Tektronix®

Model 4200A-CVIV

Multi-Switch

USER'S MANUAL

4200A-CVIV-900-01F March 2025

KEITHLEY
A Tektronix Company

Model 4200A-CVIV

Multi-Switch

User's Manual

Document number: 4200A-CVIV-900-01 Rev. F March 2025

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Safety precautions

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

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

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

The types of product users are:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The  symbol indicates a connection terminal to the equipment frame.

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

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

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

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

Instrumentation and accessories shall not be connected to humans.

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

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

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

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

Safety precaution revision as of June 2018.

Table of contents

Section 1

Introduction

In this section:

Introduction

The Keithley 4200A-CVIV Multi-Switch is a multiplexed switching accessory for the 4200A-SCS that allows you to switch between I-V and C-V measurements with no changes to cables or connections to the device under test (DUT). You can also perform I-V testing with up to four SMUs (4200-SMU, 4201-SMU, 4210-SMU, or 4211-SMU) and switch the outputs of the 4210-CVU or 4215-CVU to any of the four output terminals. This accessory creates a faster and more efficient device testing workflow for any application that requires I-V and C-V measurements on the same device.

Figure 1: 4200A-CVIV Multi-Switch

The built-in display provides clear real-time test information near the DUT. You can personalize the output naming convention on the display with the Clarius software. The 4200A-CVIV can be rotated to match your testing environment and the display can be turned off to reduce light near the DUT.

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 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 Tektronix 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-tek.

General ratings

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

Category	Specification
Voltage rating	210 V
Current rating	1 A
Input and output connections	See DUT connections panel summary (on page 2-1) and Inputs panel summary (on page 2-2)
Environmental conditions	For indoor use only **Temperature range** **Operating:** 10 °C to 40 °C **Storage:** –15 °C to 60 °C **Humidity range** **Operating:** 5% to 80% relative humidity, noncondensing **Storage:** 5% to 90% relative humidity, noncondensing **Altitude** **Operating:** 0 to 2000 m (0 to 6252 ft) **Storage:** 0 to 4600 m (0 to 15092 ft) **Pollution degree** 1 or 2

Specifications

For instrument specifications, refer to the 4200A-SCS Parameter Analyzer Datasheet, available at tek.com/keithley.

Hardware and software requirements

The following are required to use the 4200A-CVIV:

- Keithley 4200A-SCS Parameter Analyzer
- For 2-wire measurements, one 4200-TRX-0.75 or CA-534-24B1 triaxial cable per channel
- For 4-wire measurements, two 4200-TRX-0.75 or CA-534-24B1 triaxial cables per channel
- One 4210-CVU or 4215-CVU
- Up to four 4200-SMUs, 4201-SMUs, 4210-SMUs, or 4211-SMUs each, with either 4200-PA Remote Preamplifiers or 4200A-CVIV-SPT SMU Pass-Thru Modules

NOTE

For each SMU connected to the 4200A-CVIV, you must also install at least one 4200-PA or 4200A-CVIV-SPT Pass-Thru module.

Section 2

Getting started

In this section:

Introduction

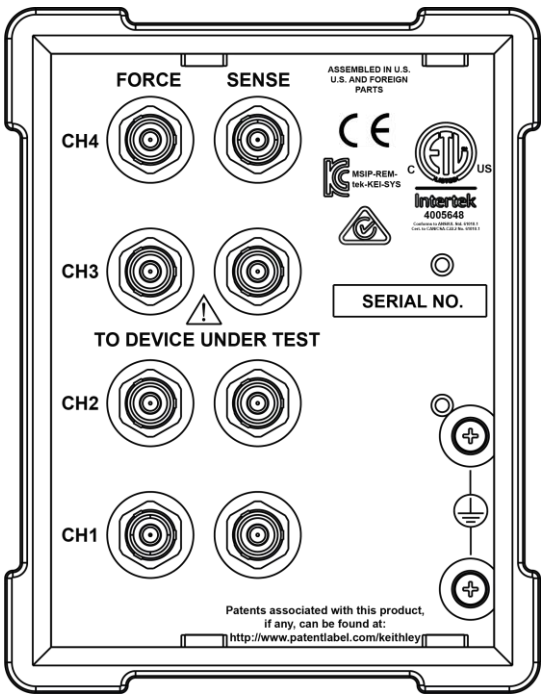
This section provides an overview of the 4200A-CVIV display and connectors.

DUT connections panel summary

Device connections are made to the device under test (DUT) instrument panel of the 4200A-CVIV.

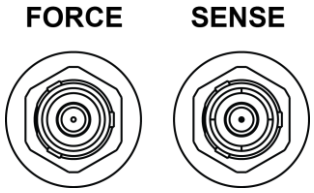
The DUT panel of the 4200A-CVIV is shown in the following figure. Descriptions of the connections are provided after the figure.

Figure 2: 4200A-CVIV DUT panel



DUT channel connections

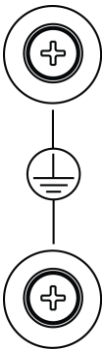
DUT channel connections



Triaxial force and sense connectors are provided on channels 1 through 4 for connection to a DUT.

Ground connections

Ground connections



Two ground screws are provided for connections to protective earth (safety ground).

Inputs panel summary

Instruments are connected to the inputs panel of the 4200A-CVIV.

The inputs panel of the 4200A-CVIV is shown in the following figure. No preamplifier or Pass-Thru modules are installed in this figure. Descriptions of the connections are provided after the figure.

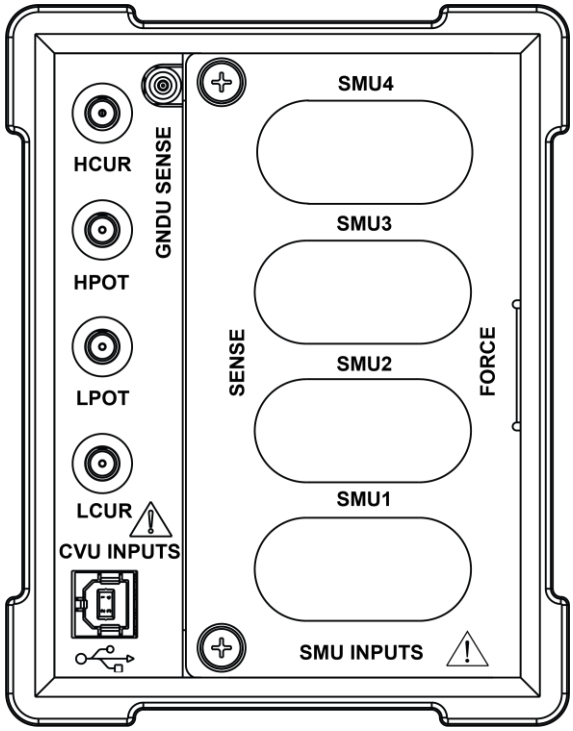
NOTE

GNDU SENSE is available with 4200A-CVIV hardware versions 2.0 or newer.

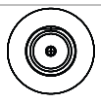
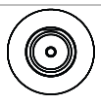
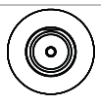
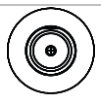
⚠ WARNING

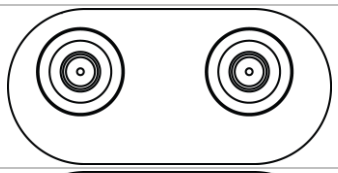
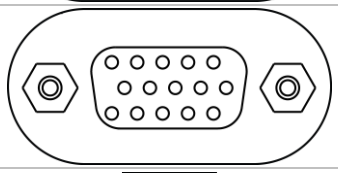
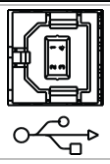
Each SMU input that is not in use must have its access restricted by a slot blocker. Refer to Install and remove slot blockers (on page 3-8) for more information.

Figure 3: 4200A-CVIV inputs panel (SMU inputs empty)



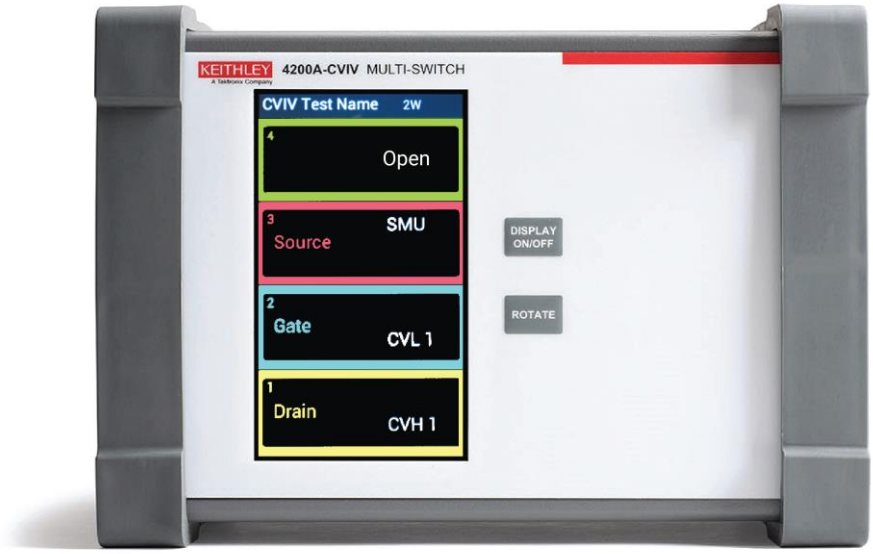
Connections

HCUR CVU input		The HCUR (force HI) CVU input is an SMA socket that connects to the 4210-CVU or 4215-CVU.
HPOT CVU input		The HPOT (sense HI) CVU input is an SMA socket that connects to the 4210-CVU or 4215-CVU.
LPOT CVU input		The LPOT (sense LO) CVU input is an SMA socket that connects to the 4210-CVU or 4215-CVU.
LCUR CVU input		The LCUR (force LO) CVU input is an SMA socket that connects to the 4210-CVU or 4215-CVU.
GNDU SENSE input		The GNDU SENSE input is a miniature triaxial socket that connects to the triaxial SENSE connector of the ground unit on the 4200A-SCS. This input is only available with 4200A-CVIV hardware versions 2.0 or newer.

SMU inputs (4200A-CVIV-SPT SMU Pass-Thru installed)		The 4200A-CVIV-SPT SMU Pass-Thru module can be installed in any bay of the 4200A-CVIV. The triaxial connectors provide a direct interface with your SMU.
SMU inputs (4200-PA Remote Preamplifier installed)		The 4200-PA Remote Preamplifier can be installed in any bay of the 4200A-CVIV. The serial interface of the preamplifier provides a connection with a 4200-SMU, 4201-SMU, 4210-SMU, or 4211-SMU installed in the 4200A-SCS.
USB input		The USB-B port connects to the 4200A-SCS. The port provides data and power to the 4200A-CVIV.

Display summary

Figure 4: 4200A-CVIV front display panel

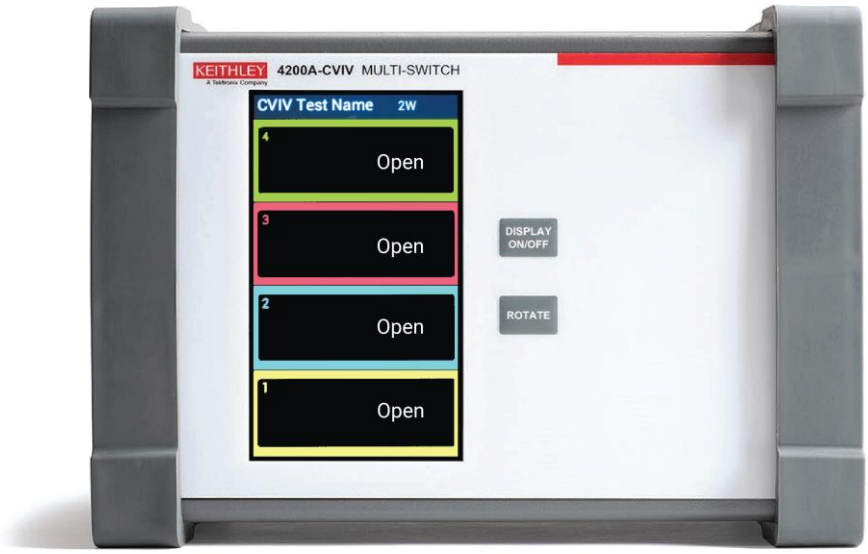


The 4200A-CVIV features a full-color LCD display that shows the name of your test, the name of the device under test (DUT), the instrument configuration for each channel, and a 2-wire or 4-wire indicator.

You can turn the display on or off with the DISPLAY ON/OFF button. Press the ROTATE button to orient the display for your test station configuration.

When you reset the 4200A-CVIV, the instrument returns to the default Open state. Any terminal setting names are removed and replaced with `Open`, as shown in the following figure.

Figure 5: Default state display of the 4200A-CVIV



Section 3

Install and configure the 4200A-CVIV

In this section:

Introduction

The 4200A-CVIV can be quickly installed and configured for a variety of testing scenarios. This section contains information on locating and mounting the instrument, safety grounding, using the instrument with preamplifier modules, and configuration of the instrument using the Keithley Configuration Utility (KCon).

Unpack and inspect the instrument

CAUTION

To prevent damage to the instrument, do not lift the 4200A-CVIV using the front bezel.

To unpack and inspect the instrument:

1. Inspect the box for damage.
2. Open the top of the box.
3. Remove the accessories and packaging insert.
4. Carefully lift the instrument out of the box.
5. Inspect the instrument for any obvious signs of physical damage. Report any damage to the shipping agent immediately.

You should have received the 4200A-CVIV with the following accessories:

- Two 4200A-CVIV-SPT SMU Pass-Thru Modules
- One 4200-MTRX-2 Mini Ultra Low Noise Triax Cable, 2 m (6.6 ft)
- One 174691500 USB type A to type B cable, 2 m (6.6 ft)
- Two CA-568-18 green/yellow ground cables 0.46 m (18 in)
- Two 4200A-CVIV slot blockers

Refer to the packing list for additional items that might have shipped with your instrument.

Mechanical dimensions

Figure 6: 4200A-CVIV mechanical dimensions, bumpers installed

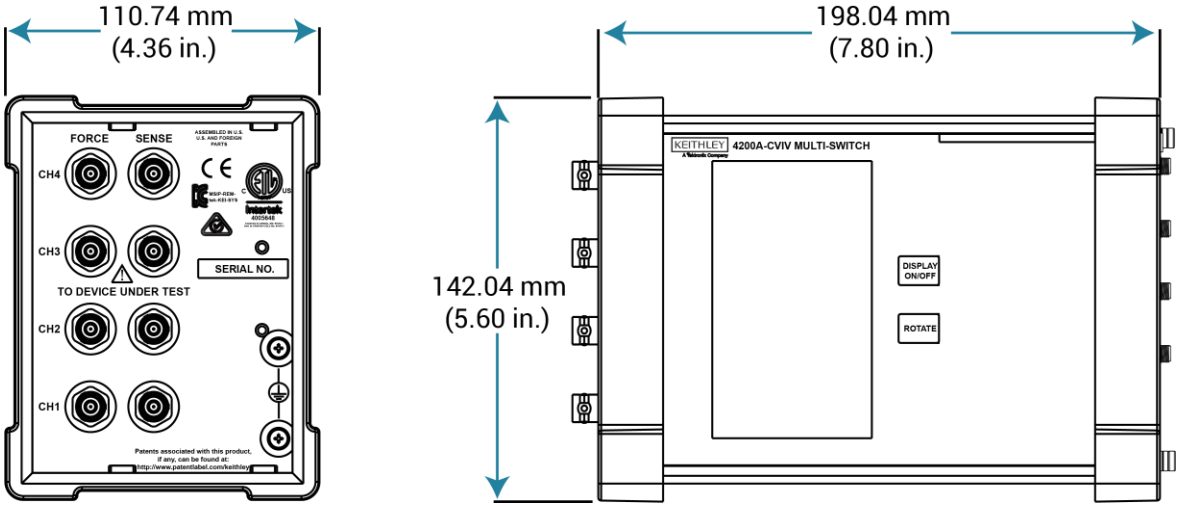
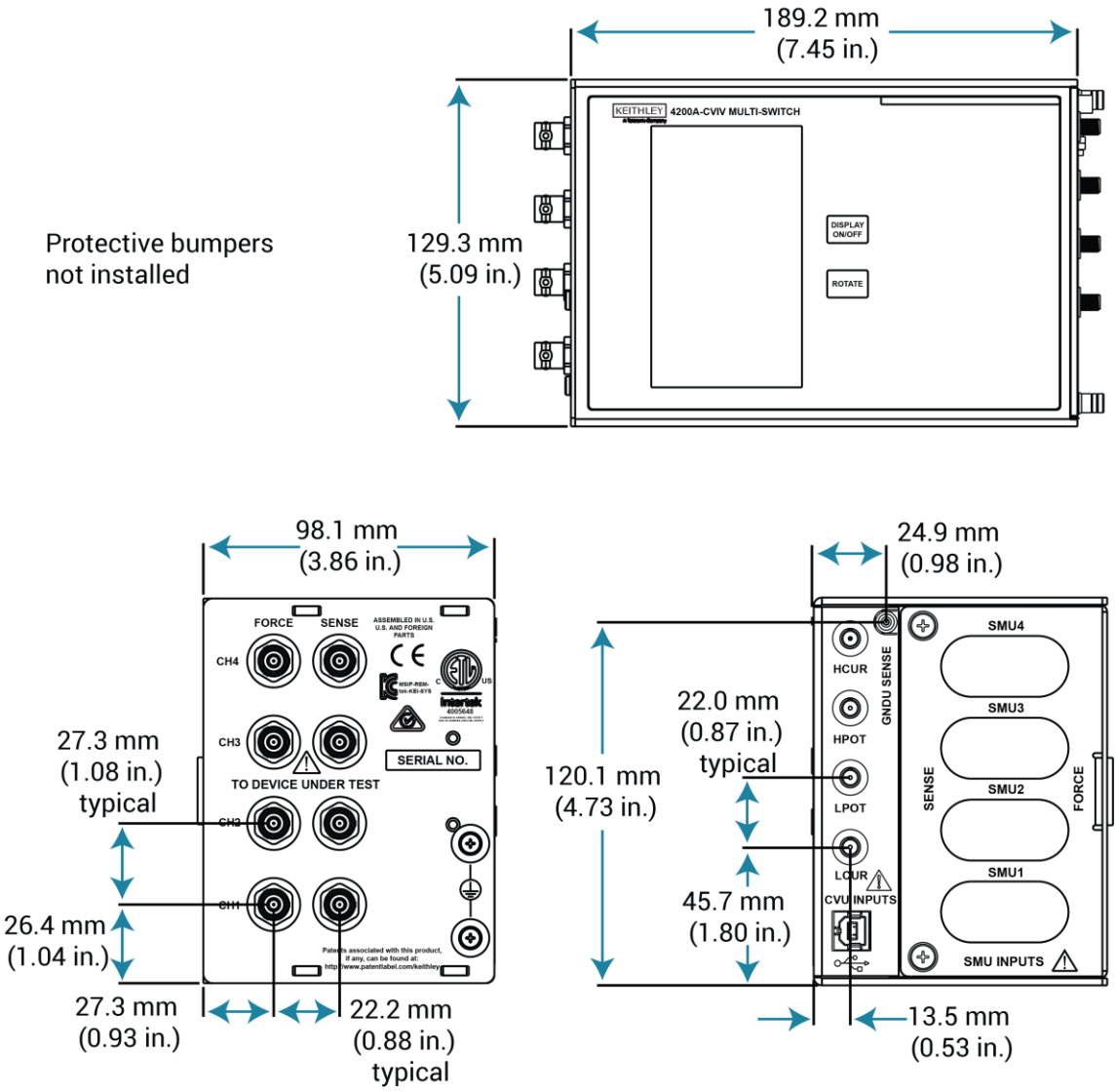


Figure 7: 4200A-CVIV mechanical dimensions, bumpers not installed



Location considerations

The 4200A-CVIV is designed to be located as close as possible to a probe station to ensure accurate measurements.

