

Model 8020 High Power Interface Panel

User's Manual

8020-900-01 Rev. D June 2022



8020-900-01D

Model 8020
High Power Interface Panel
User's Manual

© 2022, Keithley Instruments, LLC

Cleveland, Ohio, U.S.A.

All rights reserved.

Any unauthorized reproduction, photocopy, or use of the information herein, in whole or in part, without the prior written approval of Keithley Instruments, LLC, is strictly prohibited.

These are the original instructions in English.

All Keithley Instruments product names are trademarks or registered trademarks of Keithley Instruments, LLC. Other brand names are trademarks or registered trademarks of their respective holders.

The Lua 5.0 software and associated documentation files are copyright © 1994 - 2015, Lua.org, PUC-Rio. You can access terms of license for the Lua software and associated documentation at the Lua licensing site (<https://www.lua.org/license.html>).

Microsoft, Visual C++, Excel, and Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Document number: 8020-900-01 Rev. D June 2022

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

Model 8020 Welcome	1-1
Welcome	1-1
Organization of manual sections	1-2
Contact information	1-2
Unpacking and inspection	1-2
What you should have received	1-3
Configure and install the 8020	2-1
Locate and mount the Model 8020	2-1
Connect to protective earth	2-2
Connect the instrument and output interlocks	2-3
Connect a single 8020 unit	2-6
Connect two 8020 units	2-7
Connect multiple 8020 units	2-9
Install output cards	2-11
Connect instruments to the 8020	3-1
Instrument panel overview	3-1
Model 8020-CVU option	3-3
Device connections panel overview	3-4
Connections to the instrument panel	3-6
Model 2611 and Model 2612 connection notes	3-8
Model 2635 and Model 2636 connection notes	3-8
Model 2651A connections	3-8
Model 4200A-SCS connections	3-9
Use the 8020 for dc tests	4-1
Overview	4-1
Channel description	4-1
Ensuring continuity in the measurement channel	4-3
How to insert a series resistor in the 8020	4-5
Connecting the high current channel	4-6
Use connector cards to interface to the device	4-7
Connect to common LO for applications > 1.5 A dc	4-7
Overcurrent protection	4-8
Overvoltage protection circuitry	4-9

Use the 8020 for dc and HV C-V tests.....	5-1
Model 8020-CVU bias tee overview.....	5-1
Bias tee theory overview.....	5-2
Bias tee modes	5-3
I-V mode.....	5-5
C-V mode.....	5-5
C-V Hi I mode.....	5-6
AC guard with dc bias mode	5-7
HV C-V measurement software	5-8
Configure the 8020 for HV C-V measurements	5-8
Discharge bias tee and system capacitance	5-10
Use the 8020-DP to discharge system capacitance	5-11
 Model 8020 Applications	 6-1
Device connections	6-1
Equipment options (all examples).....	6-2
Software	6-3
2-terminal device connections for I-V measurements.....	6-3
Use the Model 2657A.....	6-4
Use the Series 2600/2600B and 42x0-SMU instruments	6-5
Use the Model 2651A.....	6-6
3-terminal device connections for I-V measurements.....	6-6
Off-state characterization of a power MOSFET using a Model 2657A and Series 2600B or 42x0-SMU instruments (up to 3 kV).....	6-7
Off-state characterization of a power MOSFET using a Series 2600B or 42x0-SMU instruments (up to 200 V).....	6-8
On-state characterization of a power MOSFET using the Model 2651A and Series 2600B or 42x0-SMU instruments (up to 100 A pulse).....	6-9
On-state characterization of a power MOSFET using two Series 2600B or 42x0-SMU instruments (up to 10 A pulse).....	6-11
2-terminal device connections for C-V measurements	6-12
Open and short compensation	6-14
3-terminal device connections for C-V measurements	6-15
Overview and theory	6-15
Instrument connections for power MOSFET capacitance measurements.....	6-17
Device connections for power MOSFET capacitance measurements.....	6-28
Open and short compensation	6-29
 Measurement considerations	 7-1
Introduction	7-1
2-wire (local) vs. 4-wire (remote)	7-1
Optimize cables and connections for low current dc measurements	7-3
Suppress device oscillations for dc and pulsed dc measurements	7-4
Optimize connections for high current dc pulses	7-5

Optimize cables and connections for high-voltage C-V measurements	7-6
Frequently asked questions.....	8-1
Why does my instrument generate an interlock error	8-1
Why are my dc current measurements unstable?	8-2
Can I break the parallel connection of the high-current SMUs?	8-2
Can I operate the 8020 with the top cover off?	8-3
Why is the pulse rising edge so slow for my SMU?	8-3
Why don't I get a signal at the output? My measurements appear to be an open circuit.....	8-4
Why are my contact check measurements failing when the SMUs are connected to the high voltage and 200 V channels?	8-4
Why is the high current LO terminal not connected to the Common LO terminal of the 8020?	8-4

Model 8020 Welcome

In this section:

Welcome	1-1
Organization of manual sections	1-2
Contact information	1-2
Unpacking and inspection	1-2

Welcome

Thank you for choosing a Keithley Instruments product. The Model 8020 High Power Interface Panel provides a highly accurate, flexible, and easy to use interface between the Keithley Instruments SourceMeter® instruments and a variety of semiconductor probe stations or custom test fixtures.

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

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

Additionally, the Model 8020 High Power Interface Panel offers the following:

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

Organization of manual sections

The first part of this user manual provides general information that helps you set up, install, and make connections to the high-power interface panel.

The sections after the general sections provide information that helps you use the Model 8020 with specific SourceMeter Instruments. This information includes applications that can help you set up your tests.

The last part of the user manual provides maintenance and troubleshooting information. It also provides references to additional resources.

Bookmarks for each section of this manual are provided in the PDF. The manual sections are also listed in the table of contents located at the beginning of the manual.

For more information about bookmarks, see Adobe® Acrobat® or Reader® help.

Contact information

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

Unpacking and inspection

Each Model 8020 was carefully inspected electrically and mechanically before shipment.

After you unpack all items from the shipping carton, check for any obvious signs of physical damage that may have occurred during transit. Report any damage to the shipping agent immediately. Save the original packing carton for possible future shipment.

See the following graphic and accompanying table to verify that you have received all accessories and documentation.

NOTE

Depending on your system configuration, your shipping carton may contain additional accessories and documentation.

What you should have received

Figure 1: Hardware accessories



Model number	Part number	Quantity shipped	Description
8020-SNS-2	174650070x	2	8 Pin to 2 Pin Phoenix Cables, 2m
CS-1195-2	CS-1195-2	1	2-Pin Phoenix Connector for 2651A Sense
8020-RES-KIT	8020-RES-KIT	1*	HV-Rated Resistors
CA-568-120	CA-568-120	2	Safety Earth Ground Cable Assembly
8020-ILC-UNT	174660101x	1	Unterminated Interlock Cable
8020-ILC-S	131933400x	1	Interlock Expansion Termination Plug
MC-1059	335346500x	1	Model 8020 cable labels
N/A	N/A	1	Safety Precautions (not shown)
N/A	N/A	1	Environmental Disclosure Report (Instruments / Systems) (not shown)
N/A	N/A	1	Statement of Compliance (not shown)
N/A	N/A	1	2-Pin Female (Plug Housing) Termination Block Information Sheet (not shown)
N/A	N/A	1	Interlock Expansion Termination Plug Information Sheet (not shown)
N/A	N/A	1	Unterminated Interlock Cable Information Sheet (not shown)
N/A	N/A	1	Phoenix Connector for 2651A Sense Information Sheet (not shown)
N/A	N/A	1	HV-Rated Resistors Information Sheet (not shown)

* The 8020-RES-KIT contains 28 resistors; four each of seven various values. See enclosed HV-Rated Resistors document.

The 8020-CVU bias tee option ships with additional accessories. See the below graphic and accompanying table.

Figure 2: 8020-CVU bias tee option ship kit



Model number	Part number	Quantity shipped	Description
8020-DP	090008800	1	Model 8020-DP High-Voltage Discharge Probe
131936100	131936100	9	SMA (M) to SMB (M) Adapter
131936200	131936200	4	SMA (F) to SMB (F) Adapter
335343600	335343600	1	High Capacitance Warning Label
CA-406B	CA-406B	1	33 cm (13in.) SMA (M) to SMA (M) connector cable
CS-1391	CS-1391	2	SMA (F) to (M) to (F) Tee Adapter
N/A	N/A	1	Model 8020-DP High-Voltage Discharge Probe Information Sheet (not shown)

Configure and install the 8020

In this section:

Locate and mount the Model 8020	2-1
Connect to protective earth	2-2
Connect the instrument and output interlocks	2-3
Connect a single 8020 unit	2-6
Connect two 8020 units	2-7
Connect multiple 8020 units	2-9
Install output cards	2-11

Locate and mount the Model 8020

The 8020 is designed to be installed on a probe station or as close as possible to a probe station to ensure optimal C-V and dc measurements. See the below figures for unit dimensions and mounting specifications.

The fully populated weight of the 8020 is 5.7 kg (12.5 lbs.).

Figure 3: Model 8020 mounting specifications, instrument and device panels

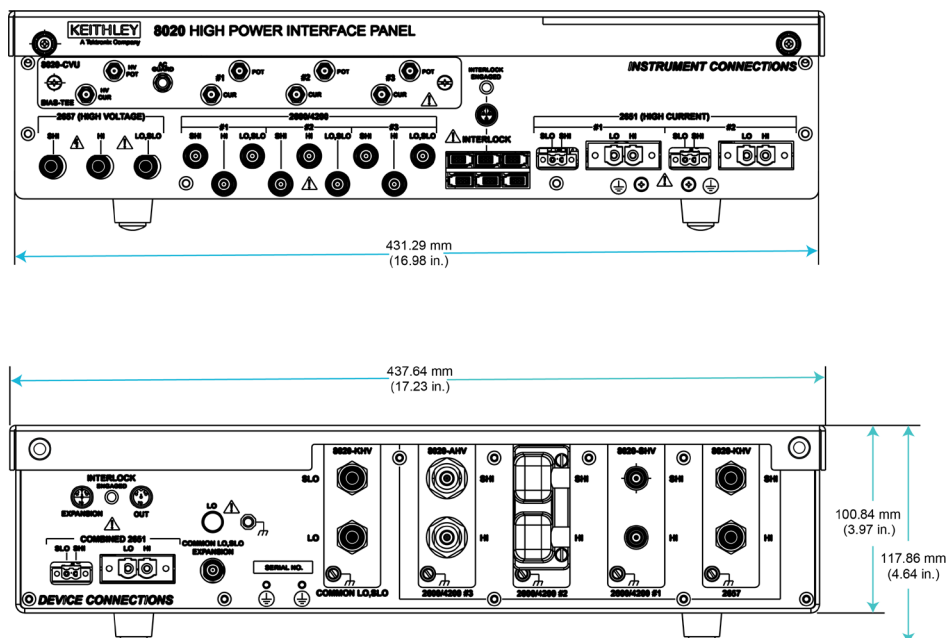
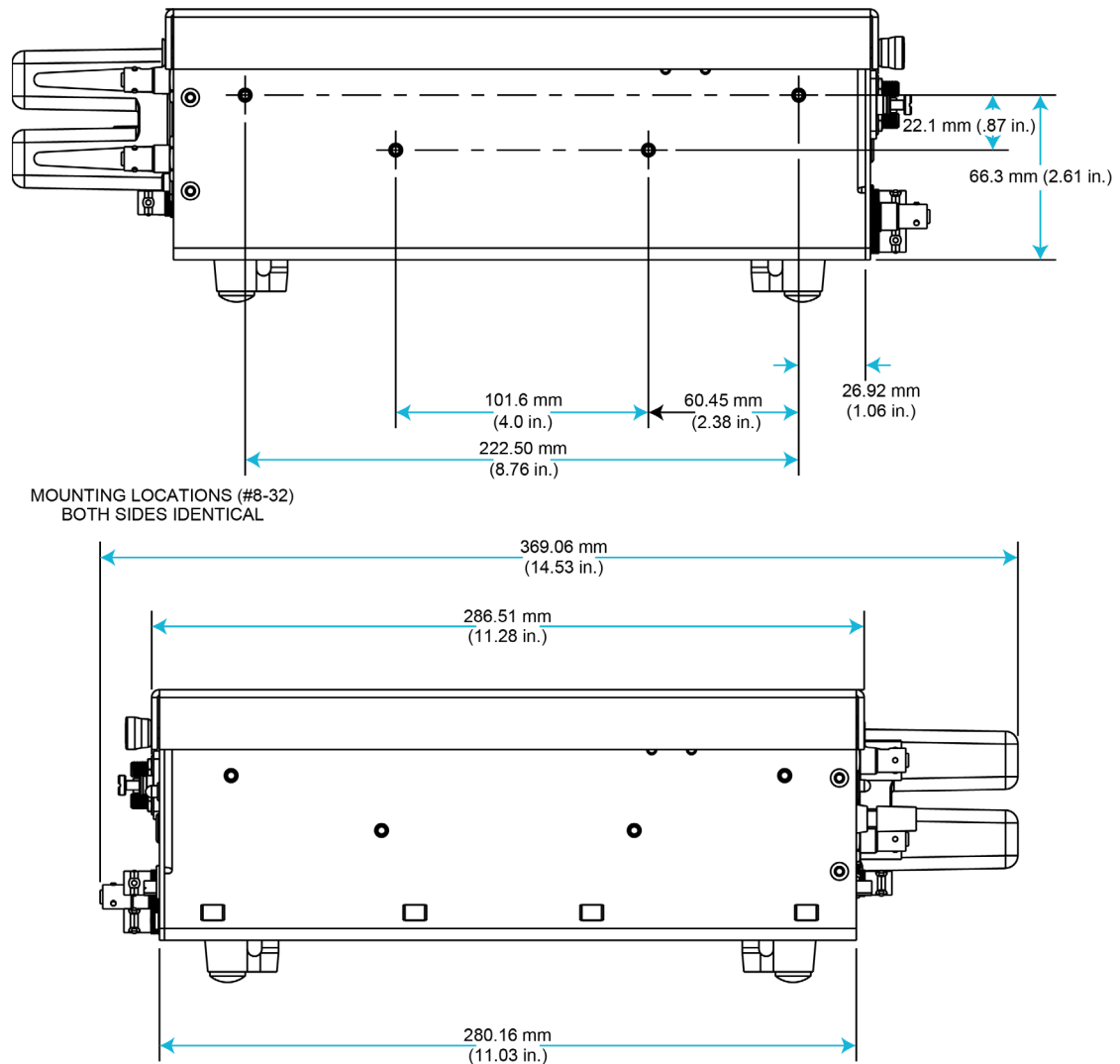


Figure 4: Model 8020 mounting specifications, unit sides

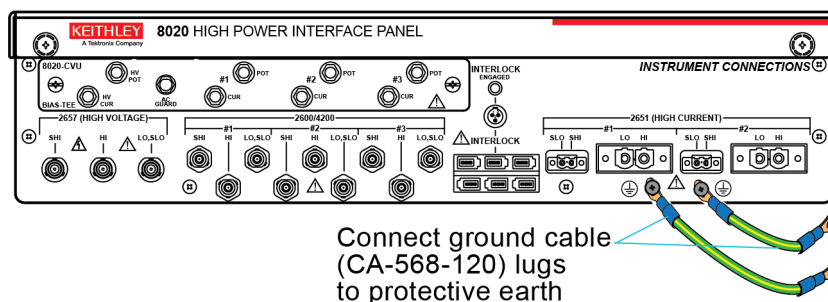
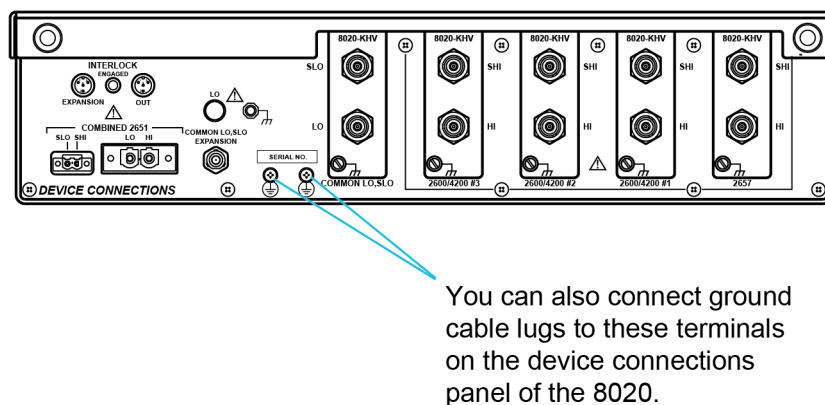
Connect to protective earth

⚠ WARNING

The 8020 must be connected to protective earth (safety ground) using both supplied green-yellow ground cables (Model CA-568-120). Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

To connect to protective earth:

1. Connect one lugged end of both supplied Model CA-568-120 ground cables to any combination of the four screw terminals on either panel side of the 8020. See the below two figures.
2. Connect the other two lugged ends of the ground cables to protective earth (safety ground).

Figure 5: Instrument side connections to protective earth**Figure 6: Device side protective earth terminals**

Connect the instrument and output interlocks

The 8020 has an interlock system to control the interlock of Series 2600/2600B and 4200A-SCS instruments. On the instrument connections side of the 8020, there are six 26xx interlock 3-pin connectors and one circular 3-pin connector for the 4200A interlock. Refer the following figure.

Use Keithley CA-558 and 236-ILC-3 interlock cable assemblies to connect to Series 2600/2600B and 4200A-SCS instruments. For proper interlock functionality, any instruments connected to the interlock must be powered on or must be disconnected from the interlock.

NOTE

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

Figure 7: 8020 Interlock Expansion pinout connectors



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

The 8020 also has internal interlock circuitry to detect when the top cover of the 8020 is installed or not. When the 8020 top cover is installed, the external interlock system controls the state of the interlock. However, when the 8020 top cover is removed, the interlock is disengaged regardless of the state of the external interlock.

WARNING

An interlock connection is required when a 2657A Series instrument is connected and a Series 2600/2600B and 4200-SMU is used to make measurements beyond 20 V. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

On the device connections side of the 8020 there are two circular 4-pin connectors. The OUT connector is used for the system interlock, and the EXPANSION connector is used for extending interlock functionality in a test configuration with two or more 8020s. The EXPANSION connector is also used with the supplied 8020-ILC-S Interlock Expansion Termination Plug when the test configuration contains only one 8020. Refer the following figure.

Figure 8: 8020 device side interlock connections

The 8020 interlock OUT connector on the device connections side of the unit is designed for use with the supplied 8020-ILC-UNT interlock to an unterminated cable. The interlock enables the high-voltage outputs of the connected instruments when the normally-open switch at the DUT access point is closed.

The 8020 interlock is asserted only when:

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

When the 8020 interlock is asserted, LEDs on the instrument connections and device panel connections of the 8020 are illuminated.

NOTE

If your 8020 is part of a Keithley Instruments S500 system, it is likely that the interlock connections are customized to meet the requirements for the system. If you have questions about the 8020 interlock you should contact your local field applications engineer, field support engineer or the factory to get the information for your specific system. You can also go to [tek.com/support](https://www.tek.com/support) to find technical support information.

The pinout diagrams for the EXPANSION (Interlock Expansion connector) and OUT (Interlock Out connector) are shown in the following figures.

NOTE

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

Figure 9: 8020 Interlock Expansion rear panel pinouts

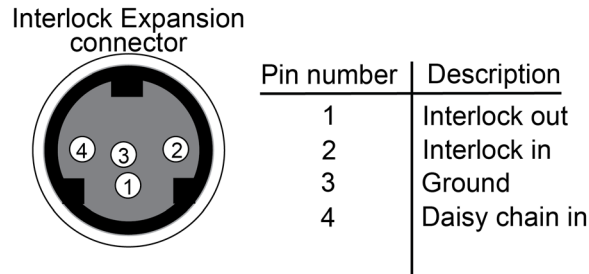
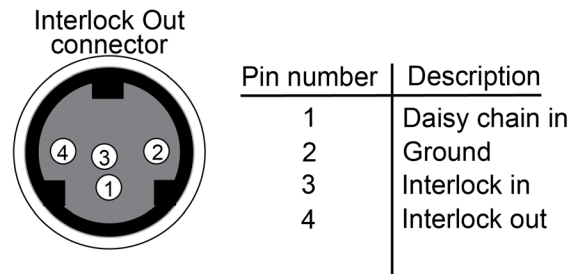


Figure 10: 8020 Interlock Out rear panel pinouts



⚠ WARNING

An interlock connection is required when a 2657A Series instrument is connected and a Series 2600/2600B and 4200-SMU is used to make measurements beyond 20 V. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

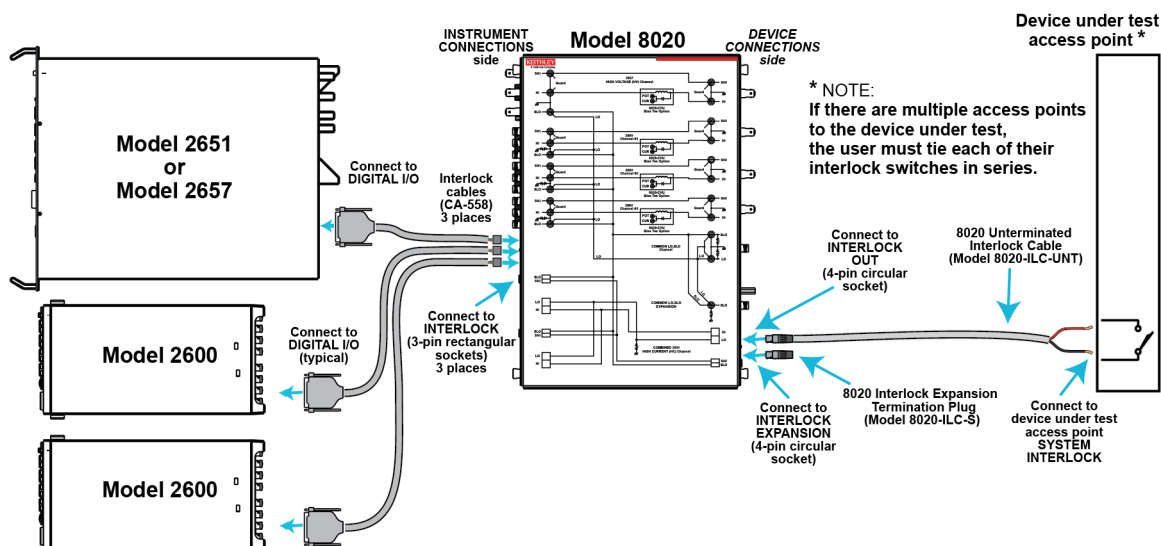
Connect a single 8020 unit

NOTE

For a test configuration using a single 8020, the 8020-ILC-S Interlock Expansion Termination Plug must be connected to the EXPANSION jack to enable interlock functionality. See the below graphic.

Figure 11: 8020 interlock plug installed

Instrument-side and device-side connections for a single 8020 are shown in the below figure.

