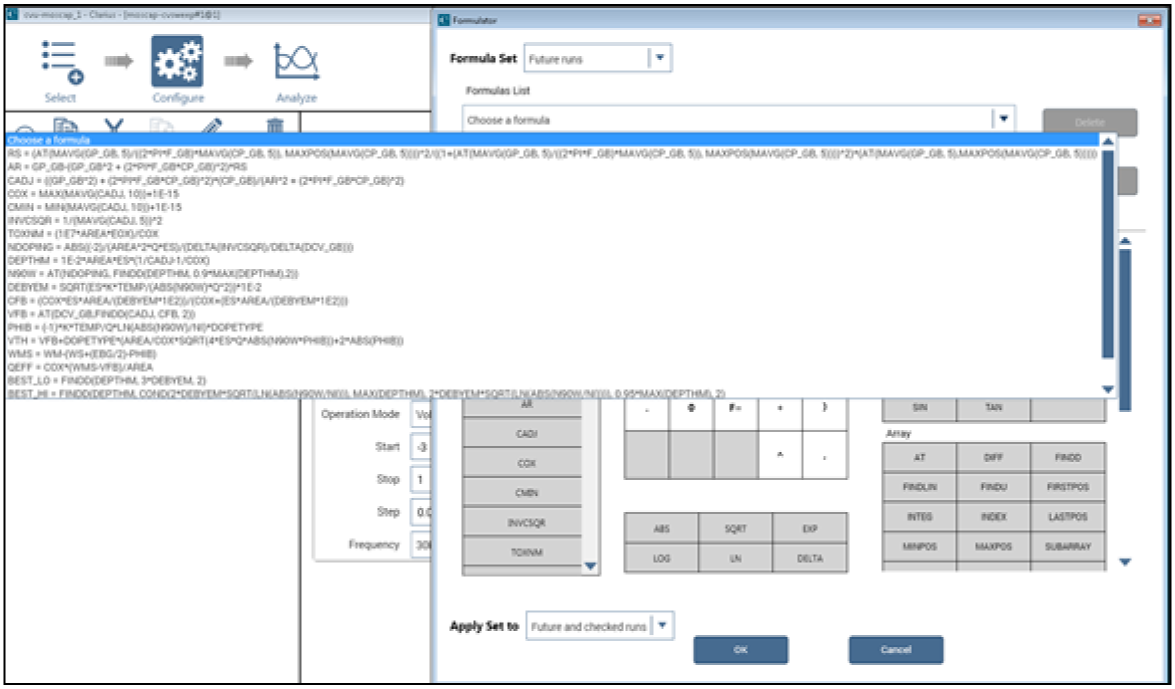
5. Adjust the **Sweep Delay** as needed.
6. Select **Formulator**. In this test, the Formulator contains equations for deriving common MOS capacitor parameters from the C-V data. Examples of these parameters include the oxide capacitance, oxide thickness, flatband voltage, flatband capacitance, threshold voltage, and doping concentration. You can view, edit, and add equations in this dialog box.

Figure 92: Formulator dialog box



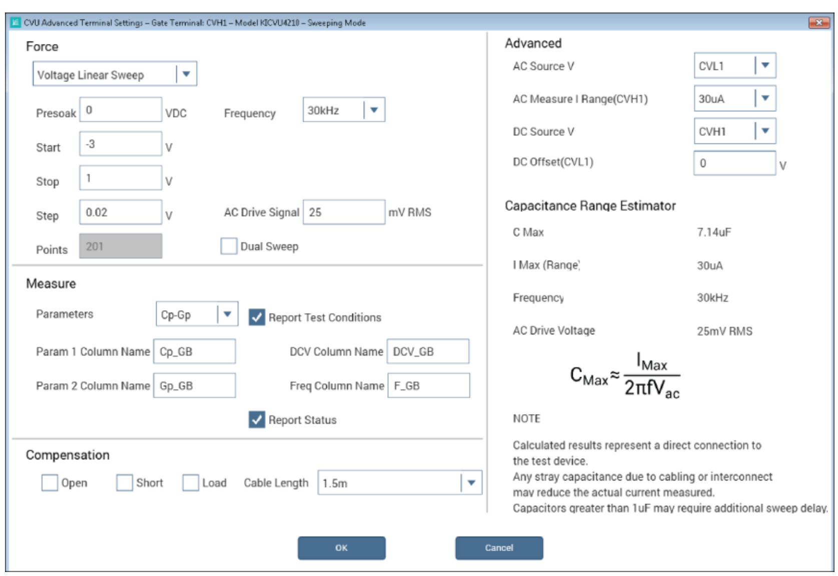
The next figure shows some of the equations that are included with this test. In the Constants area of the Formulator, you can change the constants that are used in the formulas, such as the gate area and temperature.

Figure 93: Formulas listed in the Formulator



7. Select **OK** to accept changes made in the Formulator.
8. From the Terminal Settings Advanced dialog box, adjust the parameters as needed.

Figure 94: Terminal Settings pane and Terminal Settings Advanced dialog box



In this test, the CVH1 terminals are internally connected to the AC ammeter and the HI of the DC voltage source by default. The CVH1 terminals are externally connected to the gate of the MOS capacitor. The CVL1 terminals are internally connected to the AC voltage source and the LO of the DC voltage source and are externally connected to the bulk of the MOS capacitor or to the prober chuck.

Perform offset compensation

C-V measurements on a MOS capacitor are generally performed on a wafer using a prober. The 4210-CVU is connected to the MOS capacitor through cables, adapters, and a prober. Cabling adds stray capacitance to measurements.

To correct for the stray capacitance, Clarius has tools for offset correction. Correction is a two-part process: You perform the corrections for open, and then you enable the corrections in the Terminal Settings pane.

Open compensation is generally used for high impedance measurements (<10 pF or >1 MΩ). A short compensation correction is generally used for low impedance measurements (>10 nF or <10 Ω). For a short compensation, you select Measure Short, and then short the probe to the chuck.

To perform the corrections:

1. Select **Tools**.

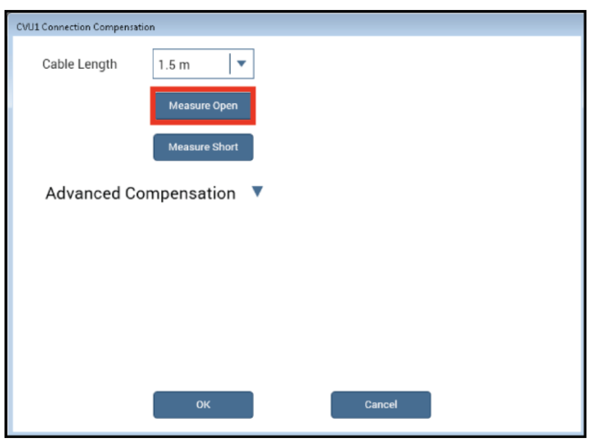
Figure 95: Tools icon in Clarius

2. Select **CVU Connection Compensation** from the Clarius Tools dialog box.

Figure 96: Clarius Tools dialog box

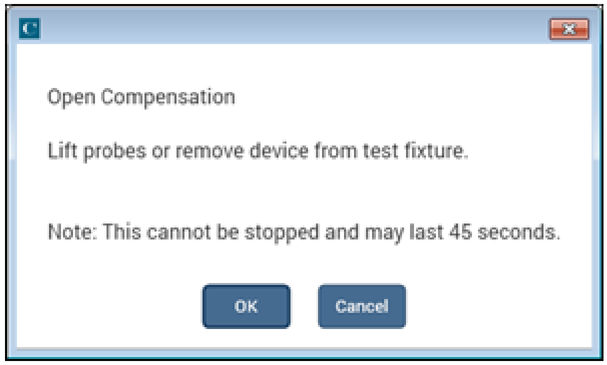
3. Disconnect the probes from the DUT.
4. Select **Measure Open**.

Figure 97: CVU Connection Compensation dialog box



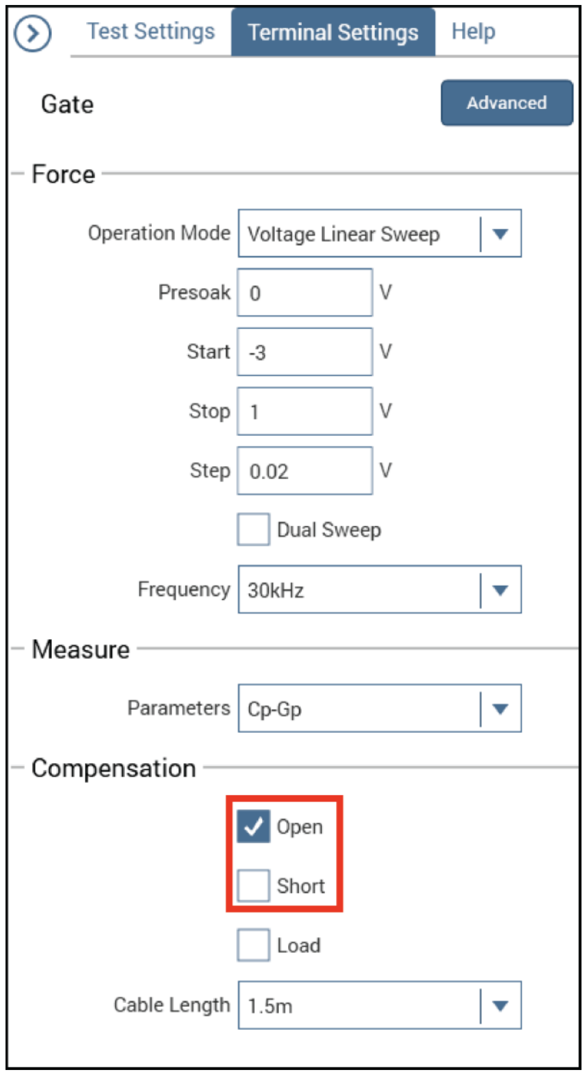
5. Select **OK**. You are prompted to verify that the probes have been disconnected from the DUT.