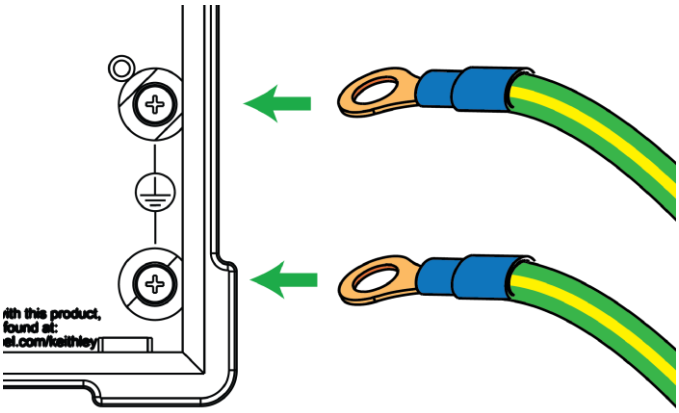
Connect to protective earth

⚠ WARNING

The 4200A-CVIV must be connected to protective earth (safety ground) using both of the supplied green-yellow ground cables. The ground wires must be attached to both ground screws on the 4200A-CVIV before powering on the unit, and they must be connected independently to earth ground (do not connect both ground wires to the same earth safety ground). Failure to attach the ground wires independently to a known protective earth may result in personal injury or death due to electric shock.

1. Connect both of the supplied grounding cables to the two grounding terminals of the 4200A-CVIV, as shown in the following figure.

Figure 8: Connecting ground cables to the 4200A-CVIV



2. Connect the ends of the grounding cables to the two independent protective earth (safety ground) terminals.

Install and remove preamplifier and Pass-Thru modules

You can install up to four Keithley 4200-PA Remote Preamplifiers or 4200A-CVIV-SPT SMU Pass-Thru modules, shown in the following figure, in the 4200A-CVIV in any combination.

Figure 9: 4200-PA Remote PreAmp and 4200A-CVIV-SPT SMU Pass-Thru modules

Make sure that the preamplifier and Pass-Thru modules are properly aligned when they are inserted into the SMU input slots of the 4200A-CVIV.

For any slot that is not used, be sure to install a slot blocker. Refer to Install and remove slot blockers (on page 3-8) for more information.

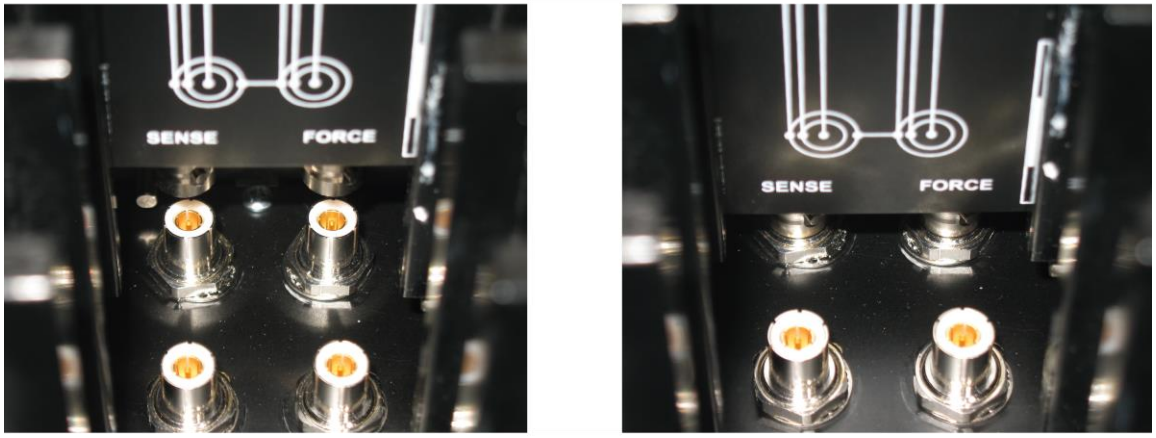
WARNING

Each SMU input on the 4200A-CVIV that is not in use must have its access restricted by a slot blocker. Failure to use a slot blocker may result in personal injury or death due to electric shock.

To install a preamplifier or Pass-Thru module:

1. Disconnect any cables from the instrument.
2. Remove the rubber bumper from the SMU Inputs side of the 4200A-CVIV.
3. Using a Phillips-head screwdriver, loosen the two captive screws securing the panel cover to the instrument.
4. Completely remove the panel cover and set it aside.
5. Align the module with the alignment rails of a vacant SMU input bay.
6. Firmly insert the module into the instrument until it is seated. Use the following figure as a guide.

Figure 10: Correct alignment (left) and fully seated module



Correct alignment Fully seated

CAUTION

Do not use excessive force when installing the preamplifier and Pass-Thru modules. The modules are designed to fit securely, but extreme pressure may cause damage to the modules or the instrument. Always verify the alignment of the module before inserting it into the 4200A-CVIV.

7. Place slot blockers into any SMU input slots without a module. See Install and remove slot blockers (on page 3-8) for installation information.
8. Reinstall the panel cover.
9. Tighten the captive screws on the panel cover using your fingers or a Philips screwdriver. Do not overtighten.
10. Reinstall the protective rubber bumper.

A 4200A-CVIV with a Pass-Thru module installed in SMU slot 4 and a preamplifier in slot 3 is shown in the following figure. Slot blockers are not installed in this figure.

Figure 11: 4200A-CVIV input panel

To remove a preamplifier or Pass-Thru module:

1. Disconnect any cables from the 4200A-CVIV before installing a module.
2. Remove the rubber bumper from the SMU Inputs side of the 4200A-CVIV.
3. Loosen the two captive screws securing the panel cover to the instrument.
4. Completely remove the panel cover and set it aside.
5. Grasp the module and pull it straight out of the 4200A-CVIV.

CAUTION

Do not twist the module when removing it from the instrument. Do not use implements to grasp the triaxial connectors of the Pass-Thru or the serial connector of the preamplifier.

6. Place slot blockers into SMU input bays that do not contain a module. Refer to Install and remove slot blockers (on page 3-8) for more information.
7. Reinstall the panel cover.
8. Tighten the captive screws on the panel cover using your fingers or a Phillips screwdriver. Do not overtighten.

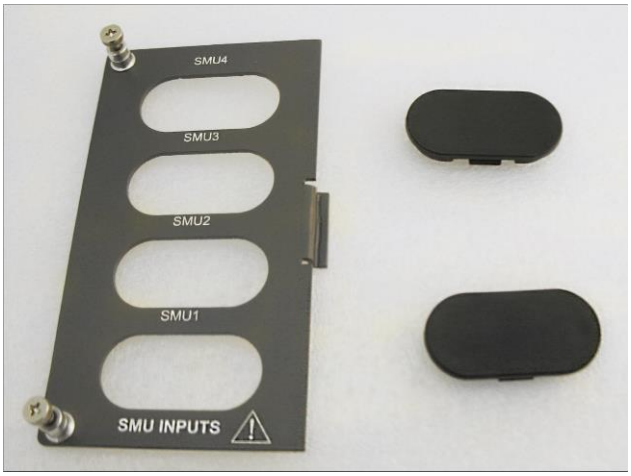
Install and remove slot blockers

WARNING

Each SMU input on the 4200A-CVIV that is not in use must have its access restricted by a slot blocker. Failure to use a slot blocker may result in personal injury or death due to electric shock.

The 4200A-CVIV is shipped with two protective slot blockers. You must install a slot blocker in each SMU input module location that is does not contain a 4200-PA Remote Preamplifier or 4200A-CVIV-SPT SMU Pass-Thru Module. The 4200A-CVIV SMU Inputs panel cover and slot blockers are shown in the following figure.

Figure 12: 4200A-CVIV SMU Inputs panel cover and slot blockers



To install a slot blocker:

1. For the empty slot, place a slot blocker into the opening with the smooth side facing out.
2. Press down on the blocker firmly until you hear a click. The blocker is now positioned correctly.

NOTE

You may need to slightly press one of the tabs on the edge of the blocker flange before it seats flush with the front of the 4200A-CVIV input panel, as shown in the following figure.

Figure 13: SMU Inputs panel cover with slot blockers installed

To remove a slot blocker:

On the rear of the panel cover, press one of the tabs on the inside edge of the blocker flange while pushing out. You can now remove the slot blocker.

CAUTION

To prevent damage to the slot blocker or the SMU Inputs panel, do not use excessive pressure when removing the slot blocker.

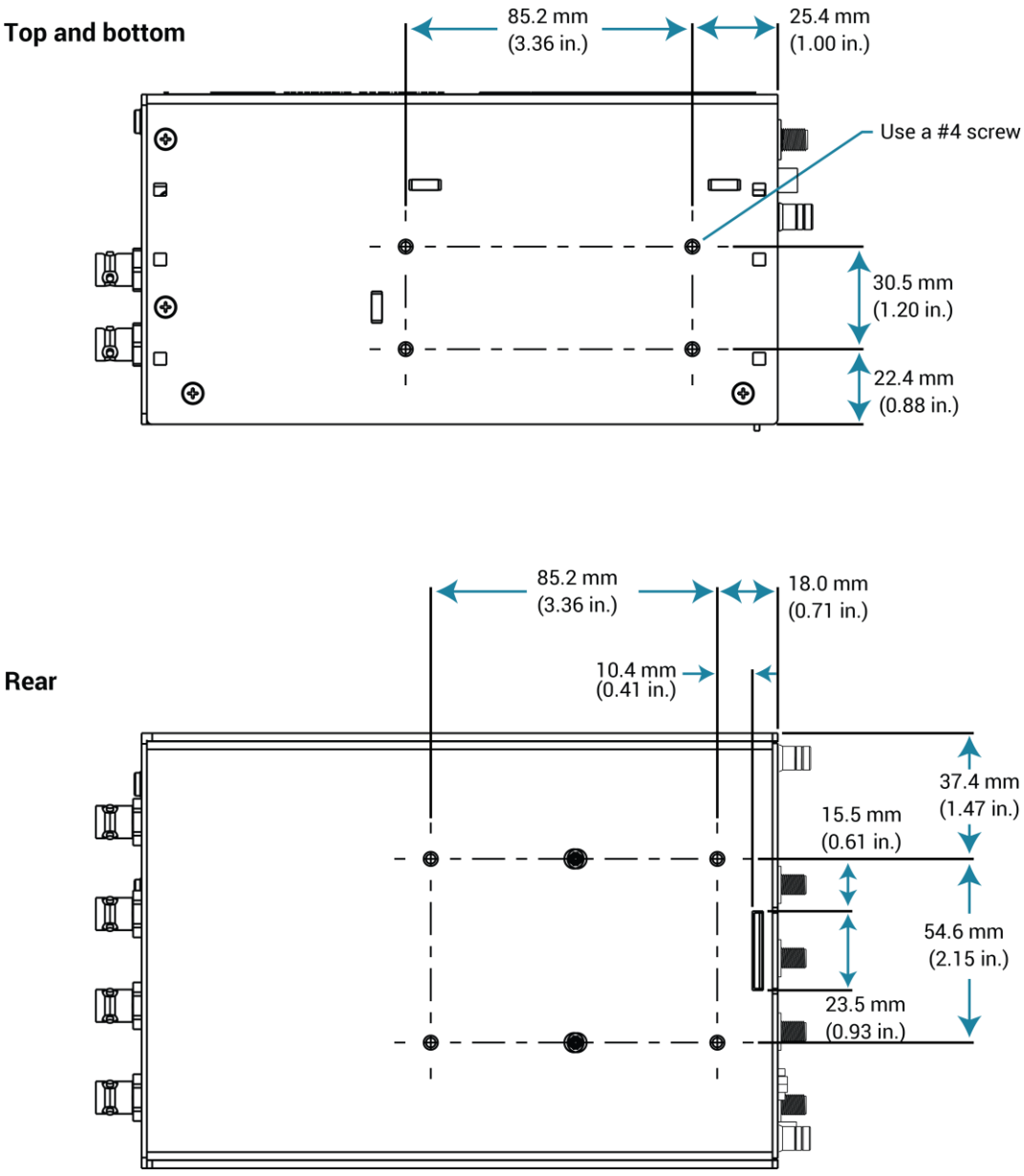
Mount the 4200A-CVIV

The 4200A-CVIV can be mounted to a flat surface using four #4 screws. Threaded mounting holes are on the top, bottom, and rear panels of the instrument.

NOTE

Be sure to consider your test station layout, ground cable layout, and other cable routing before mounting the instrument.

Figure 14: 4200A-CVIV mounting dimensions



Make connections to the 4200A-CVIV

Make connections using 4200-TRX-0.75 or CA-534-24B1 triaxial cables.

To make connections to the 4200A-CVIV:

1. If the CVIV is connected to the 4200A-SCS, turn off 4200A-SCS system power.
2. Make connections from the output of the SMU cards to the inputs of the Preamps or Pass-Thru modules.
3. Make connections from the CVU HCUR, HPOT, LPOT, and LCUR connections to the corresponding SMA jacks on the 4200A-CVIV.

Configure the 4200A-CVIV with KCon

Before using the 4200A-CVIV, you must add the instrument to the 4200A-SCS using the Keithley Configuration Utility (KCon). This must be done each time an instrument is added, changed, or removed from the 4200A-CVIV. The outputs of the 4200A-CVIV are configured in Clarius and are not affected by KCon.

For more information on KCon, see “Keithley Configuration Utility (KCon)” in *Model 4200A-SCS Setup and Maintenance*.

To update the 4200A-CVIV configuration:

1. Connect the 4200A-CVIV to any USB port on the front or back of the 4200A-SCS using the included USB Type A to USB Type B cable.
2. Turn on 4200A-SCS system power.
3. Start the KCon application.
4. Select **Update**.
5. Select **Save**.

Section 4

Switching and software configuration

In this section:

Introduction

This section describes the 4200A-CVIV switching output modes and how to do measurement compensation. It also describes how to control the 4200A-CVIV with Clarius and with LPT commands.

4200A-CVIV switching

The 4200A-CVIV has the following switching output modes:

- Open (on page 4-3): Default setting. Also disconnects a channel from the device.
- SMU switching (on page 4-4): I-V measurements. Connects Force HI and Sense HI to the device.
- CV HI switching (on page 4-5): C-V measurements. Connects the 4210-CVU or 4215-CVU (HPOT and HCUR) to the device.
- CV LO switching (on page 4-6): C-V measurements. Connects the 4210-CVU or 4215-CVU (LPOT and LCUR) to the device.
- CV Guard switching (on page 4-8): C-V measurements. Guards unwanted impedance when making C-V measurements on multi-terminal devices. Apply CV Guard to the terminal to be excluded from the C-V measurement.
- Ground unit switching (on page 4-8): I-V measurements. Connects Force LO and Sense LO to the device.
- AC-coupled AC ground configuration (on page 4-9): C-V measurements. Allows an AC path to ground without providing a DC path.

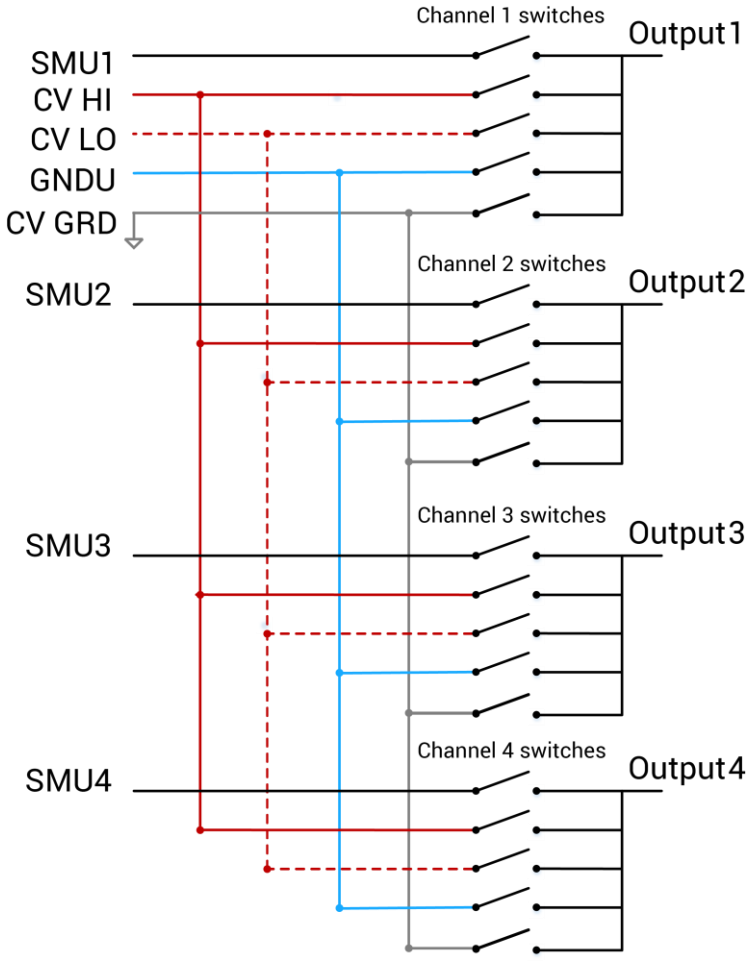
- Bias tee switching for C-V measurements: C-V measurements up to 200 V DC bias.
  - Bias tee SMU CV HI or bias tee SMU CV LO (on page 4-10): Allows a DC current of up to 1 A, which is ideal for on-state device measurements.
  - Bias tee SMU LO I CV HI and bias tee SMU LO I CV LO (on page 4-11): Allows a DC current of up to 100 µA, which is ideal for off-state device measurements.
  - Bias tee SMU AC ground (on page 4-11): Guards unwanted impedance when making C-V measurements on multi-terminal devices. Apply BiasT SMU AC Gnd to the terminal that is to be excluded from the C-V measurement.

Changing the switching output mode for each channel reconfigures the switches in the 4200A-CVIV to route the correct signal to the output terminal. There is also a global 2-Wire/4-Wire CVU setting that affects all channels configured for CV HI and CV LO.

The following figure shows a simplified diagram of the 4200A-CVIV. In this figure, all the source-sense pairs are shown as a single wire for simplicity. Each channel has a set of switches that controls which input channel is routed to the output connectors. Only one option can be selected for an output at any time.

The sections following the figure describe the switching options in more detail.