Figure 12: 8020 interlock connections (single unit)

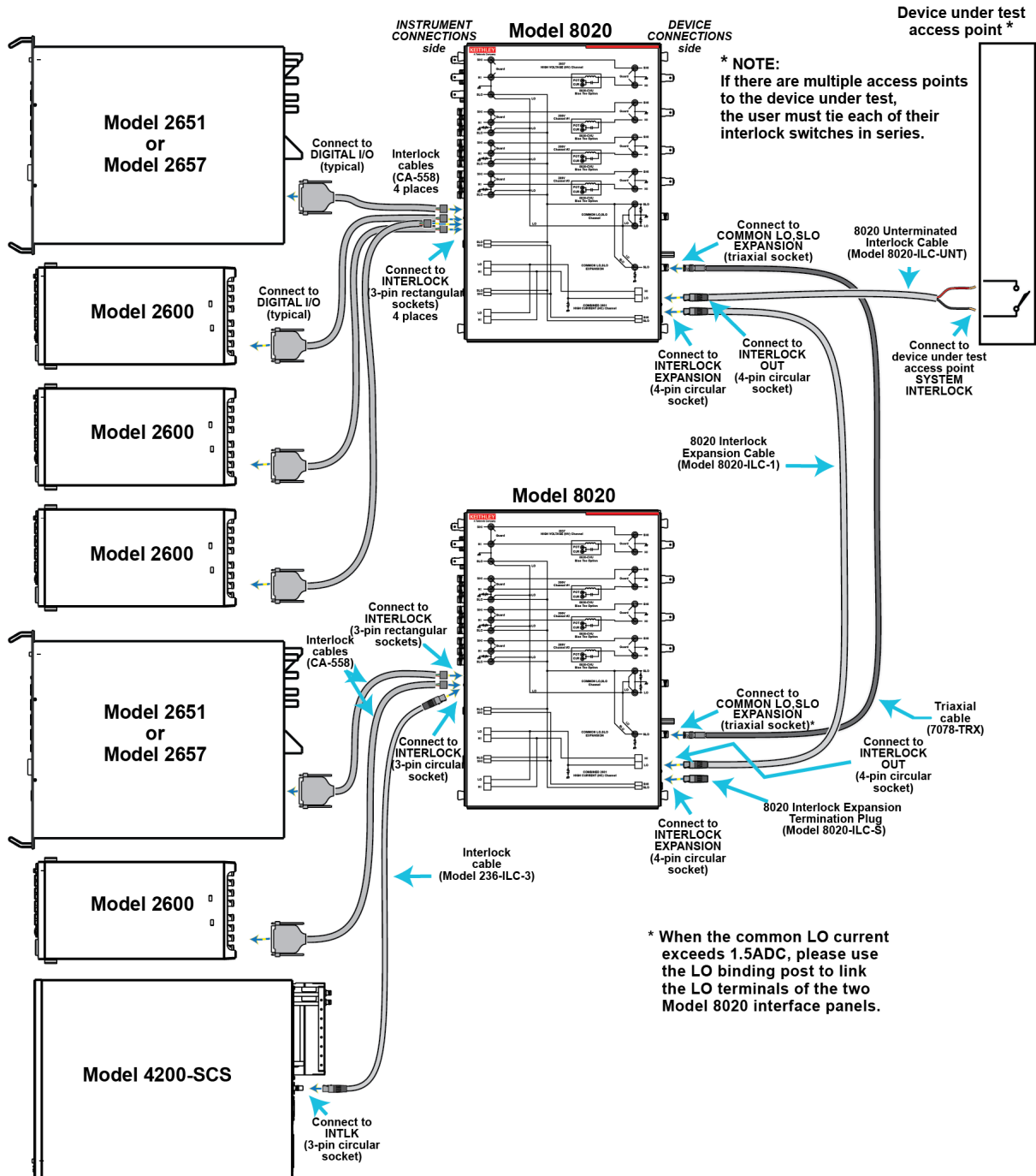
Connect two 8020 units

The 8020 High Power Interface Panel can be connected with another 8020 unit when you have a need for more than one Model 2657A in the test configuration or more than three Series 2600/2600B or 4200-SMUs. The 8020 allows you to expand the common LO/SLO reference signal as well as the interlock system to a second 8020. This ensures that the instruments have a common LO reference and are triggered from a common interlock.

Both the common LO/SLO signals and the interlock signal of the 8020 can be daisy-chained between units. Expansion is via the common SLO/LO standard triaxial, interlock OUT, and EXPANSION connectors on the device side of the 8020 units. The system interlock and either of the 8020 units' top cover interlocks will enable or disable the interlock feature for all connected instruments.

The following example diagram uses two 8020s. One additional triaxial cable is used in this instance. Additionally, note that the 8020-ILC-S Interlock Expansion Termination Plug must be connected to the interlock EXPANSION connector of the second unit.

Figure 13: 8020 interlock connections (2 units)



Connect multiple 8020 units

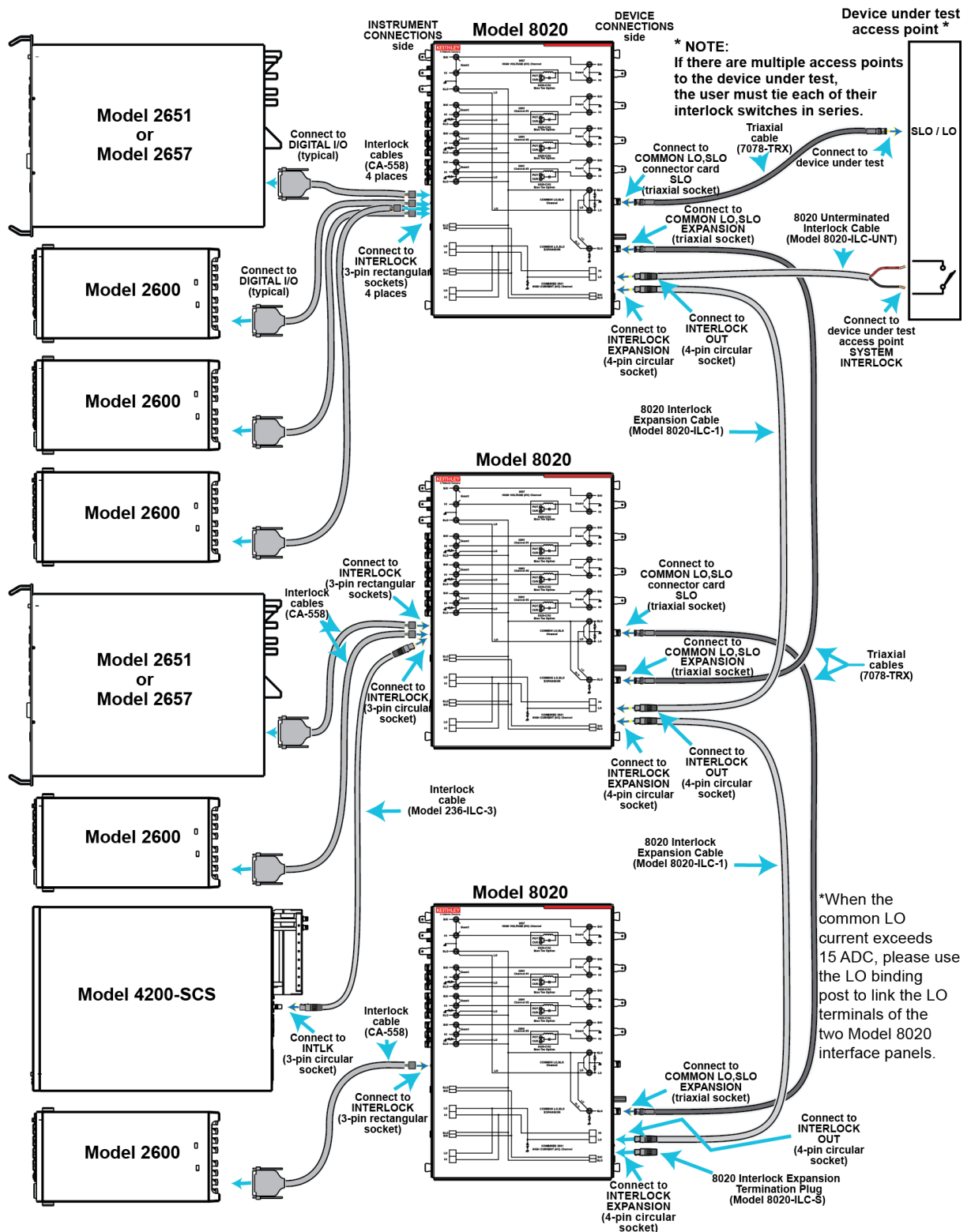
More than two 8020 units may be connected so that any of the connected units' interlocks will enable or disable the interlock feature for all connected instruments. The common LO/SLO may also be maintained with this configuration, as well. The connections are the same as those used for two 8020 units, with two differences:

- An 8020-1-ILC expansion cable connects the first unit in the series' interlock EXPANSION connector to the interlock OUT of the next 8020. This connection is repeated for all successive 8020 units.
- The common LO/SLO signal is maintained by connecting the second unit's SLO/LO channel to the next unit's common LO/SLO expansion. This connection is repeated for all successive 8020 units. When the common LO current exceeds 1.5 A dc, please use the LO binding post to link the LO terminals of the 8020 interface panels. See [Connect to common LO for applications >1.5 A dc](#) (on page 4-7).

The interlock EXPANSION connector of the final 8020 unit must be terminated with the 8020-ILC-S Interlock Expansion Termination Plug.

See the following diagram for a test array using three 8020 units.

Figure 14: 8020 interlock connections (multiple units)



Install output cards

The following optional connector cards are available for use with the 8020:

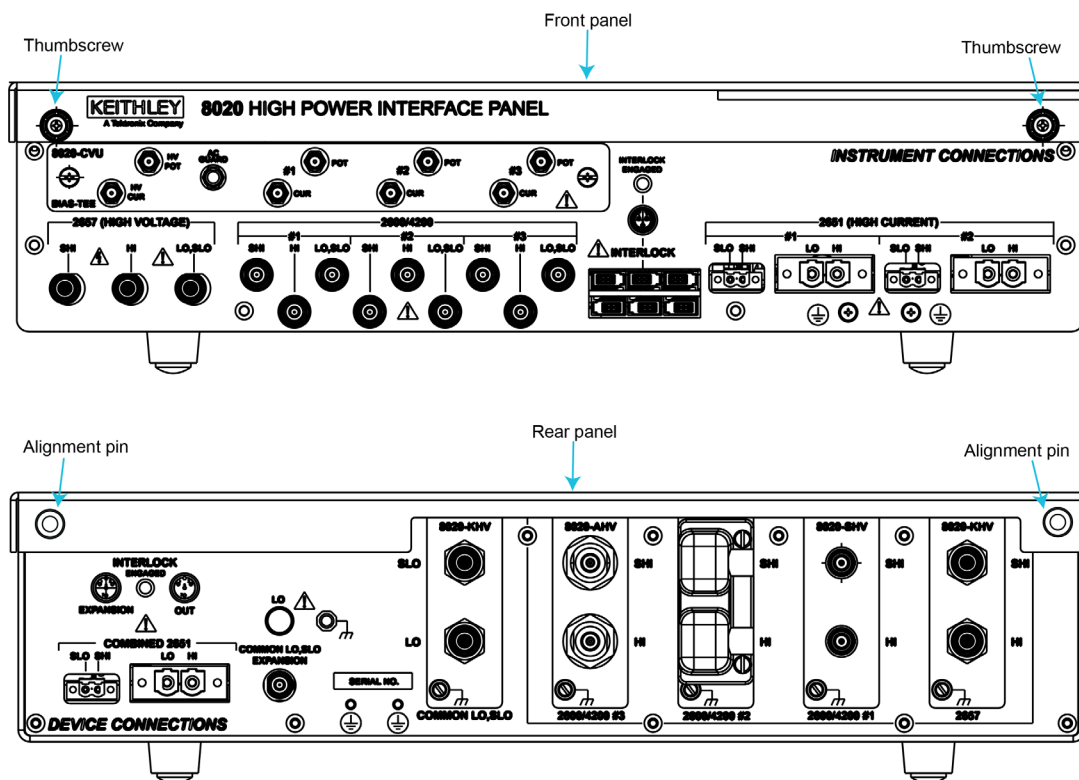
- 8020-AHV: Kelvin Agilent HV Triaxial
- 8020-SHV: Kelvin SHV
- 8020-KHV: Kelvin Keithley HV Triaxial
- 8020-STC: Kelvin Standard Triaxial

Installation of the connector cards requires removal of the 8020's top cover and output module guide retainer. Refer to the following graphics and instructions below.

To install output cards:

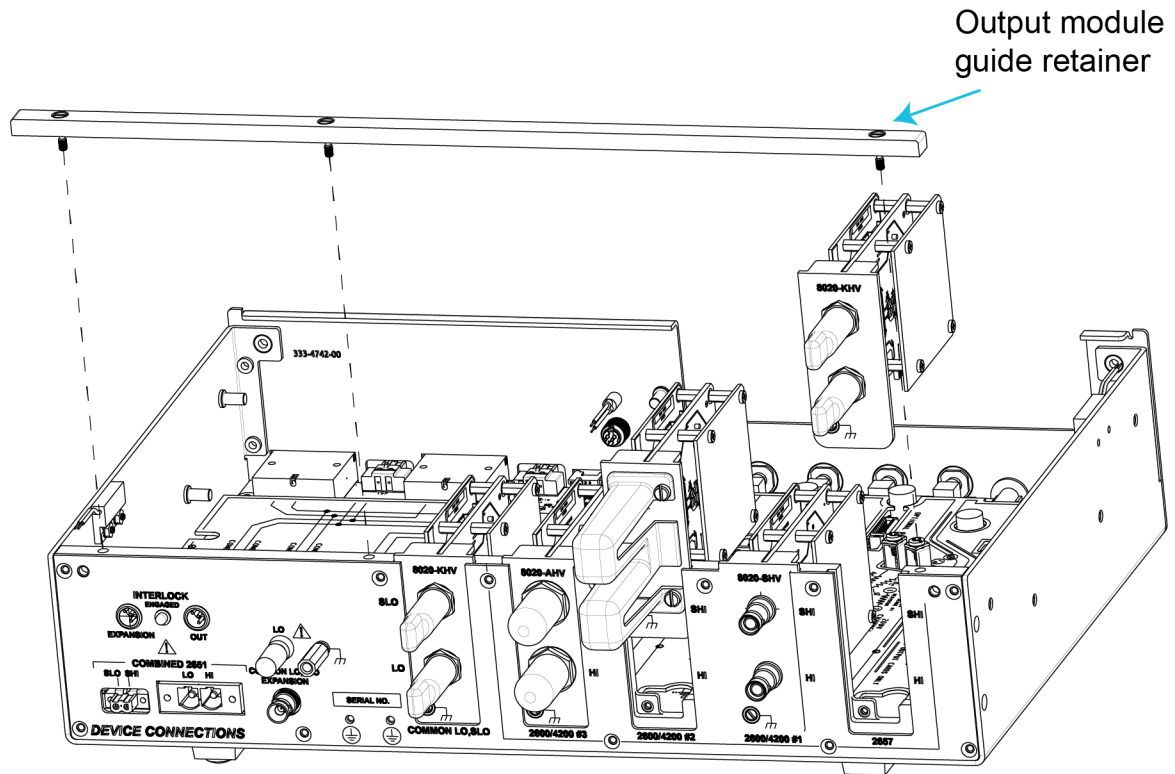
1. Remove the top cover of the 8020 by loosening the two thumbscrews, lift the lid slightly and slide the back over the alignment pins (refer to the following graphic).

Figure 15: Model 8020 thumbscrews and alignment pins location



- Using a slot screwdriver, loosen the three screws on the output module guide retainer and set it aside.

Figure 16: Model 8020 output card installation



- Slide the output card into a vacant card slot as shown in the above figure. Make sure that the captive screw on the card is backed-out far enough so that it does not catch on the output card side rail.

NOTE

While an HV card will fit in any available card slot, the 8020-STC card will not fit in the HV output channel (right-most card slot on the device connections side of the unit). Only output cards with a maximum voltage rating of 3 kV or higher can be used in the HV output channel.

- Using a slot screwdriver, tighten the screw at the lower-left corner of the output card.
- Place the output module guide retainer back onto the unit chassis and tighten the three screws.
- Reinstall the top cover by sliding the lid over the alignment pins and tighten the thumbscrews.

Connect instruments to the 8020

In this section:

Instrument panel overview	3-1
Model 8020-CVU option	3-3
Device connections panel overview	3-4
Connections to the instrument panel	3-6

Instrument panel overview

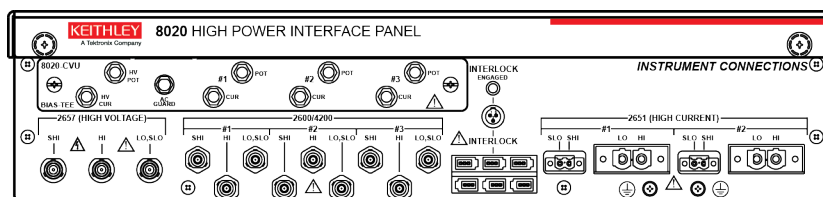
⚠ WARNING

The input/output terminals of the 8020 are rated for connection to circuits rated Installation Category I only, with transients rated less than 1500 V peak above the rated input. Do not connect the 8020 terminals to CAT II, CAT III, or CAT IV circuits. Connection of the terminals to circuits higher than CAT I can cause damage to the equipment or expose the operator to hazardous voltage. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

Instrument connections are made to the instrument panel of the 8020.

The instrument panel of the 8020 (with 8020-CVU option installed) is shown below. Descriptions of the connections are provided after the graphic.

Figure 17: Model 8020 Instrument Panel, 8020-CVU option installed

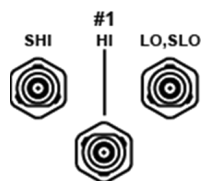




The Model 2657A (high-voltage) connectors provide sense HI, HI, LO, and sense LO input connections for the Model 2657A instruments.

Connections are as follows:

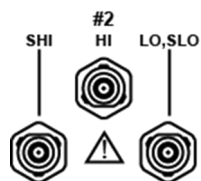
- SHI = Sense HI
- HI = HI
- LO, SLO = LO, sense LO



The Series 2600/2600B and Model 4200A #1 connectors provide sense HI, HI, LO, and sense LO input connections for the Series 2600/2600B or 4200A instruments. These connections are intended for use with 200 V-compatible 2600/2600B or 4200A Series instruments.

Connections are as follows:

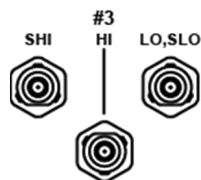
- SHI = Sense HI
- HI = HI
- LO, SLO = LO, sense LO



The Series 2600/2600B and Model 4200A #2 connectors provide sense HI, HI, LO, and sense LO input connections for the Series 2600/2600B or 4200A instruments. These connections are intended for use with 200 V-compatible 2600/2600B or 4200A Series instruments.

Connections are as follows:

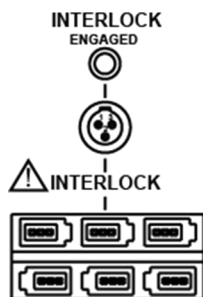
- SHI = Sense HI
- HI = HI
- LO, SLO = LO, sense LO



The Series 2600/2600B and Model 4200A #3 connectors provide sense HI, HI, LO, and sense LO input connections for the Series 2600/2600B or 4200A instruments. These connections are intended for use with 200 V-compatible 2600/2600B or 4200A Series instruments.

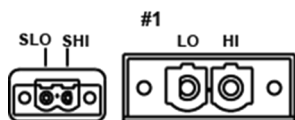
Connections are as follows:

- SHI = Sense HI
- HI = HI
- LO, SLO = LO, sense LO



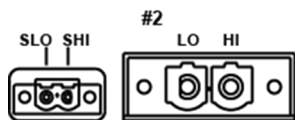
The INTERLOCK connectors provide and enable interlock functionality for the Series 2600/2600B instruments.

An illuminated LED beneath the ENGAGED label indicates that the interlock is engaged and active.



The 2651A (high-current) #1 connectors provide Model 2651A input connections for source LO, source HI, LO, and HI. Connections are as follows:

- SLO = Sense LO
- SHI = Sense Hi
- LO = LO
- HI = HI

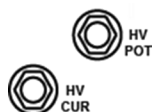


The 2651A (high-current) #2 connectors provide Model 2651A input connections for source LO, source HI, LO, and HI. Connections are as follows:

- SLO = Sense LO
- SHI = Sense Hi
- LO = LO
- HI = HI



Ground screws for connections to protective earth (safety ground).



The HV bias tee input connectors provide SMA input connections for ac HV CUR (force) and HV POT (sense). These connectors are designed for connection to a CV-measurement instrument.

Model 8020-CVU option

This is for the ac guard and the bias tee input connectors.



The ac GUARD SMA connector provides +12 V dc to enable the ac guard mode of a bias tee. This connector is only present with the integrated 8020-CVU bias tee option.



The bias tee input connectors #1, #2, and #3 provide SMA input connections for ac CUR (force) and POT (sense). These connectors are designed for connection to a CV-measurement instrument.

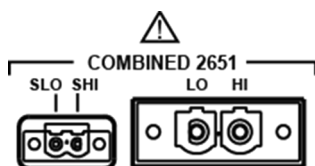
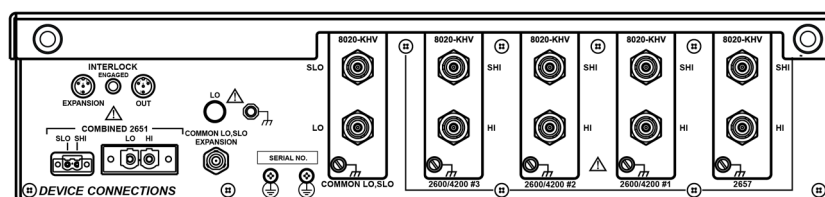
The connectors are only present with the integrated 8020-CVU bias tee option.

Device connections panel overview

Device under test connections are made to the device connections panel of the 8020.

The device panel of the 8020 is shown below. Descriptions of the device panel connections are provided after the graphic.

Figure 18: Model 8020 device connections panel



The connectors provide the combined output of the Model 2651A. You can use these connections to connect the 8020 to one or two Model 2651A units.

Connections are as follows:

- SLO = Sense LO
- SHI = Sense HI
- LO = LO
- HI = HI



The Common LO, SLO expansion triaxial connector provides an additional terminal for common LO and SLO. This is useful when connecting two or more 8020 units.



The OUT-interlock connector provides an interface to control the interlock of Series 2600/2600B and 4200A instruments.

The EXPANSION interlock is used in a test configuration system using two or more 8020 units.

The ENGAGED LED illuminates when the interlock is engaged and active.

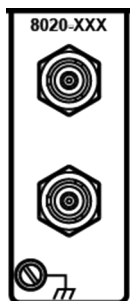


The LO connector provides a common LO connection. This jack may be connected to the chassis ground lug connector (see below) via the ground lug link.

This connector is useful when LO may carry more current than can be passed through the LO triaxial connector. This connection supports up to 4.5 ADC or 10 A fuse.



The chassis ground lug connector provides a grounding point for the chassis of the 8020. You can connect this lug to the common LO jack with the supplied connector link.



Five connector card slots are available on the device panel side of the 8020. The card slot in which the connector card is installed corresponds to a set of connections on the instrument side of the 8020. For more information on this topic, see [Channel description](#) (on page 4-1).