Figure 98: Prompt to remove probes from DUT



6. Make sure that the probes have been disconnected from the DUT, then select **OK**. The compensation runs, and a dialog box confirms that the compensation has run successfully.
7. Select **Exit** to close the Tools dialog box.
8. From the Terminal Settings pane, enable corrections by selecting the **Open** checkbox.

Figure 99: Enabling CVU Compensation



Run the test

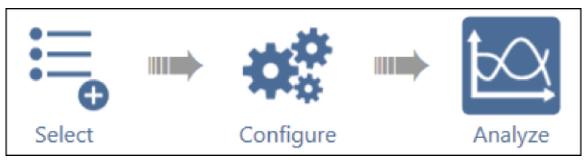
Select **Run** to execute the test.

Figure 100: Run

View and analyze the test results

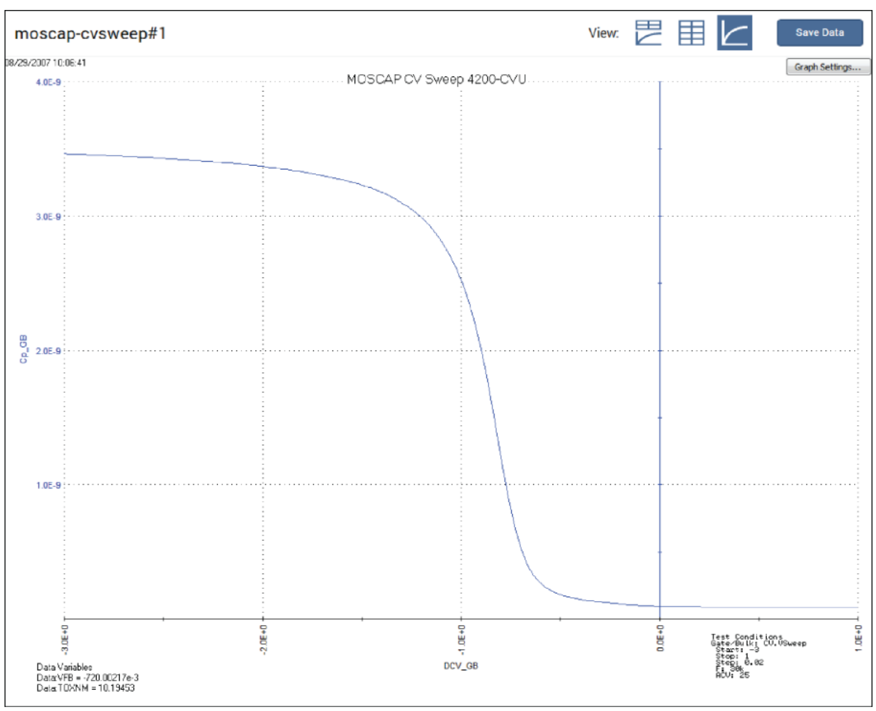
Select **Analyze** when you run the project to view test results in real-time.

Figure 101: Analyze highlighted



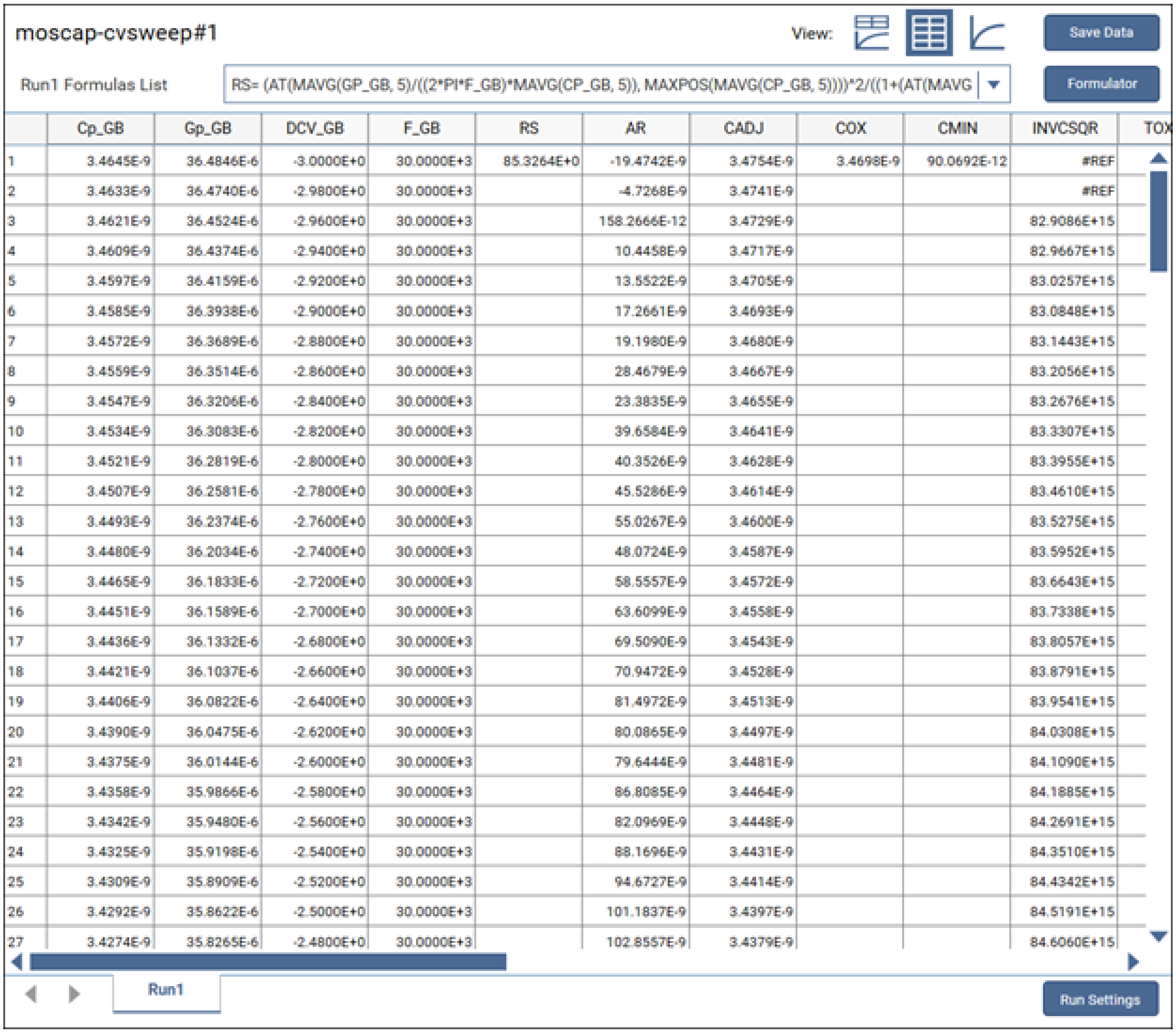
The C-V data is plotted on the graph as the `moscap-cvsweep` test executes.

Figure 102: Graph in the Analyze pane



You can also click the data only view of the Analyze sheet, as highlighted in the next figure, to display more data. For example, you can display a holistic view of the parameters for a device.

Figure 103: C-V data in the sheet



	Cp_GB	Gp_GB	DCV_GB	F_GB	RS	AR	CADJ	COX	CMIN	INVCSQR	TOX
1	3.4645E-9	36.4846E-6	-3.0000E+0	30.0000E+3	85.3264E+0	-19.4742E-9	3.4754E-9	3.4698E-9	90.0692E-12	#REF	
2	3.4633E-9	36.4740E-6	-2.9800E+0	30.0000E+3		-4.7268E-9	3.4741E-9			#REF	
3	3.4621E-9	36.4524E-6	-2.9600E+0	30.0000E+3		158.2666E-12	3.4729E-9			82.9086E+15	
4	3.4609E-9	36.4374E-6	-2.9400E+0	30.0000E+3		10.4458E-9	3.4717E-9			82.9667E+15	
5	3.4597E-9	36.4159E-6	-2.9200E+0	30.0000E+3		13.5522E-9	3.4705E-9			83.0257E+15	
6	3.4585E-9	36.3938E-6	-2.9000E+0	30.0000E+3		17.2661E-9	3.4693E-9			83.0848E+15	
7	3.4572E-9	36.3689E-6	-2.8800E+0	30.0000E+3		19.1980E-9	3.4680E-9			83.1443E+15	
8	3.4559E-9	36.3514E-6	-2.8600E+0	30.0000E+3		28.4679E-9	3.4667E-9			83.2056E+15	
9	3.4547E-9	36.3206E-6	-2.8400E+0	30.0000E+3		23.3835E-9	3.4655E-9			83.2676E+15	
10	3.4534E-9	36.3083E-6	-2.8200E+0	30.0000E+3		39.6584E-9	3.4641E-9			83.3307E+15	
11	3.4521E-9	36.2819E-6	-2.8000E+0	30.0000E+3		40.3526E-9	3.4628E-9			83.3955E+15	
12	3.4507E-9	36.2581E-6	-2.7800E+0	30.0000E+3		45.5286E-9	3.4614E-9			83.4610E+15	
13	3.4493E-9	36.2374E-6	-2.7600E+0	30.0000E+3		55.0267E-9	3.4600E-9			83.5275E+15	
14	3.4480E-9	36.2034E-6	-2.7400E+0	30.0000E+3		48.0724E-9	3.4587E-9			83.5952E+15	
15	3.4465E-9	36.1833E-6	-2.7200E+0	30.0000E+3		58.5557E-9	3.4572E-9			83.6643E+15	
16	3.4451E-9	36.1589E-6	-2.7000E+0	30.0000E+3		63.6099E-9	3.4558E-9			83.7338E+15	
17	3.4436E-9	36.1332E-6	-2.6800E+0	30.0000E+3		69.5090E-9	3.4543E-9			83.8057E+15	
18	3.4421E-9	36.1037E-6	-2.6600E+0	30.0000E+3		70.9472E-9	3.4528E-9			83.8791E+15	
19	3.4406E-9	36.0822E-6	-2.6400E+0	30.0000E+3		81.4972E-9	3.4513E-9			83.9541E+15	
20	3.4390E-9	36.0475E-6	-2.6200E+0	30.0000E+3		80.0865E-9	3.4497E-9			84.0308E+15	
21	3.4375E-9	36.0144E-6	-2.6000E+0	30.0000E+3		79.6444E-9	3.4481E-9			84.1090E+15	
22	3.4358E-9	35.9866E-6	-2.5800E+0	30.0000E+3		86.8085E-9	3.4464E-9			84.1885E+15	
23	3.4342E-9	35.9480E-6	-2.5600E+0	30.0000E+3		82.0969E-9	3.4448E-9			84.2691E+15	
24	3.4325E-9	35.9198E-6	-2.5400E+0	30.0000E+3		88.1696E-9	3.4431E-9			84.3510E+15	
25	3.4309E-9	35.8909E-6	-2.5200E+0	30.0000E+3		94.6727E-9	3.4414E-9			84.4342E+15	
26	3.4292E-9	35.8622E-6	-2.5000E+0	30.0000E+3		101.1837E-9	3.4397E-9			84.5191E+15	
27	3.4274E-9	35.8265E-6	-2.4800E+0	30.0000E+3		102.8557E-9	3.4379E-9			84.6060E+15	