Figure 15: 4200A-CVIV simplified switching



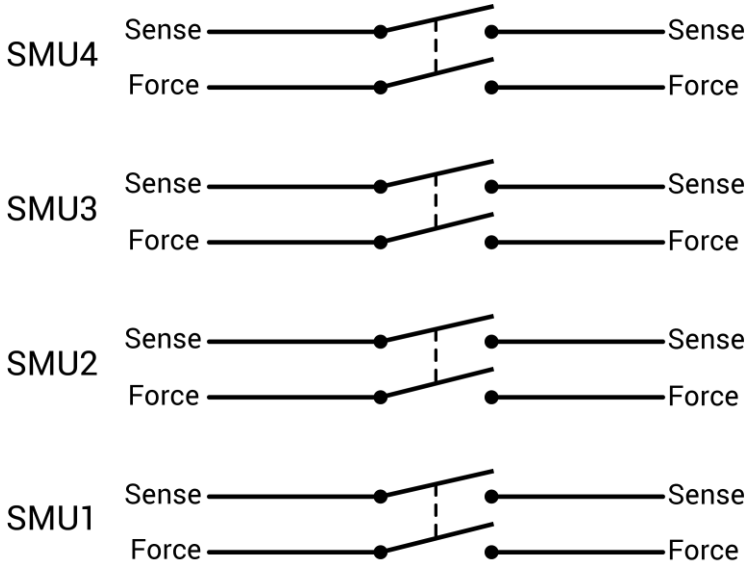
Open

Select the Open setting for an output channel if nothing is connected to the output terminal. This is the default setting for the channels on power up. The switches in the previous figure are all shown in the open position.

SMU switching

The 4200A-CVIV can connect and disconnect the force and sense terminals of the SMU channels to the output terminals. For example, select the SMU option for all four channels to perform I-V testing on a four-terminal device. This setting closes the relays that connect the SMU channels to the output connectors. The following figure shows a simplified diagram of the SMU switching configuration.

Figure 16: 4200A-CVIV SMU switching configuration



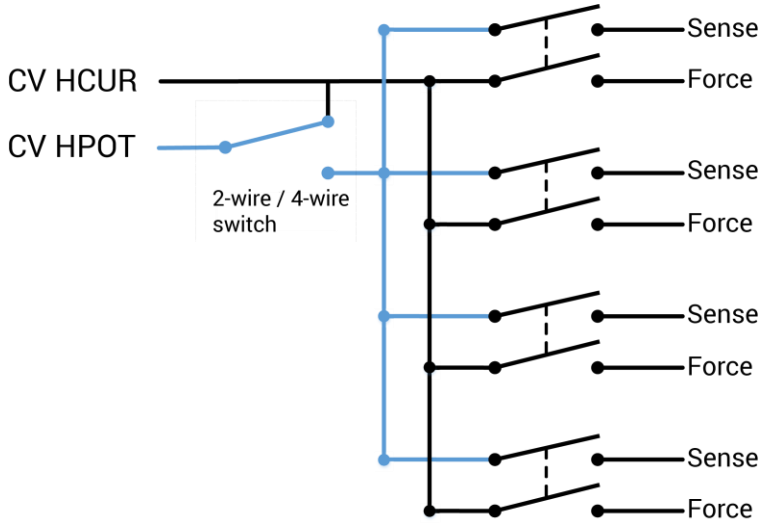
NOTE

The 4200A-CVIV instrument is not a full SMU switching matrix. You cannot connect an input SMU channel to a different output channel.

CV HI switching

The 4200A-CVIV can switch the HI connections of the 4210-CVU or 4215-CVU (HPOT and HCUR) to any of the output channels. You can make C-V measurements between any set of output terminals. The CV HI setting can be applied to more than one output terminal at a time if you are connecting multiple device terminals during C-V measurements. The following figure shows a simplified diagram of the CV HI switching configuration.

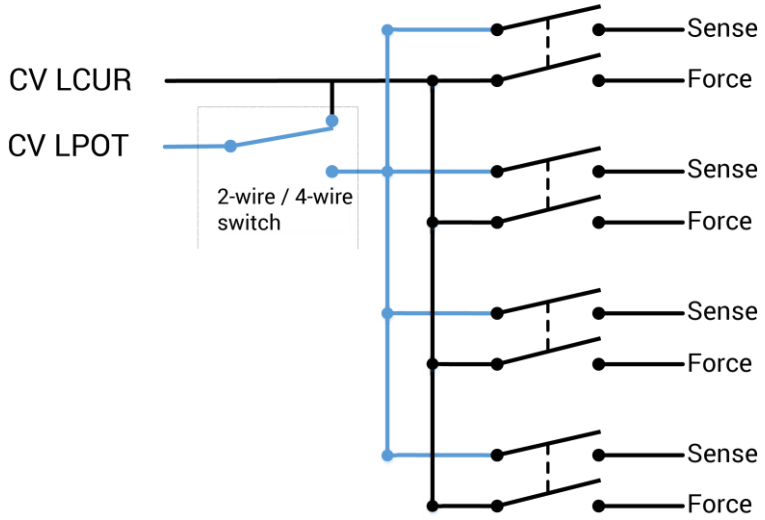
Figure 17: 4200A-CVIV CV HI switching configuration



CV LO switching

The 4200A-CVIV can switch the LO connections of the 4210-CVU or 4215-CVU (LPOT and LCUR) to any of the output channels. You can perform C-V measurements between any set of output terminals. The CV LO setting can be applied to more than one output terminal if you are connecting multiple device terminals during C-V measurements. The following figure shows a simplified diagram of the CV LO switching configuration.

Figure 18: 4200A-CVIV CV LO switching configuration

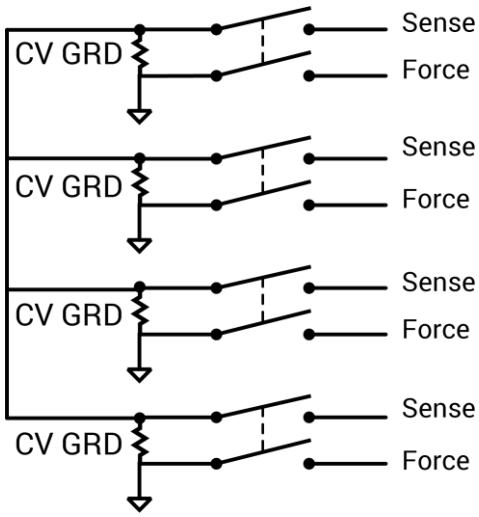


CV Guard switching

The 4200A-CVIV can apply an effective guard signal to any output terminal. You can make C-V measurements while guarding device terminals that should not be included in the measurement. The CV GRD setting can be applied to more than one output terminal at a time if you are guarding multiple device terminals during C-V measurements.

The following figure shows a simplified diagram of the CV GRD switching configuration. This configuration provides an AC low impedance ground return through the 4200A-CVIV to be used for guarding out terminals used in CV measurements.

Figure 19: 4200A-CVIV CV GRD switching configuration



NOTE

CV Guard switching mode cannot be used as a DC ground for SMUs in a test configuration. Model 4200A-SCS ground unit multiplexing is available for the 4200A-CVIV with hardware version 2.0 or later. See Ground unit switching (on page 4-8) for more information.

Ground unit switching

The 4200A-CVIV supports a ground unit (GNDU) that can be switched to any one of the four output channels. You can use a miniature triaxial-to-triaxial cable assembly to connect GNDU SENSE on the 4200A-CVIV to the SENSE connector of the ground unit on the 4200A-SCS. The connection is made through the outer shield of the triaxial cable, so you do not need to make a physical connection between the FORCE connection of the 4200A-SCS ground unit and the 4200A-CVIV.

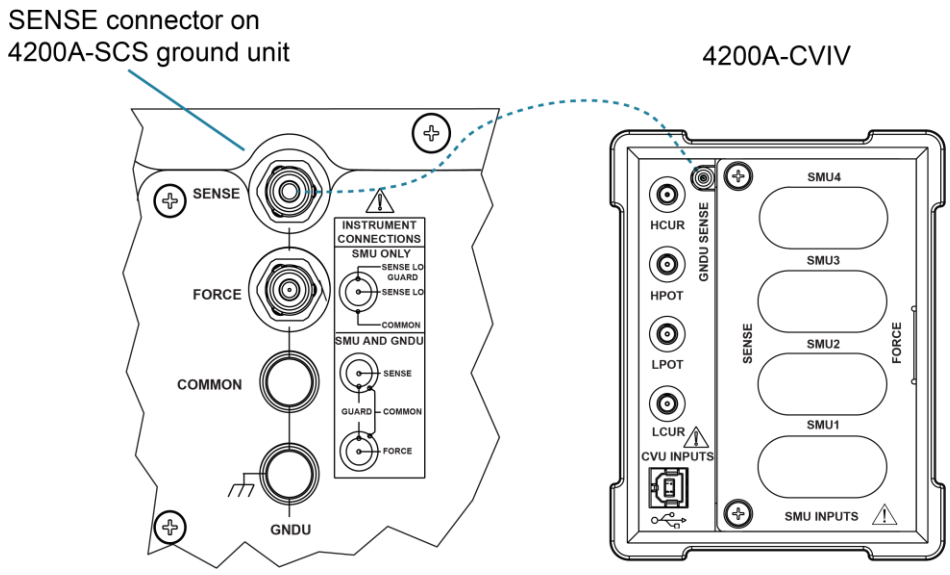
Keithley does not recommend configuring multiple GNDU channels when GNDU SENSE is connected. Different terminals can have different potentials, which may cause measurement errors.

The GNDU detects whether the test configuration is 2-wire or 4-wire.

NOTE

Ground unit switching is only available with 4200A-CVIV hardware versions 2.0 or newer.

Figure 20: 4200A-CVIV GNDU switching configuration connection

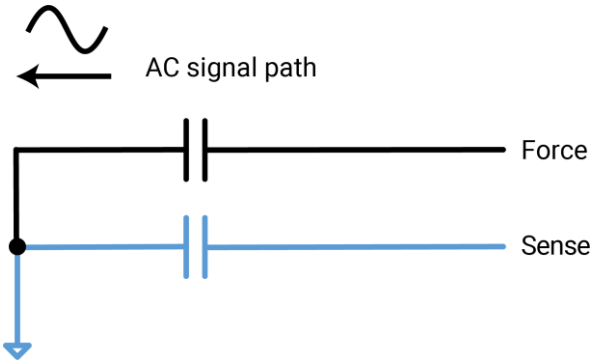


AC-coupled AC ground configuration

The following figure shows a 4200A-CVIV AC coupled with AC ground configuration. This configuration provides an AC-coupled, low-impedance return to ground through the 4200A-CVIV, and also blocks the DC component of the signal. This configuration allows the DC signal to float, and the AC signal is grounded.

A typical application for this configuration is when performing a C-V measurement on a three-terminal device. Two of the terminals are designated as CV HI and CV LO, and the third terminal is grounded through a capacitor. The DC bias is provided by the DUT and the AC signal is grounded.

Figure 21: 4200A-CVIV AC-coupled AC ground configuration



Bias tee switching

The 4200A-CVIV supports a bias tee on each of its four channels to allow DC biasing of AC signals at the channel outputs. The bias tee options use the CVU to measure the capacitance and the SMUs to sweep the voltage or apply a DC bias of up to ±200 V, or 400 V differential. The bias tees also enable current compliance of up to 100 mA or 1 A, depending on the SMU.

NOTE

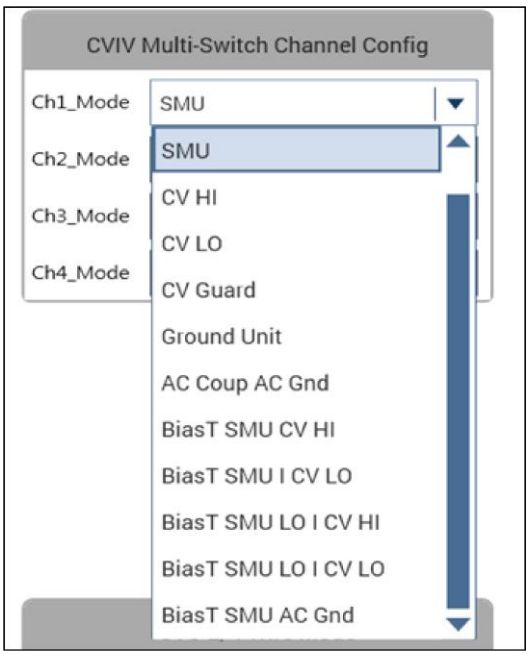
Bias tee configuration switching is for C-V measurements only. For I-V measurements, use the SMU switching configuration.

NOTE

If you are making low current measurements through the 4200A-CVIV, select the SMU channel configuration. Do not use the BiasT configurations. The BiasT configurations are designed for making optimal C-V measurements and use the SMU for forcing voltage, not measuring leakage current.

You can select bias tee configurations in Clarius, as shown in the following figure. The `CvsT` and `SweepV` tests in the `hivcvulib` user library can be used with the bias tee options.

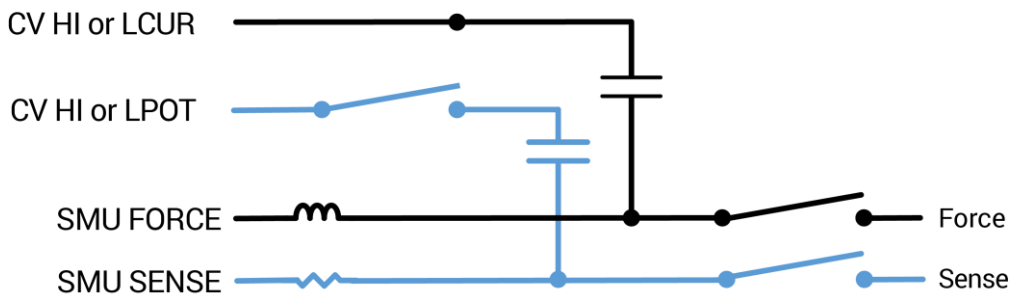
Figure 22: Bias tee configuration selection



BiasT SMU CV HI and BiasT SMU CV LO

The following figure shows a 4200A-CVIV bias tee high-current SMU configuration with a CV HI or LO switching configuration. This combines the DC bias from a 4200-SMU, 4201-SMU, 4210-SMU, or 4211-SMU with an AC signal from CV HI or LO through a 4200A-CVIV bias tee circuit. This configuration is ideal for performing C-V measurements where a DC bias current of up to 1 A is required, such as when making C-V measurements on a semiconductor in the on-state.

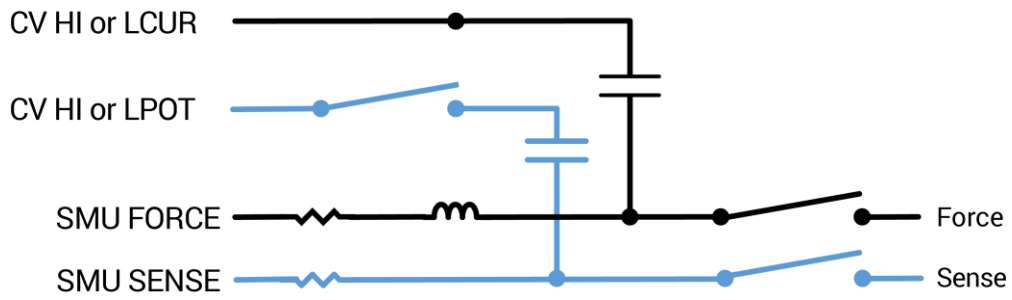
Figure 23: 4200A-CVIV bias tee, high current SMU CV HI or LO switching configuration



BiasT SMU LO I CV HI and BiasT SMU LO I CV LO

The following figure shows a 4200A-CVIV bias tee low-current SMU configuration with a CV HI or LO switching configuration. This combines the DC bias from a 4200-SMU, 4201-SMU, 4210-SMU, or 4211-SMU with an AC signal from CV HI or LO through the 4200A-CVIV bias tee circuit. This configuration is optimized for use with currents below 100 µA. It is the preferred configuration for semiconductors in the off-state.

Figure 24: 4200A-CVIV bias tee, low current SMU CV HI or LO switching configuration

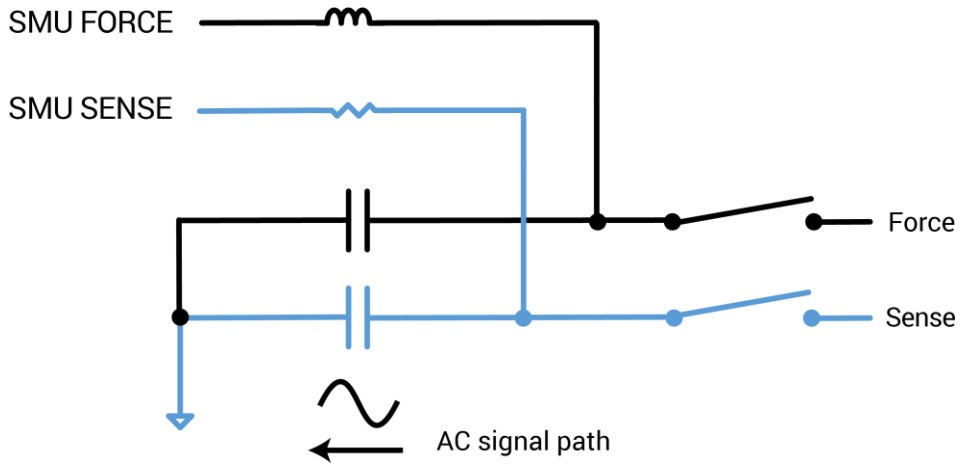


Bias tee SMU AC ground

The following figure shows a 4200A-CVIV bias tee with an AC ground configuration. This combines the DC bias from a 4200-SMU, 4201-SMU, 4210-SMU, or 4211-SMU with local AC ground through the 4200A-CVIV bias tee circuit.

A typical application for this configuration is performing a C-V measurement on the drain to the source of a MOSFET while applying a DC bias to the gate. The AC signals at the gate have a ground return path.

Figure 25: 4200A-CVIV bias tee AC ground configuration

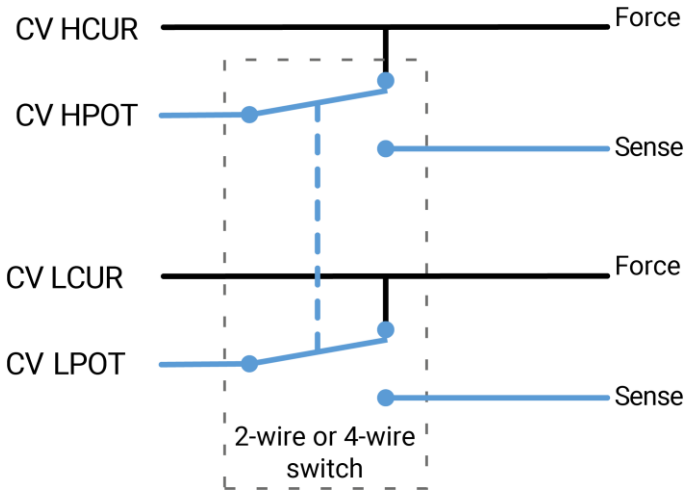


Automate switching between 2-wire and 4-wire mode

C-V measurements are typically performed in 4-wire mode. In 4-wire mode, each source and sense pair is terminated together as close to the device under test (DUT) as possible. The source and sense pairs are the HCUR and HPOT pair and the LCUR and LPOT pair. However, this setup can become difficult in switching applications where I-V and C-V measurements are made using the same cabling. The 4200A-CVIV can make 4-wire measurements, but it can also switch to 2-wire measurements when only two cables are connected to the DUT.