Connections to the instrument panel

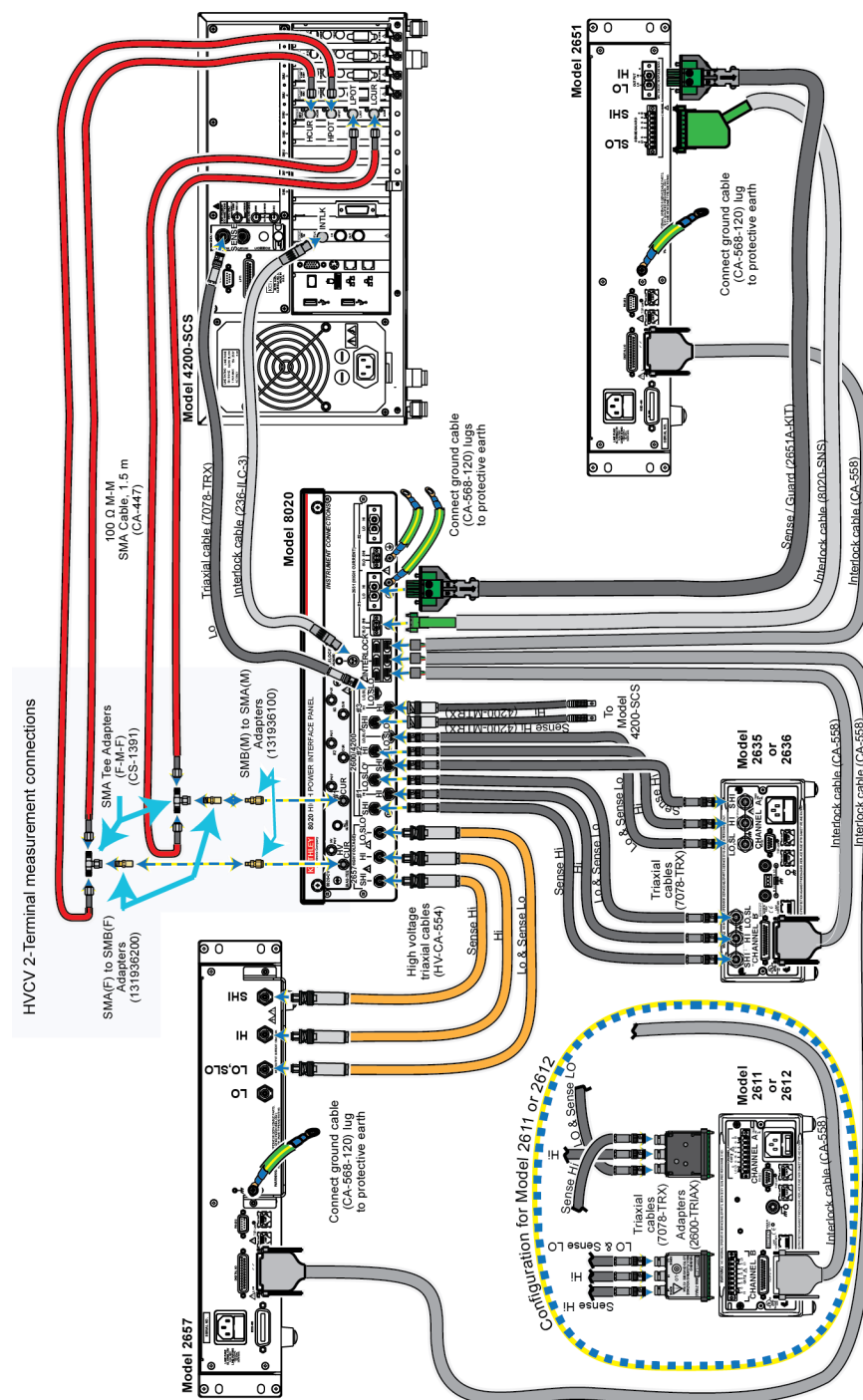
This section describes the connections you can make to the instrument connections panel of the 8020 high-power interface panel.

WARNING

Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages. The ground wires must be attached to a known protective earth (safety ground) before powering on instruments. Failure to attach the ground wires to a known protective earth may result in electric shock.

Do not convert triaxial cables to BNC cables. Using BNC cables will remove protection from SourceMeter Instrument voltages and may result in instrument damage. You must use triaxial cables for connections to the 8020.

Figure 19: Connections to the 8020 instrument panel



Model 2611 and Model 2612 connection notes

The Model 8020 includes overvoltage protection circuitry for the Model 2611 and 2612 SMUs. In a test configuration having both a 200 V SMU and a Model 2657A connected to the DUT, this circuitry protects the SMUs from high voltage from the Model 2657A.

NOTE

The LO terminal is connected to chassis ground if you connect the Model 2611 or Model 2612 to the 8020 through the Model 2600-TRX SMU Connector.

Model 2635 and Model 2636 connection notes

The Model 8020 includes overvoltage protection circuitry for the Model 2635 and 2636 SMUs. In a test configuration having both a 200 V SMU and a Model 2657A connected to the DUT, this circuitry protects the SMUs from high voltage from the Model 2657A.

Model 2651A connections

The 8020 connects up to two Model 2651A instruments in parallel for up to 100 A pulsed current output.

NOTE

There is no safety interlock on the Model 2651A — the safety interlock is not necessary because output voltage of the Model 2651A is below hazardous levels. The CA-558-2 cable is shown here in case you want to use Output Enable to shut off the output when the Model 8020 top cover is removed. To activate Output Enable, refer to the Model 2651A Reference Manual. Output Enable can be activated using the front panel or by remote control.

Model 4200A-SCS connections

Model 42XX-SMUs

The 8020 includes internal protection circuitry for the Model 42XX-SMU series of source measurement units. In a test configuration having both a 200 V SMU and a Model 42XX-SMU connected to the DUT, this circuitry protects the SMUs from high voltage from the Model 2657A.

Model 4210-CVU

When the 8020-CVU option is installed, the Model 4210-CVU Capacitance-Voltage Instrument connects to the CUR and POT SMA connectors, which are the ac inputs of the bias tee. Please refer to Bias tee theory overview for more detail on using the 8020-CVU bias tee option.

Model 4200-PA

The 4200-PA preamplifier should be removed when the 4200A-SCS is connected to the 8020 high-power interface panel. Refer to the following compatibility table:

Model 4200A-SCS instrument module	8020 compatibility
4200-SMU and 4210-SMU	Fully compatible
4200-PA	Not compatible
4210-CVU	Fully compatible
4220-PGU, 4225-PMU, and 4225-RPM	Not compatible

Use the 8020 for dc tests

In this section:

Overview	4-1
Channel description	4-1
Ensuring continuity in the measurement channel.....	4-3
Connecting the high current channel	4-6
Use connector cards to interface to the device	4-7
Connect to common LO for applications > 1.5 A dc.....	4-7
Overcurrent protection	4-8
Overvoltage protection circuitry.....	4-9

Overview

The 8020 high-power interface panel offers a convenient way to combine SMU instruments and C-V instruments to perform a variety of dc I-V tests and HV C-V tests. This section will discuss the configuration of the 8020 to make dc I-V tests. See [Model 8020-CVU bias tee overview](#) (on page 5-1) for more information.

Channel description

The following are the 8020 dc test channels:

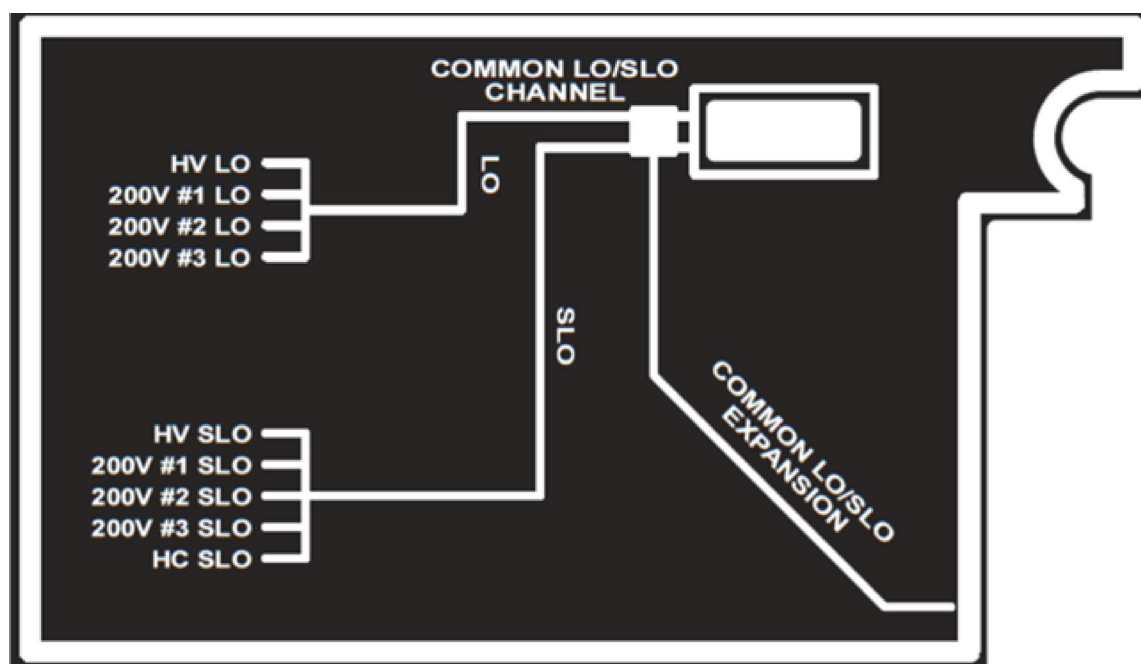
- High-voltage channel
- 200 V channels #1, #2, and #3
- Common LO channel
- High-current channel

For dc measurements, the high-voltage channel passes the high-voltage signal at the instrument connections panel directly to the designated connector card at the device connections panel.

The 200 V channels incorporate overvoltage protection; when used in conjunction with a high-voltage SMU instrument during device testing, a breakdown at the device will not damage the SMU instruments routed through the 200 V channels.

The common LO channel (see the below graphic) combines the sense LO of all channels to a common sense LO terminal and combines LO of the high voltage and 200 V channels to a common LO terminal. These common terminals are also available via a binding post connector and a 3-lug triaxial connector on the device connection panel of the 8020. The binding post connector is useful when dc current above 1.5 A travels through common LO. The 3-lug triaxial connector is useful for expanding continuity to other 8020 units in a test configuration. See [Connect multiple 8020 units](#) (on page 2-9) for detail.

Figure 20: 8020 common LO/SLO channel (top shield view)



Common LO and sense LO are clamped to 42 V from the chassis and can be tied to the chassis using the binding posts and link at the device connections panel of the instrument. See the below graphic.

Figure 21: LO connector connected to chassis ground lug



The high-current channel can accept up to two Model 2651A 50 A SMU instruments and places these instruments in parallel to allow up to 100 A pulses. Connectors for this model on both the instrument and device connection panels are Phoenix screw terminal. This makes it easy to connect banana or unterminated cables to the connector of your choice. The channel resistance is very low, where 50 A dc and 100 A pulses can be transmitted with little voltage drop across the 8020.

Ensuring continuity in the measurement channel

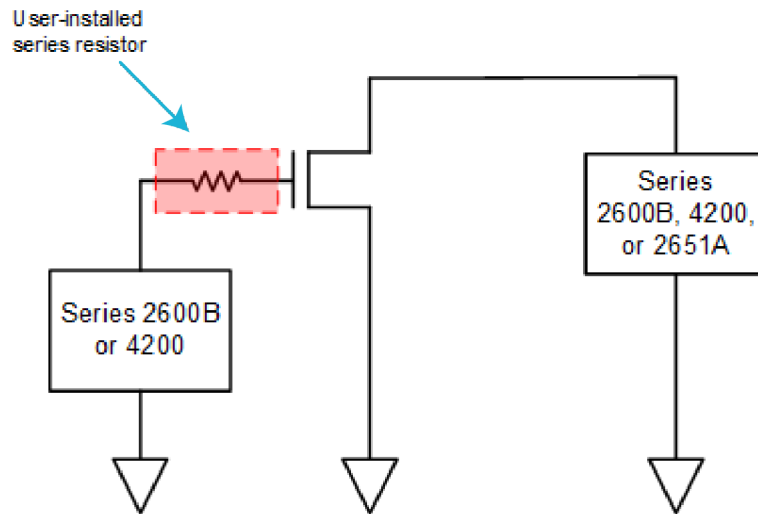
To ensure channel continuity for dc I-V tests on the high voltage and 200 V channels, install a short or resistor in the dc path between nodes 1A and 2 on the 8020 main board. See the below graphic as well as [How to insert a series resistor in the 8020](#) (on page 4-5). The 8020-RES-KIT resistor kit supplied with the 8020 includes a 0 Ω resistor, among several other resistor values ranging from 20 Ω to 1 M Ω .

Figure 22: Resistor installed between nodes 1a and 2

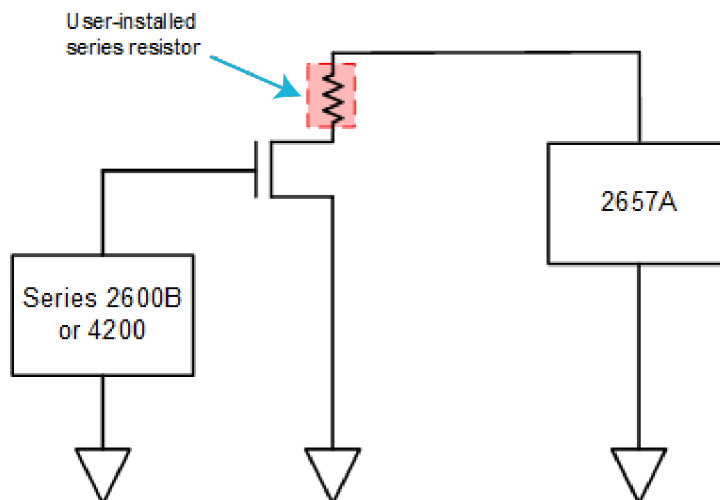


Some high-gain devices are prone to oscillation during testing and a series resistor is useful for suppressing such oscillations. You may also use series resistors to limit the absolute current from the SMU instrument, such as for a breakdown voltage measurement. The wide variety of resistor values in the 8020-RES-KIT resistor kit is useful for suppressing oscillations or enforcing an absolute current limit. You will need to experiment with different resistor values to identify the best resistance value for your application.

The following schematics illustrate the circuits created when series resistors are installed at a pathway node on the 8020 main board.

Figure 23: Resistor installed for on-state characteristic measurements

Using a series resistor for gate stabilization when measuring on-state characteristics

Figure 24: Resistor installed for off-state characteristic measurements

Using a series, current-limiting resistor for measuring off-state characteristics with the 2657A

For more information on the measurement conditions that benefit from a series resistor, see [Measurement considerations](#) (on page 7-1).

NOTE

When the series resistance is greater than 0 Ω , disconnect sense HI of the instrument at the device connections panel. The instrument can remain in remote sense, as remote sense connections are maintained to node 1a.

How to insert a series resistor in the 8020

WARNING

Before installing cards or components, make sure you remove all electrical connections to the test fixture and follow the discharge procedure outlined in the next section of this manual. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

The following instructions explain how to install a resistor in a path of the 8020.

To insert a series resistor in the 8020:

1. Remove any external power that is connected to the interface through connected devices or devices under test (DUTs).
2. Loosen the two thumbscrews securing the top cover to the unit.
3. Remove the top cover by lifting the lid slightly and slide the back over the alignment pins and set aside.
4. Place the series resistor on the 8020 motherboard nodes according to your application. See the following conditions and graphic.

Without 8020-CVU bias tee option

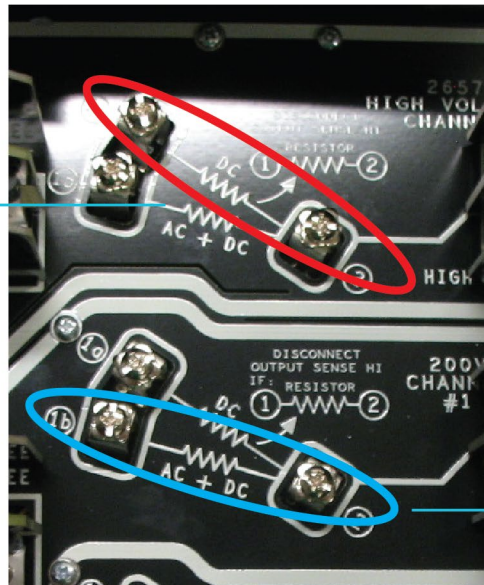
- Place the series resistor between nodes 1a and 2.

With 8020-CVU bias tee option

- For a static dc signal on the gate, place the series resistor between nodes 1b and 2.
- For a pulsed dc signal on the gate, place the series resistor between nodes 1a and 2.

Figure 25: Model 8020 motherboard resistor between nodes 1 and 2

Install resistor here when 8020-CVU bias tee option **is not** installed or when generating **pulsed** DC signals on the device gate terminal.



Install resistor here when 8020-CVU bias tee option **is** installed or when generating **static** DC signals on the device gate terminal.

5. Tighten the screws that secure the resistor leads.
6. Bend the exposed leads back toward the resistor body.

CAUTION

The resistor lead must point back toward the resistor body to reduce the possibility of current leakage from the bias tees in the adjacent 8020-CVU (if installed).

7. Reinstall the top cover by sliding the lid over the alignment pins and tighten the thumbscrews.
8. Reconnect any external connections to the 8020.

Connecting the high current channel

The LO of the high current channel is isolated from the common LO of the 8020. This eliminates the possibility of voltage errors on the 200 V channels due to high current pulses. For optimal voltage measurement on all connected SMU instruments, keep the high current force connections, both HI and LO, isolated from connections to other SMU instruments. For multi-terminal devices, tie together the common LO to the LO of the high current channel at the device terminal or as close as possible to the device terminal.

Use connector cards to interface to the device

The connector cards interface each instrument or measurement channel to the connector or terminal at the device under test. Each connector card is designed for Kelvin connectors and has separate force and sense connections. There are several connector cards available.

WARNING

All card slots must have connector cards installed or the 8020-BLK blank card faceplate installed. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

Refer to the 8020 specifications for a complete list of compatible connector cards. The high voltage channel is keyed so that only high voltage connector cards or cards with ratings of at least 3 kV can be installed. To install a new or different connector card, refer to [Connect multiple 8020 units](#) (on page 2-9).

NOTE

For optimal accuracy in making low current measurements, use triaxial connector cards such as the Keithley Instruments 8020-KHV, 8020-STC or 8020-AHV.

Connect to common LO for applications > 1.5 A dc

Some connector cards are not rated for the full current capability of the 8020. This is especially important to remember as you consider the connector card for the Common LO channel. Refer to the connector card specifications for specific current limits.

The common LO channel is a sum of the LO terminals from the high voltage and 200 V SMU instruments. The maximum current limit of the common LO channel is 4.5 A dc, but this is only available at the binding post at the device connections panel. See the graphic below.

If the sum of the dc current in the high voltage and 200 V channels exceeds the connector card specification, access common LO from the LO binding post.

Figure 26: 8020 common LO binding post

The LO output can also be connected to ground via the link attached to the chassis ground lug. See the below graphic.

Figure 27: LO connector connected to chassis ground lug

Overcurrent protection

Each connector card contains a 10 A fuse to allow maximum pulse current for each SMU instrument. Removing this fuse enables transient overcurrent protection. This transient overcurrent protection is useful for protecting probes and other sensitive interface hardware at the device under test.

Transient overcurrent protection is only available on the 200 V channels within the 8020. When using a connector card in the HV channel, be sure that the 10 A fuse is installed.

Although each SMU instrument has a programmed current limit, it is possible to exceed this limit for very brief periods, especially during events in which there is a very large change in device impedance. Additionally, high currents may be present in the test system due to rapid discharge of cable and system capacitance, which may be at hundreds to thousands of volts. The transient overcurrent protection is useful for suppressing such current transients.

The transient overcurrent protection is designed for use in low-current applications. It is not intended for applications in which there is continuous current greater than 100 mA, as such current could result in voltage errors. Additionally, the overcurrent protection will degrade the pulse shape of pulses output from the SMU instrument; bypass the overcurrent protection in these cases by installing the 10 A fuse on the connector card.

Overvoltage protection circuitry

The Model 8020 includes overvoltage protection circuitry that protects instruments in applications where a device breakdown or other potential failure could connect the high-voltage output of a Model 2657A high-voltage SMU to a lower voltage SMU.

The Model 8020 includes overvoltage protection circuitry for the Models 2611, 2612, 2635, 2636, and 4200A-SCS SMUs. The protection circuitry is automatically connected whenever you make connections between the Model 8020 and these SMUs.

Use the 8020 for dc and HV C-V tests

In this section:

Model 8020-CVU bias tee overview	5-1
HV C-V measurement software	5-8
Configure the 8020 for HV C-V measurements.....	5-8
Discharge bias tee and system capacitance	5-10
Use the 8020-DP to discharge system capacitance.....	5-11

Model 8020-CVU bias tee overview

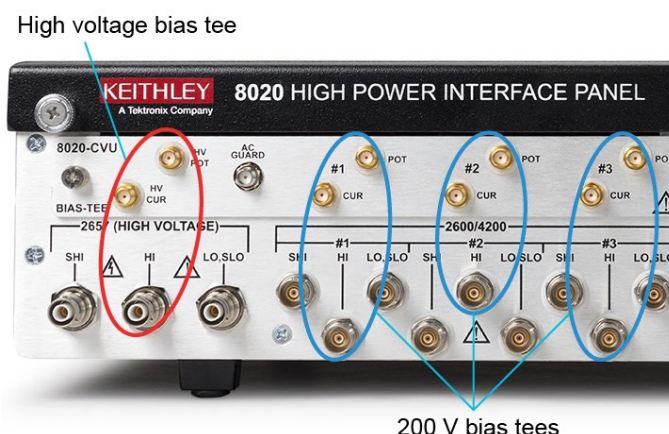
The 8020-CVU bias tee is a factory-installed option for the 8020 high-power interface panel. The 8020-CVU bias tees couple the dc bias from a SMU instrument with the ac measurement of an impedance measurement instrument to enable capacitance-voltage (C-V) measurements with dc bias up to 3000 V and ac measurement frequencies from 10 kHz to 2 MHz. This bias tee option is intended for use with the Keithley Series 2600/2600B and 4200-SMU instruments and the Keithley Model 4210-CVU C-V instrument.

The 8020-CVU includes four bias tees. A bias tee is installed in circuit with the high voltage SMU channel and each of the 200 V SMU channels of the 8020, as shown in the below figure. Using all four bias tees enables C-V measurements with dc bias at up to four device terminals and allows complete characterization of circuit-level and component-level capacitance parameters of power devices without connection changes at the device.

When the 8020-CVU is installed, the front panel contains nine SMA connectors. Four pairs of SMA connectors that are the ac inputs to the four bias tees, and one SMA connector that provides +12 V dc to enable the ac guard mode of a bias tee. The next figure shows the 8020 with the bias tees installed. The ac inputs for each bias tee are labeled POT and CUR to represent the sense and force terminals of the 4210-CVU, respectively. However, high voltage C-V measurements done through the 8020 are two-wire (local sense) measurements and the two ac inputs for each bias tee are shorted together in the bias tee. Therefore, for high voltage capacitance measurements, Kelvin connections are terminated at the instrument side of 8020.

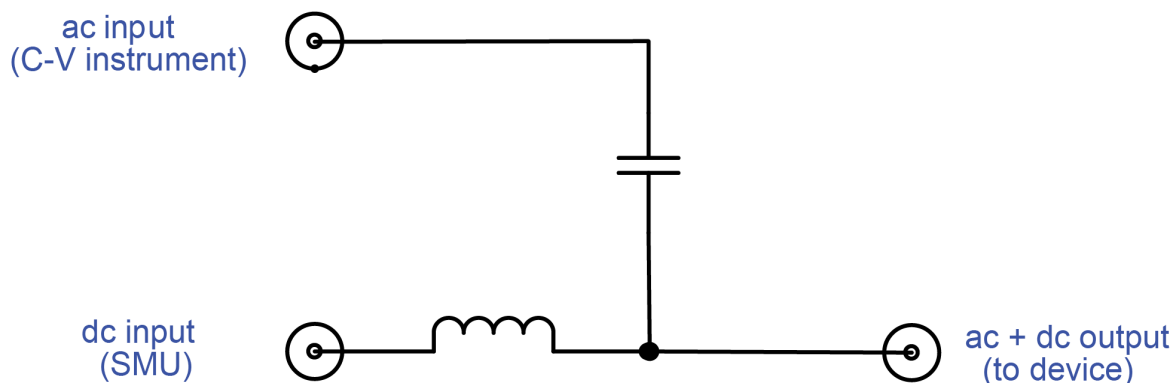
NOTE

When measuring capacitance through the 8020, disconnect the SMU sense Hi and sense LO cables at the device connections panel of the 8020.