Use the 4200A-CVIV Multi-Switch

In this section:

Introduction

This section shows you how to use the 4200A-SCS and Model 4200A-CVIV Multi-Switch to perform I-V and C-V measurements on the same device without having to manually change connections to the device between tests.

The 4200A-CVIV allows you to switch between I-V and C-V measurements and make C-V measurements between output terminals of the 4200A-CVIV.

The 4200A-CVIV can be equipped with up to four 4200-PA Remote Preamplifiers or 4200-CVIV-SPT SMU Pass-Thru modules.

A MOSFET is used as the device in this example, but the same procedure applies for all devices.

For additional information on the 4200A-CVIV, see the *Model 4200A-CVIV Multi-Switch User's Guide*.

Equipment required

- One 4200A-SCS with the following instruments:
  - Four 420x-SMUs or 421x-SMUs
  - Four 4200-PAs or 4200A-CVIV-SPTs (two 4200A-CVIV-SPTs are supplied with the 4200A-CVIV)
  - One 421x-CVU
- One 4200A-CVIV
- Four 4200-TRX-2 or 4200-MTRX-2 triaxial cables (supplied with the SMU)
- Four 4200-TRX-0.75 triaxial cables, 0.75 m (30 in.)
- Four CA-447A SMA cables (supplied with the CVU)
- One shielded four-terminal test fixture with triaxial inputs

Device connections

To use 4200-PA preamplifiers with the 4200A-CVIV, the preamplifiers are installed in the 4200A-CVIV chassis. If you are not using 4200-PA preamplifiers, you must install 4200A-CVIV-SPT Pass-Thru modules in the 4200A-CVIV chassis and connected to an SMU using triaxial cables. For more information on installing and connecting preamplifiers and Pass-Thru modules, see the *Model 4200A-CVIV Multi-Switch User's Guide*.

You will also make connections from the CVU to the SMA inputs of the 4200A-CVIV using the CA-447A SMA cables supplied with the CVU. The *Model 4200A-CVIV Multi-Switch User's Guide* contains additional connection information.

From the output of the 4200A-CVIV, use the 4200-TRX-0.75 triaxial cables to connect the CVIV to the shielded test fixture. The triaxial terminals on the shielded test fixture allow you to connect directly to the MOSFET while maintaining a completely shielded and guarded test setup. The triaxial cables can also be connected to a wafer probing station. A triaxial-to-coaxial adapter can be used to connect to test fixtures or probe stations that only have coaxial inputs.

NOTE

The inner shield of the triaxial cable can have voltages up to 200 V present during SMU operation. Any triaxial-to-coaxial adapter used for conversion should connect the inner conductor and the outer shield to the coaxial connector only.

⚠ WARNING

Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

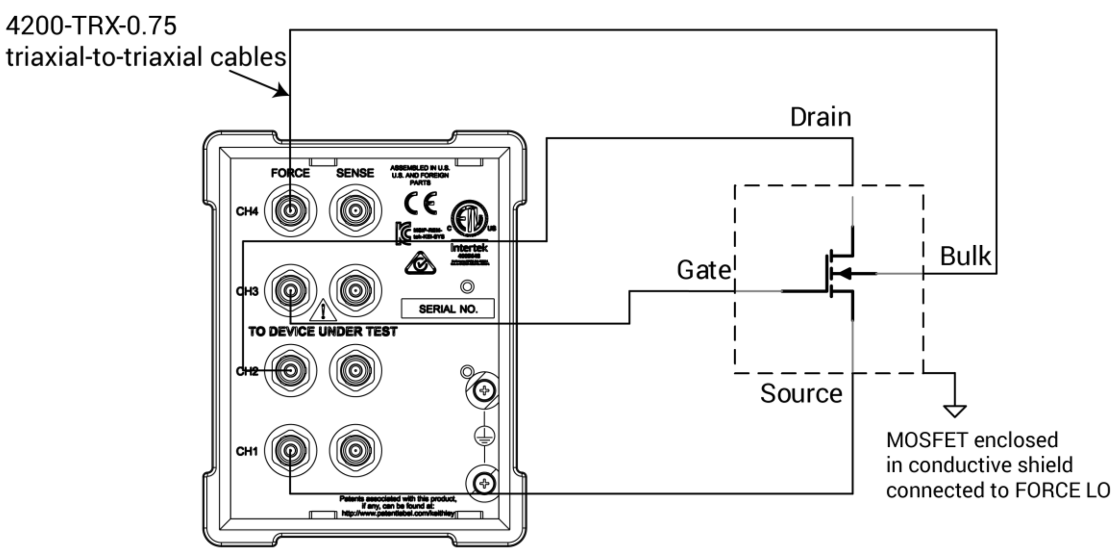
To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

Connection schematic

Make the hardware connections from the output terminals of the 4200A-CVIV to the MOSFET, as shown in the following figure. In this example, 2-wire (local sense) measurements are made at the MOSFET, so four triaxial cables are connected from each Force output terminal of the 4200A-CVIV to the device.

Each 4200A-CVIV output is connected to a different terminal of the 4-terminal MOSFET. The 4200-TRX-0.75 triaxial cables are recommended for use on the output of the 4200A-CVIV. These cables are used to ensure that both low current I-V measurements and high frequency C-V measurements can be made with high accuracy.

Figure 104: Connections from the 4200A-CVIV to MOSFET



Set up the measurements in Clarius

This section describes how to set up the 4200A-SCS to control the 4200A-CVIV to automatically switch between I-V and C-V measurements.

For this example, you use the Clarius application to:

- Create a new project
- Add and configure a CVU compensation action
- Add a MOSFET device
- Add and configure an action for switching the SMUs
- Add a test for making I-V measurements
- Add and configure an action for switching the CVU
- Add a test for making C-V measurements
- Run the project
- View and analyze the test results

The project created in this example is used for two different purposes:

1. The project collects C-V connection compensation constants for all of the 4200A-CVIV channel configurations that include C-V measurements. This step only needs to be performed once for each configuration.
2. The project runs the tests on the MOSFET. The 4200A-SCS is configured to connect the SMUs to the MOSFET and produce a Vds-Id family of curves. Then the project re-configures the 4200A-SCS to connect the CVU to the MOSFET and make a C-V measurement between the gate of the MOSFET (CV HI) and the source, drain, and bulk (CV LO).

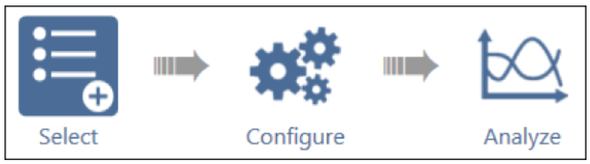
You can use this same general procedure to create tests for other devices and for other applications. You can also configure the project to make multiple I-V measurements and multiple C-V measurements on the same device with different 4200A-CVIV configurations.

Create and rename a project for I-V and C-V measurements with compensation

To create and rename a project for I-V and C-V measurements with compensation:

1. Choose **Select**.

Figure 105: Select highlighted

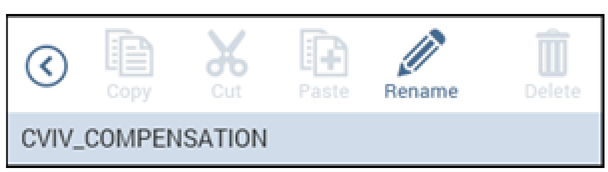


2. In the Library, select **Projects**.
3. Select **New Project**.
4. Select **Create**.

Figure 106: Select a New Project from the Project Library

5. Select **Yes** when prompted to replace the existing project.
6. Select **Rename** above the project tree. Enter a project name into the text box, then select **Enter**. `CVIV_COMPENSATION` is the test name for this example.

Figure 107: Rename function located above the project tree



Add an action to perform CVU compensation

The `cvu-cviv-comp-collect` action configures the 4200A-CVIV to the selected channel configuration and performs compensation.