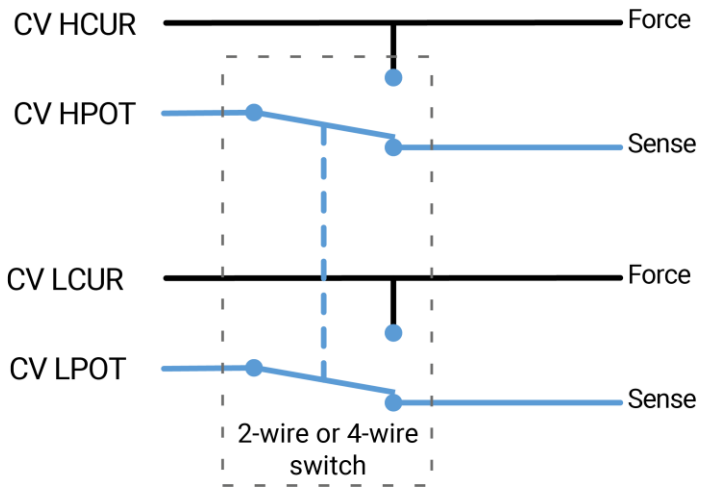
In 2-wire C-V mode, the source and sense pairs are terminated together internally and the coupled signal is passed to the selected output terminal on the source signal line. This setup is useful when you want to run the fewest number of triaxial cables to the DUT or if you are only making 2-wire I-V measurements and do not want to run extra triaxial cables for the C-V measurements. The following figure shows the CV HI and CV LO circuits in 2-wire sense mode. The output channel switches are omitted in the figure.

Figure 26: 4200A-CVIV CV HI and CV LO channels configured in 2-wire sense mode



In 4-wire C-V mode, the source and sense pairs are independent of each other as they pass through the 4200A-CVIV. The HCUR and LCUR signals are routed directly to the source output terminal of the specified output channel. The HPOT and LPOT signals are routed directly to the sense output terminal of the specified output channel. This setup is useful if you already have 4-wire Kelvin connections to the DUT for I-V testing. The following figure shows the CV HI and CV LO circuits in 4-wire sense mode. The output channel switches are omitted in the figure.

Figure 27: 4200A-CVIV CVHI and CVLO channels configured in the 4-wire sense mode



It is best to use 4-wire sense mode for measuring low impedance in both I-V and C-V applications. Four-wire sense mode removes the effect of the cable impedance by sensing voltage directly at the device terminals. The effect of cable impedance is more pronounced with low impedance devices because parasitic impedance in the cabling can become larger than that of the device itself.

Measurement compensation

Using the 4200A-CVIV with a 4210-CVU or 4215-CVU causes some degradation in CVU measurement accuracy. To resolve this, perform compensation with the 4200A-CVIV.

You run the `cvu-comp-cviv-collect` action in Clarius to gather open, short, and load compensation values that you apply to CVU readings.

CVU compensation

Offset and gain errors caused by the connections between the 4210-CVU or 4215-CVU, 4200A-CVIV, and the device under test (DUT) can be corrected by using connection compensation. General CVU compensation is a two-PArt process:

1. Generate connection compensation values for open, short, and load conditions. The compensation values are stored for future use.
2. Enable the compensation values for open, short, or load before running the interactive test module (ITM).

When using the 4200A-CVIV, perform compensation for each switch configuration used for C-V measurements in the test application. For example, perform compensation three times (one time for each C-V setup) if you plan to switch between three different C-V measurement setups on the terminals of a 3-terminal device.

The compensation values for all 4200A-CVIV configurations are stored by the Clarius software. When you run a test, the enabled compensation values are factored into each measurement. If you do not perform compensation for the present 4200A-CVIV configuration, the software uses the default compensation constants, which are equivalent to no compensation. If you disable open, short, and load compensation in a test, the software does not apply the compensation values to the test results.

NOTE

Perform connection compensation whenever the connection setup is changed or disturbed. Changes in temperature or humidity do not affect connection compensation.

Guidelines to determine required compensation

Use the following general guidelines to determine which compensation to do:

- **Open compensation:** Offset compensation for small capacitances (> 1 MΩ, large impedance)
- **Short compensation:** Offset compensation for large capacitances (< 10 Ω, small impedance)
- **Load compensation:** Resistive load compensation for gain error (seldom used)

Once you complete compensation for a specific 4200A-CVIV configuration, you do not need to gather compensation values each time you return to that configuration. However, over time the compensation values required for each configuration can drift from their original values. To avoid this, gather compensation values periodically for each switching configuration to make sure that the system is using the most accurate values.

4200A-CVIV compensation connections

Connect the output cables for open, short, or load compensation. Repeat this process for each channel configuration being compensated. The examples in the following figures are shown using channels 1 and 2, but the same types of connections apply for any channel configuration.

For all compensation connections, make sure that the outer shields of the triaxial cables are shorted together as close to the DUT as possible for optimal measurements. This is commonly done by attaching the triaxial connectors to a test fixture.

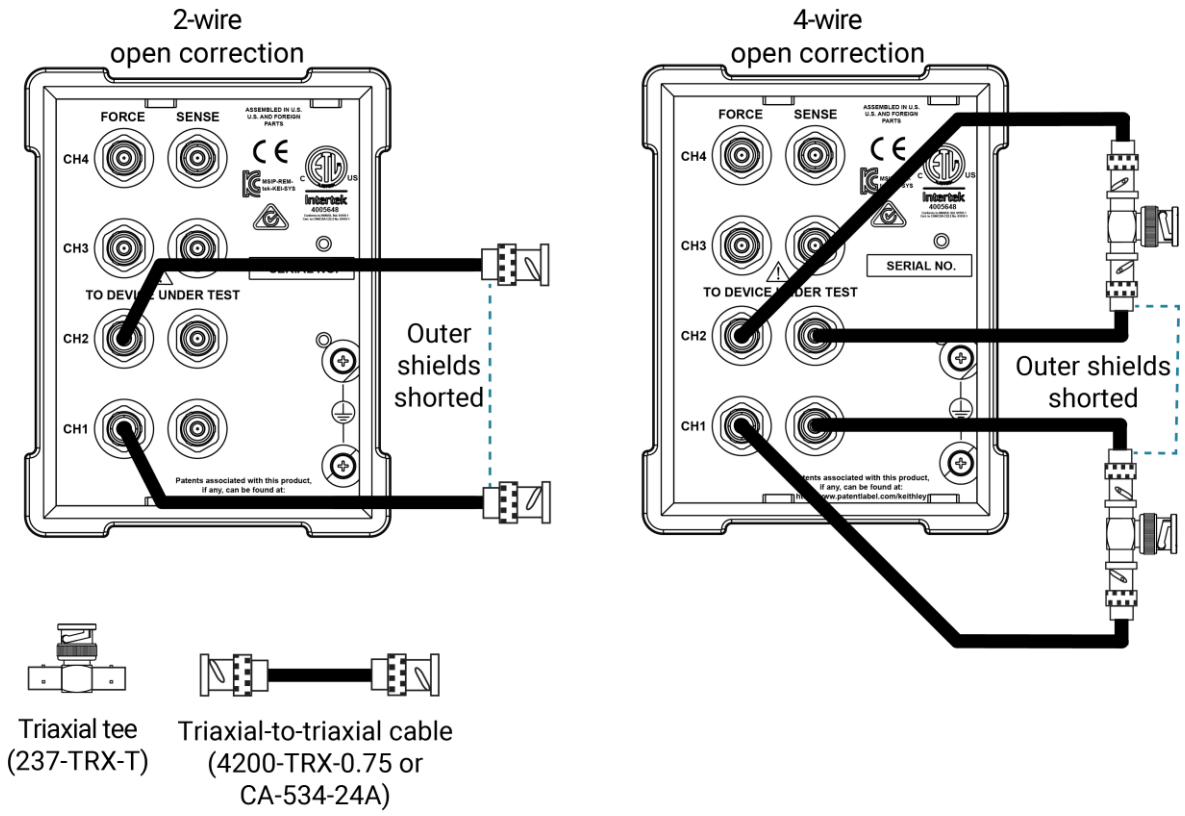
See “Connection compensation” in the *Model 4200A-SCS Capacitance-Voltage Unit (CVU) User’s Manual* for additional compensation information

NOTE

The DUT side of the 4200A-CVIV is intended to be used only with the 4200-TRX-0.75 or CA-534-24A blue triaxial cables. Four-wire connection compensation is not supported with other cables.

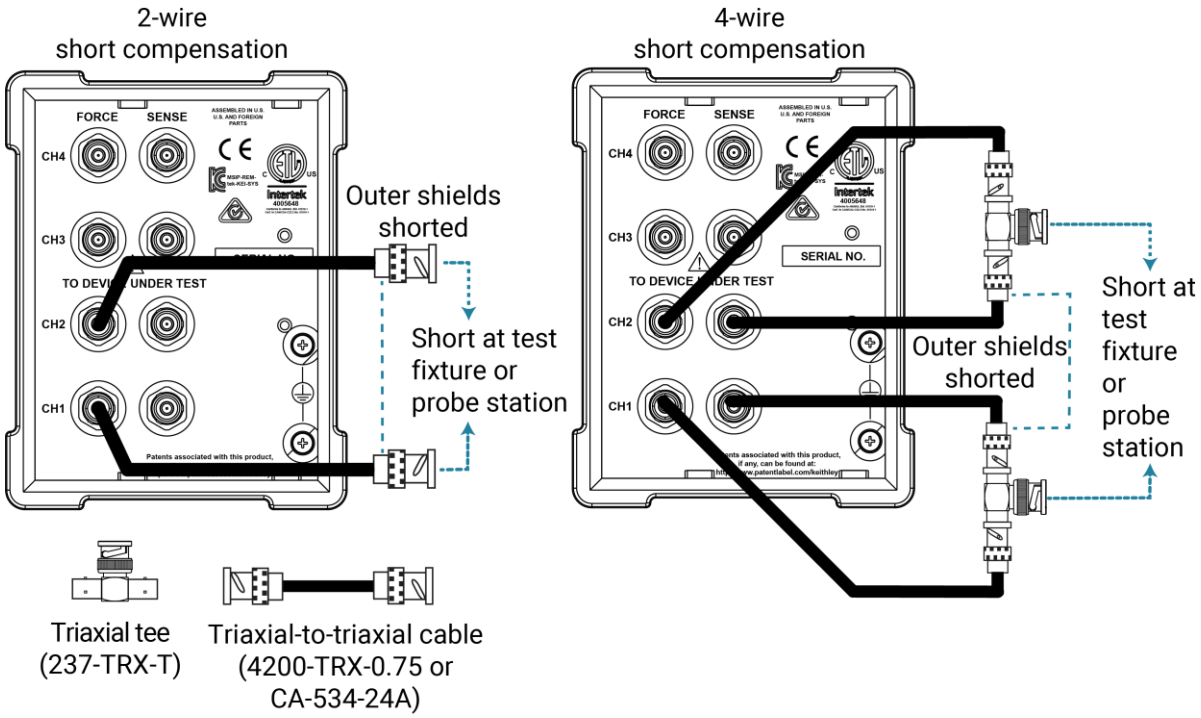
The following figure shows the connections for 2-wire and 4-wire open compensation. In 2-wire sense mode, leave the ends of the triaxial cables disconnected. In 4-wire sense mode, connect the force and sense triaxial cables for each channel with a triaxial tee connector.

Figure 28: Connections for open connection compensation



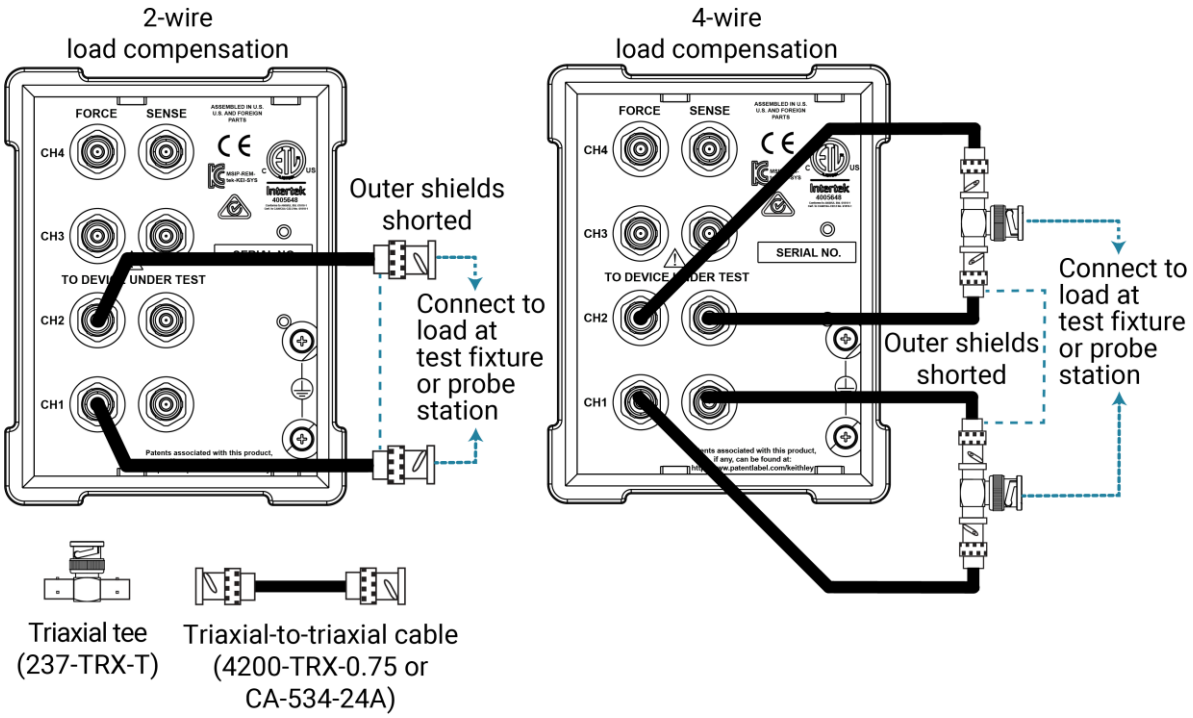
The following figure shows the connections for 2-wire and 4-wire short compensation. For 2-wire, short the force leads at the test fixture or at a probe station. For 4-wire, connect the force and sense triaxial cables for each channel with a triaxial tee connector. Short the outputs at the test fixture or at a probe station.

Figure 29: Connections for short connection compensation



The following figure shows the connections for 2-wire and 4-wire load compensation. For 2-wire, connect the ends of the triaxial cables to the load. The load can be in a test fixture or a probe station. For 4-wire, connect the force and sense triaxial cables for each channel with a triaxial tee connector. Connect the triaxial tee outputs to the load.

Figure 30: Connections for load connection compensation



Control the 4200A-CVIV with Clarius

The Keithley Clarius+ software suite is preinstalled on your 4200A-SCS Parameter Analyzer. You can use the Clarius application to control the outputs of your 4200A-CVIV and its onboard display.

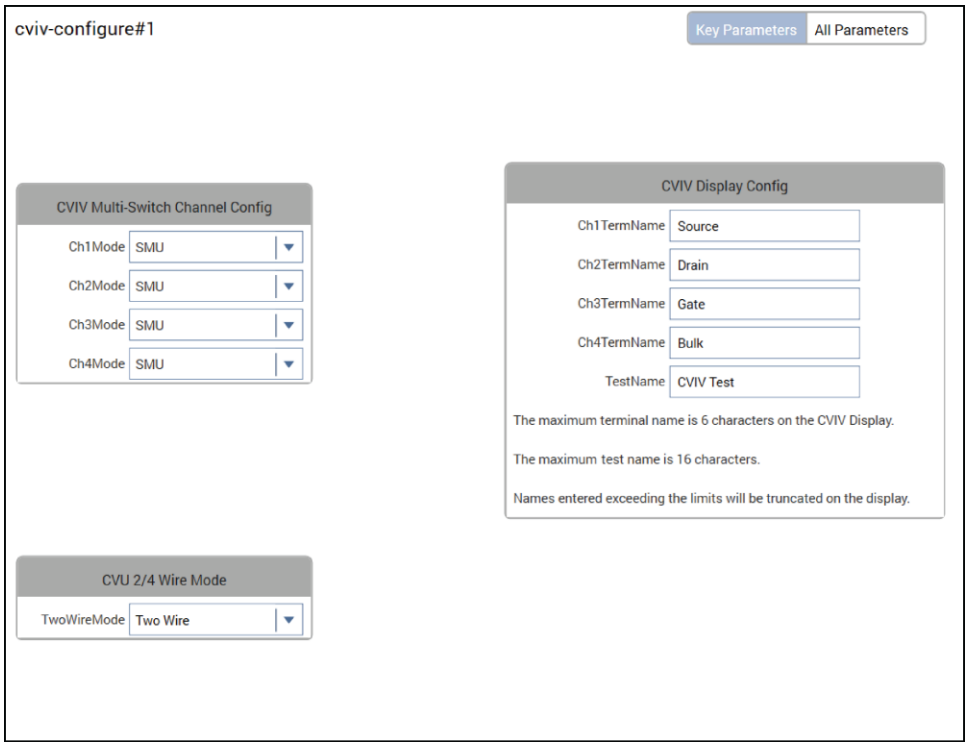
There are two actions available in Clarius that are used to control the 4200A-CVIV: `cviv-configure` and `cvu-cviv-comp-collect`. Each of these actions is also available as a user module in the `cvivulib` user library.

For more information on Clarius, see the *Model 4200A-SCS Clarius User's Manual*.

cviv-configure

The `cviv-configure` action sets up and controls the 4200A-CVIV output channels when performing a C-V or I-V test. To use the action, add it to the project tree structure and execute it when you want to reconfigure channels. The `cviv-configure` action can control the channel configuration, 2-wire and 4-wire CVU sense settings, and the names of the test and channels shown on the 4200A-CVIV display. The parameters for the action are shown in the table following the figure.

Figure 31: Clarius cviv-configure action



Adjustable parameters in the cviv-configure action

Ch1_Mode to Ch4_Mode: The instrument terminal that is connected to an output channel specified by 1 through 4. The options are:

- **Open:** No Connection. The output channel is an open circuit.
- **SMU:** The output channel signals pass through the SMU terminals.
- **CV HI:** The output channel is connected to the CVU HI side terminals.
- **CV LO:** The output channel is connected to the CVU LO side terminals.

- **CV Guard:** The output channel is connected to the guard (outside shield) of the CVU cables.
- **Ground Unit:** The output channel is connected to the SENSE connector of the ground unit on the 4200A-SCS.
- **AC Coup AC Gnd:** The output channel is connected to AC-coupled AC ground.
- **BiasT: SMU CV HI:** The output channel is connected to the SMU and the CVU HI side terminals.
- **BiasT: SMU CV LO:** The output channel is connected to the SMU and the CVU LO side terminals.
- **BiasT: SMU LO I CV HI:** The output channel is connected to the SMU and the CVU HI side terminals. This parameter is optimized for lower SMU current (I).
- **BiasT: SMU LO I CV LO:** The output channel is connected to the SMU and the CVU LO side terminals. This parameter is optimized for lower SMU current (I).
- **BiasT: SMU AC Gnd:** The output channel is connected directly to ground and the SMU through the bias tee.

Ch1_TermName to Ch4_TermName: The text that appears on the 4200A-CVIV display next to the output channel specified by numbers 1 through 4. The text can be up to six characters.

TestName: The text at the top of the 4200A-CVIV display. The text can be up to sixteen characters. This allows you to enter a name for the test.

TwoWireMode: Selects whether the 4210-CVU or 4215-CVU outputs in two-wire or four-wire mode. This affects all output channels configured to CV HI or CV LO. Output channels configured to SMU or CV Guard are not affected.

- **Two Wire:** The sense output terminal is not used. The CUR and POT lines of CV HI or CV LO are shorted internally and connected to the force terminal of an output channel specified by `Ch1_Mode` to `Ch4_Mode`.
- **Four Wire:** The POT and CUR lines of CV HI and CV LO are not shorted internally. POT is connected to sense. CUR is connected to force for any output channel specified by `Ch1_Mode` to `Ch4_Mode`.