Figure 28: Model 8020 instrument connections panel

Bias tee theory overview

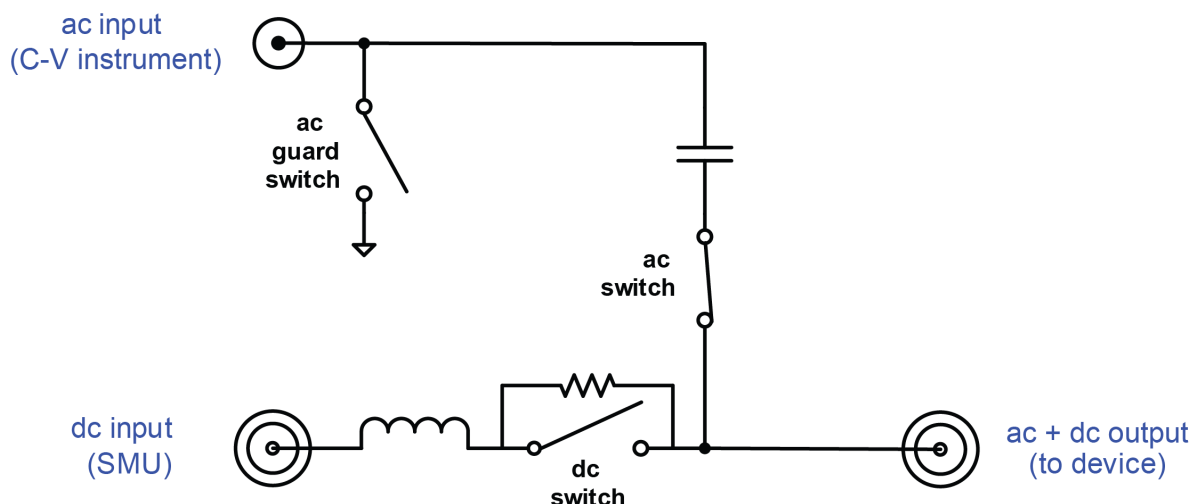
The 8020-CVU bias tees combine C-V measurement with dc bias while isolating the C-V instrument and SMU instrument from each other. A typical bias tee uses a capacitor to isolate the C-V instrument from interfering with dc measurements and an inductor is used in series with the SMU instrument to isolate the SMU from interfering with ac measurement (see the following figure).

Figure 29: 8020 typical coaxial bias tee block diagram

Isolating the C-V instrument and SMU from each other is not foolproof or completely stable across the range of frequencies used by the C-V instrument. Balancing the performance of dc I-V and ac C-V signal path needs can result in compromises in the usable frequency range for ac C-V measurements and the minimum current sensitivity for dc low current measurements. Also, bias tees are typically coaxial and not triaxial, which further compromises low current dc measurements by removing the ability to use a driven dc guard to shunt extraneous leakage currents. Such performance compromises often prompt users to remove the bias tee before dc I-V characterization. These measurement setup changes are time-consuming and prone to error.

The 8020-CVU bias tee option has multiple operation modes that optimize the performance for each measurement type while nearly eliminating measurement configuration changes between dc I-V and C-V measurements. Additionally, the bias tees are fully guarded and configured for triaxial connections so that the low current dc measurements may be performed through the bias tee (see the following figure).

Figure 30: 8020-CVU single bias tee block diagram



Bias tee modes

Each 8020-CVU bias tee can be configured in one of four modes:

1. [IV mode](#) (on page 5-5)
2. [C-V mode](#) (on page 5-5)
3. [CV Hi I mode](#) (on page 5-6)
4. [AC guard with dc bias mode](#) (on page 5-7)

Configure the bias tee mode by programming the dc bias voltage provided by the C-V instrument at the ac bias tee input. The Model 4210-CVU capacitance-voltage instrument has built-in dc bias capability that can be utilized to configure the bias tee mode. In the 8020-CVU bias tee option, the 4210-CVU dc bias is not available to the DUT, and may only be used as a control voltage. For more information on Keithley software that automatically controls the bias tee mode, see the [HV C-V measurement software](#) (on page 5-8) topic. The next table provides an overview of the four available bias tee modes.

Four available bias tee modes

Mode	Application	Block diagram	Control voltage*	AC switch state	AC guard switch state	DC switch state
I-V mode (on page 5-5)	Use for best dc low current measurement performance. Ideal for any dc measurements made with the 8020-CVU installed. DC currents up to 1 A are permissible in this mode. Example tests: I_{dss} , $V_{ds}-I_d$	I-V mode (on page 5-5)	0 V (default state)	Open	Open	Closed
C-V mode (on page 5-5)	Use for C-V measurements with a maximum dc bias current of 100 μ A. Frequency range of 10 kHz - 2 MHz possible**. Example tests: C_{iss} , C_{oss}	C-V mode (on page 5-5)	-10 V	Closed	Open	Open
C-V Hi I mode (on page 5-6)	Use for C-V measurements with a maximum dc bias current of 1 A. Frequency range of ~100 kHz - 2 MHz possible***. Not for low current dc measurements. Example tests: C_{iss} , C_{oss}	C-V Hi I mode (on page 5-6)	+10 V	Closed	Open	Closed
AC guard (on page 5-7)	Use for measuring capacitance between two terminals of a device with three or more terminals. This mode guards capacitance to third terminal by shunting ac current away from the ac measurement circuit. Example tests: C_{gd} , C_{gs} , C_{ds}	AC guard (on page 5-7)	+12 V****	Closed	Closed	Closed

* The control voltage is a dc voltage driven at the ac input of the bias tee. Each control voltage must be maintained within ± 250 mV. A minimum drive current of 15 mA is required to close any of the desired switches.

** Dependent on test system inductance.

*** Dependent on test system inductance.

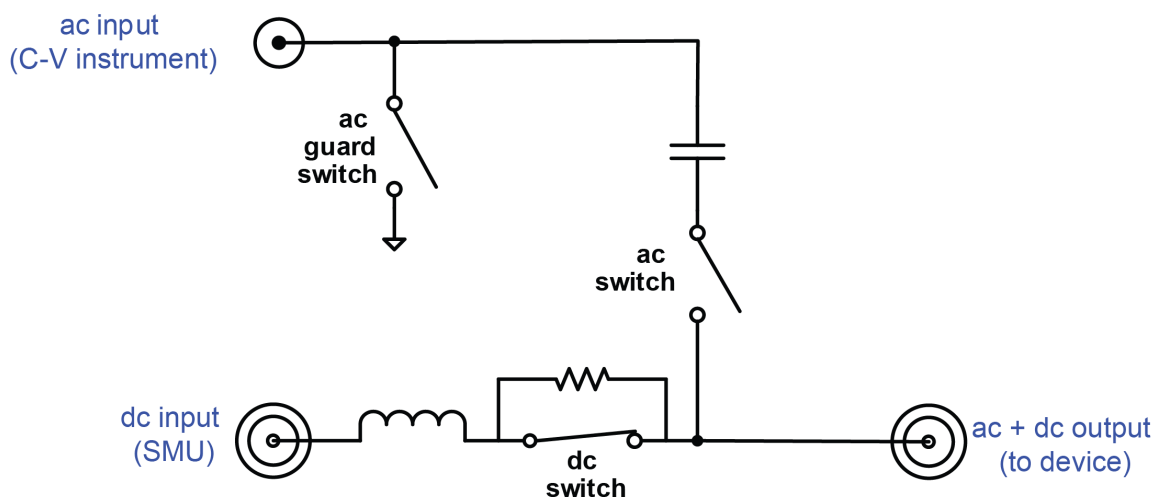
**** Available at "AC Guard" terminal of 8020-CVU bias tee option.

I-V mode

This is the default state for the bias tees. Use this mode for performing any dc measurements through the 8020-CVU bias tees. Low current dc measurements made with the 8020-CVU bias tee installed require additional settling time over those made without an 8020-CVU; refer to the 8020 specifications for more detail.

This mode achieves low dc leakage current by opening the ac switch in the bias tee. Do not use this mode for C-V measurements. The next figure shows the basic bias tee default mode electrical block diagram.

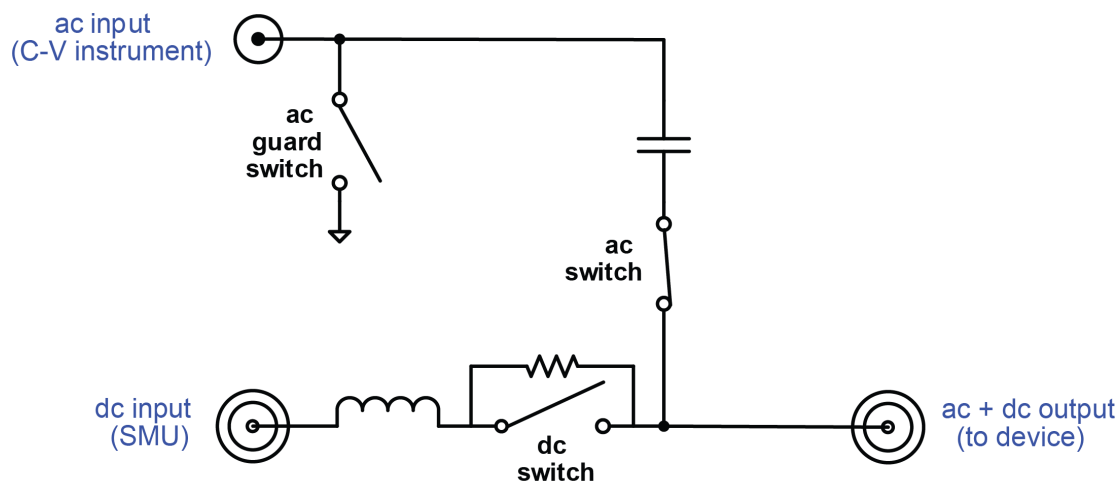
Figure 31: 8020 bias tee I-V mode block diagram



C-V mode

This mode is preferred mode for most C-V measurements. This mode achieves an ac measurement frequency range of 10 kHz to 2 MHz by opening the bias tee dc switch. In this mode, the maximum dc bias current from the dc SMU through the bias tee is 100 μ A. Though the dc switch is open, full dc voltage can still pass through the DUT through the bias tee resistor. This mode is not intended for dc I-V measurements.

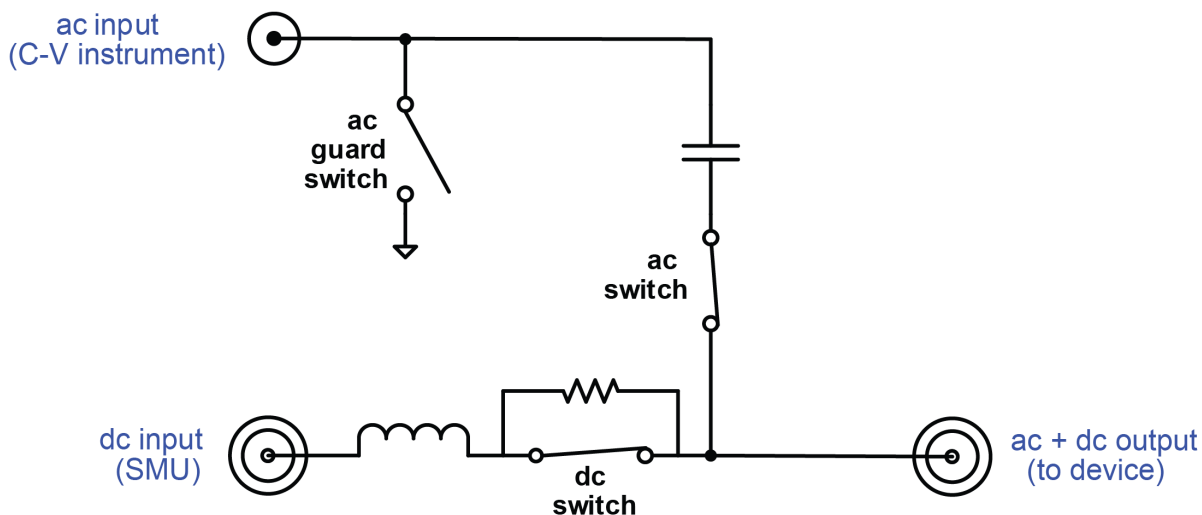
The next figure shows the basic bias tee electrical block diagram in off-state C-V mode.

Figure 32: 8020 bias tee C-V mode block diagram

C-V Hi I mode

This mode is ideal for performing C-V measurements where dc bias current up to 1 A is required. This high current may be useful for making C-V measurements on a semiconductor device in the on-state. In this mode, both bias tee ac and dc switches are closed. Compared to the off-state C-V mode, C-V measurements in this mode are degraded below 100 kHz.

The next figure shows the basic bias tee electrical block diagram in on-state C-V mode.

Figure 33: 8020 bias tee C-V Hi I mode

AC guard with dc bias mode

This mode allows an ac guard to be placed at a device terminal while allowing for dc bias at that terminal. This can be useful for characterizing C-V between two device terminals that have three or more terminals. This is shown using a network of three capacitors in the next two figures with the goal of accurately measuring C_{dut} . The C-V instrument applies ac voltage at one terminal and measures the ac current at the device's second terminal. However, capacitance to the third terminal causes some current leakage. Without the ac guard, the measured current leads to erroneous impedance measurements. Using the ac guard routes the leakage capacitance current away from the ac measurement terminal.

Figure 34: 8020 without ac guard leakage path causes measurement errors

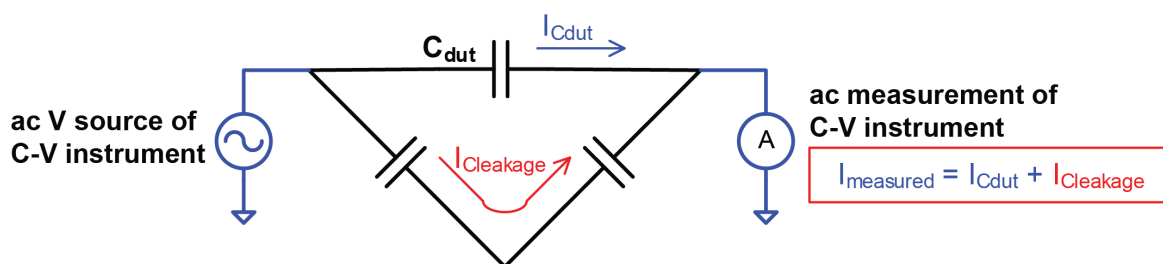
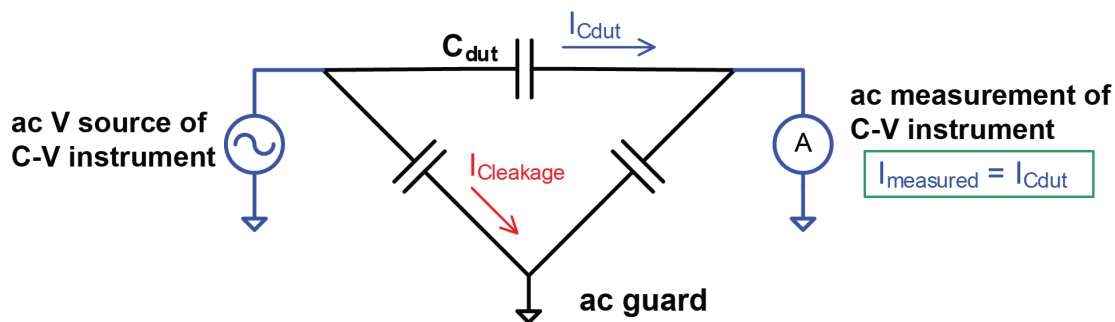


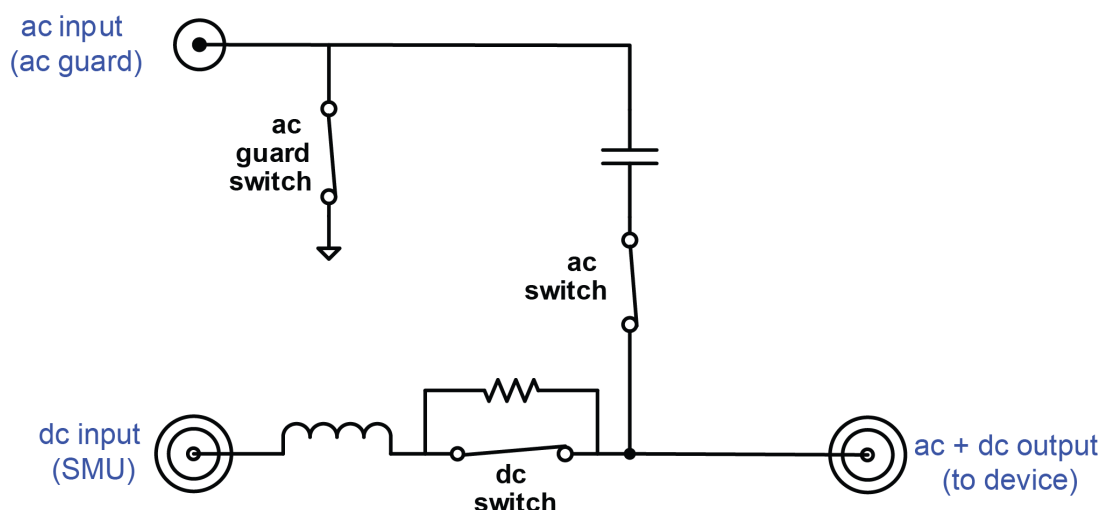
Figure 35: 8020 ac guard eliminates measurement errors



Programming the bias tee to ac guard mode requires applying a +12 V control signal to either the POT or CUR terminal of the bias tee. The required control voltage is available at the SMA connector on the 8020-CVU labeled "AC Guard." Connect the POT or CUR terminal of the bias tee to the AC Guard terminal.

The next figure shows the basic bias tee electrical block diagram in AC Guard mode.

Figure 36: 8020 ac guard mode block diagram



HV C-V measurement software

The multi-bias tee and multi-mode capability of the 8020-CVU allows you to use the C-V characterization with variety of devices. ACS Basic Edition software version 2.1 (or higher) includes a large device test library and automatically controls the mode of the bias tee with each test. For example, the software programs the bias tee mode to I-V mode before measuring the I_{dss} (drain-to-source current) test of a FET. For a C_{iss} (input capacitance) measurement of a power MOSFET, the software programs the bias tee for C-V mode.

Configure the 8020 for HV C-V measurements

⚠ WARNING

You must discharge the system capacitance before installing resistance in the 8020. See [Use the 8020-DP to discharge system capacitance](#) (on page 5-11) in this section for details and instructions. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

To enable high voltage C-V measurements with the 8020-CVU bias tee options, ensure that there is continuity in the correct path between nodes 1 and 2 on the 8020 motherboard for the high voltage and 200 V channels.

For C-V measurements, install a short to ensure that continuity is in the "ac + dc Output" path between nodes 1b and 2 on the 8020 motherboard (see the following two figures). For static dc measurements, you may want to install a resistor. See [How to insert a series resistor in the 8020](#) (on page 4-5) for details.

Figure 37: 8020 ac + dc signal path on motherboard to enable C-V measurements

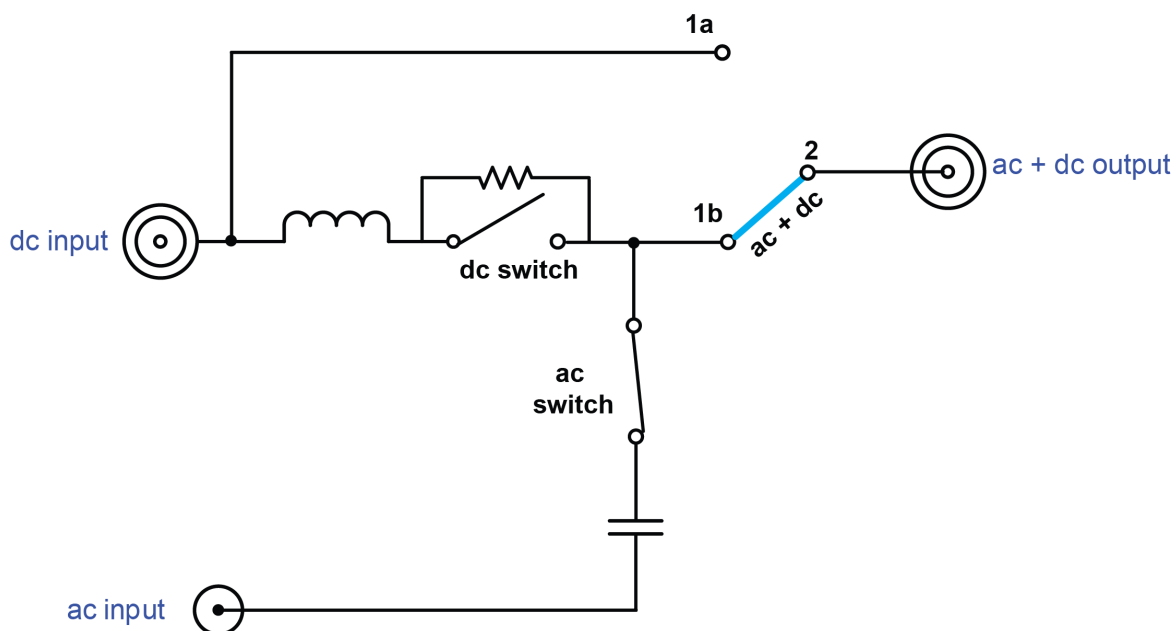
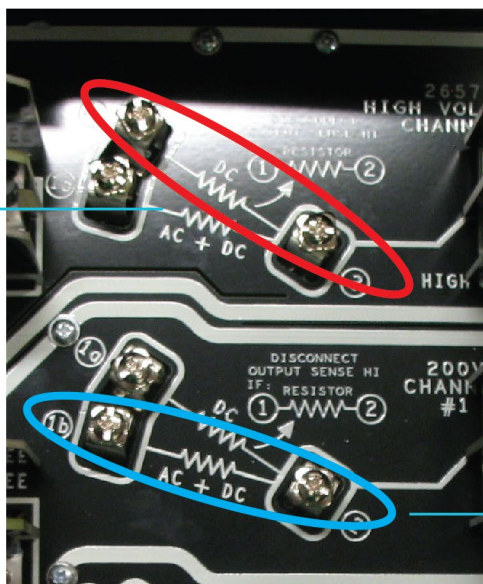


Figure 38: 8020 signal path nodes 1a, 1b, and C on motherboard

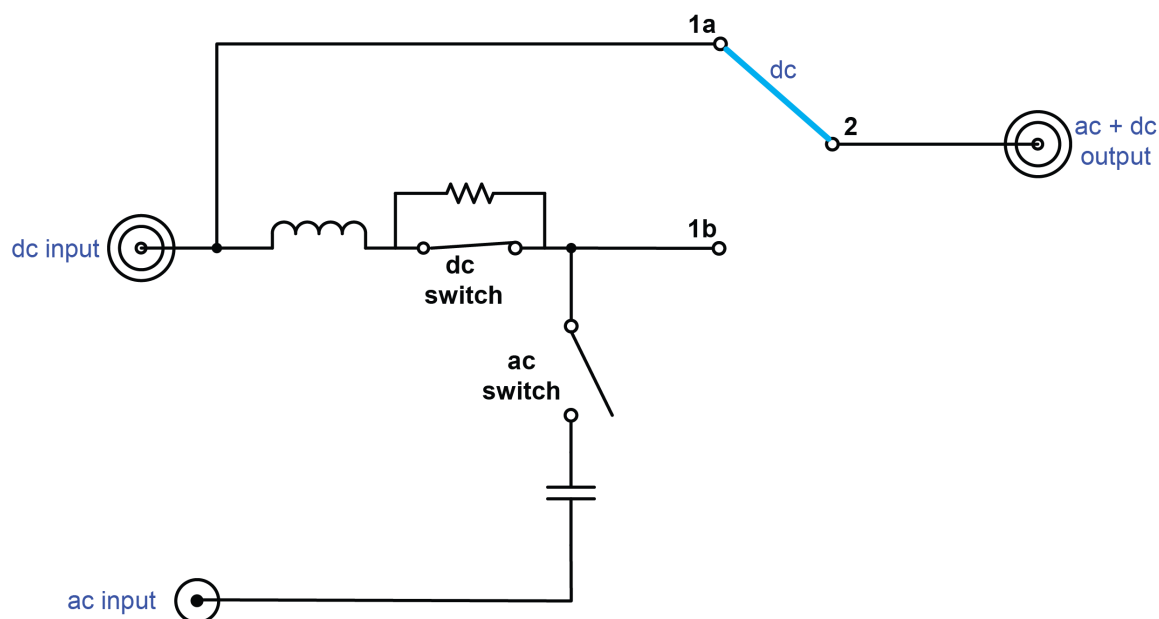
Install resistor here for static DC measurements



Install short here for C-V measurements

For pulsed dc measurements with the 8020-CVU installed, install a short or a resistor to ensure that there is signal continuity in the dc input path on the 8020 motherboard (see the previous figure). This path bypasses the inductor of the bias tee, which can have an adverse effect on pulse shape. See the next figure.