To add an action:

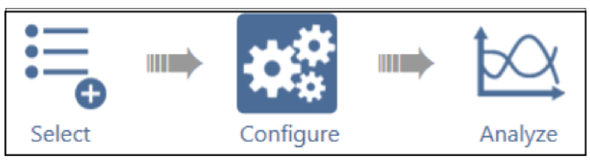
1. Select **Actions**.
2. To find the action, enter `cviv` into the search bar, then select **Search**.
3. Select the `cvu-cviv-comp-collect` action.
4. Select **Add** to copy it to the project tree.

Configure the action

To configure the action:

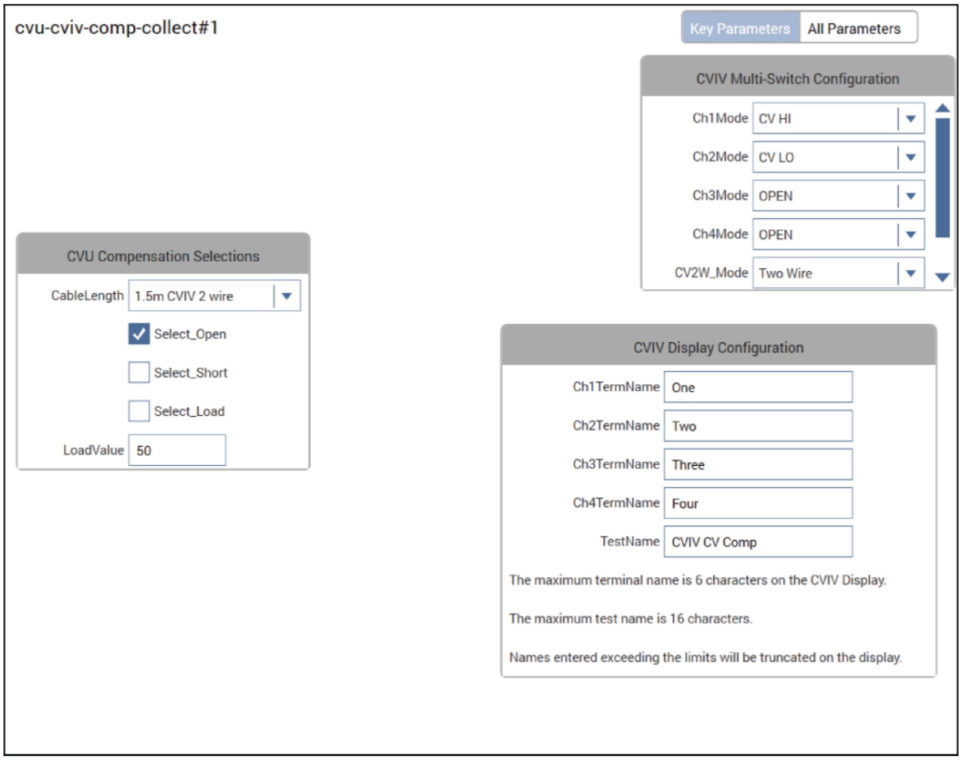
1. Choose **Configure**.

Figure 108: Configure highlighted



2. From the project tree, select the `cvu-cviv-comp-collect` action.

Figure 109: cvu-cviv-comp-collect Action



3. From the CVIV Multi-Switch Configuration terminal settings box, set the output mode of the 4200A-CVIV to **Two Wire**.

NOTE

The following step changes the name of each channel to match the corresponding MOSFET terminal of each channel. This step is not necessary for the action to run, but it does allow you to see which terminals correspond to each output terminal on the 4200A-CVIV display.

4. In the CVIV Display Configuration box, set channel 3 (Gate) to **CV HI** and the remaining channels (1, 2, and 3) to **CV LO**.
5. From the CVU Compensation Selections, enable open correction by selecting **Select_Open**.
6. Make sure that the DUT is disconnected.
7. Select **Run** to configure the 4200A-CVIV and collect compensation constants.

Figure 110: Run the action

8. A dialog box is displayed with instructions to remove the device-under-test (DUT) from the test fixture or lift the probes before performing open compensation. Remove the DUT before selecting **OK**.
9. Return the DUT to the test fixture when compensation completes.
10. In the project tree, clear the check box next to the `cvu-cviv-comp-collect` action.

NOTE

Clearing this action alerts the software to not perform the compensation collection if the whole project is executed. It is not necessary to collect compensation constants each time the test is executed. To collect the compensation constants again, select the action and its check box in the project tree, then select **Run**.

The compensation constants are stored in a database that links each 4200A-CVIV configuration to a set of compensation values. These values are recalled if compensation is enabled in a CVU test while using this 4200A-CVIV configuration.

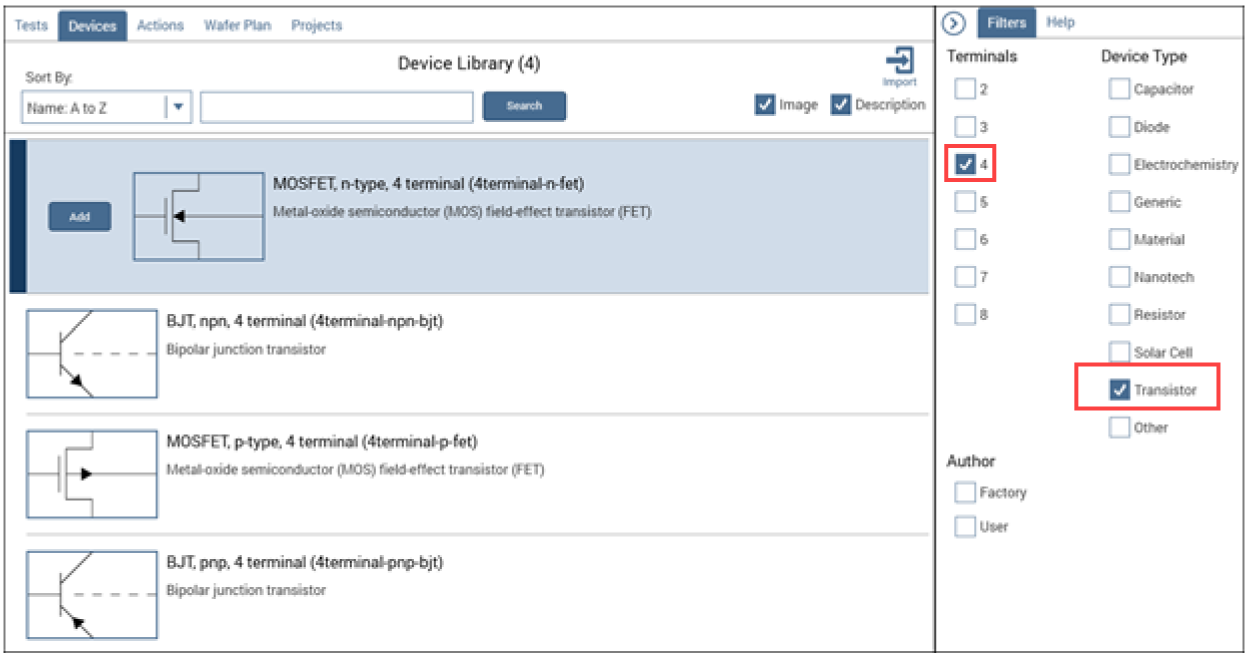
For optimal results, the compensation collection action must be executed for every 4200A-CVIV configuration that is used throughout the test sequence.

Add a device

To add a device:

1. Choose **Select**.
2. Select **Devices**.
3. In the Filters pane, select **4** under the Terminals column and **Transistor** under the Device Type column.

Figure 111: Searching for a device using Filters



4. Select the **MOSFET, n-type, 4 terminal (4terminal-n-fet)** device.
5. Select **Add** to copy it to the project tree.

Add an action for switching the SMUs to the device

To add the action:

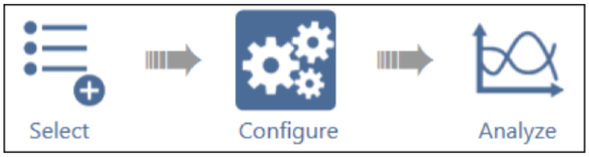
1. Select **Actions**.
2. Type `cviv` into the search bar, then select **Search**.
3. Select the `cviv-configure` action.
4. Select **Add** to copy it to the project tree.

Configure the action

To configure the action:

1. Select **Configure**.

Figure 112: Configure highlighted



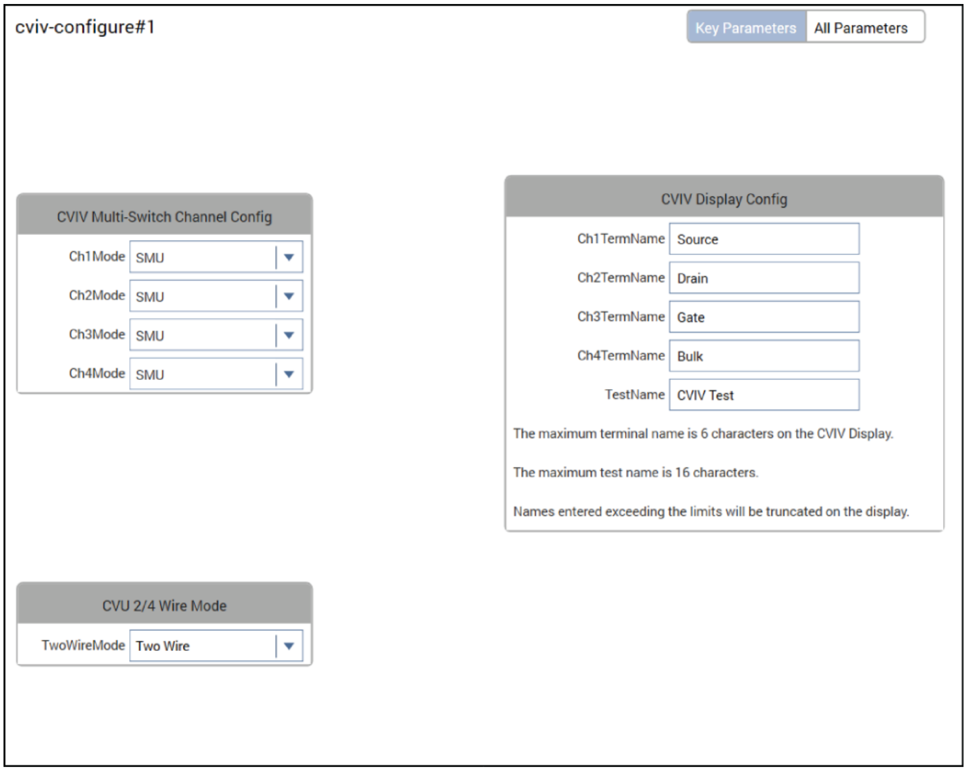
2. In the project tree, select the `cviv-configure` action.
3. In the CVU 2/4 Wire Mode settings, set the output mode of the 4200A-CVIV to **Two Wire**.
4. In the CVIV Display Config settings, change the name of each channel to match the corresponding MOSFET terminal. These names appear on the display of the 4200A-CVIV.