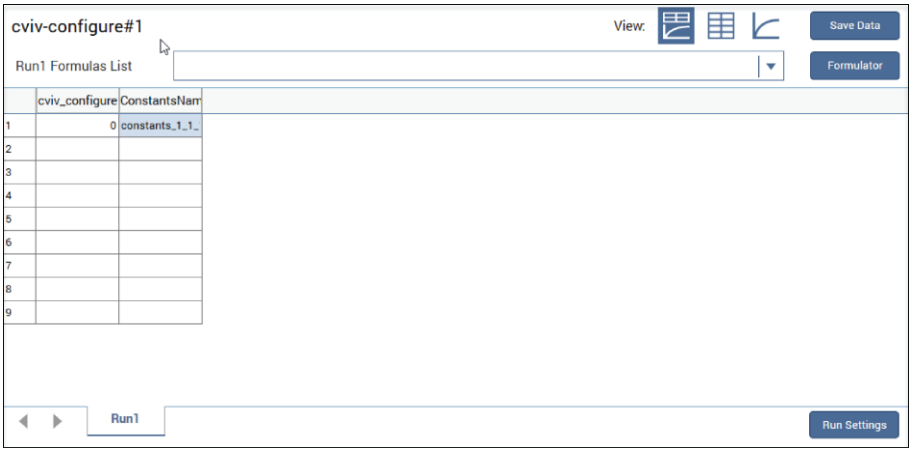
cviv-configure return values

Two values are returned from `cviv-configure` to the Analyze sheet:

- `cviv_configure`: A status number that indicates if the action completed with any errors.
- `ConstantsName`: The configuration settings as a short string of text that is used when CVU compensation is performed.

An example of these values is shown in the following figure. Additional details on the values are provided following the figure.

Figure 32: Analyze view of the completed cviv-configure action



`cviv_configure`: The following values are the possible parameters:

- `0`: Pass (no errors)
- `-1`: Invalid CVIV instrument identification
- `-2`: Display configuration error
- `-78`: Received Timeout Waiting for CVIV Response
- `-88`: Bad Configuration of Data Sent to CVIV
- `-122`: Invalid parameter
- `-150`: CVIV Device Not Found
- `-167`: Invalid CVIV Connection Configuration
- `-169`: CVIV instrument name not configured

NOTE

If you receive `-1`, `-150`, or `-169`, run the KCon application and select **Validate**.

`ConstantsName`: The name of the file contains the 4200A-CVIV configuration that was set in the user module. Any CVU tests run after the `cviv-configure` action use this file and its contents.

The format of the string is:

`constants_<2W/4W>_<Ch1_Mode>_<Ch2 Mode>_<Ch3 Mode>_<Ch4 Mode>_<cable length>`

The possible values are:

- `<2W/4W>` : `0` = 4-wire, `1` = 2-wire
- `<Chx_Mode>` : `0` = Open, `1` = SMU, `2` = CV HI, `3` = CV LO, `4` = CV Guard `5` = Ground Unit, `6` = AC Coup AC Gnd, `7` = BiasT: SMU CV HI, `8` = BiasT: SMU CV LO, `9` = BiasT: SMU LO I CV HI, `10` = BiasT: SMU LO I CV LO, `11` = BiasT: SMU AC Gnd
- `<cable length>`:
  - `4` = 1.5 m CVIV 2-wire
  - `5` = 1.5 m CVIV 4-wire 0.75 m (for use with the 4200-TRX-0.75 triaxial cables)
  - `6` = 1.5 m CVIV 4-wire 0.61 m (for use with CA-534-24B1 blue triaxial cables)

For example, the file name `constants_1_2_3_0_0_4` signifies 2-wire mode, CV HI connected to channel 1, CV LO connected to channel 2, open connections for channels 3 and 4, and a cable length of 1.5 m CVIV 2-wire.

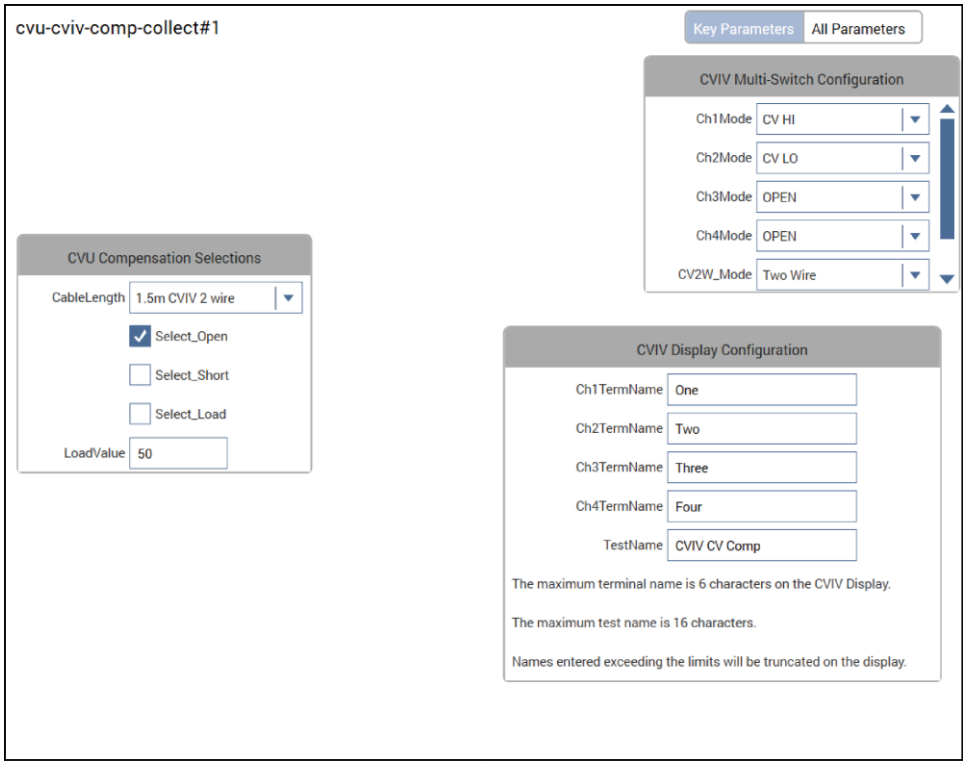
cvu-cviv-comp-collect

The `cvu-cviv-comp-collect` action performs open, short, and load compensations on the 4200A-CVIV channels before running a C-V test. This action configures the 4200A-CVIV channels before performing compensation, so it is not necessary to use the `cviv-configure` action before compensation. To use this action, it must be added into the project tree structure and executed once for each C-V measurement configuration used in the project.

The parameters in `cvu-cviv-comp-collect` define the connections to the 4200A-CVIV output channels that will be used in your test. You must run the action for each 4200A-CVIV configuration that will be used, as compensation values are unique for each configuration. Details on each parameter are listed in the following.

If more than one type of compensation is selected, open compensation is done first, then short, then load. Dialog boxes prompt you to make the proper connections. For more information about compensation and the connections required for each type, see Measurement compensation (on page 4-14). For a specific example of how to set up a project that includes CVIV compensation switching in Clarius, see Use the 4200A-CVIV Multi-Switch (on page 6-1).

Figure 33: Clarius cvu-cviv-comp-collect action



Input parameters in the cvu-cviv-comp-collect action

Parameter	Options	Description
CableLength	■ 1.5 m CVIV 2 wire ■ 1.5 m CVIV 4 wire, 0.75 m ■ 1.5 m CVIV 4 wire, 0.61 m, blue	Length of the cables from the output channels of the DUT to the 4200A-CVIV. The `1.5 m CVIV 4 wire, 0.75 m` option is intended for use with 4200-TRX-0.75 triaxial cables. The `1.5 m CVIV 4 wire, 0.61 m` option is intended for use with CA-534-24B1 blue triaxial cables.
Select_Open	Selected or cleared	Selects whether to perform open compensation.
Select_Short	Selected or cleared	Selects whether to perform short compensation.
Select_Load	Selected or cleared	Selects whether to perform load compensation.
LoadValue	0 to 10e3	The value of the resistance standard (in Ω) to be used in load compensation.

Parameter	Options	Description
Ch1_Mode Ch2_Mode Ch3_Mode Ch4_Mode	Open, SMU, CV HI, CV LO, CV Guard, Ground Unit, AC Coup AC Gnd, BiasT: SMU CV HI, BiasT: SMU CV LO, BiasT: SMU CV LO, BiasT: SMU LO I CV HI, BiasT: SMU LO I CV LO, BiasT: SMU AC Gnd	The instrument terminal that will be connected to the corresponding output channel.
CV_2W_Mode	Two Wire, Four Wire	Selects whether the CVU terminals are shorted internally (Two Wire) or not (Four Wire).
Ch1_TermName Ch2_TermName Ch3_TermName Ch4_TermName	Up to 6 alphanumeric characters	Text that appears on the 4200A-CVIV display labeling the corresponding output channel.
TestName	Up to 16 alphanumeric characters	Text that appears at the top of the 4200A-CVIV display.

Detailed descriptions of the input parameters are as follows:

CableLength: For the most accurate results, the cables from the output channels of the 4200A-CVIV must all be the same length. The recommended length is 75 cm.

Select_Open: Select this box to perform open compensation when the action is executed.

Select_Short: Select this box to perform short compensation when the action is executed.

Select_Load: Select this box to perform load compensation when the action is executed.

LoadValue: The value of the resistance standard used in the load compensation. The preferred values range from 0 Ω to 200 Ω, but any value up to 10 kΩ may be used. This value is not used if `Select_Load` is cleared.

Ch1_Mode to Ch4_Mode: The instruments to be connected to each respective output channel. These must be the same connections that are used in the `cviv-configure` action when you execute your test.

CV_2W_Mode: Determines if the 4210-CVU or 4215-CVU is in 2-wire or 4-wire mode. This is the same setting that is used in the `cviv-configure` action when you execute your test.

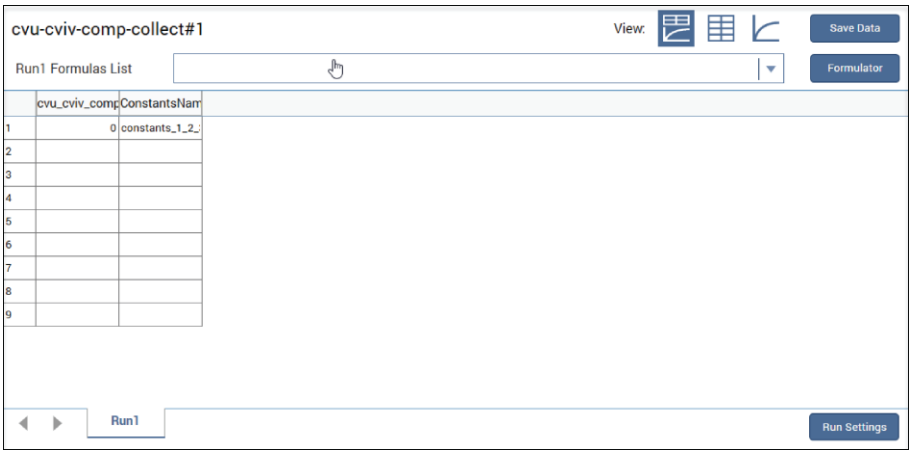
Ch1_TermName to Ch4_TermName: Text that appears on the 4200A-CVIV display when the action is running. This text labels the corresponding output channels and does not affect compensation.

TestName: Text that appears at the top of the 4200A-CVIV display while the action is running. This text does not affect compensation.

cvu-cviv-comp-collect return values

Two values are returned from `cvu-cviv-comp-collect` to the Analyze sheet. The `cvu_cviv_comp_collect` value returns a status number that indicates how the test completed. The `ConstantsName` value returns a string that contains the coded configuration settings.

Figure 34: Analyze view of the completed cvu-cviv-comp-collect action



Detailed descriptions of the return parameters are as follows:

`cvu-cviv-comp-collect`: A value that indicates if the action completed with any errors. Possible values and associated explanations are:

- `0` : Pass (no errors)
- `-1` : Invalid CVU instrument identification
- `-2` : Invalid CVIV instrument identification
- `-3` : Error: No CV HI connection configured
- `-4` : Error: No CV LO connection configured
- `-5` : Display configuration error
- `-6` : Load Value out of range (0 to 10 K)
- `-78` : Receive timeout waiting for CVIV response
- `-88` : Bad configuration of data sent to CVIV instrument
- `-122` : Invalid parameter
- `-150` : CVIV device not found
- `-167` : Invalid CVIV connection configuration
- `-169` : CVIV instrument name not configured

NOTE

If you receive the `-2`, `-150`, or `-169` return values, run the KCon application and select **Validate**.

`ConstantsName`: This is the CVU compensation file containing open, short, and load correction values. The name of the file contains the 4200A-CVIV configuration set in the user module. Any CVU tests run after the `cvu-cviv-comp-collect` action use this file and its contents.

The format of the string is:

`constants_<2W/4W>_<Ch1_Mode>_<Ch2 Mode>_<Ch3 Mode>_<Ch4 Mode>_<cable length>`

The possible values are:

- `<2W/4W>` : `0` = 4-wire, `1` = 2-wire
- `<Chx_Mode>` : `0` = Open, `1` = SMU, `2` = CV HI, `3` = CV LO, `4` = CV Guard `5` = Ground Unit, `6` = AC Coup AC Gnd, `7` = BiasT: SMU CV HI, `8` = BiasT: SMU CV LO, `9` = BiasT: SMU LO I CV HI, `10` = BiasT: SMU LO I CV LO, `11` = BiasT: SMU AC Gnd
- `<cable length>`:
  - `4` = 1.5 m CVIV 2-wire
  - `5` = 1.5 m CVIV 4-wire 0.75 m (for use with the 4200-TRX-0.75 triaxial cables)
  - `6` = 1.5 m CVIV 4-wire 0.61 m (for use with CA-534-24B1 blue triaxial cables)

For example, the file name `constants_1_2_3_0_0_4` signifies 2-wire mode, CV HI connected to channel 1, CV LO connected to channel 2, open connections for channels 3 and 4, and a cable length of 1.5 m CVIV 2-wire.

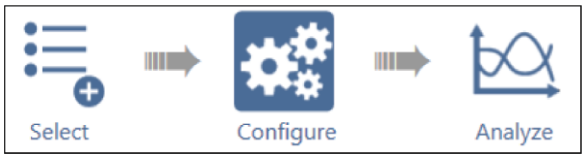
Enable compensation for a test

After you use the `cvu-cviv-comp-collect` action to gather compensation values for the channels of the 4200A-CVIV, you must enable the compensation for the test you want to run.

To enable compensation for a test:

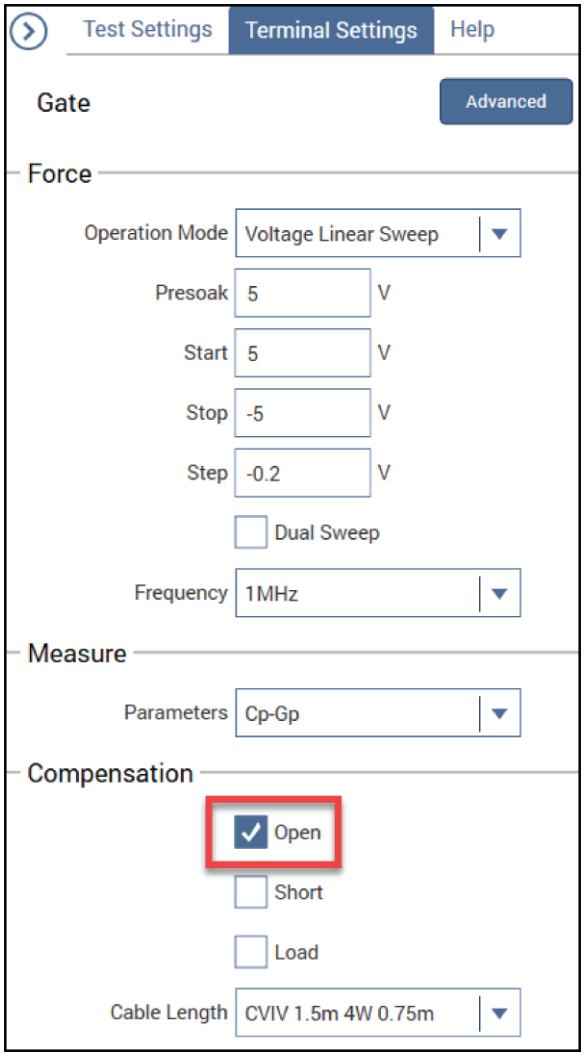
1. Place the `cviv-configure` action into the project tree before your C-V test.
2. In the project tree, select the C-V test to apply compensation to.
3. Select **Configure**.

Figure 35: Configure highlighted



4. From the Terminal Settings pane, select the type of compensation to perform.

Figure 36: Enabling open compensation for the test



5. Select **Run** to run the test. The compensation values are applied to the measurements.

Control the 4200A-CVIV with LPT commands

The 4200A-CVIV can be controlled though LPT commands if you want to configure the CVIV outputs or display from a user module created with the Keithley User Library Tool (KULT).

For more information on KULT, see *Model 4200A-SCS KULT and KULT Extension Programming* (4200A-KULT-907-01).

cviv_config

This command sends switching commands to the 4200A-CVIV Multi-Switch.

Usage

```
int cviv_config(int instr_id, int channel, int mode);
```

instr_id	The instrument identification code of the 4200A-CVIV: `CVIV1`
channel	4200A-CVIV channel: `1` to `4` 4200A-CVIV all channels: `5`
mode	For channels 1 to 4, the switch settings for the selected channel: ■ Open connection to output terminal: `KI_CVIV_OPEN` or `0` ■ Connect channel to SMU (4200-SMU, 4201-SMU, 4210-SMU, or 4211-SMU): `KI_CVIV_SMU` or `1` ■ Connect channel to CVU HI (4210-CVU or 4215-CVU: `KI_CVIV_CVH` or `2` ■ Connect channel to CVU LO (4210-CVU or 4215-CVU): `KI_CVIV_CVL` or `3` ■ Connect CV guard to the output connector shell with AC ground to center: `KI_CVIV_CV_GRD` or `4` ■ Connect channel to ground unit: `KI_CVIV_GNDU` or `5` ■ Connect channel to AC-coupled AC ground: `KI_CVIV_AC_COUPLED_AC_GND` or `6` ■ Connect channel to bias tee SMU CV HI: `KI_CVIV_BT_CVH` or `7` ■ Connect channel to bias tee SMU CV LO: `KI_CVIV_BT_CVL` or `8` ■ Connect channel to bias tee low current SMU CV HI: `KI_CVIV_BT_LOI_CVH` or `9` ■ Connect channel to bias tee low current SMU CV LO: `KI_CVIV_BT_LOI_CVL` or `10` ■ Connect channel to bias tee AC ground: `KI_CVIV_BT_AC_GND` or `11` If *channel* is set to `5` (all channels), the switch settings for the 4200A-CVIV instrument are: ■ All CV channels to C-V 2-wire: `KI_CVIV_CVU_2WIRE` or `1` ■ All CV channels to C-V 4-wire: `KI_CVIV_CVU_4WIRE` or `0`

Details

The 4200A-CVIV includes input connections for four SMU cards and one CVU card. Use this command to control switching inside the 4200A-CVIV to connect the SMU and CVU instruments to the output terminals.

The 4200A-CVIV connections are cleared by the `clrcon` command.

Example

```
cviv_config(CVIV1, 1, KI_CVIV_SMU);
```

This command connects channel 1 of the CVIV to a SMU.