Figure 39: 8020 dc signal path on motherboard to enable pulsed dc measurements



NOTE

Configuring the 8020 for pulsed dc measurements will disable ac measurement capabilities.

Discharge bias tee and system capacitance

The 8020-CVU option has internal capacitance that can hold charge. A shock hazard exists if a proper discharge is not performed and the user removes the 8020 top cover or in other ways accesses a live terminal in the system. Use the SMU instruments to safely discharge the capacitance.

⚠ WARNING

Do not ever assume that the safety interlock discharges the system. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

A best practice is to discharge system capacitance with the SMU output on. Configure the SMU to force 0 V and measure current with a current limit of at least 1 mA. A current measurement of approximately 0 mA indicates a proper discharge. Keithley's ACS Basic software executes this discharge procedure after completing a CV test.

Be sure to use the SMU to discharge the capacitance properly after each test and before opening the top cover of the 8020 and touching the 1a, 1b, and 2 nodes of the 8020 motherboard. Note that an operator error, a power outage, or an unforeseen event, can leave a dangerous charge in the system.

Use the 8020-DP discharge probe to manually discharge the bias tee capacitance and system capacitance prior to making adjustments on the 8020 motherboard or at the device interface.

Use the 8020-DP to discharge system capacitance

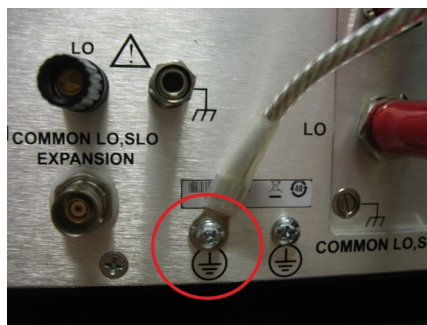
⚠ WARNING

Prior to connecting the 8020-DP High Voltage Discharge Probe, ensure that the 8020 is connected to protective earth. Refer to [Connecting to protective earth](#) (on page 2-2) in Section 2. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

To use the 8020-DP to discharge system capacitance:

1. Ensure proper connection from the 8020-DP to a protective earth (safety ground) screw on either the device or instrument side of the 8020 (see graphic). The device connections panel is shown in the below graphic.

Figure 40: 8020-DP connected to protective ground



2. Remove the top cover of the 8020 by loosening the two thumbscrews, lift the lid slightly and slide the back over the alignment pins.
3. While holding the discharge probe handle, touch each post for nodes 1a, 1b, and 2 of the high voltage channel on the 8020 main board and hold there for at least one second to safely discharge system capacitance. See the following three graphics.

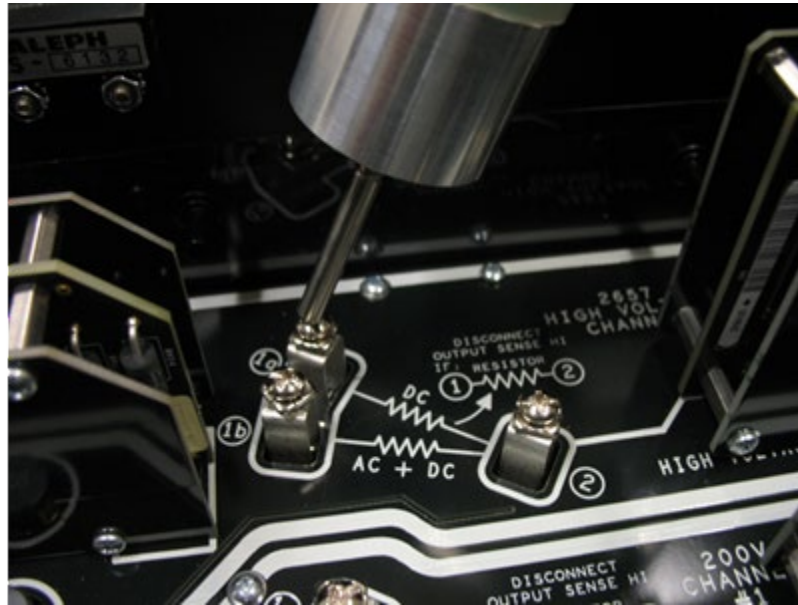
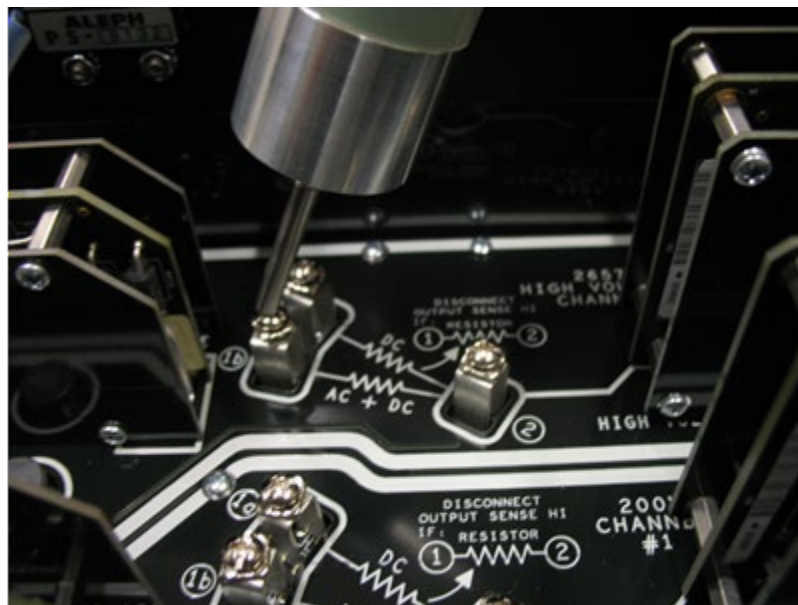
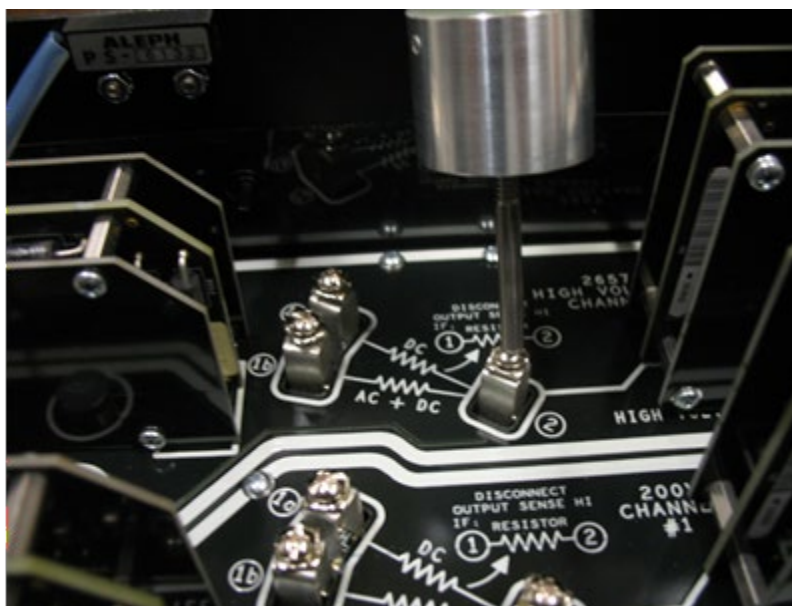
Figure 41: 8020-DP node 1a**Figure 42: 8020-DP node 1b**

Figure 43: 8020-DP node 2

4. Repeat the discharge procedure for nodes 1a, 1b, and 2 of the 200 V channels on the 8020 main board.

Model 8020 Applications

In this section:

Device connections	6-1
Equipment options (all examples)	6-2
Software	6-3
2-terminal device connections for I-V measurements.....	6-3
3-terminal device connections for I-V measurements.....	6-6
2-terminal device connections for C-V measurements	6-12
3-terminal device connections for C-V measurements	6-15

Device connections

This section of the manual provides several example connection diagrams to connect the 8020 high-power interface panel and the device under test using several multi-instrument configurations. The information is provided to assist you in making connections for different measurements on power semiconductor devices.

For information on connecting the SMUs to the Instrument Connections Panel of the 8020, please refer to [Connections to the instrument panel](#) (on page 3-6).

This section provides connection diagrams for the following examples:

- 2-terminal device characterization for I-V measurements using a single SMU
 - Using a 2657A
 - Using a Series 2600/2600B or 4200A instrument
 - Using a 2651A (Kelvin connections shown)
- 3-terminal I-V Connections
 - Off-state characterization of a power MOSFET using a Model 2657A and Series 2600B or 42x0-SMU (up to 3 kV)
 - Off-state characterization of a power MOSFET using a Series 2600B or 42x0-SMU (up to 200 V)
 - On-state characterization of a power MOSFET using a Model 2651A and Series 2600B or 42x0-SMU (up to 100 A pulse)
 - On-state characterization of a power MOSFET using two Series 2600B or 42x0-SMU (up to 10 A pulse)

- 2-terminal device characterization for C-V measurements using two SMUs
- 3-terminal C-V connections of component-level and circuit-level capacitance parameters of a power MOSFET

NOTE

All 3-terminal examples are shown using a power MOSFET as an example device. Similar connections can be made for measuring IGBT and BJT devices.

Equipment options (all examples)

Depending on your testing needs, you can order any of the following configurations:

Part number	Description
8020	Model 8020 High Power Interface Panel
2600-PCT-3B	High-voltage Parametric Curve Tracer
PCT-CVU	Parametric Curve Tracer - Capacitance Voltage Unit
8020-CVU*	Model 8020-CVU Integrated 3 kV and 200 V Bias Tees for Model 8020

Part number	Description
8020	Model 8020 High Power Interface Panel
2600-PCT-4B	High-Voltage and Current Parametric Curve Tracer
PCT-CVU	Parametric Curve Tracer - Capacitance Voltage Unit
8020-CVU*	Model 8020-CVU Integrated 3 kV and 200 V Bias Tees for Model 8020

Part number	Description
8020	Model 8020 High Power Interface Panel
2600-PCT-2B	High-Current Parametric Curve Tracer
PCT-CVU	Parametric Curve Tracer - Capacitance Voltage Unit
8020-CVU*	Model 8020-CVU Integrated 3 kV and 200 V Bias Tees for Model 8020

Part number	Description
8020	Model 8020 High Power Interface Panel
2600-PCT-1B	Low Power Parametric Curve Tracer
PCT-CVU	Parametric Curve Tracer - Capacitance Voltage Unit
8020-CVU*	Model 8020-CVU Integrated 3 kV and 200 V Bias Tees for Model 8020

* The 8020-CVU option is required for the measurement examples in this section.

Software

The ACS Basic software, available from Keithley Instruments, contains dozens of power semiconductor test libraries. This software is recommended for configuring and controlling multiple SMU instruments to make measurements on semiconductor devices. ACS Basic also includes many C-V libraries for common capacitance measurements on power semiconductor devices.

2-terminal device connections for I-V measurements

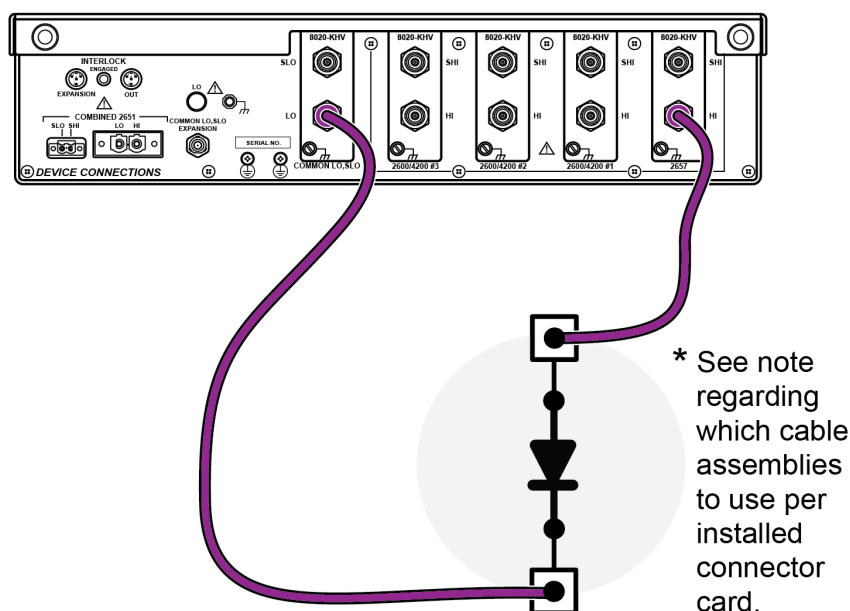
The following examples for the Model 2657A, Model 2651A, Series 2600B, or the 4200A-SCS instrument, show 2-terminal device connections for I-V measurements.

Use the Model 2657A

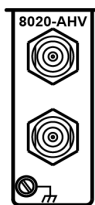
This example illustrates how to make local sense connections to a 2-terminal device using the Model 2657A 3 kV SMU instrument.

Figure 44: 2-terminal connections using the Model 2657A

Device side connections for I-V measurement of 2-terminal devices:
I-V TESTS - Off-state characteristics with a 2657A

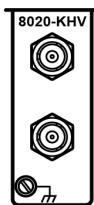


* Cable assemblies will depend upon the connector card the user installs



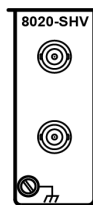
Connector Card:
8020-AHV

Cable Assembly:
User supplied



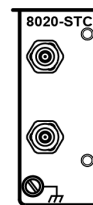
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



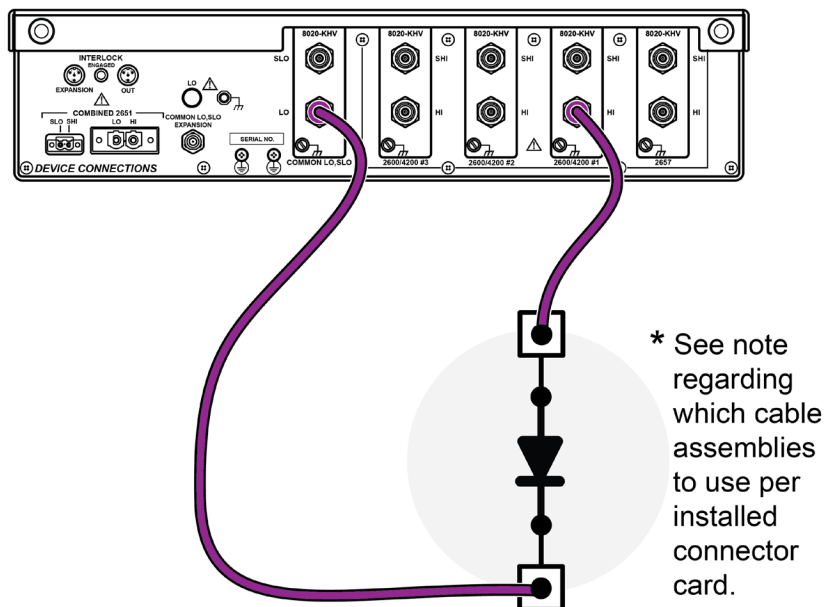
Connector Card:
8020-STC

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

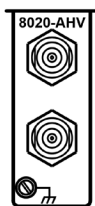
Use the Series 2600/2600B and 42x0-SMU instruments

This example illustrates how to make local sense connections to a 2-terminal device using a Series 2600/2600B or 42x0-SMU instruments.

Figure 45: 2-terminal connections using the Series 2600/2600B and 42x0-SMU instruments

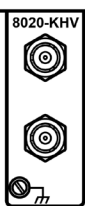


* Cable assemblies will depend upon the connector card the user installs



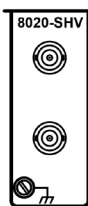
Connector Card:
8020-AHV

Cable Assembly:
User supplied



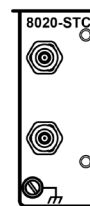
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



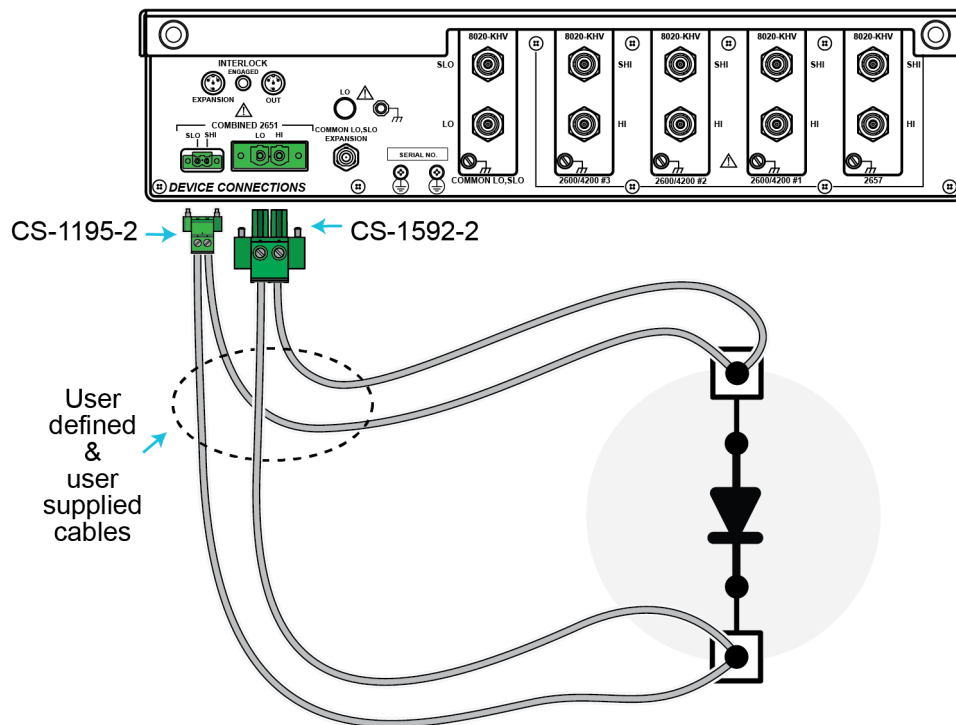
Connector Card:
8020-STC

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

Use the Model 2651A

This example illustrates how to make remote sense connections to a 2-terminal device using the Model 2651A-SMU instrument.

Figure 46: 2-terminal connections using the Model 2651A



3-terminal device connections for I-V measurements

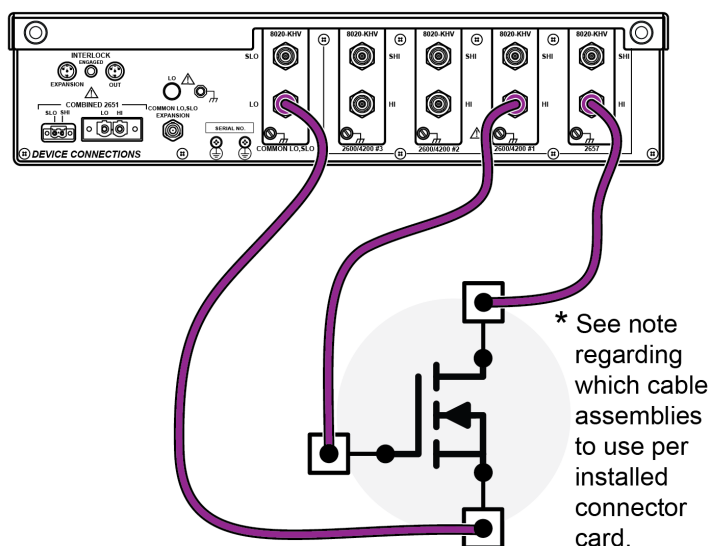
The following off-state and on-state example connections for I-V measurements uses Model 2651A and 2657A instruments, Series 2600B instruments, or 42x0-SMU instruments.

Off-state characterization of a power MOSFET using a Model 2657A and Series 2600B or 42x0-SMU instruments (up to 3 kV)

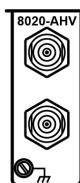
This example illustrates how to make local sense connections to a MOSFET using one Model 2657A and up to two Series 2600B instruments or a 42x0-SMU through the 8020 high-power interface panel.

The following diagram demonstrates how to make connections between the device connections panel of the 8020 and the DUT.

Figure 47: Off-state characterization of a power MOSFET (up to 3 kV)

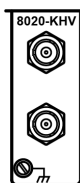


* Cable assemblies will depend upon the connector card the user installs



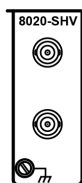
Connector Card:
8020-AHV

Cable Assembly:
User supplied



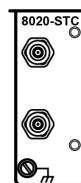
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



Connector Card:
8020-STC

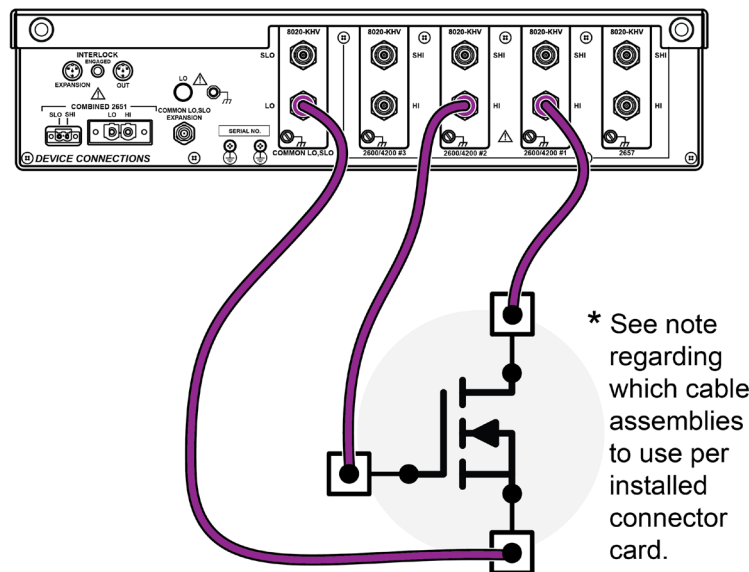
Cable Assembly:
Model 7078-TRX
or
Model 4200-TRX

Off-state characterization of a power MOSFET using a Series 2600B or 42x0-SMU instruments (up to 200 V)

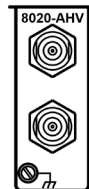
This example illustrates how to make local sense connections to a MOSFET using two Series 2600B or a 42x0-SMU instrument.

The following diagram demonstrates how to make connections between the device connections panel of the 8020 and the DUT.