NOTE

This step is not necessary for the test to run, but it allows you to see which terminal each output is connected to on the 4200A-CVIV display.

5. In the CVIV Multi-Switch Channel Config box, set all of the terminals to **SMU**.

Figure 113: cviv-configure action for I-V testing

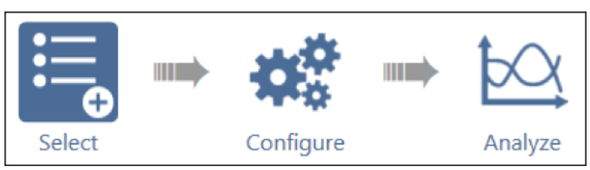


Add a test for making I-V measurements

To add a test:

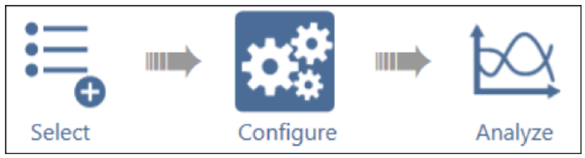
1. Choose **Select**.

Figure 114: Select highlighted



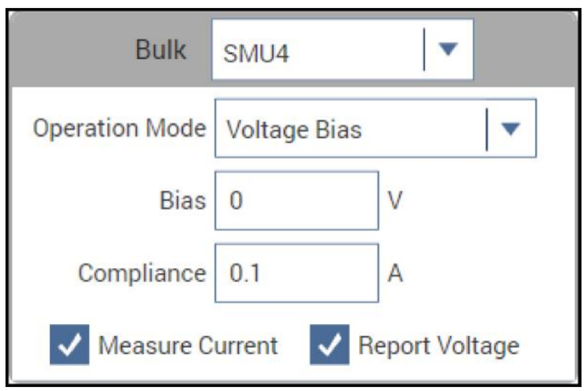
2. Select **Tests**.
3. To find the test, type `vds-id` into the search bar, then select **Search**.
4. Select the `vds-id` test, then select **Add** to copy it to the project tree.
5. Select **Configure**.

Figure 115: Configure highlighted



6. Configure the source and measure parameters of SMU 1 (Source), SMU 2 (Drain), and SMU 3 (Gate) as needed.
7. Assign the instrument of the Bulk terminal to be **SMU 4** and set its Operation Mode to **Voltage Bias**.

Figure 116: Bulk channel 4 SMU voltage bias configuration



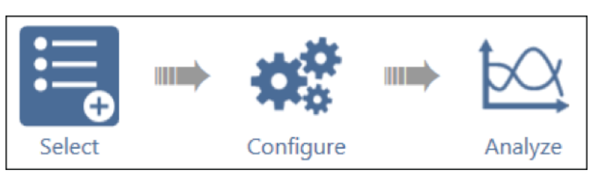
8. Verify that the Bias is set to **0 V** and the Compliance is set to **0.1 A**.

Add an action for switching the CVU to the output terminals of the 4200A-CVIV

To add an action:

1. Choose **Select** to return to the Library.

Figure 117: Select highlighted



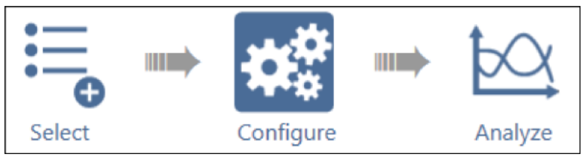
2. Select **Actions**.
3. To find the action, type `cviv` into the search bar, then select **Search**.
4. Select the `cviv-configure` action, then select **Add** to copy it to the project tree.

Configure the action

To configure the action:

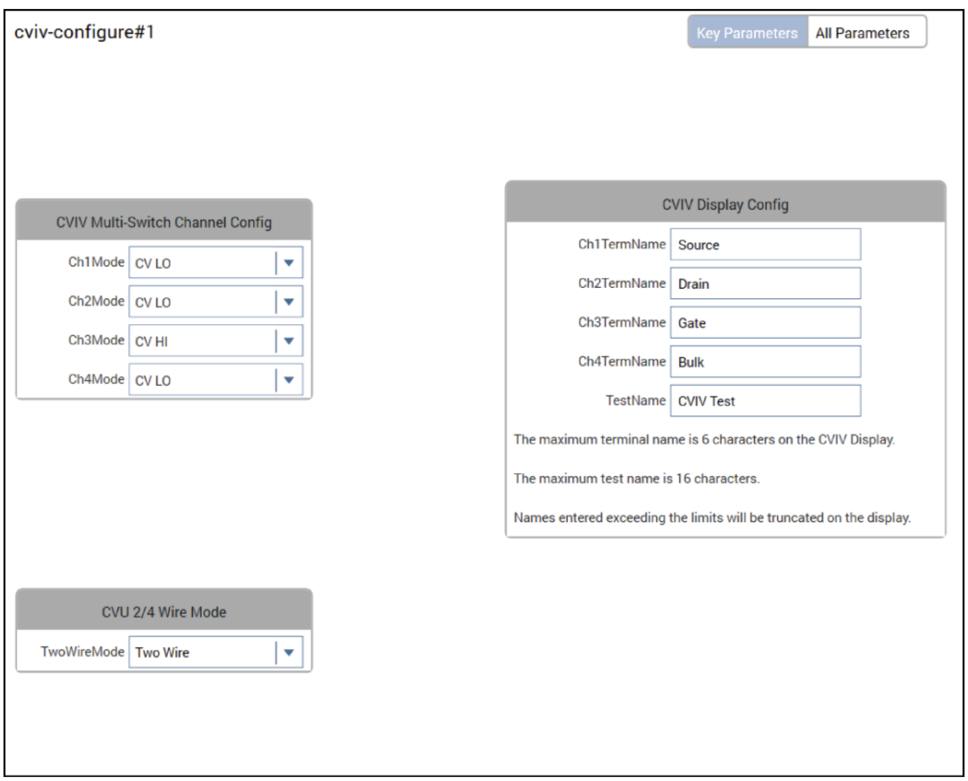
1. Select **Configure**.

Figure 118: Configure highlighted



2. In the project tree, select the `cviv-configure` action.

Figure 119: Populated cviv-configure action



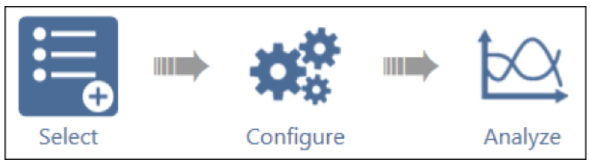
3. In the CVU 2/4 Wire Mode box, set the output mode of the 4200A-CVIV to **Two Wire.**
4. In the CVIV Display Config box, change the name of each channel to match the corresponding MOSFET terminal they are connected to.
5. In the CVIV Multi-Switch Channel Config box, set Ch3Mode to **CV HI** and the remaining three terminals to **CV LO**.

Add a test for making C-V measurements

To add a test:

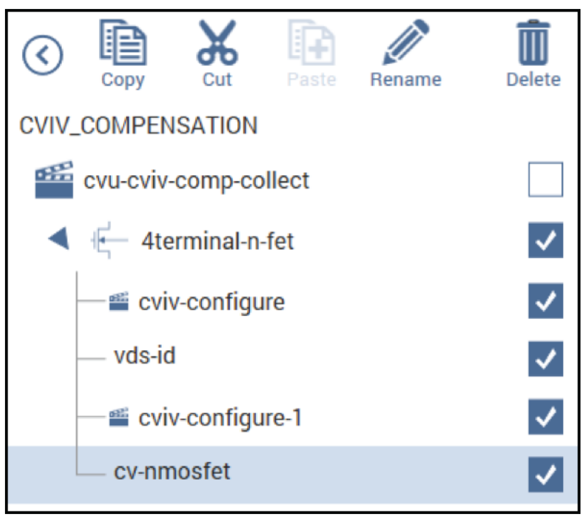
1. Choose **Select**.

Figure 120: Select highlighted



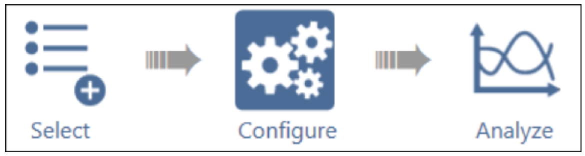
2. Select **Tests**.
3. Type `cv-nmosfet` into the search bar, then select **Search**.
4. Select the `cv-nmosfet` test, then select **Add** to copy it to the project tree.