Also see

clrcon (on page 4-31)
cviv_display_config (on page 4-29)
cviv_display_power (on page 4-30)

cviv_display_config

This command configures the display on the 4200A-CVIV Multi-Switch.

Usage

```
int cviv_display_config(int instr_id, int channel, int identifier, char *value);
```

instr_id	The instrument identification code of the 4200A-CVIV: `CVIV1`
channel	4200A-CVIV channel (use to set a terminal name): `1` to `4` 4200A-CVIV virtual channel (use to set the test name): `5` See **Details**
identifier	Display the name of the terminal: `KI_CVIV_TERMINAL_NAME` or `1` Display the name of the test: `KI_CVIV_TEST_NAME` or `0` See **Details**
value	A string that defines the name (up to 16 characters for a test name or 6 characters for a terminal name)

Details

Sets the name for the channel terminal or test. This name is displayed on the 4200A-CVIV for the selected channel.

The *channel* and *identifier* settings must be set for either terminal or test name. For example, if *channel* is set to `2`, *identifier* must be set to `KI_CVIV_TERMINAL_NAME`.

If the `clrcon` command is sent, the 4200A-CVIV display is updated to show the change in connections. If the 4200A-CVIV display is turned off, it remains off after a `clrcon`.

Example

```
cviv_display_config(CVIV1, 2, KI_CVIV_TERMINAL_NAME, "Source");
```

This command sets the name of the channel 2 terminal on the 4200A-CVIV display to `Source`.

Also see

clrcon (on page 4-31)
cviv_config (on page 4-28)
cviv_display_power (on page 4-30)

cviv_display_power

This command sets the display state of the LCD display on the 4200A-CVIV.

Usage

```
int cviv_display_power(int instr_id, int state);
```

instr_id	The instrument identification code of the 4200A-CVIV: `CVIV1`
state	Display on: `KI_CVIV_DISPLAY_ON` or `1` Display off: `KI_CVIV_DISPLAY_OFF` or `0`

Details

This command turns the display of the 4200A-CVIV on or off.

When the display is turned off, the 4200A-CVIV clears the displays. A small green circle is displayed to indicate that the 4200A-CVIV instrument is powered.

When the display is turned on, the latest configuration is displayed.

If the `clrcon` command is sent, the 4200A-CVIV display is updated to show the change in connections. If the 4200A-CVIV display is turned off, it remains off after a `clrcon`.

Example

```
cviv_display_power(CVIV1, KI_CVIV_DISPLAY_OFF);
```

Turns off the 4200A-CVIV display.

Also see

cviv_config (on page 4-28)
cviv_display_config (on page 4-29)

clrcon

This command opens or de-energizes all device under test (DUT) pins and instrument matrix relays, disconnecting all crosspoint connections.

Usage

```
int clrcon(void);
```

Details

The `clrcon` command is called automatically by the `devint`, `pulse_output` (only for RPMs), and `execut` commands. The first in a series of one or more connection-type commands automatically calls a `clrcon` command. Because this command is automatically called, it is not normally used by a programmer.

If any sources are actively generating current or voltage, the `devclr` command is automatically called before the relay matrix is de-energized.

Also see

In *Model 4200A-SCS LPT Library Programming:*

devclr
devint
execut
pulse_output

Section 5

Typical applications

In this section:

Introduction

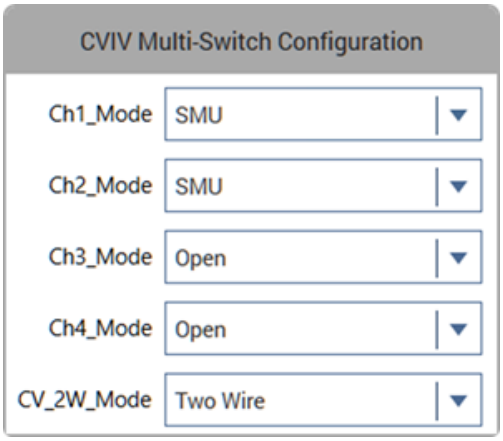
This section provides several simplified connection and switch configuration diagrams to connect the 4200A-CVIV and a device under test (DUT).

I-V characterization on a 2-terminal device

You need two SMUs to perform I-V characterization of a 2-terminal device. The SMUs can be installed in any channel of the 4200A-CVIV. In this example, they are in channel 1 and 2. Use the `cviv-configure` action in Clarius to configure the 4200A-CVIV to the following settings:

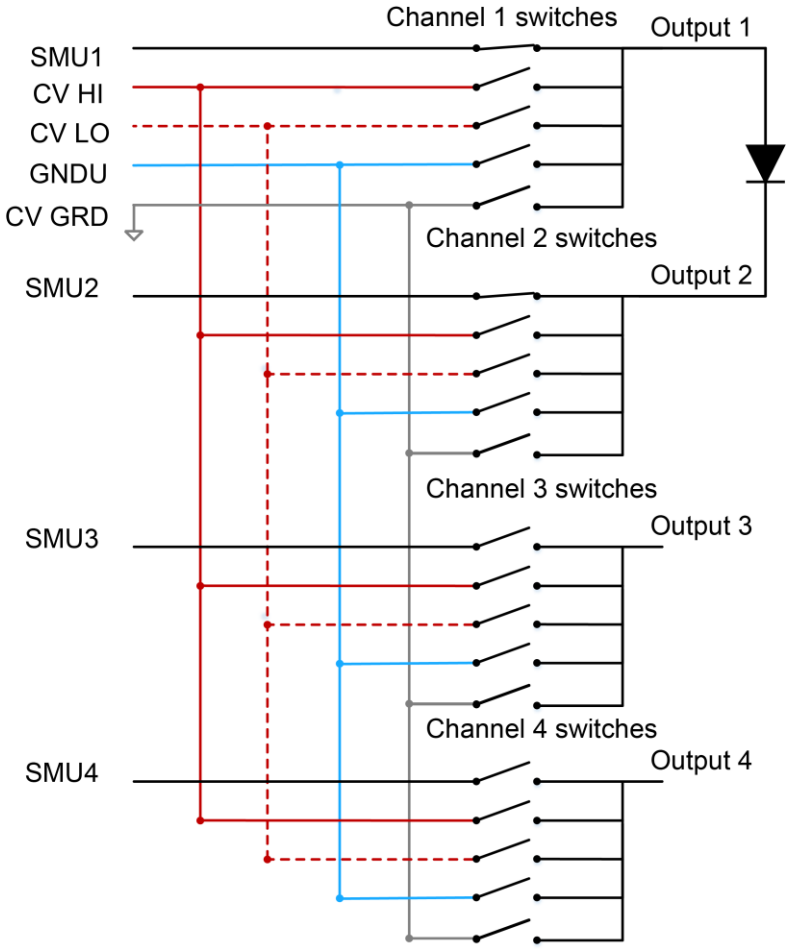
- **Ch1_Mode:** Set Channel 1 to SMU
- **Ch2_Mode:** Set Channel 2 to SMU
- **Ch3_Mode:** Set Channel 3 to Open
- **Ch4_Mode:** Set Channel 4 to Open

Figure 37: Configuration settings for I-V characterization on a 2-terminal device



If you are using 2-wire sense, connect a single triaxial cable to the force output connectors of channels 1 and 2 of the 4200A-CVIV to the device under test. If you are using 4-wire sense, connect two triaxial cables to the force and sense output connectors of each channel and terminate them together at the device under test. See the following figure for an example of the internal switch configurations and device connections.

Figure 38: 4200A-CVIV connections to a 2-terminal device for I-V characterization

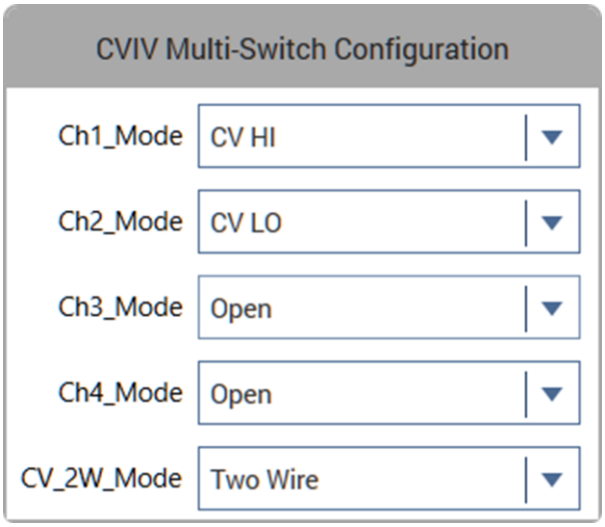


C-V characterization on a 2-terminal device

Only the 4210-CVU or 4215-CVU is necessary for C-V measurements through the 4200A-CVIV. The 2-terminal device can be connected to any two terminals on the 4200A-CVIV. In this example, channel 1 and channel 2 are used. Use the `cviv-configure` action in Clarius, to configure the 4200A-CVIV to the following settings:

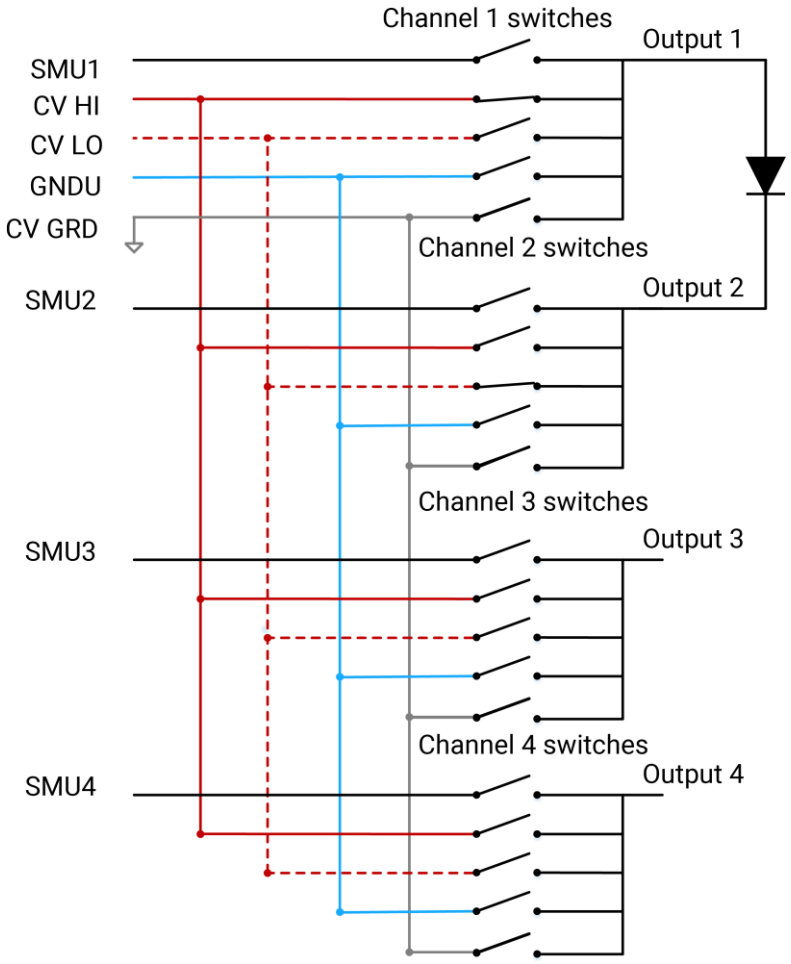
- **Ch1_Mode:** Set Channel 1 to CV HI
- **Ch2_Mode:** Set Channel 2 to CV LO
- **Ch3_Mode:** Set Channel 3 to Open
- **Ch4_Mode:** Set Channel 4 to Open

Figure 39: Configuration settings for C-V characterization on a 2-terminal device



If you are using 2-wire sense, connect a single triaxial cable to the force output connector of channels 1 and 2 of the 4200A-CVIV to the device under test. If you are using 4-wire sense, connect two triaxial cables to the force and sense output connectors of each channel and terminate them together at the device under test. See the following figure for an example of the internal switch configurations and device connections.

Figure 40: 4200A-CVIV connections to a 2-terminal device for C-V characterization

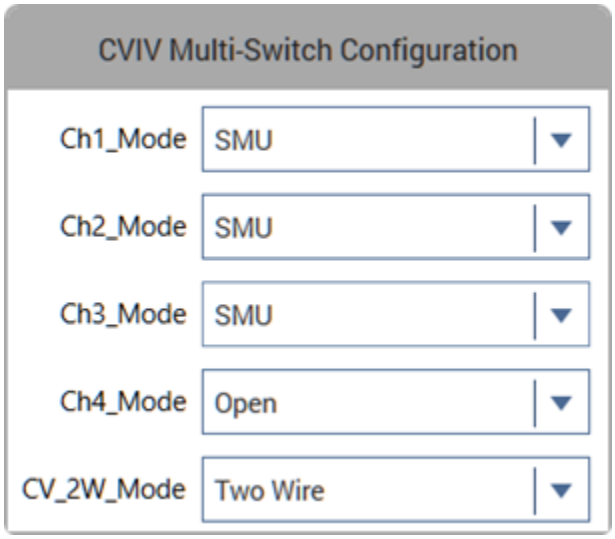


I-V characterization on a 3-terminal device

Three SMUs are necessary to perform an I-V characterization of a 3-terminal device. The SMUs can be installed in any channel of the 4200A-CVIV. In this example, they are in channels 1, 2 and 3. Use the `cviv-configure` action in Clarius to configure the 4200A-CVIV to the following settings:

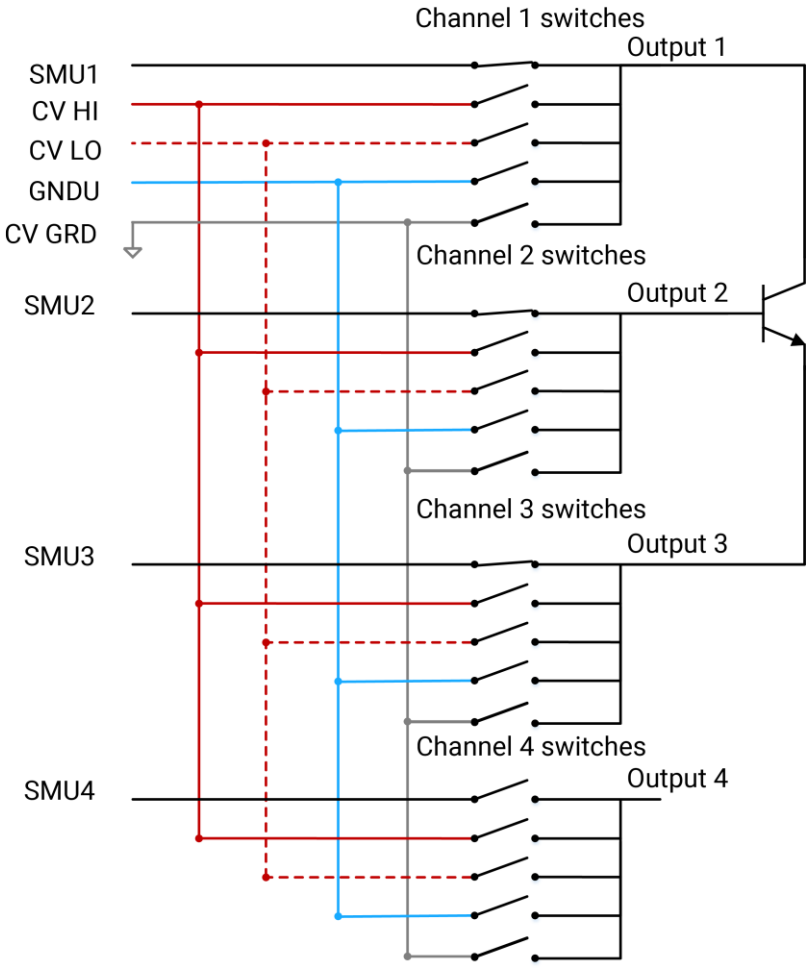
- **Ch1_Mode:** Set Channel 1 to SMU
- **Ch2_Mode:** Set Channel 2 to SMU
- **Ch3_Mode:** Set Channel 3 to SMU
- **Ch4_Mode:** Set Channel 4 to Open

Figure 41: Configuration settings for I-V characterization on a 3-terminal device



If you are using 2-wire sense, connect a single triaxial cable to the force output connector on channels 1, 2, and 3 of the 4200A-CVIV to the device under test. If you are using 4-wire sense, connect two triaxial cables to the force and sense output connectors of each channel and terminate them together at the device under test. See the following figure for an example of the internal switch configurations and device connections.

Figure 42: 4200A-CVIV connections to a 3-terminal diode device for I-V characterization

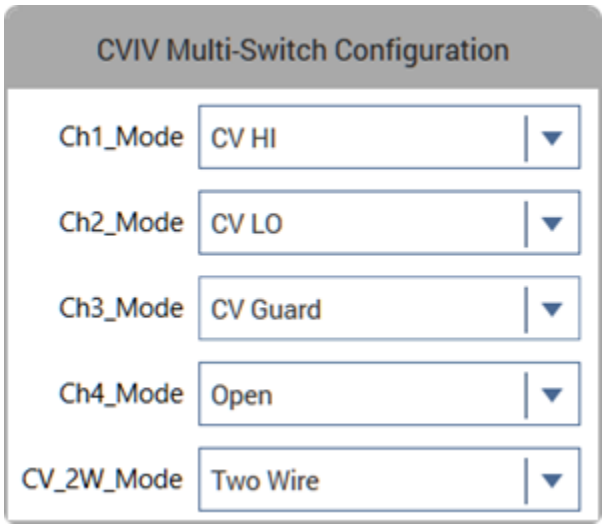


C-V characterization on a 3-terminal device

Only the 4210-CVU or 4215-CVU is necessary for C-V measurements through the 4200A-CVIV. The 3-terminal device can be connected to any three terminals on the 4200A-CVIV. This example uses channels 1, 2, and 3. This measurement setup demonstrates how to guard a device terminal so that it is excluded from the measurements. Use the `cviv-configure` action in Clarius to configure the 4200A-CVIV to the following settings:

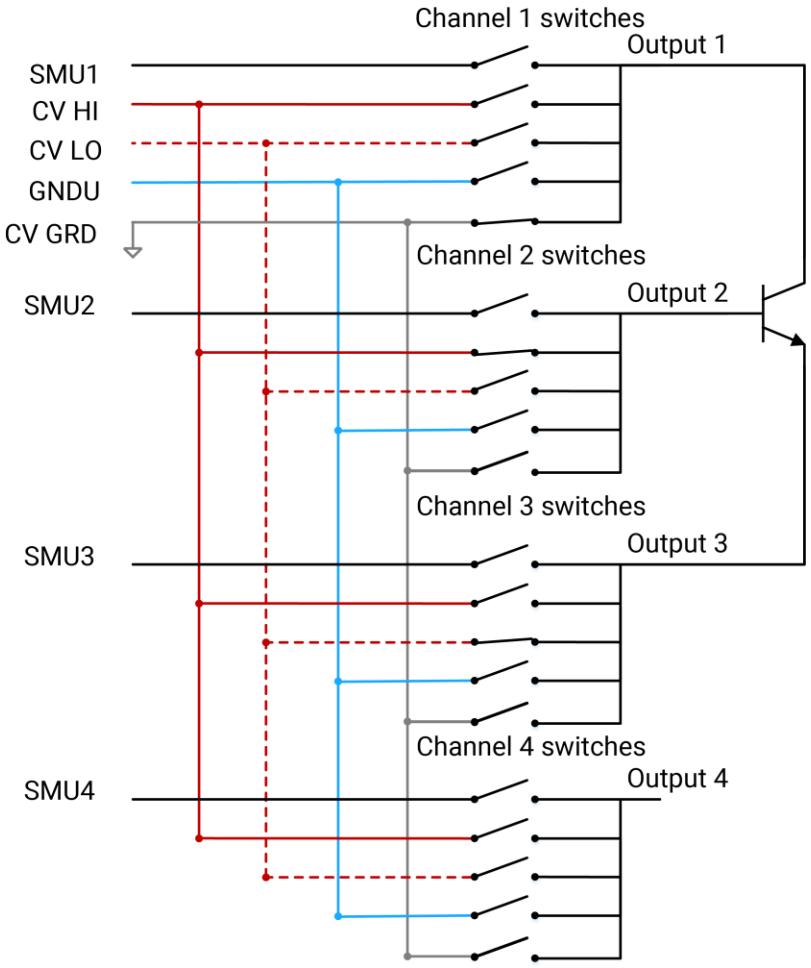
- **Ch1_Mode:** Set Channel 1 to CV HI
- **Ch2_Mode:** Set Channel 2 to CV LO
- **Ch3_Mode:** Set Channel 3 to CV Guard
- **Ch4_Mode:** Set Channel 4 to Open

Figure 43: CVIV Multi-switch channel configuration



If you are using 2-wire sense, connect a single triaxial cable to the force output connectors of channels 1, 2, and 3 of the 4200A-CVIV to the device under test. If you are using 4-wire sense, connect two triaxial cables to the force and sense output connectors of each channel and terminate them together at the device under test. See the following figure for an example of the internal switch configurations and device connections.