Figure 48: Off-state characterization of a power MOSFET (up to 200 V)



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



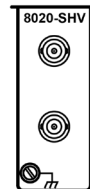
Connector Card:
8020-AHV

Cable Assembly:
User supplied



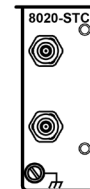
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



Connector Card:
8020-STC

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

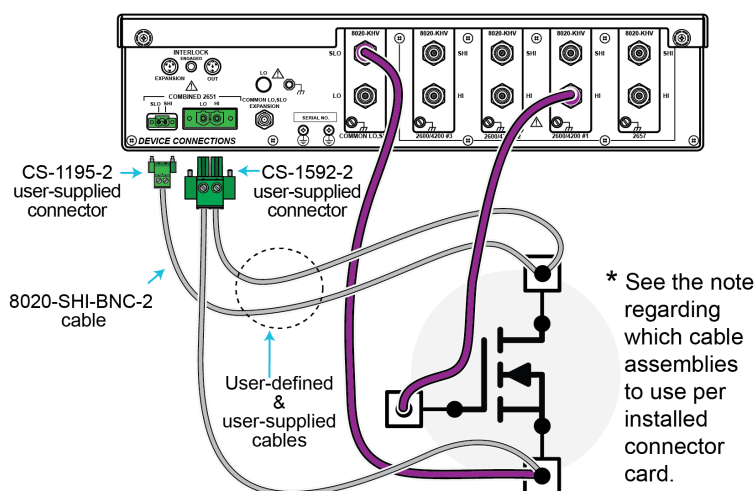
On-state characterization of a power MOSFET using the Model 2651A and Series 2600B or 42x0-SMU instruments (up to 100 A pulse)

This example illustrates how to make remote sense connections to a MOSFET using one or two Model 2651A SMUs and one Series 2600B SMU or a 42x0-SMU instrument.

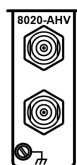
The following diagram demonstrates how to make connections between the device connections panel of the Model 8020 and the DUT.

The sense lines of the gate SMU are not required for FET-type devices where there is little to no gate current. This connection method is based on the fact that within the 8020, the common LO and common sense LO terminals are connected with a resistor. This allows the LO connection of the gate SMU to be made through the common sense LO connection of the 8020. This cost-effective connection method eliminates probes while providing accurate voltage reference for the gate SMU.

Figure 49: On-state characterization of a power MOSFET (up to 100 A pulse)

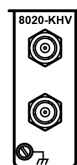


* Cable assemblies will depend upon the connector card the user installs



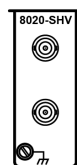
Connector Card:
8020-AHV

Cable Assembly:
User supplied



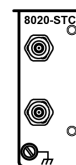
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



Connector Card:
8020-STC

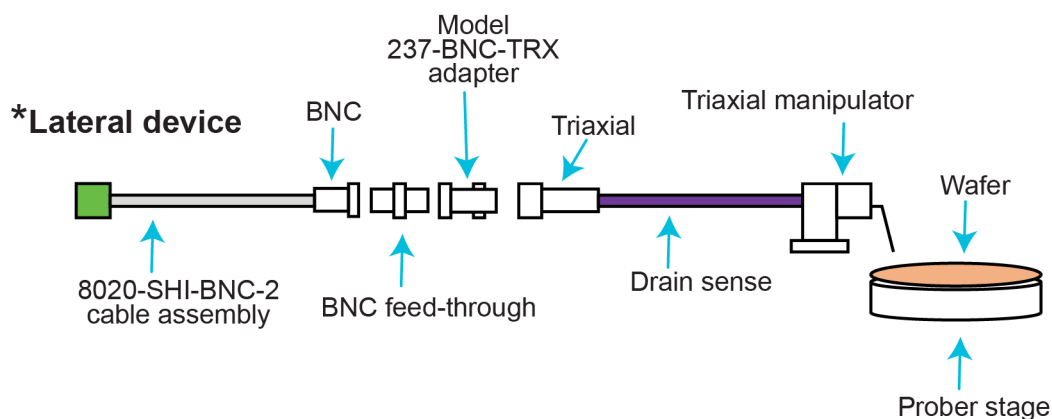
Cable Assembly:
Model 7078-TRX
or
Model 4200-TRX

The next two examples indicate how to connect the sense HI of the Model 2651A to a probe station.

On-state characterization of a power MOSFET using a Model 2651A SHI connection to a prober for lateral devices

For lateral device connections, the Model 2651A sense HI connection using the 8020-SHI-BNC-2 cable is easily adapted to connect to a triaxial manipulator that is common with many probe station vendors.

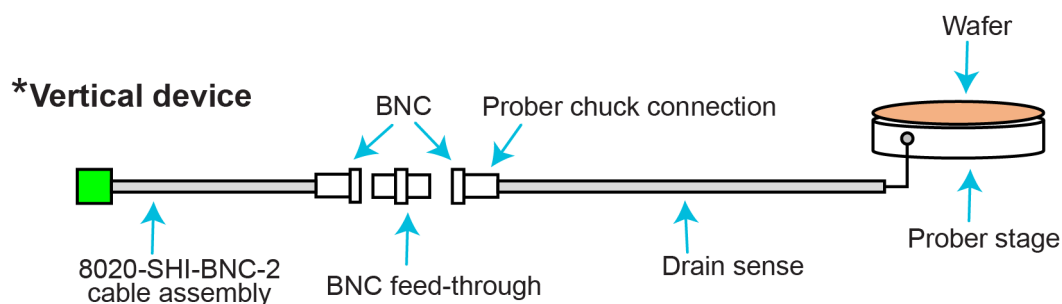
Figure 50: On-state characterization of a power MOSFET using a Model 2651A SHI connection



On-state characterization of a power MOSFET using a Model 2651A SHI connection to a prober for vertical devices

For vertical device connections, the following figure shows cable connections and indicates how to connect the 8020-SHI-BNC-2 cable using a BNC connection to the prober chuck.

Figure 51: On-state characterization of a power MOSFET using a Model 2651A SHI connection



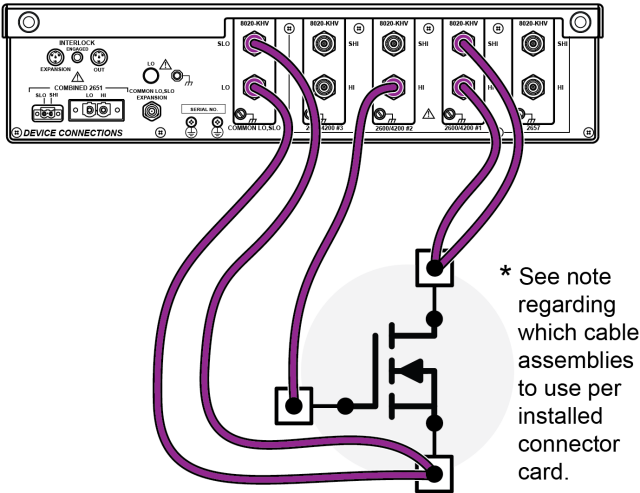
On-state characterization of a power MOSFET using two Series 2600B or 42x0-SMU instruments (up to 10 A pulse)

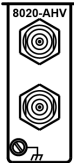

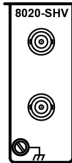
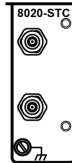
This example illustrates how to make remote sense connections to a MOSFET using two Series 2600B or 42x0-SMU instruments. The following diagram demonstrates how to make connections between the Device Connections Panel of the 8020 and the DUT.

This cable connection allows for a resistance to be placed in series with the gate of the device for stability ([Ensuring continuity in the measurement channel](#) (on page 4-3)). Remote sense connections are maintained to node 1a within the 8020 and the Gate SMU may be configured for 4-wire mode.

Should there be no need for gate resistance for a particular device test, then you may connect the sense HI of the gate SMU to the DUT for optimal remote sense connections.

Figure 52: On-state characterization of a power MOSFET (up to 10 A pulse)



* Cable assemblies will depend upon the connector card the user installs			
			
Connector Card: 8020-AHV	Connector Card: 8020-KHV	Connector Card: 8020-SHV	Connector Card: 8020-STC
Cable Assembly: User supplied	Cable Assembly: Model HV-CA-554	Cable Assembly: User supplied	Cable Assembly: Model 7078-TRX or Model 4200-TRX

2-terminal device connections for C-V measurements

NOTE

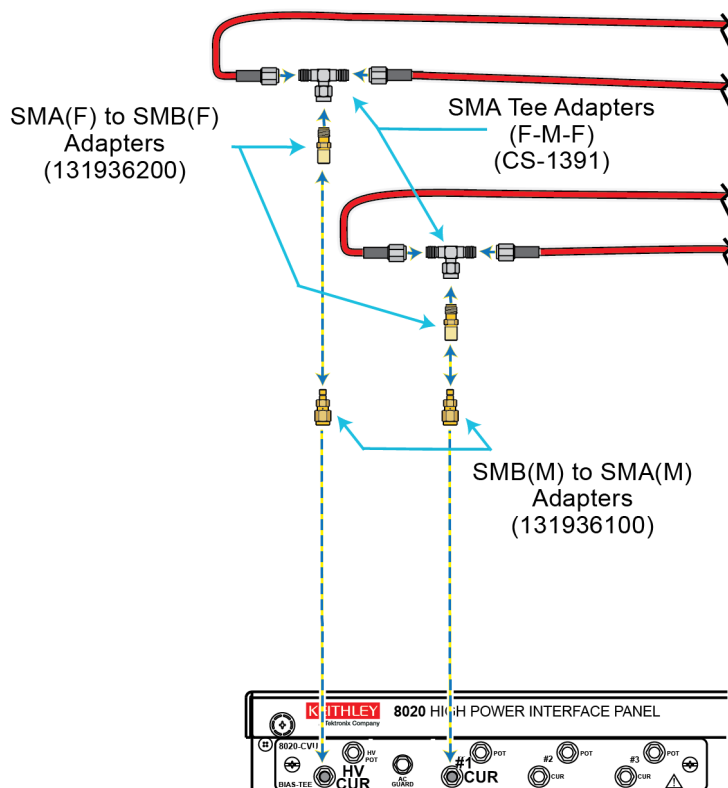
The factory-installed 8020-CVU option must be installed to make the connections illustrated in this sub-section.

This example illustrates how to make connections to a two-terminal device for 3 kV C-V measurements using a Model 2657A SMU and a Series 2600/2600B or 42x0-SMU instrument.

The following diagram illustrates the connections between the 4210-CVU instrument card of the Model 4200A-SCS and the instrument connections panel of the 8020.

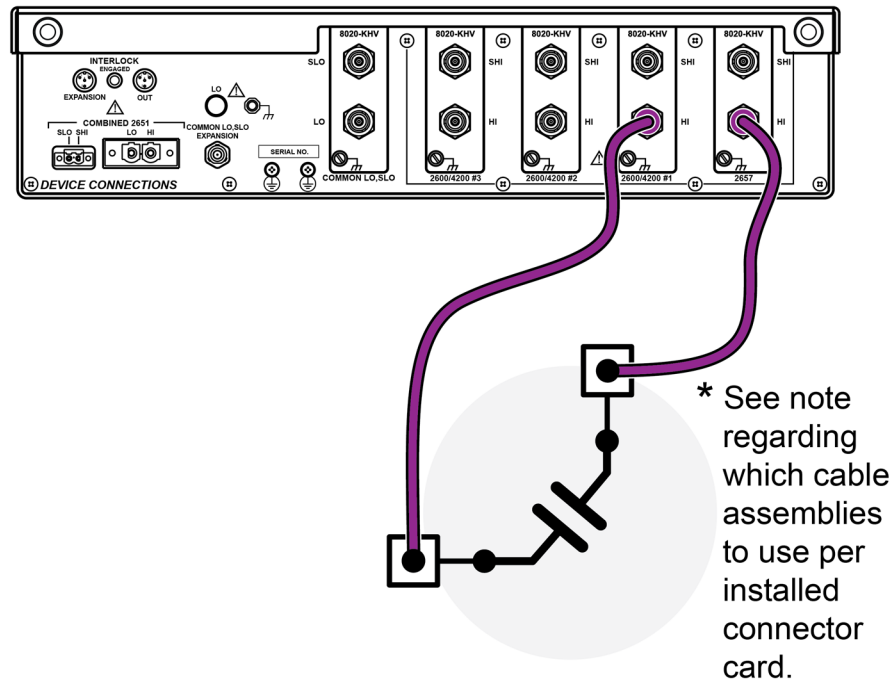
Figure 53: HV C-V 2-terminal measurement connections

HV C-V 2-Terminal measurement connections

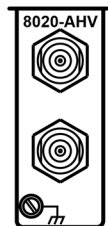


The following diagram illustrates the connections between the device connections panel of the 8020 and the device under test.

Figure 54: 2 terminal, device side, C-V measurement connections

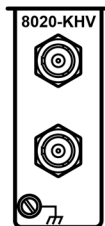


* Cable assemblies will depend upon the connector card the user installs



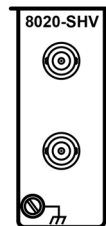
Connector Card:
8020-AHV

Cable Assembly:
User supplied



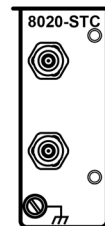
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied

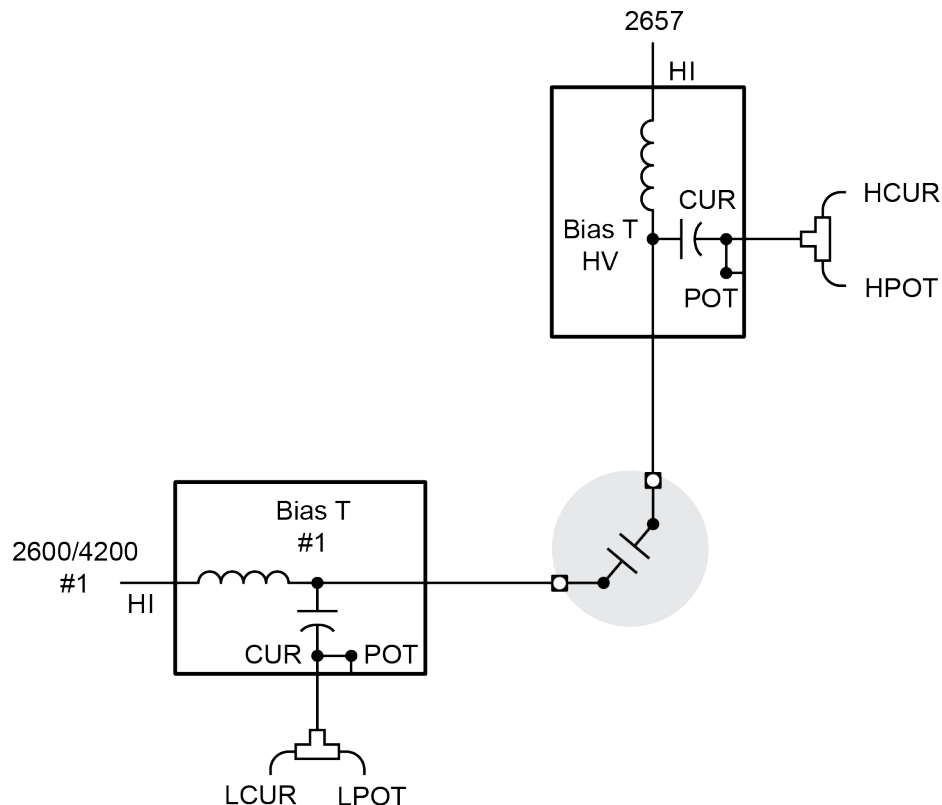


Connector Card:
8020-STC

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

Below is a simple schematic for 2-terminal C-V measurements.

Figure 55: 2-terminal C-V measurement schematic



Open and short compensation

Perform open and short compensation to remove error due to bias tee impedance as well as the stray resistance, capacitance, and inductance in the test setup. For more information on the importance of open and short compensation refer to [Optimize cables and connections for high-voltage C-V measurements](#) (on page 7-6).

To perform an open compensation for a two-terminal C-V measurements, remove the device under test or lift the probes on a probe station to disconnect from the device, and then run an open compensation in the software.

To perform a short compensation for a two-terminal C-V measurement, replace the device under test with a short circuit, and then run a short compensation in the software.

3-terminal device connections for C-V measurements

NOTE

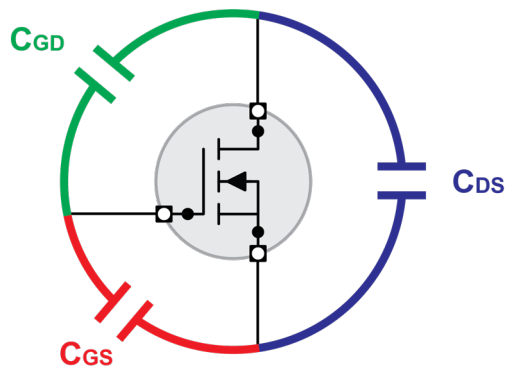
The factory-installed 8020-CVU option must be installed to make the connections illustrated in this sub-section.

Overview and theory

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

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

Figure 56: Component level capacitances for power MOSFET



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

Figure 57: Diagram of input capacitance for a power MOSFET

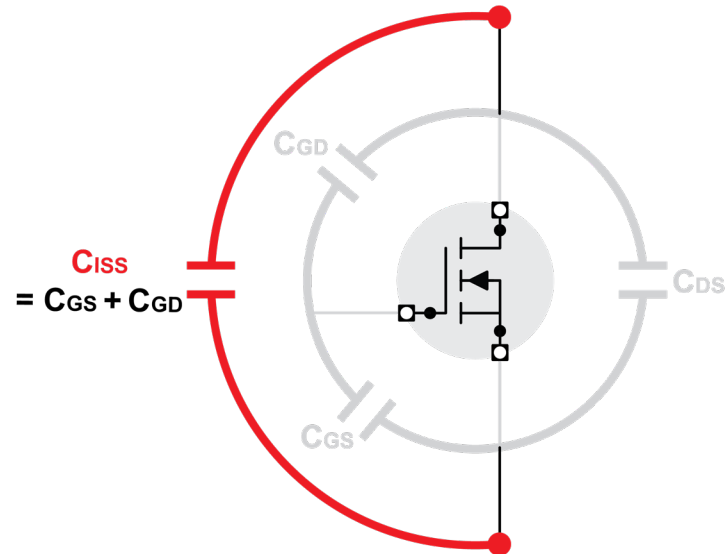


Figure 58: Diagram of output capacitance for a power MOSFET

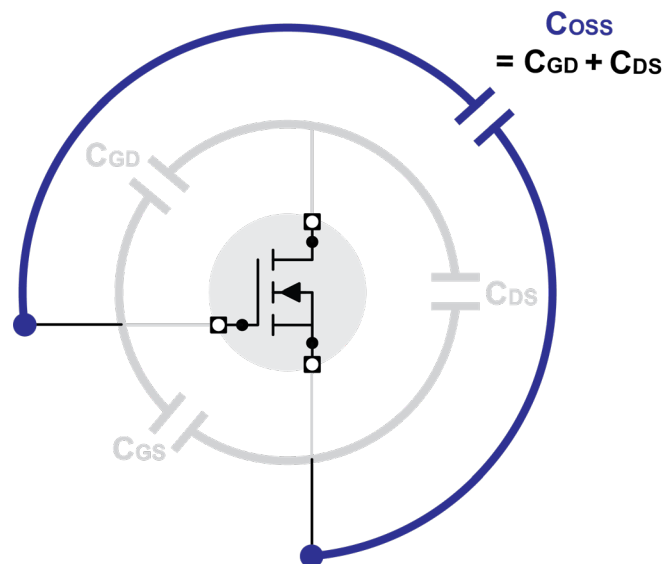
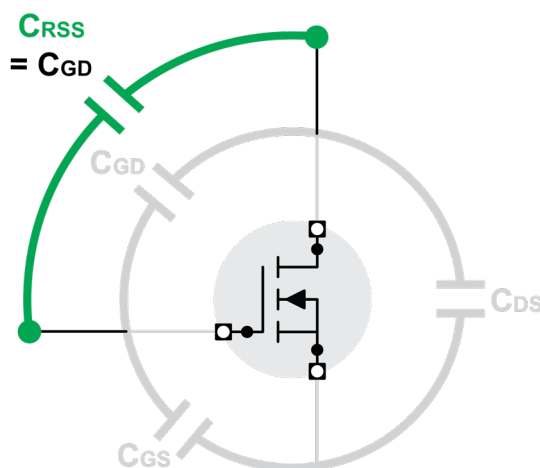


Figure 59: Diagram of reverse transfer capacitance for a power MOSFET

Device capacitance typically varies with applied voltage. Complete characterization of the DUT requires knowledge of the capacitance at the maximum rated voltage. The remainder of this section will review the connection diagrams between the instrumentation, the 8020, and the DUT for high-voltage capacitance measurements.

Instrument connections for power MOSFET capacitance measurements

The graphics in this section illustrate the connections between the 4210-CVU instrument card and the instrument connections panel of the 8020. The graphics also assume that connections to the SMU have already been made. For detail on how to connect SMU to the 8020, please refer to [Connections to the instrument panel](#) (on page 3-6).