Figure 121: Project tree before enabling open compensation



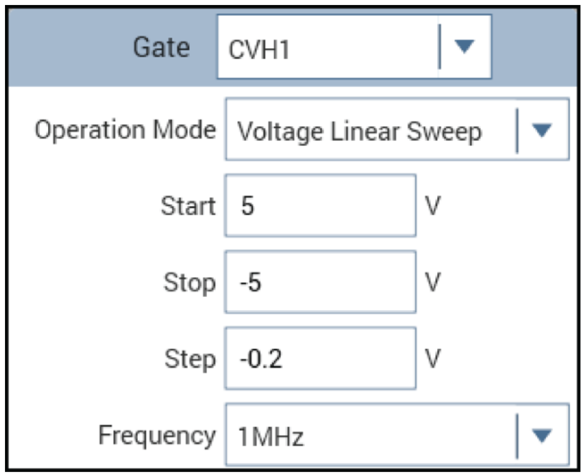
5. Select **Configure** to configure the test.

Figure 122: Configure highlighted



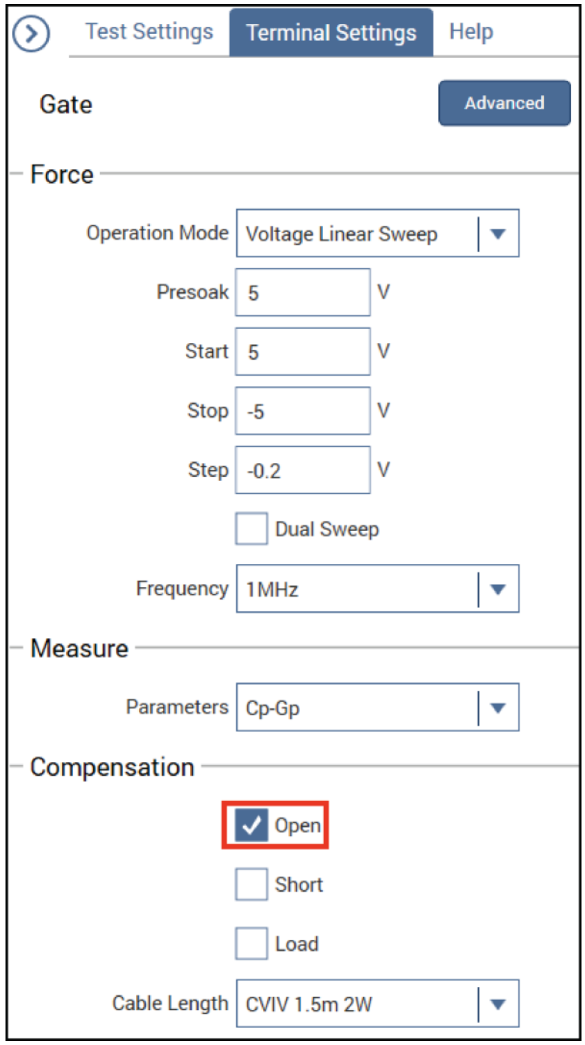
6. Select the **Gate** terminal.

Figure 123: Selected Gate terminal



7. Configure the voltage settings and test frequency as needed.
8. In the right pane, select **Terminal Settings** and enable **Open** compensation.

Figure 124: Terminal Settings panel with Open compensation selected

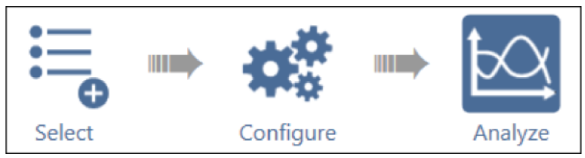


Run the project and review the results

To run the project and review the results:

1. Select the test name at the top of the project tree. In this example, it is `CVIV_COMPENSATION`.
2. Select **Run** to start the test. The two actions and two tests run sequentially, and the 4200A-CVIV is configured by the `cviv-configure` action.
3. Select **Analyze** to view the results.

Figure 125: Analyze highlighted



4. Select the `cv-nmosfet` test to view the results of the C-V test.
5. Select the `vds-id` test to view the results of the I-V test.

Section 9

PMU for pulsed I-V measurements on a MOSFET

In this section:

Introduction

The Model 4225-PMU Ultra-Fast I-V Module can be used to make both pulsed I-V measurements and transient I-V measurements (waveform capture) on a device.

Pulsed I-V refers to a test with a pulsed voltage source and a corresponding high speed, time-based current measurement that provides DC-like results. You can define the parameters of the pulse, including the pulse width, duty cycle, rise/fall times, and amplitude.

Transient I-V, or waveform capture, is a time-based current and/or voltage measurement that is typically the capture of a pulsed waveform. Transient I-V measurements can be used to test a dynamic test circuit or as a diagnostic tool for choosing the appropriate pulse settings in the pulsed I-V mode.

This section provides an example of how to use the 4225-PMU and the optional Model 4225-RPM Remote Preamplifier/Switch Module to make a pulsed I-V measurement on a MOSFET. The example explains how to set up a pulsed voltage step applied to the gate terminal using PMU1 channel 1 and a pulsed voltage sweep to the drain terminal using PMU1 channel 2. The drain current is measured as a function of the drain voltage and displayed in the graph in the Analyze pane.

Equipment required

- One 4200A-SCS with the following instruments:
  - One 4225-PMU
  - Two 4225-RPMs
- Two CA-547-2A RPM interconnect cables (supplied with the 4225-RPM)
- Two CS-712 male triaxial to female BNC adapters, guard removed (supplied with 4225-RPM)
- Two CS-1247 male BNC to female SMA adapters (supplied with the 4225-RPM)
- Two CA-452A SMA to SMA cables (supplied with the 4225-RPM)
- Two 4200-PRB-C SMA to SSMC Y adapter cables

Device connections

Using the supplied cables, make connections from the output terminals of the two 4225-RPMs to the MOSFET.

WARNING

Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never connect or disconnect from the 4200A-SCS while the output is on.

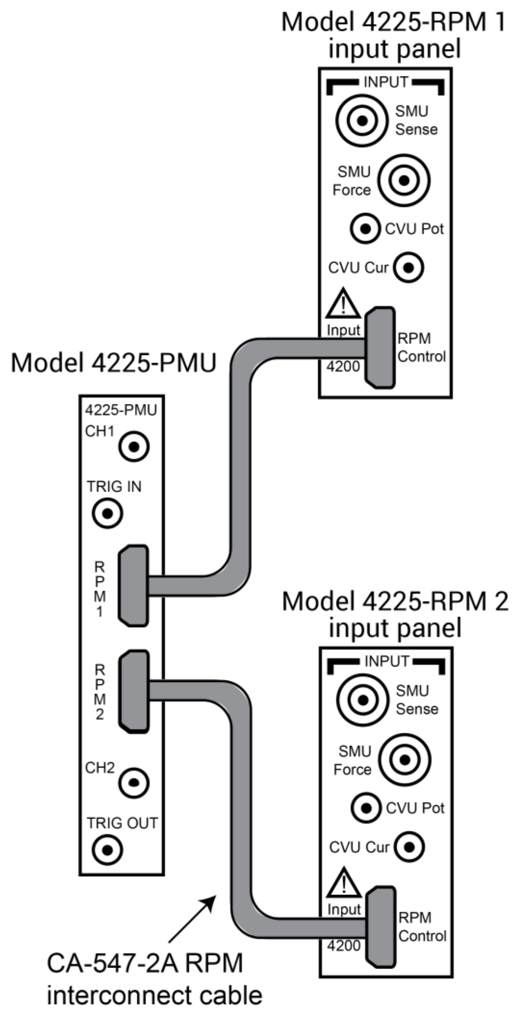
To prevent electric shock, test connections must be configured such that the user cannot come in contact with test leads, conductors, or any device under test (DUT) that is in contact with the conductors. It is good practice to disconnect DUTs from the instrument before powering up the instrument. Safe installation requires proper shields, barriers, and grounding to prevent contact with test lead and conductors.

Connection schematic

The hardware connections from the output terminals of the PMU and the two RPMs to the MOSFET are shown in the following figures.

Connect one CA-547-2A RPM interconnect cable from each PMU channel to the appropriate RPM.

Figure 126: Connections from the PMU to the RPM inputs



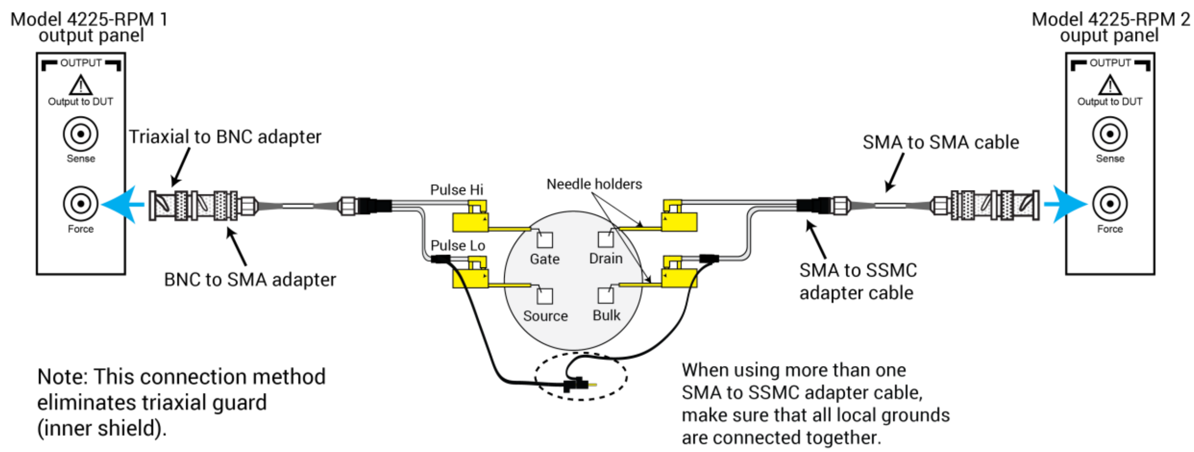
At the output of each RPM, connect the triaxial to BNC adapter, BNC to SMA adapter, and finally the SMA-to-SMA cable.