Figure 44: 4200A-CVIV connections to a 3-terminal device for C-V characterization

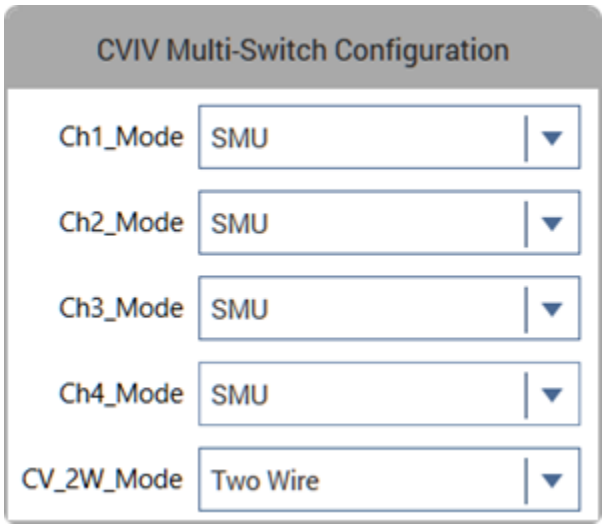


I-V characterization on a 4-terminal device

Four SMUs are necessary to perform an I-V characterization of a 4-terminal device. Using the `cviv-configure` action in Clarius, configure the 4200A-CVIV to the following settings:

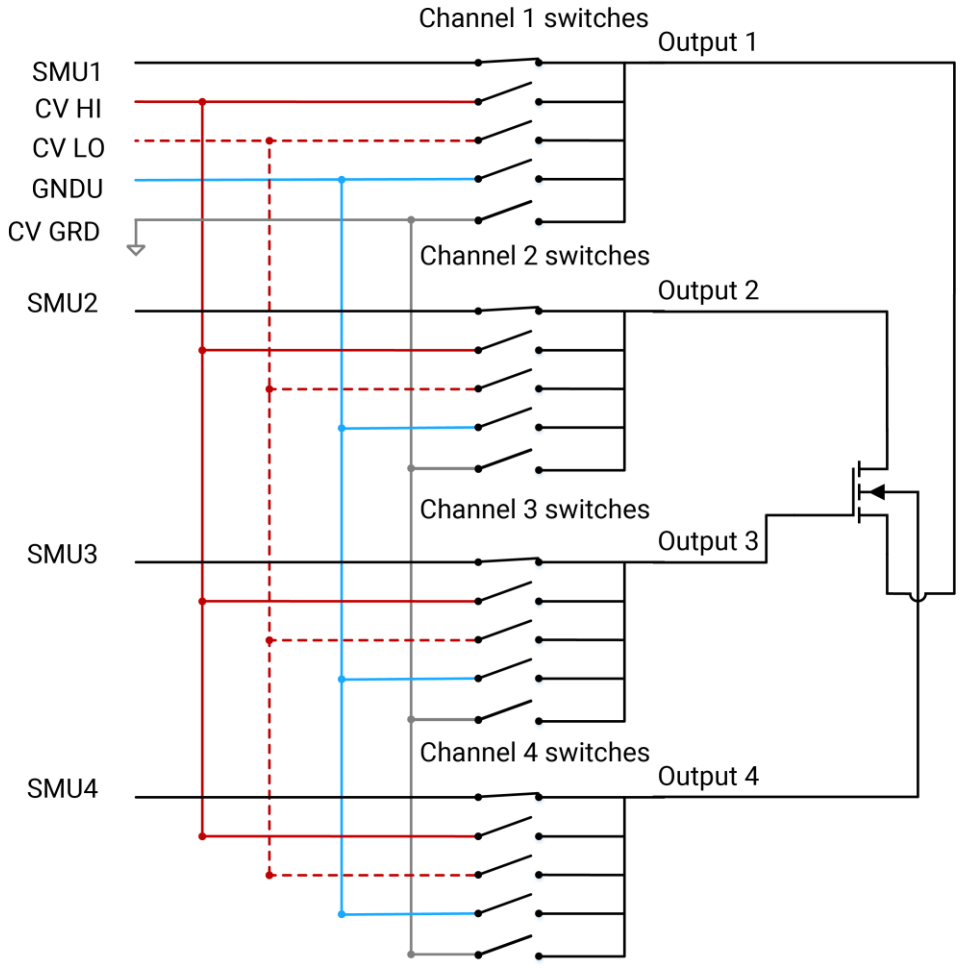
- **Ch1_Mode:** Set Channel 1 to SMU
- **Ch2_Mode:** Set Channel 2 to SMU
- **Ch3_Mode:** Set Channel 3 to SMU
- **Ch4_Mode:** Set Channel 4 to SMU

Figure 45: Configuration for I-V settings on a 4-terminal device



If your test uses 2-wire sense, connect a single triaxial cable to the force output connector on channels 1, 2, 3, and 4 of the 4200A-CVIV to the device under test. If you are using 4-wire sense, connect two triaxial cables to the force and sense output connectors of each channel and terminate them together at the device under test. See the following figure for an example of the internal switch configurations and device connections.

Figure 46: 4200A-CVIV connections to a 4-terminal MOSFET device for I-V characterization

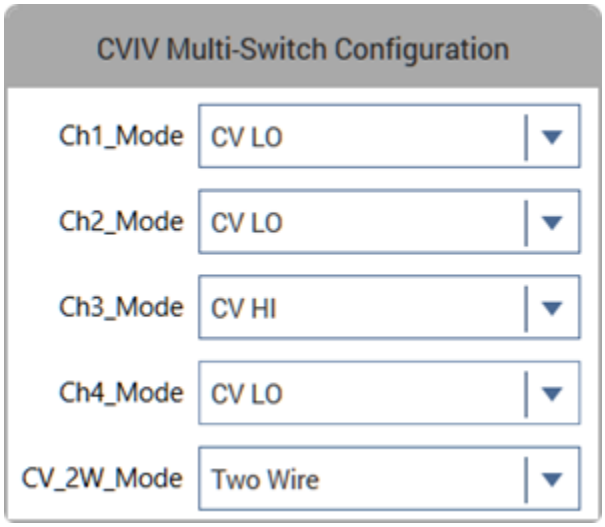


C-V characterization on a 4-terminal device

Only the 4210-CVU or 4215-CVU is necessary for C-V measurements through the 4200A-CVIV. All four output channels are used in this example. This measurement setup demonstrates how to connect multiple device terminals for a single C-V measurement by assigning them to the same C-V channel. Use the `cviv-configure` action in Clarius to configure the 4200A-CVIV to the following settings:

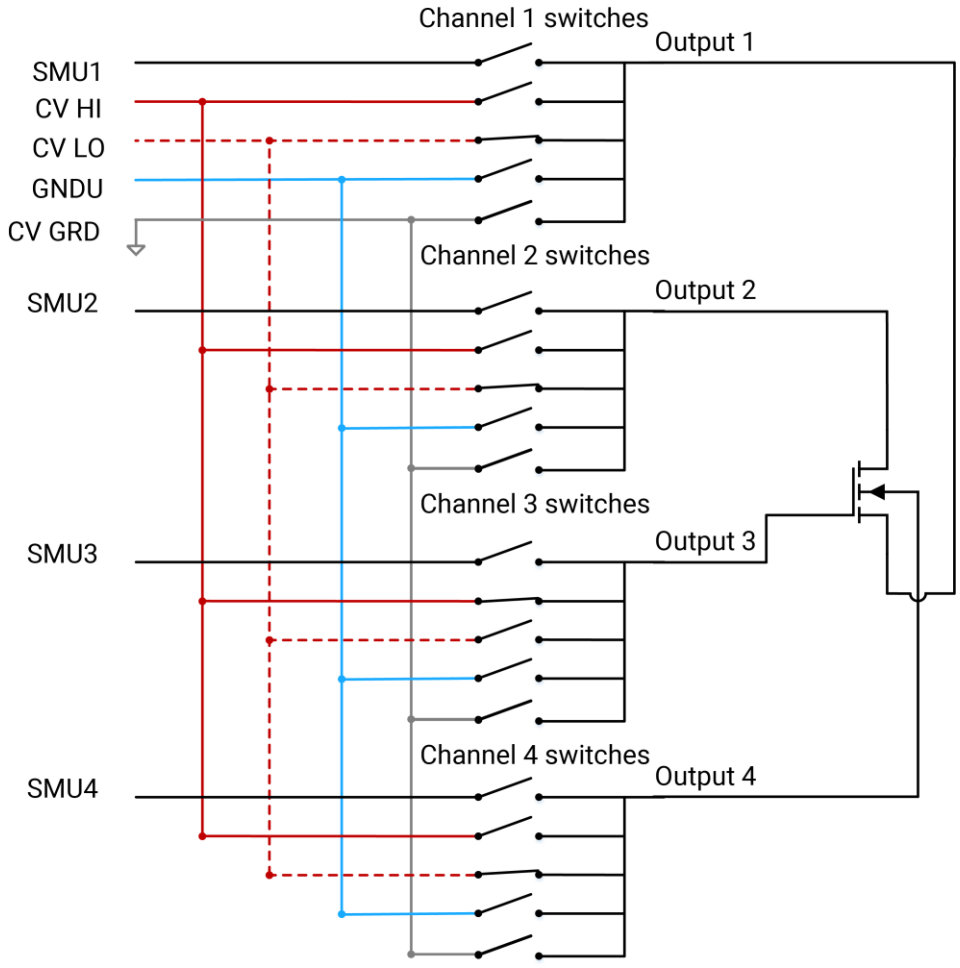
- **Ch1_Mode:** Set Channel 1 to CV LO
- **Ch2_Mode:** Set Channel 2 to CV LO
- **Ch3_Mode:** Set Channel 3 to CV HI
- **Ch4_Mode:** Set Channel 4 to CV LO

Figure 47: Configuration settings for C-V characterization on a 4-terminal device



If using 2-wire sense, connect a single triaxial cable to the force output connector on channels 1, 2, 3, and 4 of the 4200A-CVIV to the device under test. If using 4-wire sense, connect two triaxial cables to the force and sense output connectors of each channel and terminate them together at the device under test. See the following figure for an example of the internal switch configurations and device connections.

Figure 48: 4200A-CVIV connections to a 4-terminal MOSFET device for C-V characterization



Section 6

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.

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

Equipment required

- One 4200A-SCS with the following instruments:
  - Four 4200-SMUs, 4201-SMUs, 4210-SMUs, or 4211-SMUs
  - Four 4200-PAs or 4200A-CVIV-SPTs (two 4200A-CVIV-SPTs are supplied with the 4200A-CVIV)
  - One 4210-CVU or 4215-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-447B 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 connect them to a SMU using triaxial cables. Refer to Install and remove preamplifier and Pass-Thru modules (on page 3-5) for more information on installing and connecting preamplifiers and Pass-Thru modules.

You will also make connections from the CVU to the SMA inputs of the 4200A-CVIV using the CA-447B SMA cables supplied with the CVU.

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

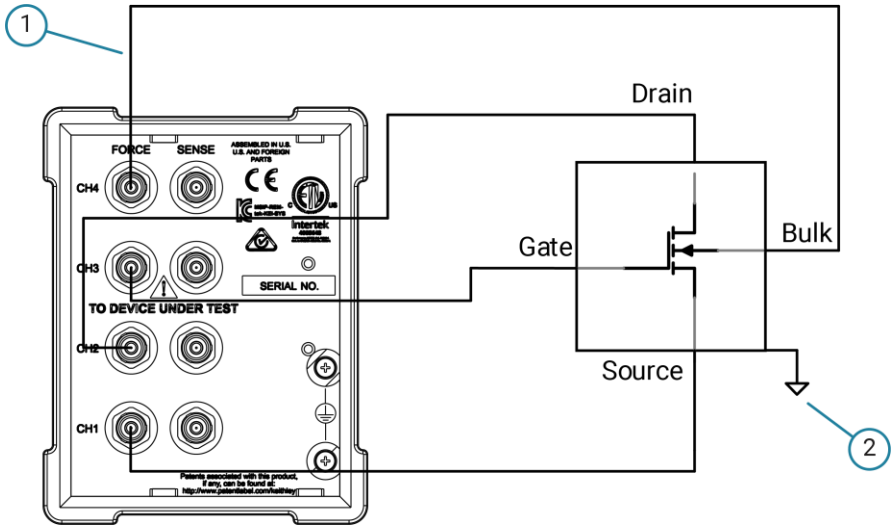
Hazardous voltages may be present on all output and guard terminals. To prevent electrical shock that could cause injury or death, never make or break connections from the instrument while the instrument is powered on. Turn off the equipment from the front panel or disconnect the main power cord from the rear of the 4200A-SCS before handling cables. Putting the equipment into an output-off state does not guarantee that the outputs are powered off if a hardware or software fault occurs.
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 49: Connections from the 4200A-CVIV to MOSFET



1	4200-TRX-0.75 triaxial-to-triaxial cables.
2	MOSFET enclosed in conductive shield connected to FORCE LO.

Set up the measurements in Clarius

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

For this example, you use Clarius 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 collects C-V connection compensation constants for all the 4200A-CVIV channel configurations that include C-V measurements. This step only needs to be performed once for each configuration.

When the project runs tests on the MOSFET, the 4200A-CVIV is configured to connect the SMUs to the MOSFET and produce a Vds-Id family of curves. Then the project re-configures the 4200A-CVIV 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).

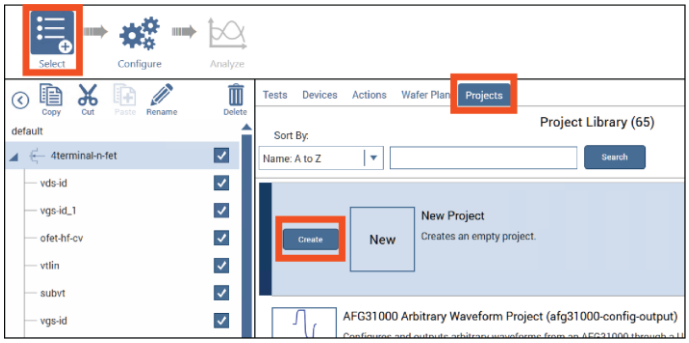
You can use this same general procedure to create tests for other devices and for other applications. You can also configure the project to make multiple I-V measurements and multiple C-V measurements on the same device with different 4200A-CVIV configurations.

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

Figure 50: Create new project



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 51: 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:

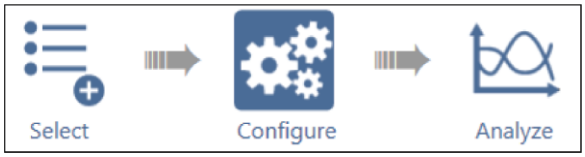
1. Select **Actions**.
2. To find the action, enter `cviv` into the search bar, then select **Search**.
3. Select the `cvu-cviv-comp-collect` action.
4. Select **Add** to copy it to the project tree.

Configure the action

To configure the action:

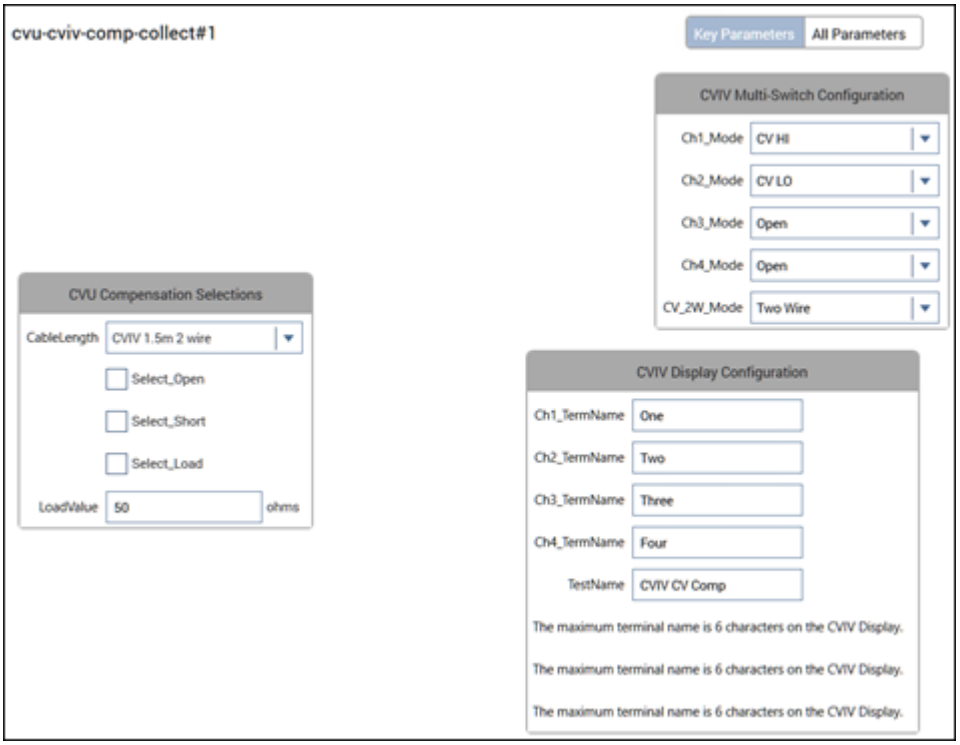
1. Choose **Configure**.

Figure 52: Configure highlighted



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

Figure 53: cvu-cviv-comp-collect Action



3. From the CVIV Multi-Switch Configuration box, set CV_2W_Mode to **Two Wire**.

NOTE

The following step demonstrates how to change the 4200A-CVIV display to see which terminals correspond to which output terminal.

4. In the CVIV Display Configuration box, set Ch3_TermName (Gate) to **CV HI**. Set the remaining channels (1, 2, and 4) to **CV LO**.
5. From the CVU Compensation Selections box, 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 54: Run the action

8. A dialog 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 checkbox 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 checkbox 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.