Cgs

Figure 60: Cgs connection diagram

HV C-V 3-Terminal CGS measurement connections

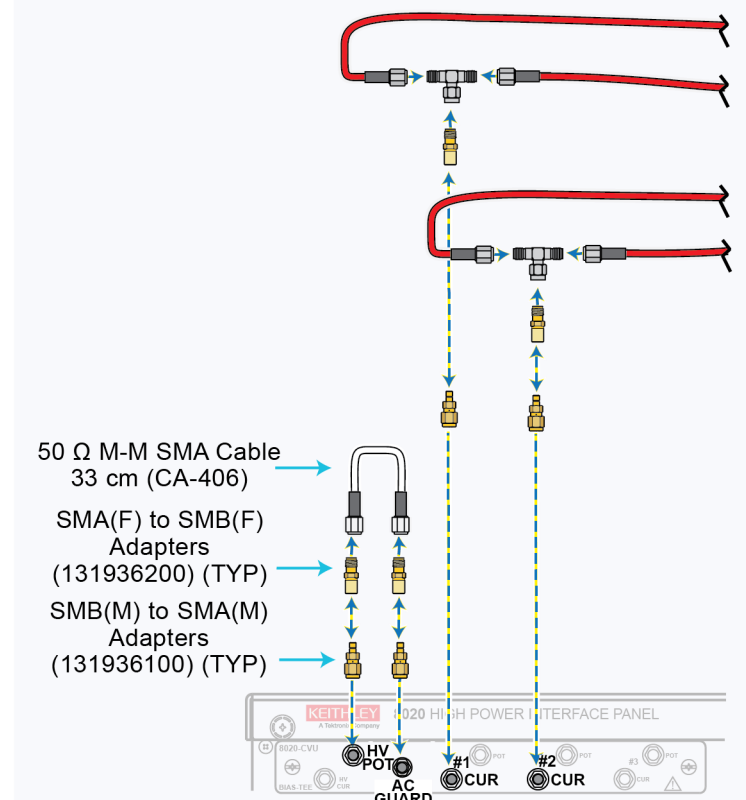
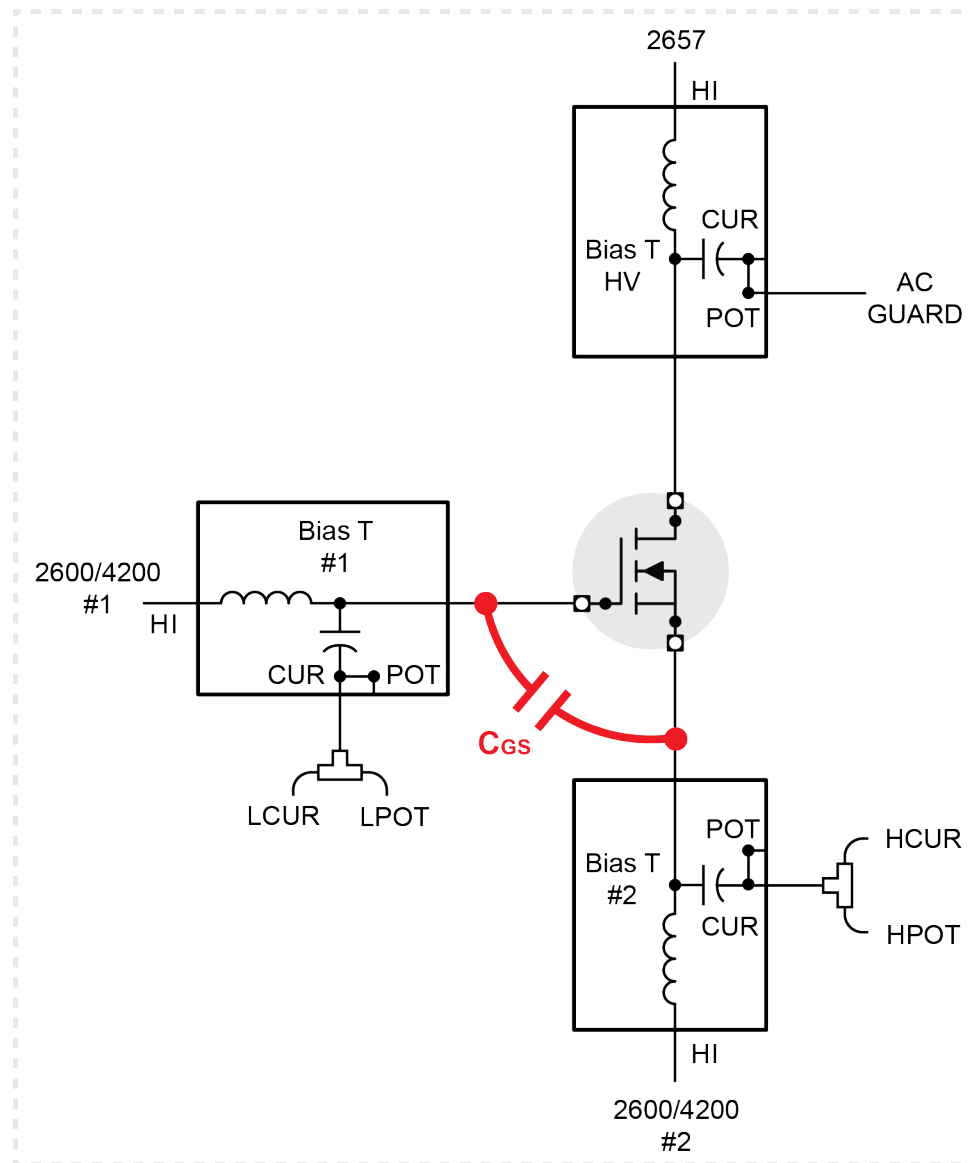


Figure 61: Cgs block diagram schematic

Cds

Figure 62: Cds connection diagram

HV C-V 3-Terminal CDS measurement connections

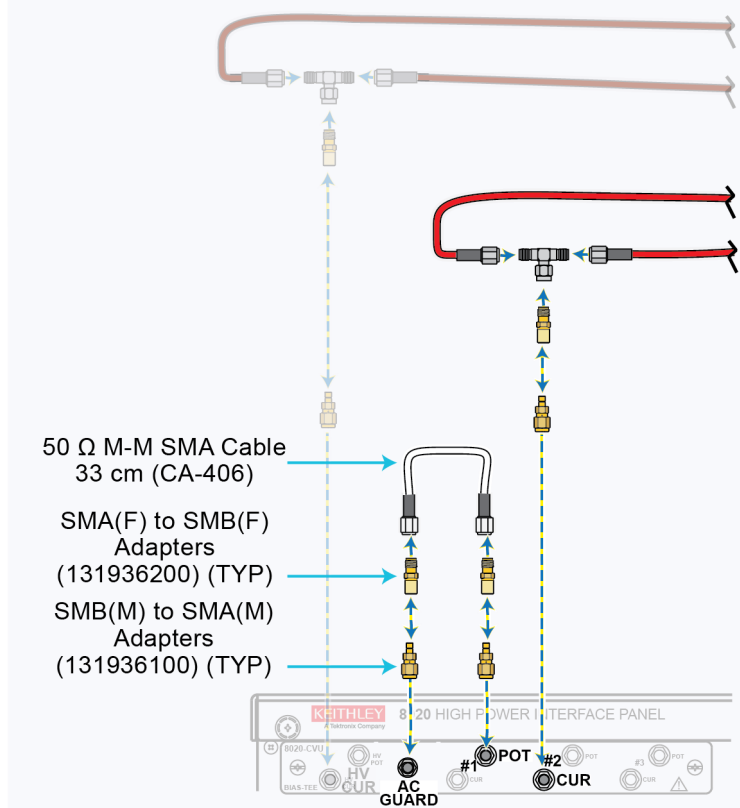
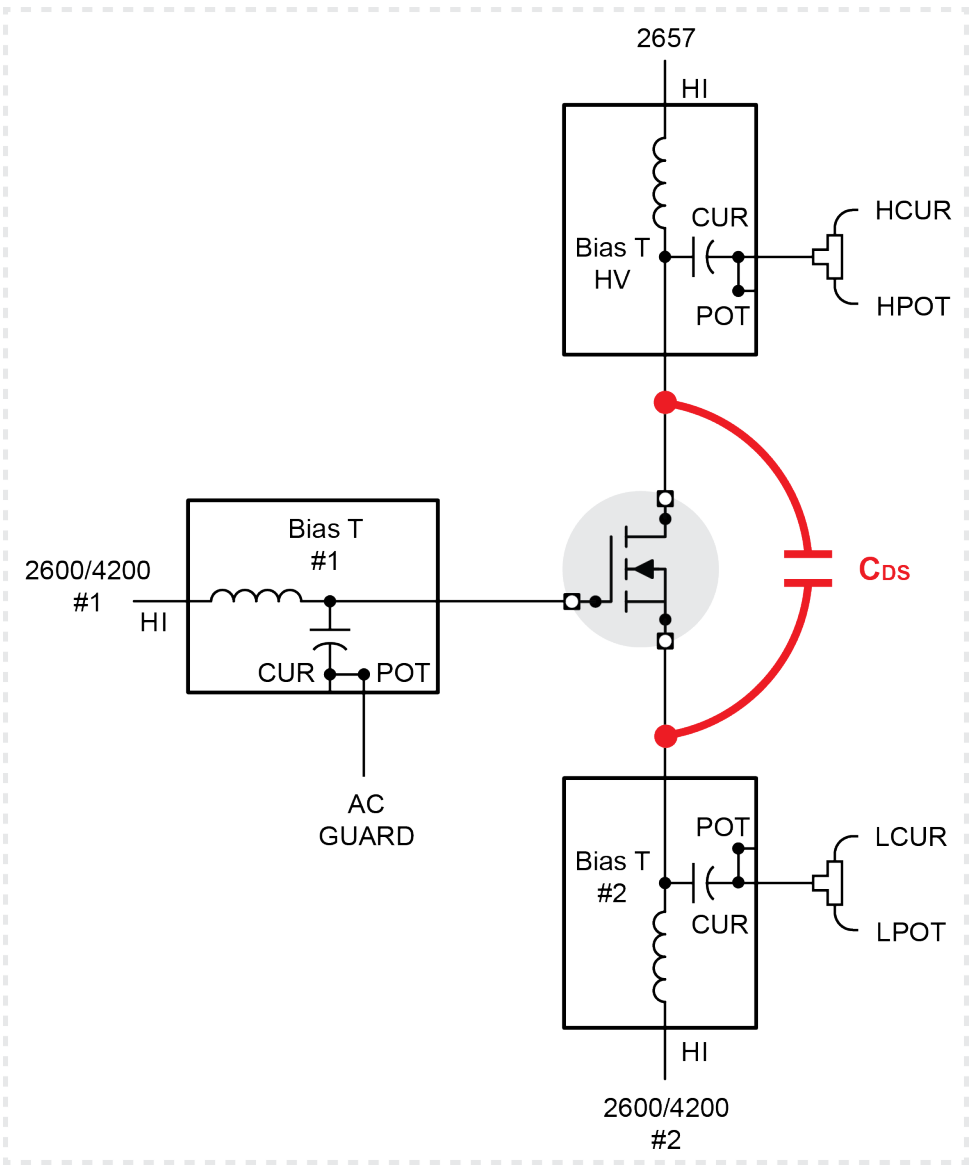


Figure 63: Cds block diagram schematic



Cgd and Crss

Figure 64: Cgd / Crss connection diagram

HV C-V 3-Terminal CRSS = CGD measurement connections

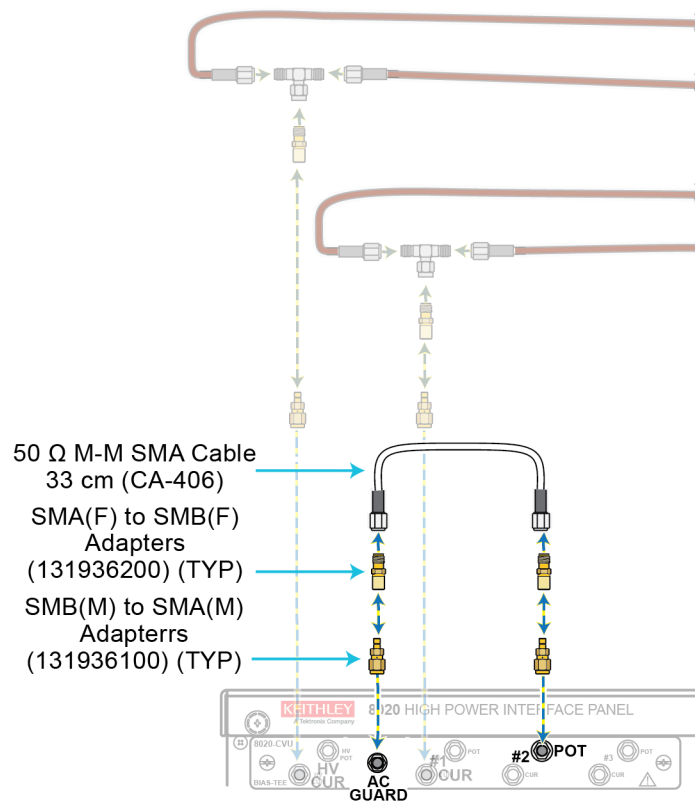
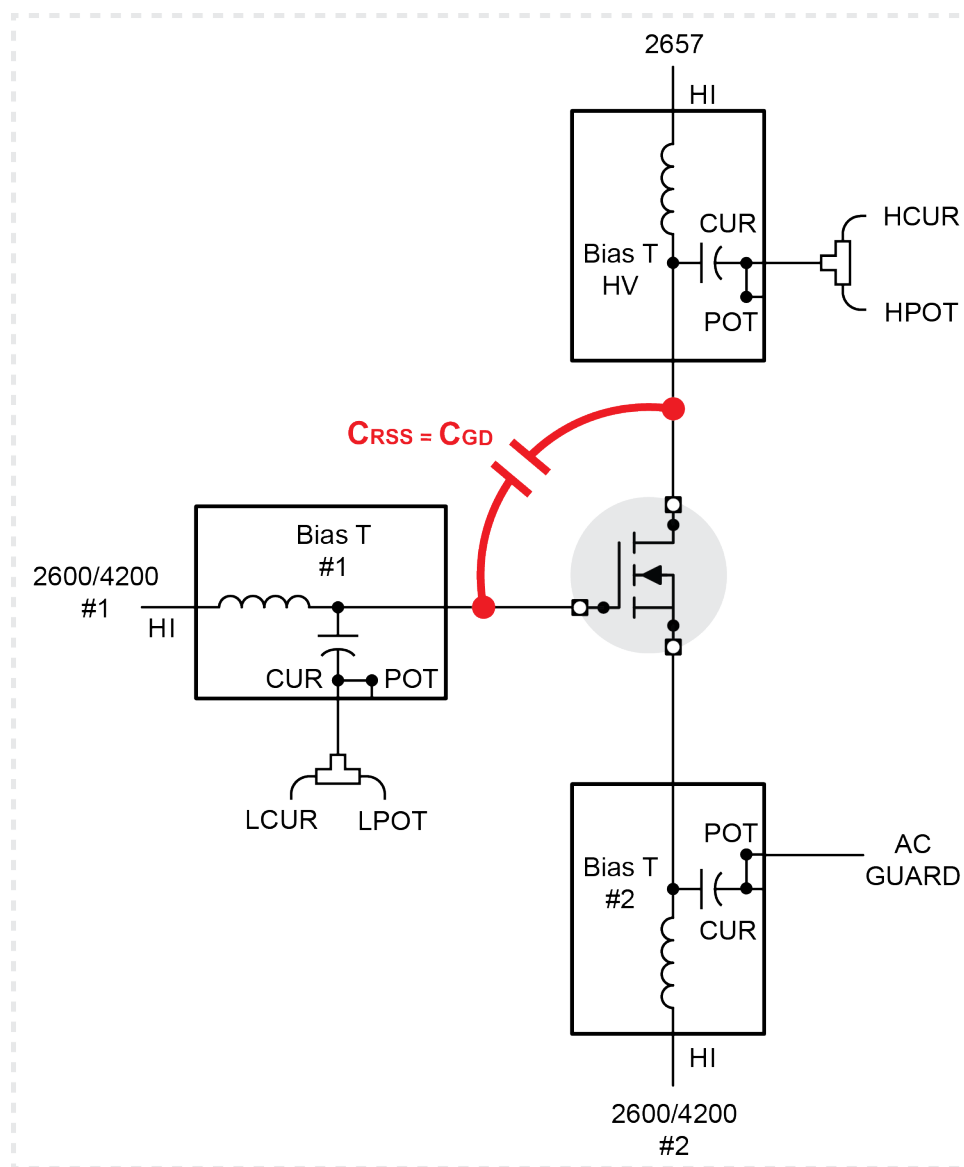


Figure 65: Cgd / Crss block diagram schematic

Ciss

Figure 66: Ciss connection diagram

HV C-V 3-Terminal Ciss measurement connections

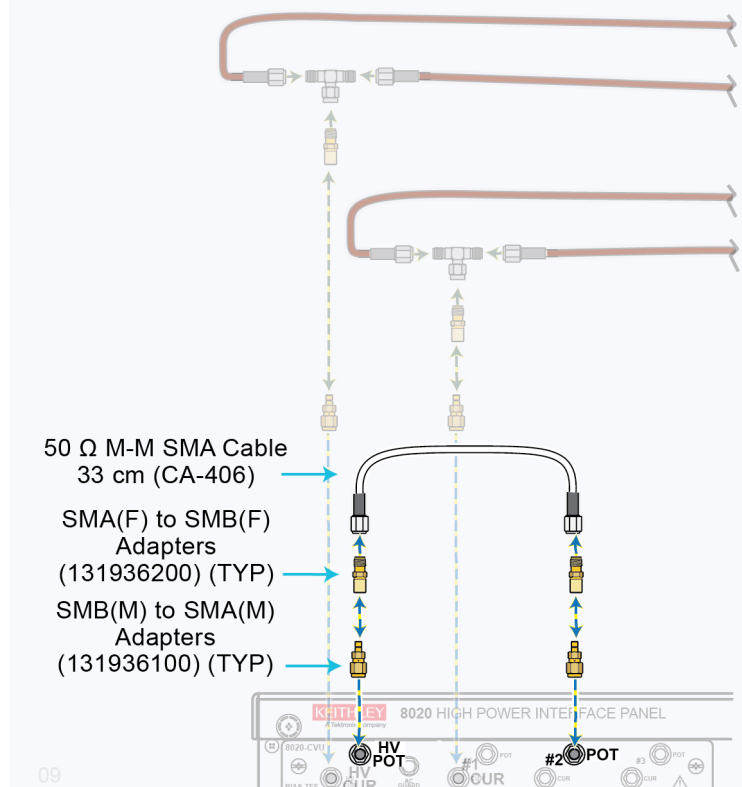
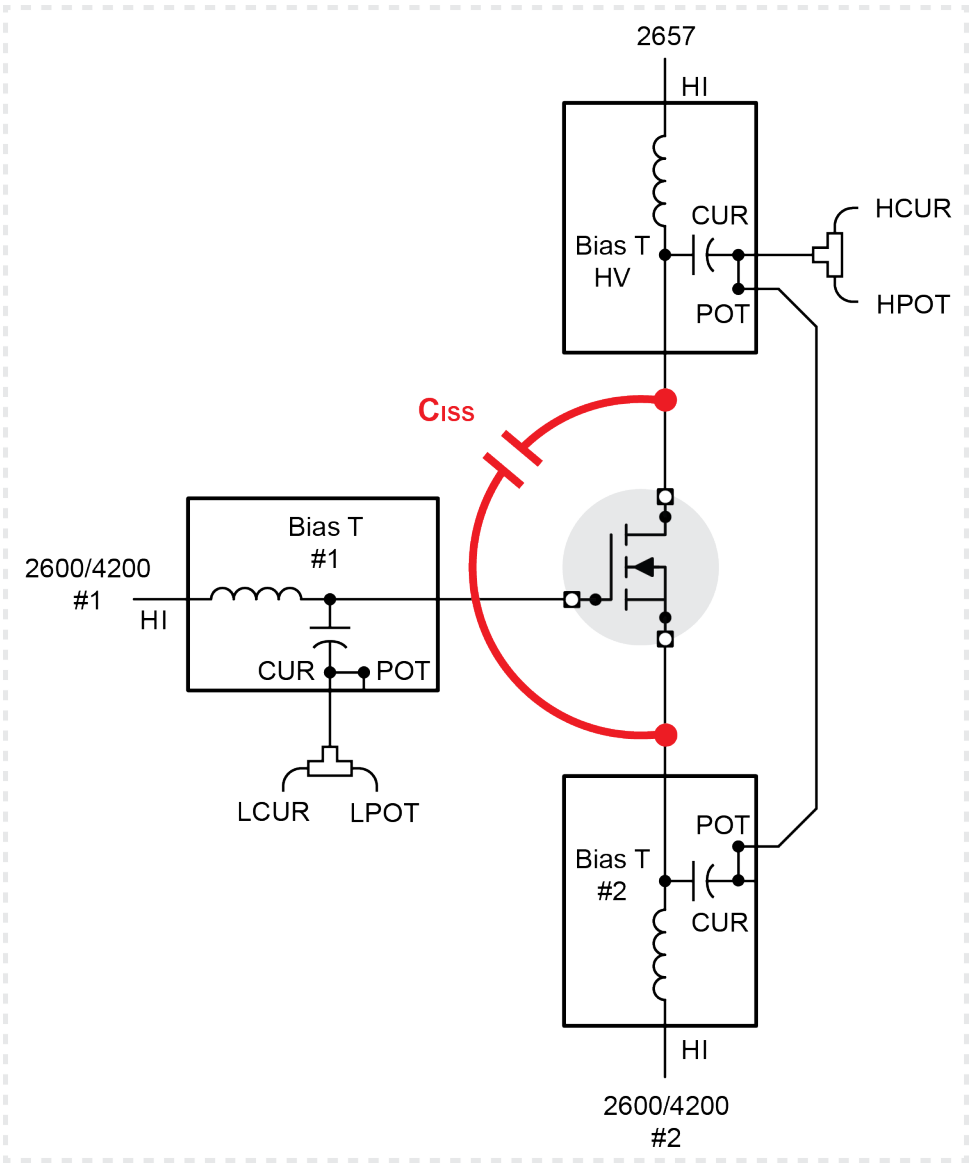


Figure 67: Ciss block diagram schematic



Coss

Figure 68: Coss connection diagram

HV C-V 3-Terminal Coss measurement connections

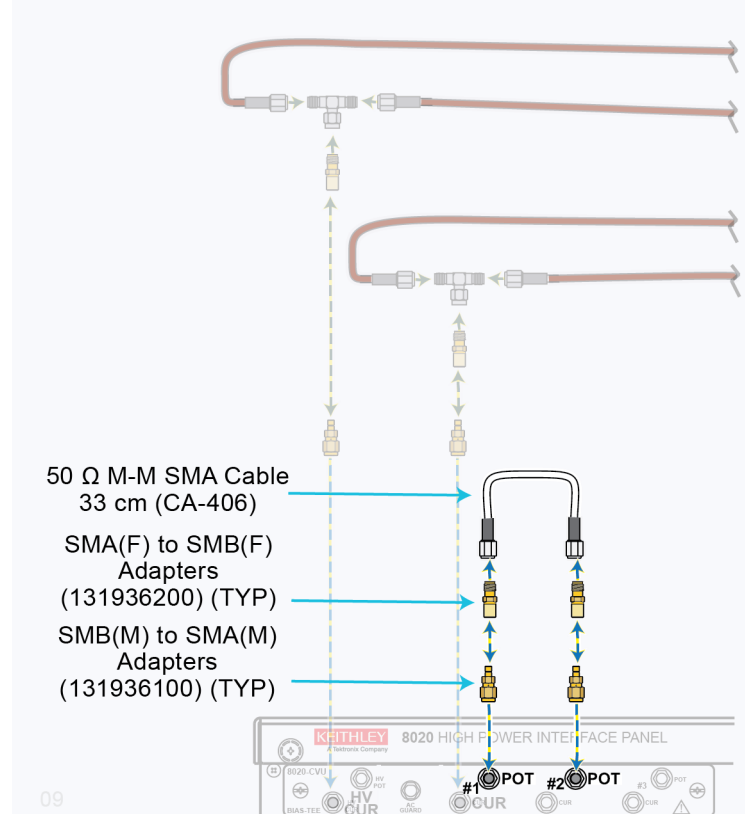
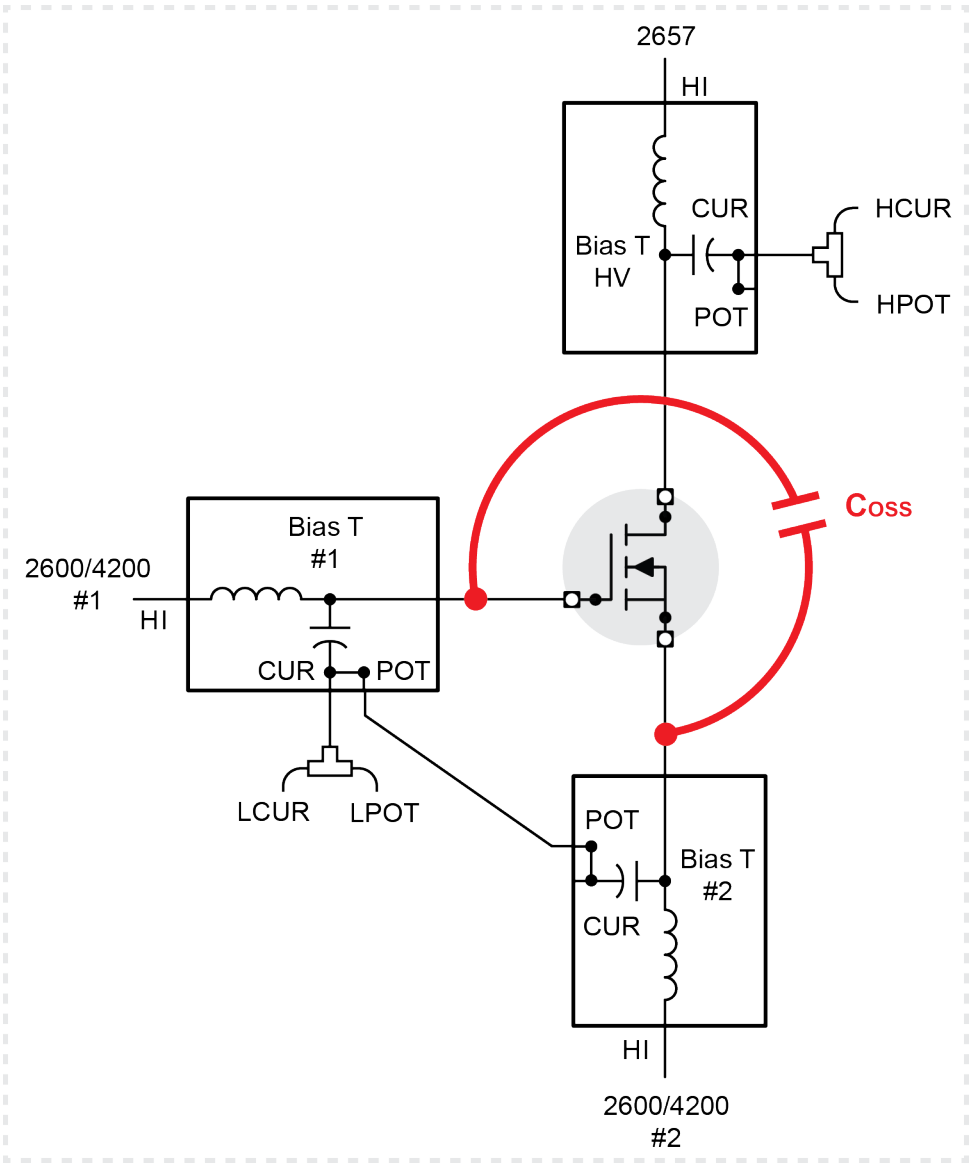


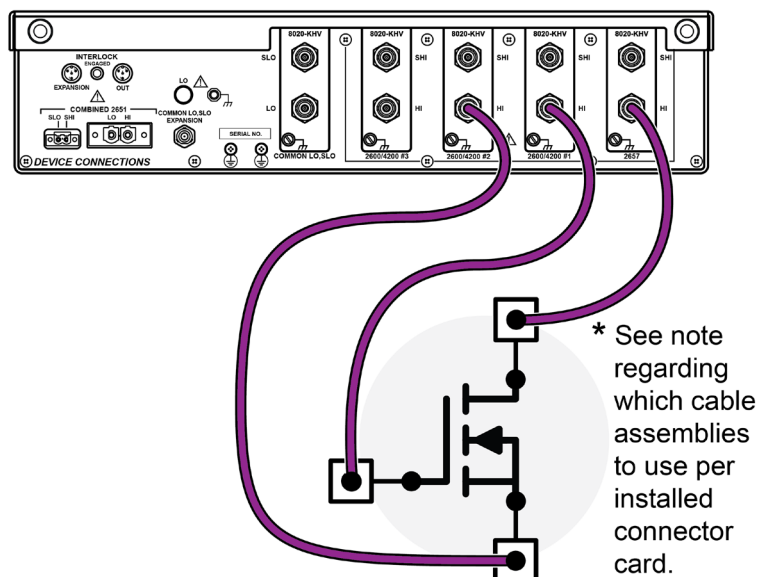
Figure 69: Coss block diagram schematic



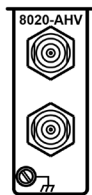
Device connections for power MOSFET capacitance measurements

For both component-level and circuit-level capacitance measurements, the connections between the device connections panel of the 8020 and the DUT are the same. The following diagram illustrates connections for high-voltage C-V measurements up to 3 kV. For measurements up to 200 V, make connections between the Series 2600/2600B or 4200A-SCS channels #1, #2, #3 and the DUT. In cases where only two Series 2600B or 4200A-SCS instruments are available, make connections between the 2600B or the 4200A-SCS channels #1 and #2, the common LO channel, and the DUT.