Connect the SMA cables to either probes or a test fixture that is connected to the MOSFET. RPM1 is connected to the gate of the MOSFET and RPM2 is connected to the drain of the MOSFET.

The shields of the SMA cables are the PMU LO connection and must be connected to the source and bulk terminals of the MOSFET. The shields of the two SMA cables should be connected together as close as possible to the device.

The example below illustrates connections from the RPMs to the SMA to SSMC adapter cables (4200-PRB-C) and then to the probes and device terminals on a wafer. For more information on these and similar connections, see the *Model 4200A-SCS Reference Manual*.

Figure 127: Connections from RPM outputs to the MOSFET on a wafer



Set up the measurements in Clarius

This section describes how to set up the Clarius application to make a pulsed I-V sweep on a MOSFET.

For this example, you will use the Clarius application to:

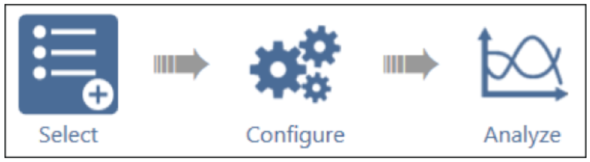
- Create a new project
- Search for and select an existing test
- Configure the test
- Run the test and analyze the results

Create a new project

To create a new project:

1. Choose **Select**.

Figure 128: Select highlighted



2. In the Library, select **Projects**.
3. Select **New Project**.
4. Select **Create**.

Figure 129: Select a New Project from the Project Library

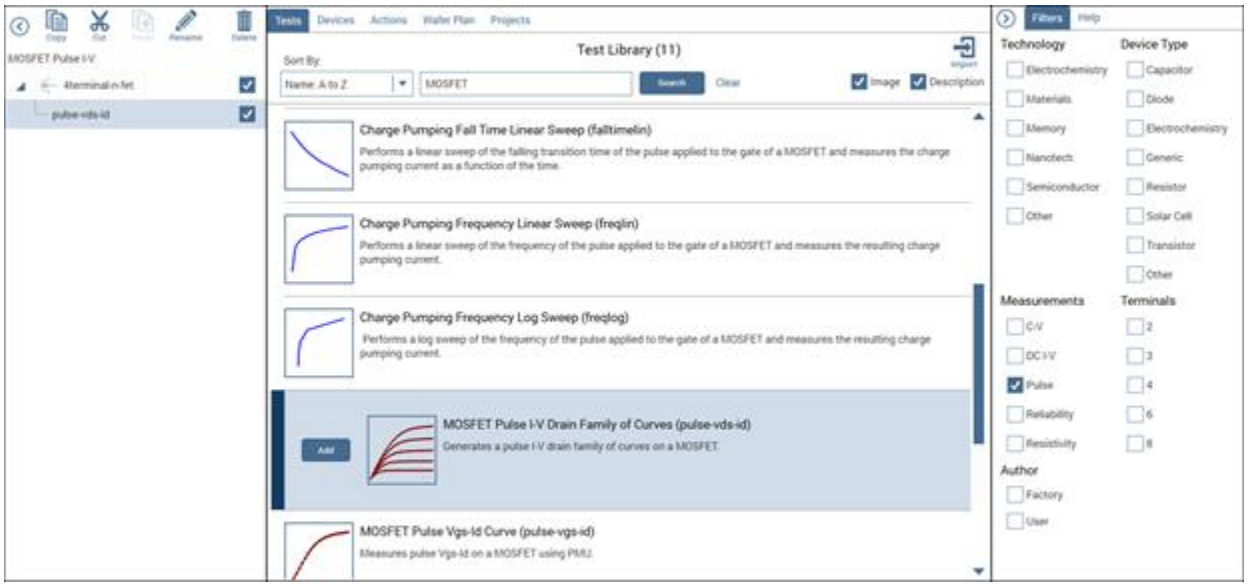
5. Select **Yes** when prompted to replace the existing project.
6. Assign a new title to the project by selecting **Rename** and then entering `MOSFET Pulse I-V`.
7. Select **Enter**.

Search for and select an existing test

To search for and select an existing test:

1. Select **Tests**.
2. Type `MOSFET` into the search bar, then select **Pulse** in the Filters pane under Measurements.
3. Select the **MOSFET Pulse I-V Drain Family of Curves (pulse-vds-id)** test, then **Add** it to the project tree. Notice that the device is automatically added.

Figure 130: Selecting the MOSFET Pulse I-V Drain Family of Curves test from the Test library

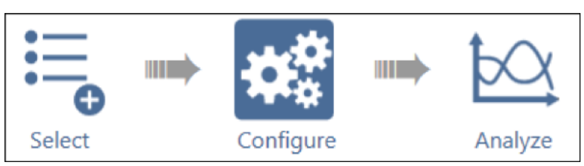


Configure the test

To configure the test:

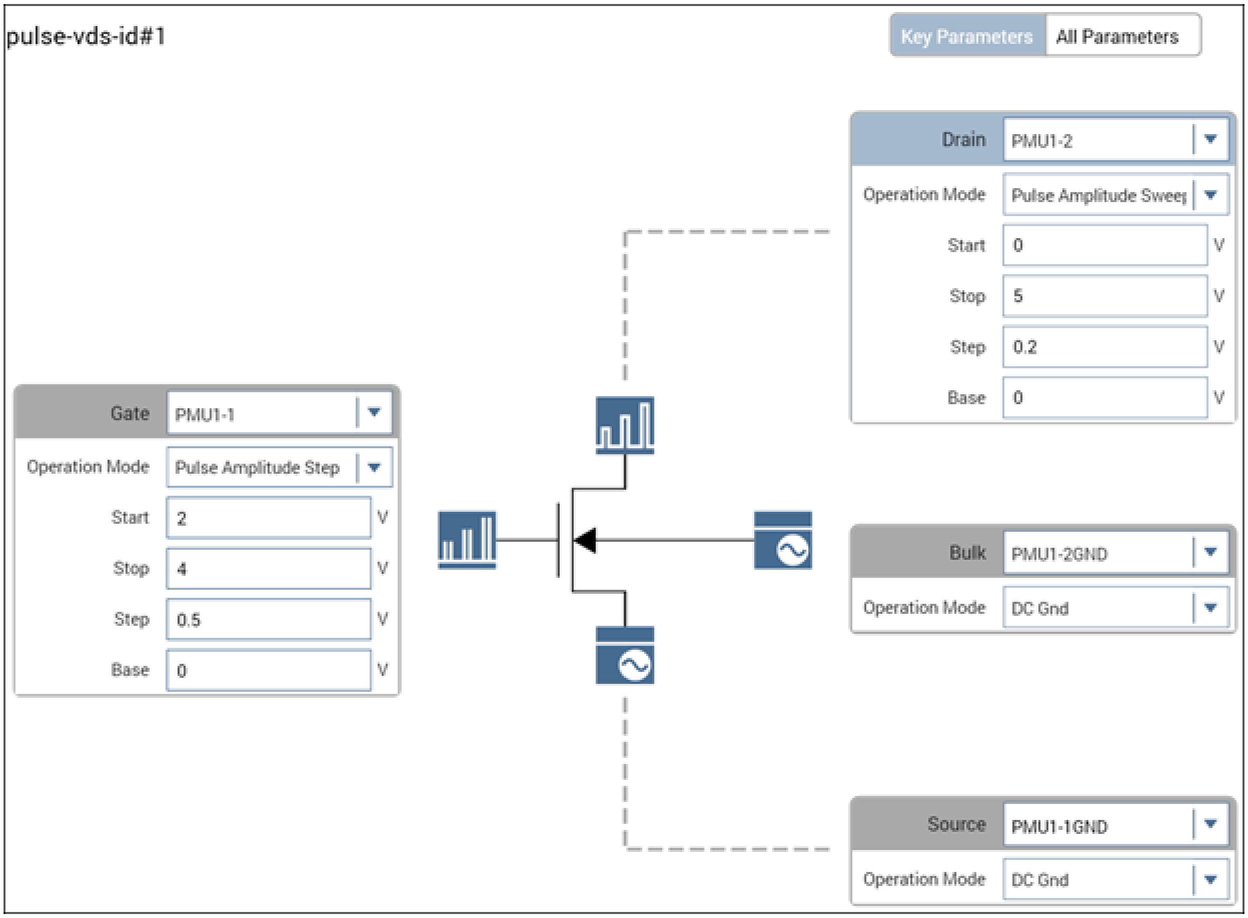
1. Select **Configure**.