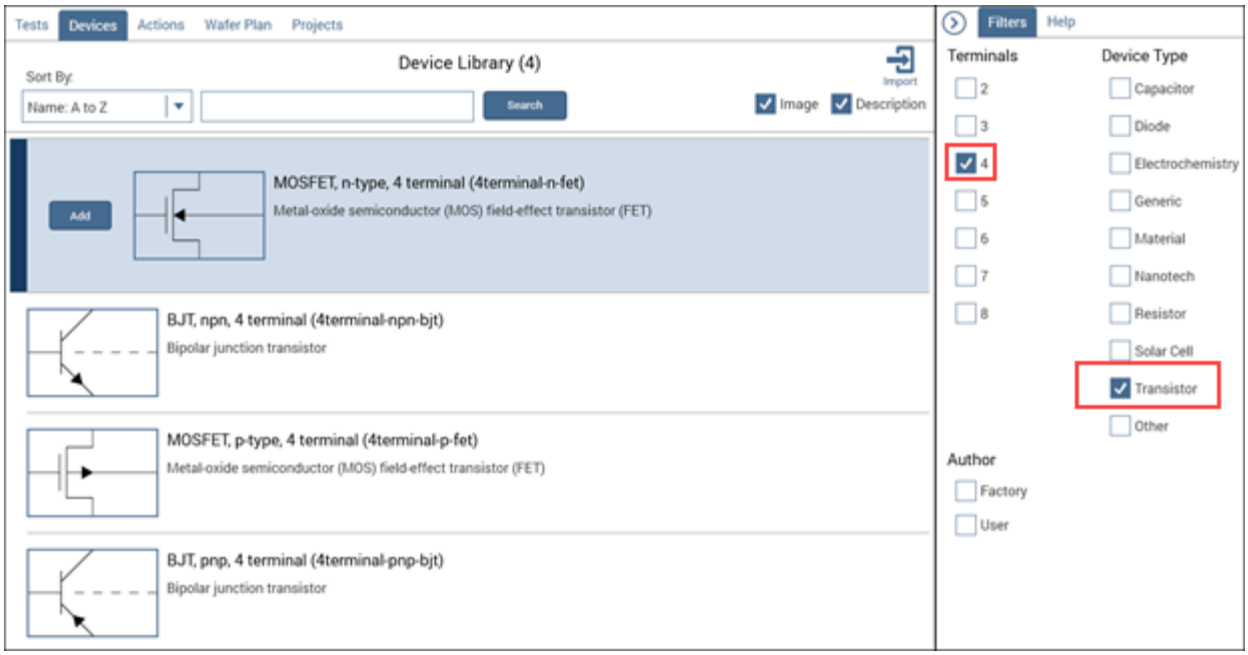
For optimal results, the compensation collection action must be executed for every 4200A-CVIV configuration that is used throughout the test sequence.

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 55: 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:

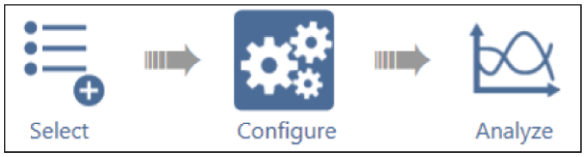
1. Select **Actions**.
2. Type `cviv` into the search bar, then select **Search**.
3. Select the `cviv-configure` action.
4. Select **Add** to copy it to the project tree.

Configure the action

To configure the action:

1. Select **Configure**.

Figure 56: Configure highlighted

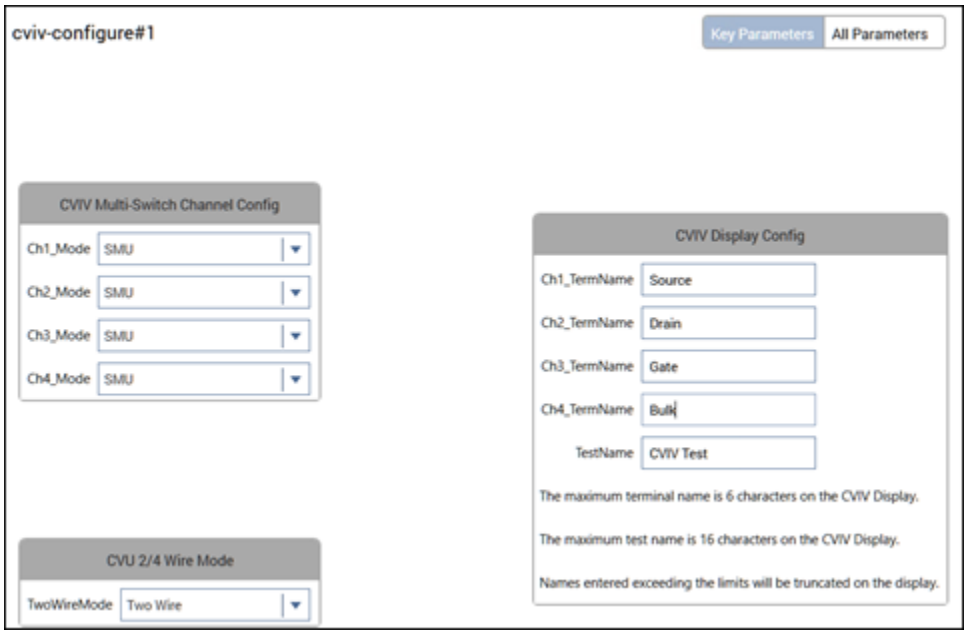


2. In the project tree, select the `cviv-configure` action.
3. In the CVIV Multi-Switch Channel Config box, set all the terminals to **SMU**.
4. In the CVU 2/4 Wire Mode box, set TwoWireMode to **Two Wire**.
5. In the CVIV Display Config box, change the name of each channel to match the corresponding 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.

Figure 57: cviv-configure action for I-V testing

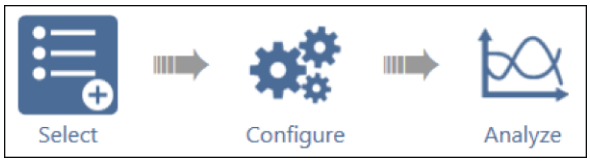


Add a test for making I-V measurements

To add a test:

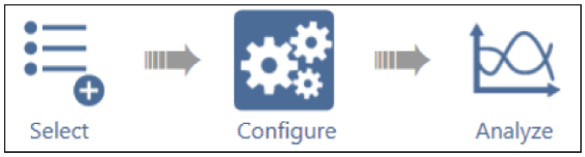
1. Choose **Select**.

Figure 58: Select highlighted



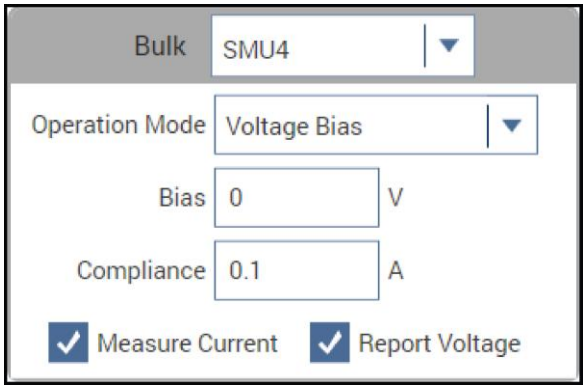
2. Select **Tests**.
3. To find the test, type `vds-id` into the search bar, then select **Search**.
4. Select the `vds-id` test, then select **Add** to copy it to the project tree.
5. Select **Configure**.

Figure 59: 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 60: Bulk channel 4 SMU voltage bias configuration



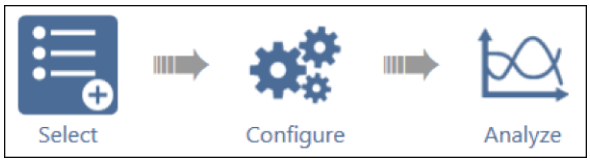
8. Verify that the Bias is set to **0 V** and the Compliance is set to **0.1 A**.

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 61: Select highlighted



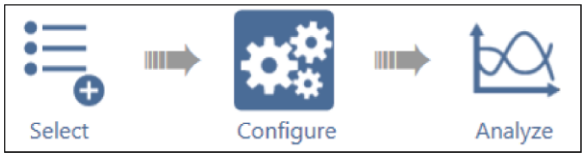
2. Select **Actions**.
3. To find the action, type `cviv` into the search bar, then select **Search**.
4. Select the `cviv-configure a`ction, then select **Add** to copy it to the project tree.

Configure the action

To configure the action:

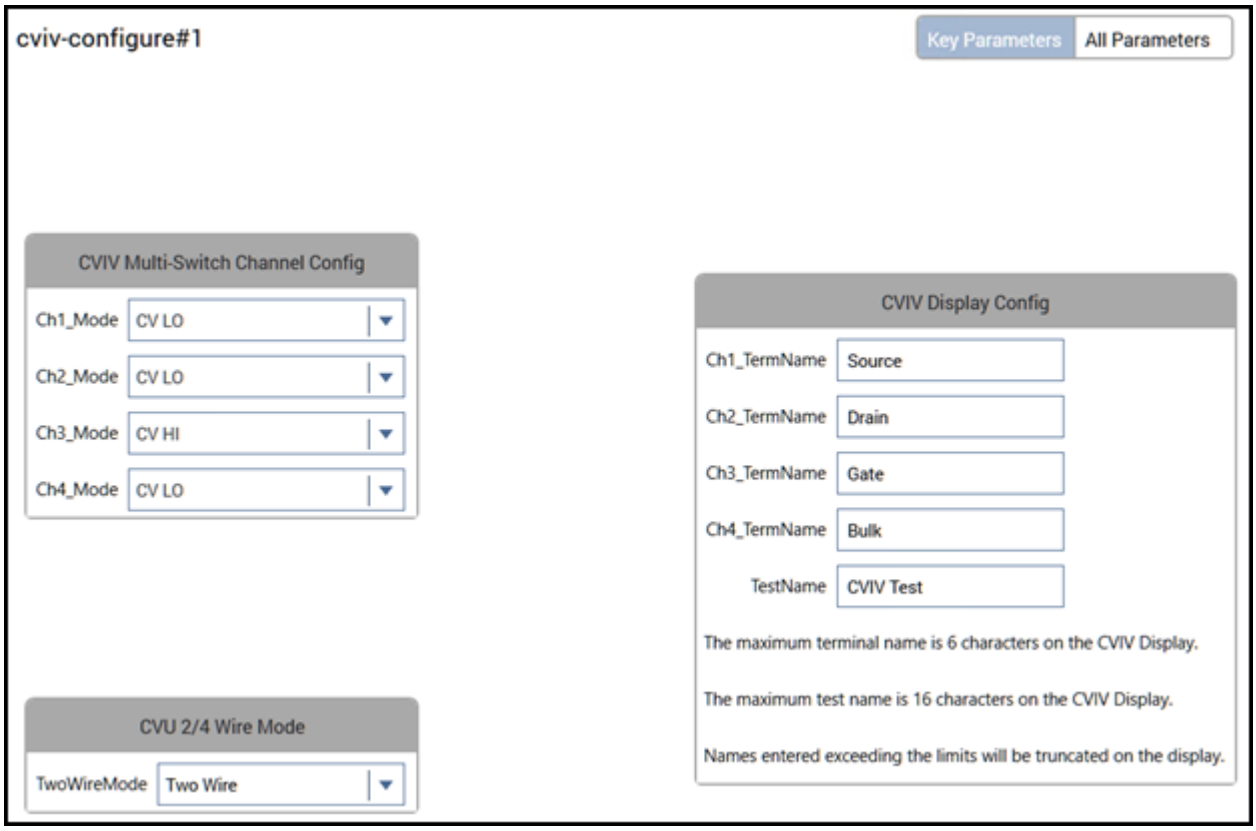
1. Select **Configure**.

Figure 62: Configure highlighted



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

Figure 63: Populated cviv-configure action



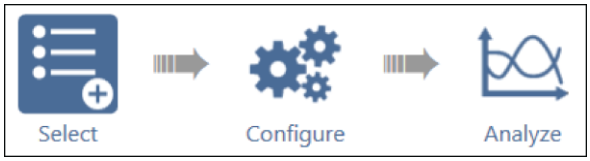
3. In the CVIV Multi-Switch Channel Config box, set Ch3_Mode to **CV HI** and the remaining three terminals to **CV LO**.
4. In the CVU 2/4 Wire Mode box, set TwoWireMode to **Two Wire.**
5. In the CVIV Display Config box, change the name of each channel to match the corresponding MOSFET terminal it is connected to.

Add a test for making C-V measurements

To add a test:

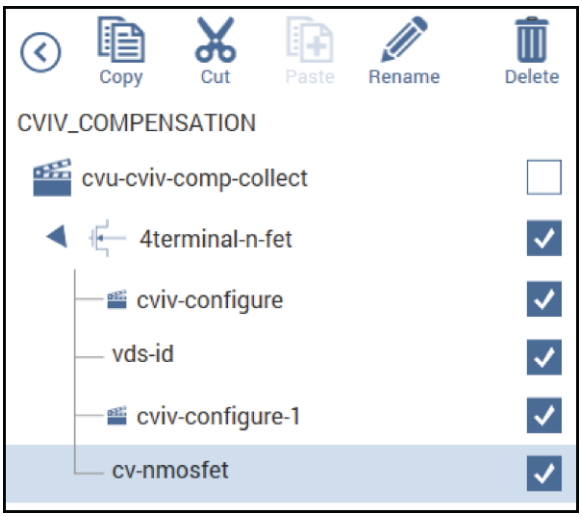
1. Choose **Select**.

Figure 64: Select highlighted



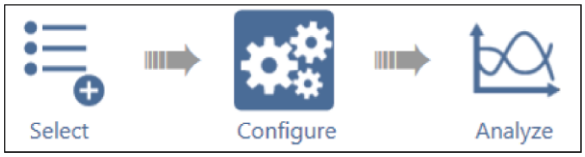
2. Select **Tests**.
3. Type `cv-nmosfet` into the search bar, then select **Search**.
4. Select the `cv-nmosfet` test, then select **Add** to copy it to the project tree.

Figure 65: Project tree before enabling open compensation



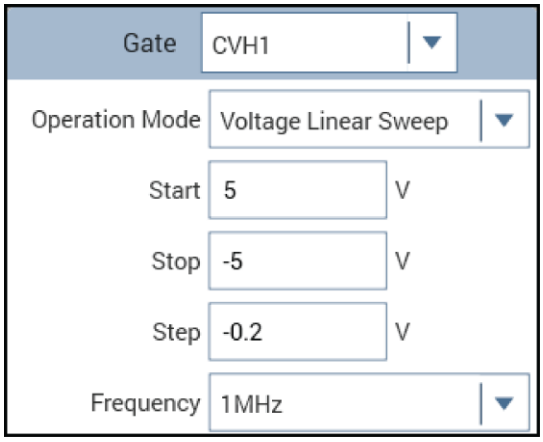
5. Select **Configure** to configure the test.

Figure 66: Configure highlighted



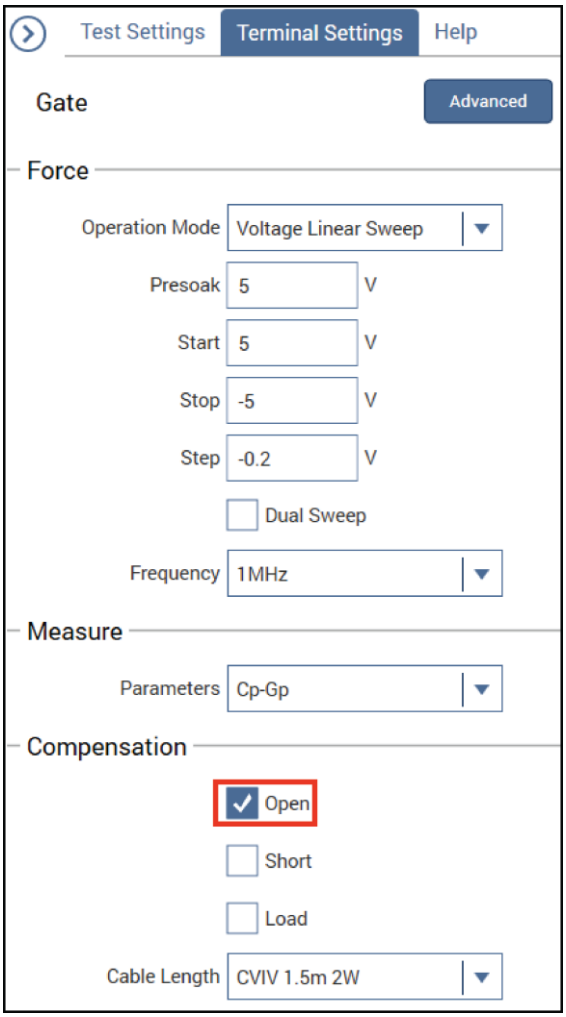
6. Select the **Gate** terminal.

Figure 67: 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 68: Terminal Settings panel with Open compensation selected

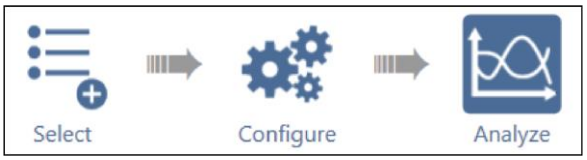


Run the project and review the results

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 actions and tests run sequentially. The 4200A-CVIV is configured by the `cviv-configure` action.
3. Select **Analyze** to view the results.

Figure 69: 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 7

Maintenance

In this section:

Introduction

The information in this section describes routine maintenance of the 4200A-CVIV instrument.

Cleaning the display

If you need to clean the front-PAnel LCD touchscreen display, use a soft dry cloth.

CAUTION

Do not use liquids to clean the display.

Upgrade the instrument firmware

Keithley releases periodic firmware updates for the 4200A-CVIV. These upgrades are included with each new software build of the Clarius+ software suite. To upgrade the firmware, run the 4200A-SCS Firmware Upgrade Utility on your 4200A-SCS Parameter Analyzer.

NOTE

If the Clarius+ software release includes updates for other 4200A-SCS instruments, such as SMU cards, those instruments are also updated when you run the 4200A-SCS Firmware Upgrade application. Refer to the *Clarius+ Software Release Notes and Installation Instructions* for detail.

CAUTION

It is strongly recommended that you connect the 4200A-SCS to an uninterruptible power supply during the firmware upgrade process. If power is lost during the firmware upgrade, the instruments may no longer be functional and will require factory service.

CAUTION

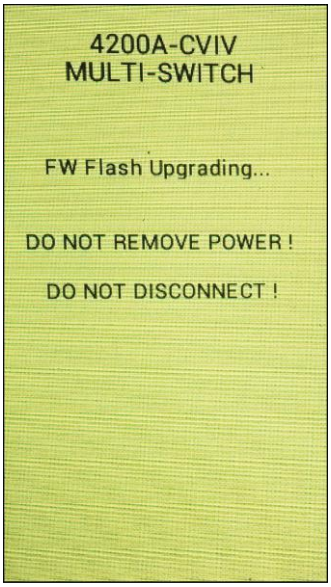
Do not remove instrument power or disconnect any cables from the 4200A-CVIV during the firmware upgrade.

To upgrade the instrument firmware:

1. Make sure that the 4200A-CVIV is powered on and connected to the 4200A-SCS Parameter Analyzer with the included USB cable.
2. From the Windows Start menu, type **Firmware Upgrade** in the search box. The results include the Firmware Upgrade utility.
3. Press **<Enter>** to open the application. It displays the list of installed instruments.
4. Check the status of each instrument.
5. If an upgrade is needed, select **Upgrade** to begin.

A progress bar is displayed as the firmware is upgraded. When the upgrade is complete, a PASS or FAIL result is displayed next to your 4200A-CVIV in the list of instruments.

Figure 70: 4200A-CVIV firmware upgrade screen



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