Figure 131: Configure button highlighted



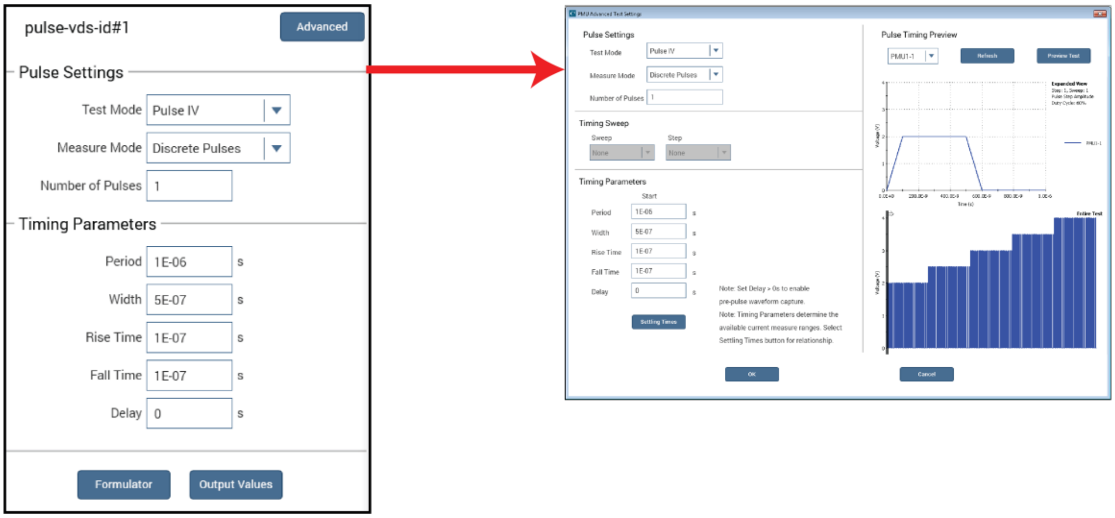
2. From the Key Parameters pane, adjust the pulse voltage sweep levels of PMU1-2 on the Drain terminal and the Pulse Step Voltage of PMU1-1 on the Gate terminal, as needed.

Figure 132: Key Parameters pane for the pulse-vds-id test



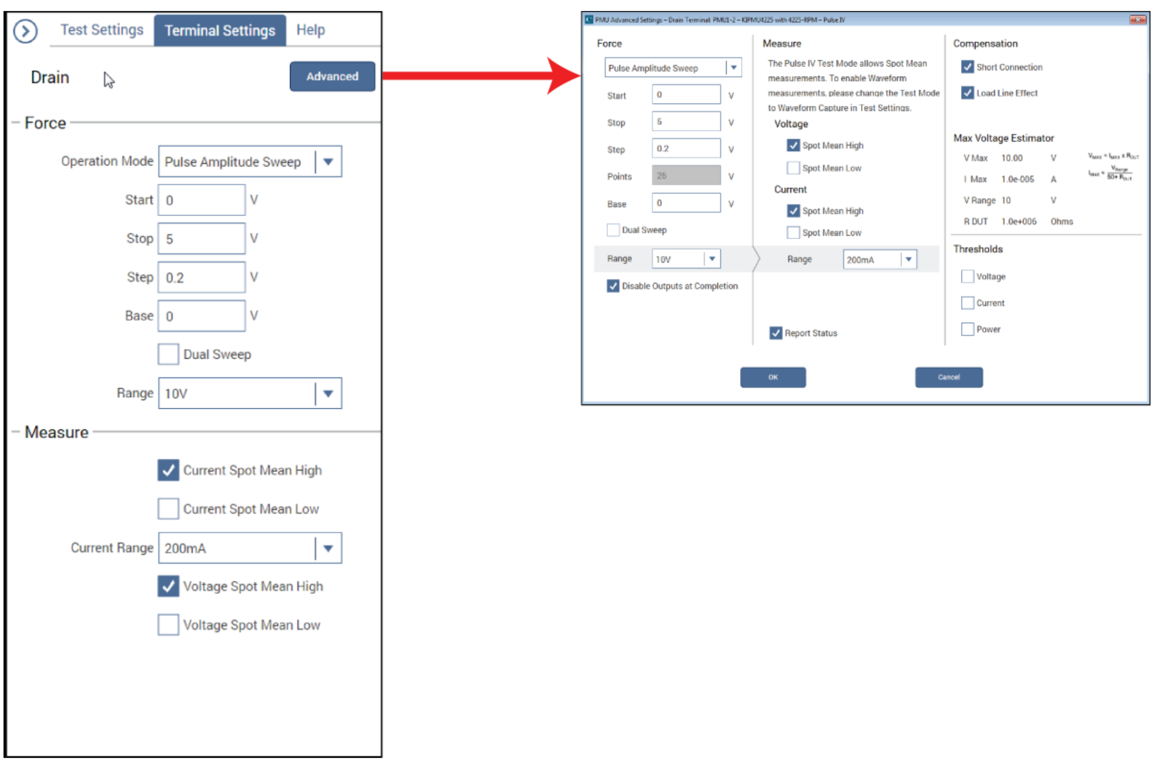
3. From the Test Settings pane and Advanced Test Settings dialog box, adjust the Pulse Settings and Timing Parameters, as needed.

Figure 133: Test Settings pane and Test Settings Advanced dialog box



4. From the Terminal Settings pane and Advanced Terminal Settings dialog box, you can adjust the voltage source and current measurement parameters, as needed.

Figure 134: Terminal Settings pane and Terminal Settings Advanced dialog box



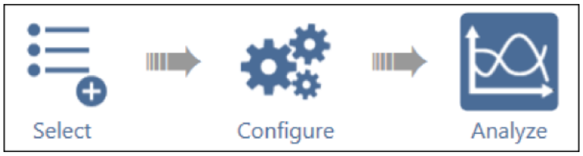
Run the test and analyze the results

Select **Run** to execute the test.

Figure 135: Run

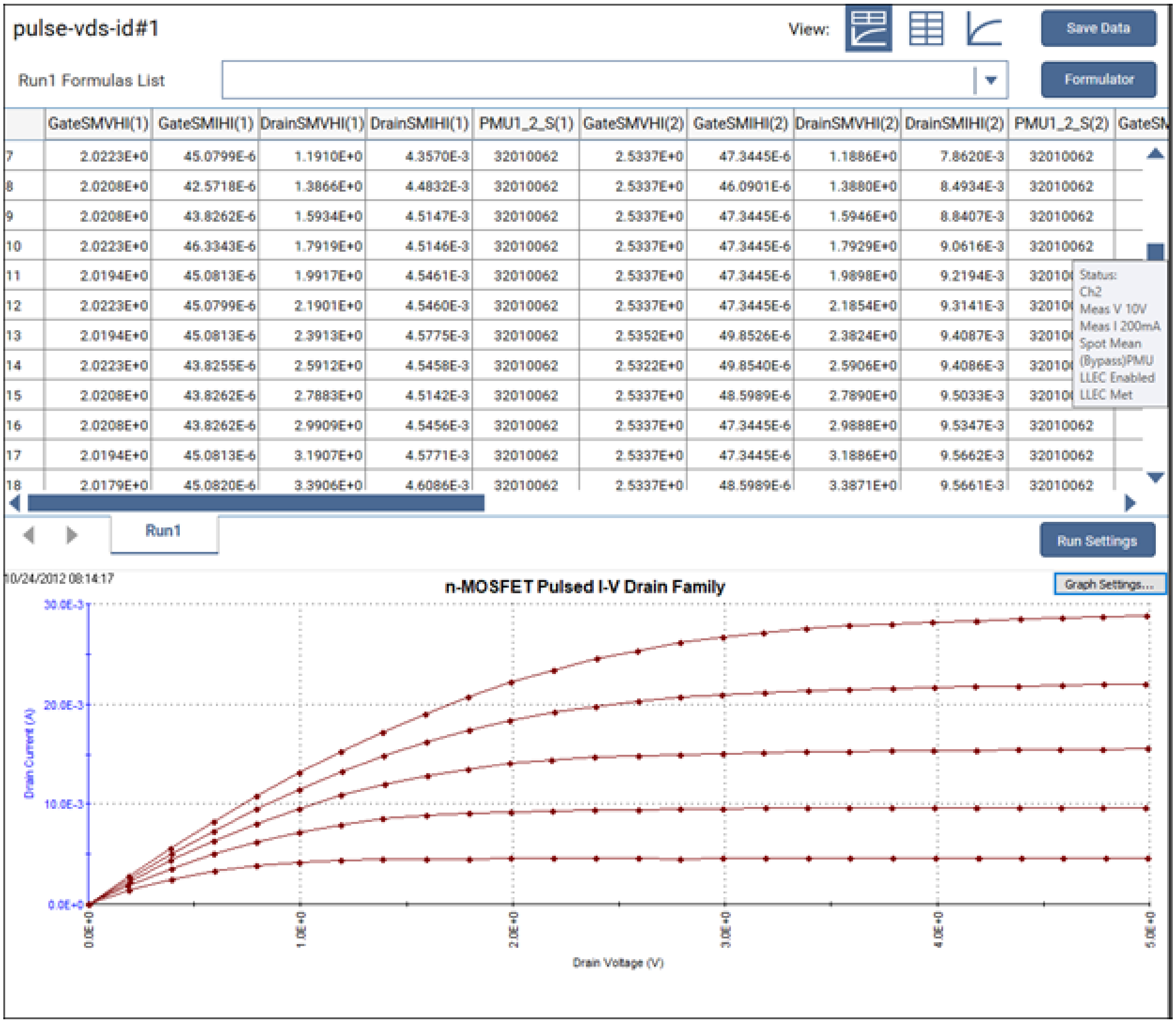
You can select **Analyze** when you run the project to view test results in real-time.

Figure 136: Analyze highlighted



The data and the graph are displayed in the Analyze pane as shown in the next figure.

Figure 137: Analyze results pane with data and graph displayed



Section 10

Next steps

In this section:

Additional information

This manual has prepared you to start using your new 4200A-SCS Parameter Analyzer for your applications. For more detailed information, refer to the Learning Center, which you can access by selecting this icon on your desktop:

Figure 138: 4200A-SCS Learning Center icon

The Learning Center contains a variety of content to help you learn how to use your 4200A-SCS, including:

- The *Model 4200A-SCS Parameter Analyzer Reference Manual*
- Videos
- Application notes
- Release notes
- Test and device descriptions
- The Keithley Instruments Low-Level Measurements Handbook

Also see the Keithley Instruments website (tek.com/keithley) for support and additional information about the instrument, including:

- Updated drivers
- Keithley forums
- Information about related products

Your local Field Applications Engineer can help you with product selection, configuration, and usage. Check the website for contact information.

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