Figure 70: 3-terminal power MOSFET capacitance measurements connections

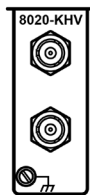


* Cable assemblies will depend upon the connector card the user installs



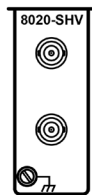
Connector Card:
8020-AHV

Cable Assembly:
User supplied



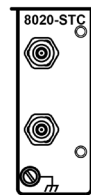
Connector Card:
8020-KHV

Cable Assembly:
Model HV-CA-554



Connector Card:
8020-SHV

Cable Assembly:
User supplied



Connector Card:
8020-STC

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

Open and short compensation

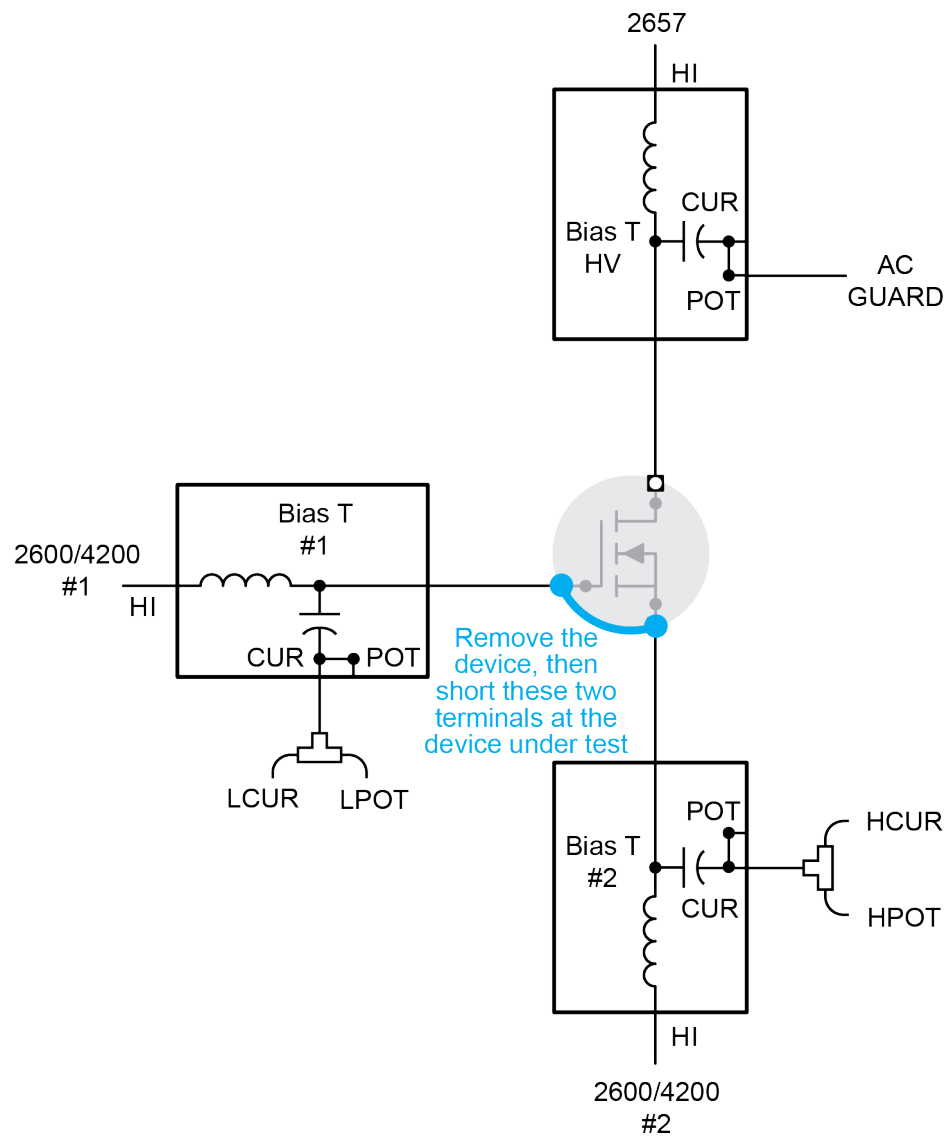
Perform open and short compensation to remove error due bias tee impedance as well as the stray resistance, capacitance and inductance in the test setup. For more information on the importance of open and short compensation, refer to [Optimize cables and connections for high-voltage C-V measurements](#) (on page 7-6).

The following sections detail the connections to properly perform open and short compensation for HV C-V measurements using the 8020 high-power interface panel.

Cgs

To perform an open compensation for a Cgs measurement, remove the DUT or lift the probes on a probe station to disconnect from the device, and then run an open compensation in the ACS Basic software.

To perform a short compensation for a Cgs measurement, remove or disconnect from the device and place a short between the connections to the gate and source terminals. Note the location of the short in the following figure. Then, run a short compensation in the ACS Basic software.

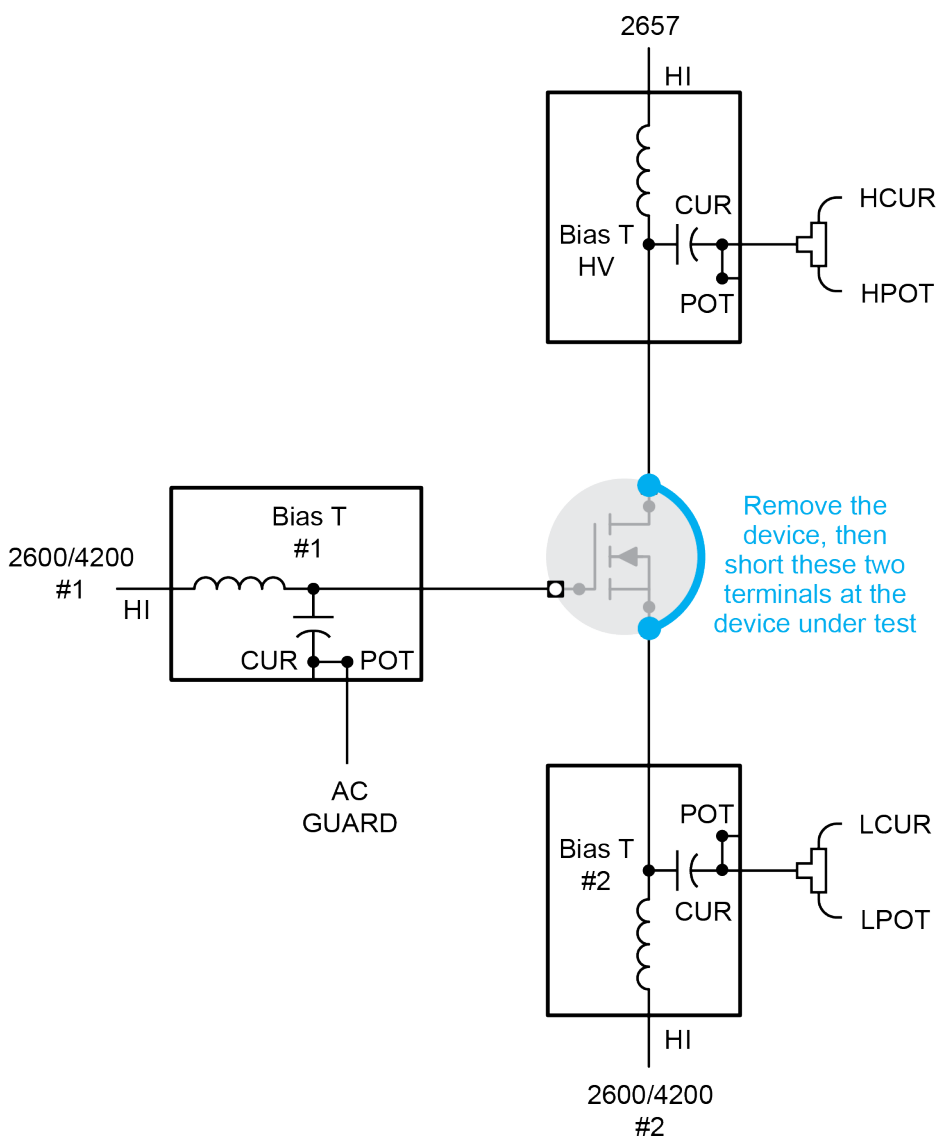
Figure 71: Cgs measurement, short compensation

Cds

To perform an open compensation for a Cds measurement, remove the DUT or lift the probes on a probe station to disconnect from the device, and then run an open compensation in the ACS Basic software.

To perform a short compensation for a Cds measurement, remove or disconnect from the device and place a short between the connections to the drain and source terminals. Note the location of the short in the following figure. Then, run a short compensation in the ACS Basic software.

Figure 72: Cds measurement, short compensation

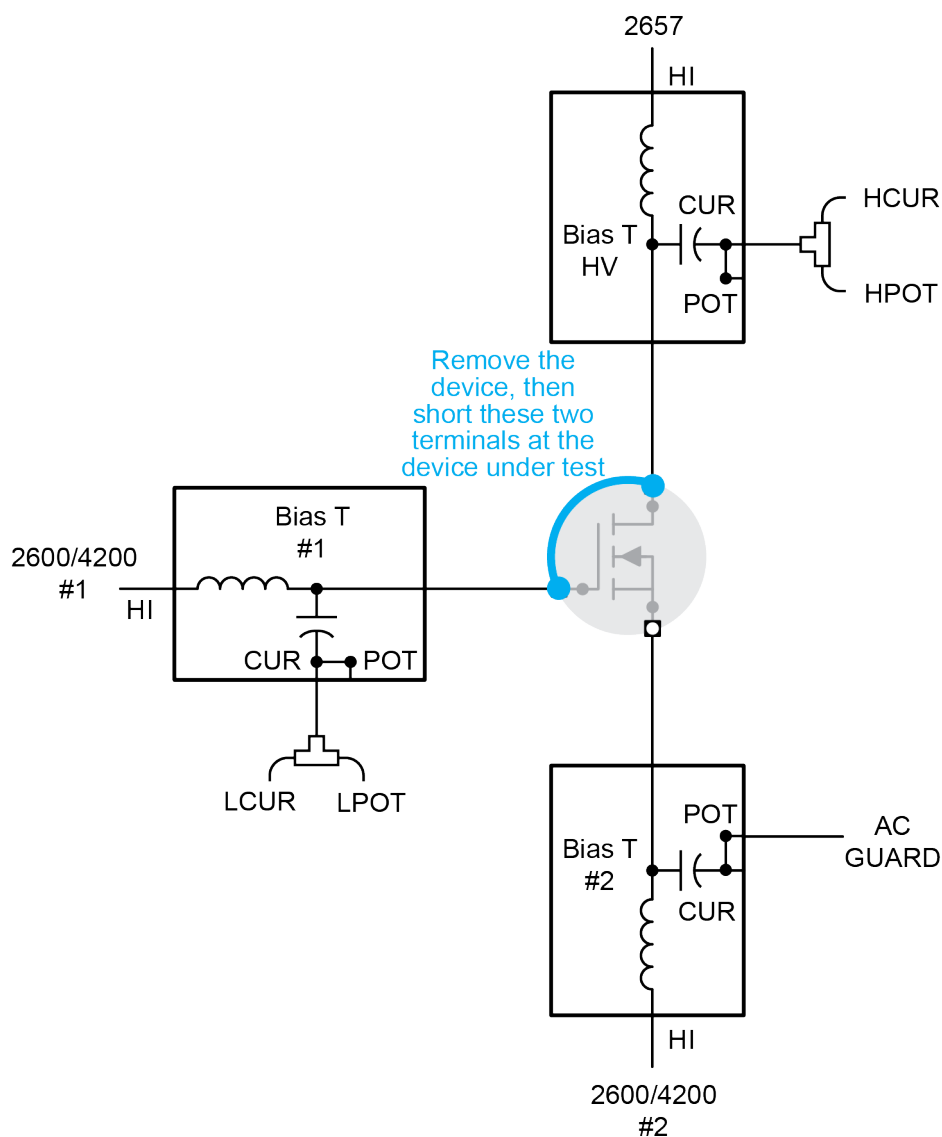


Cgd and Crss

To perform an open compensation for a Cgd measurement, remove the DUT or lift the probes on a probe station to disconnect from the device, and then run an open compensation in the ACS Basic software (refer to [Cgd and Crss](#) (on page 6-22) for instrument connections and more detail).

To perform a short compensation for a Cgd measurement, remove or disconnect from the device and place a short between the connections to the gate and drain terminals. Note the location of the short in the following figure below. Then, run a short compensation in the ACS Basic software.

Figure 73: Cgd / Crss measurement, short compensation

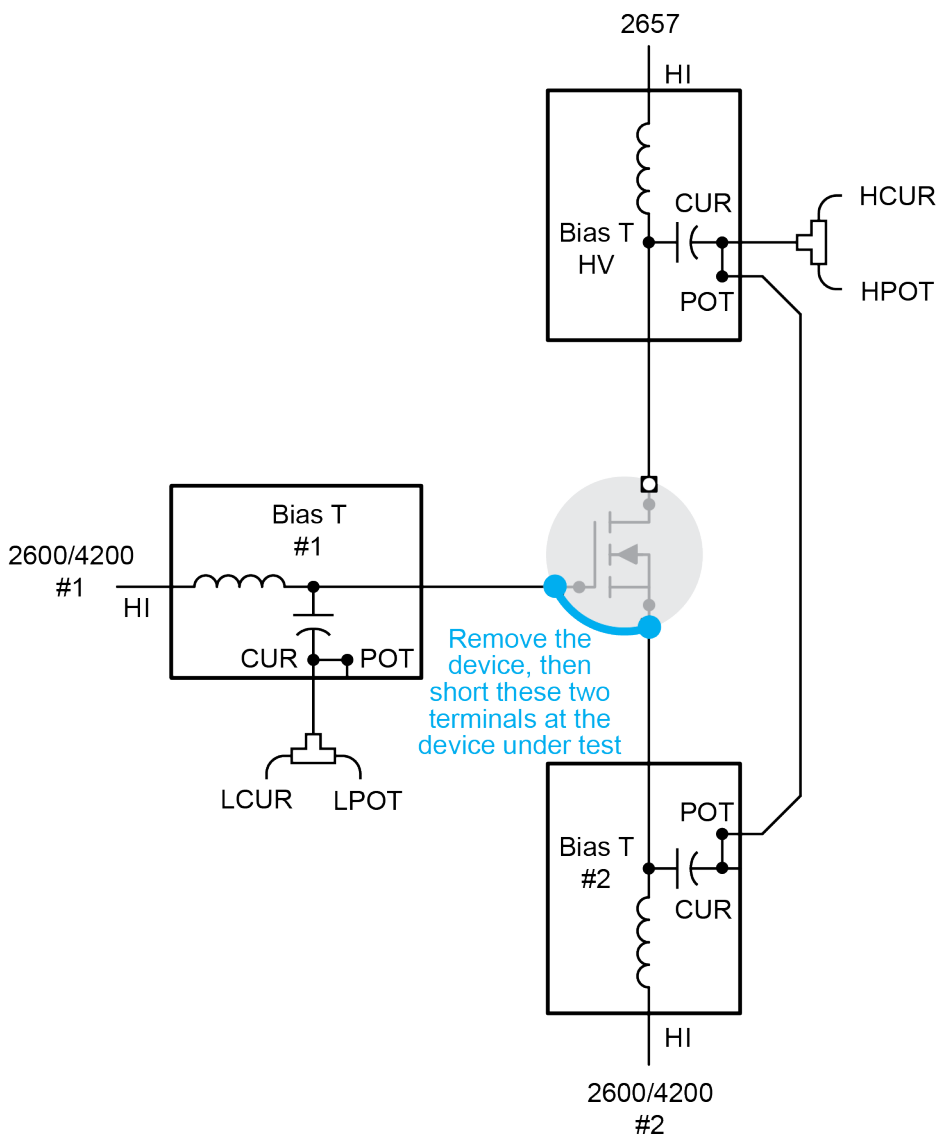


Ciss

To perform an open compensation for a Ciss measurement, remove the DUT or lift the probes on a probe station to disconnect from the device, and then run an open compensation in the ACS Basic software.

To perform a short compensation for a Ciss measurement, remove or disconnect from the device and place a short between the connections to the gate and source terminals. In this compensation, we are only compensating for the largest capacitance of the two-terminal combination. Note the location of the short in the following figure. After installing the short, run a short compensation in the ACS Basic software.

Figure 74: Ciss measurement, short compensation

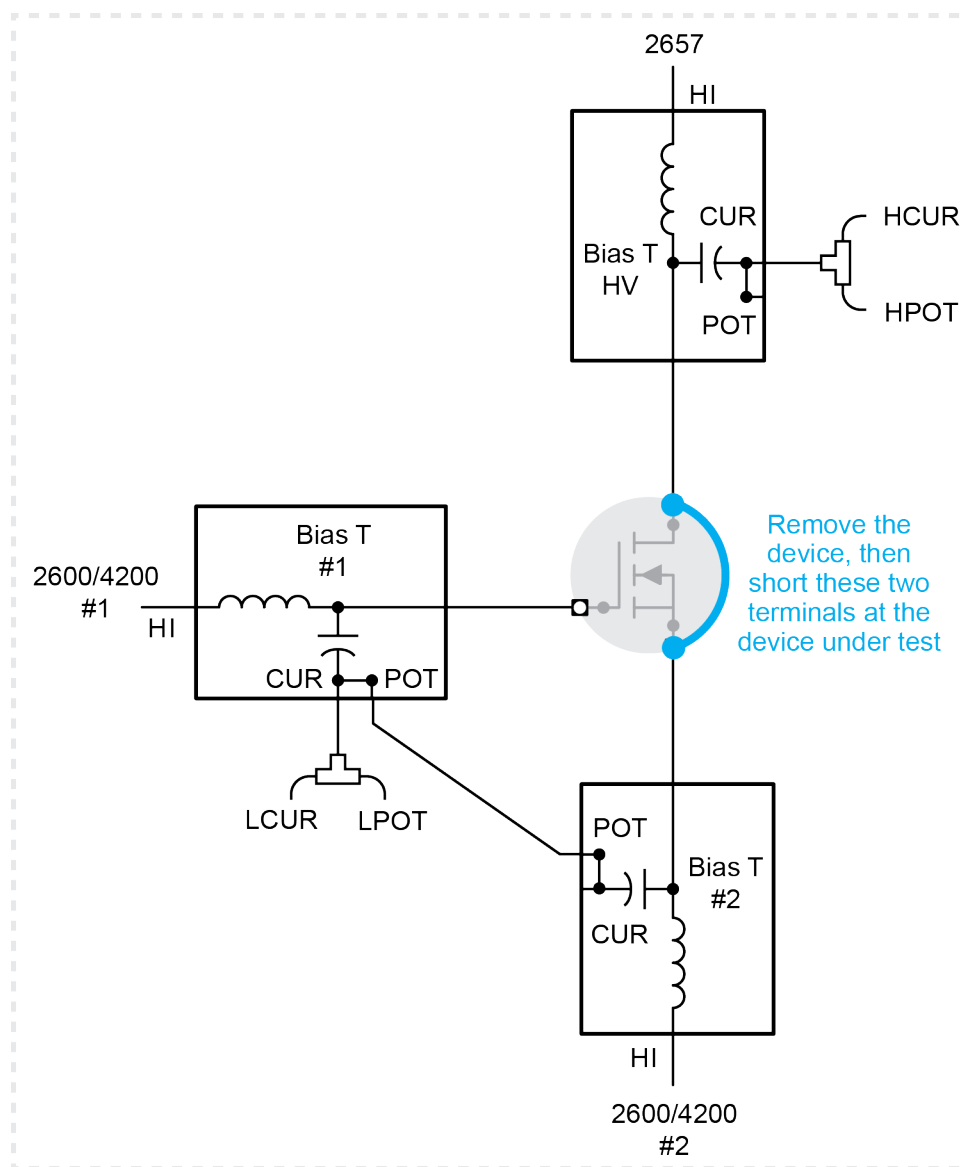


Coss

To perform an open compensation for a Coss measurement, remove the DUT or lift the probes on a probe station to disconnect from the device, and then run an open compensation in the ACS Basic software.

To perform a short compensation for a Coss measurement, remove or disconnect from the device and place a short between the connections to the drain and source terminals. In this compensation, we are only compensating for the larger of Cgd and Cds (typically Cds). Note the location of the short in the following figure. After installing the short, run a short compensation in the ACS Basic software.

Figure 75: Coss measurement, short compensation



Measurement considerations

In this section:

Introduction	7-1
2-wire (local) vs. 4-wire (remote).....	7-1
Optimize cables and connections for low current dc measurements	7-3
Suppress device oscillations for dc and pulsed dc measurements	7-4
Optimize connections for high current dc pulses.....	7-5
Optimize cables and connections for high-voltage C-V measurements	7-6

Introduction

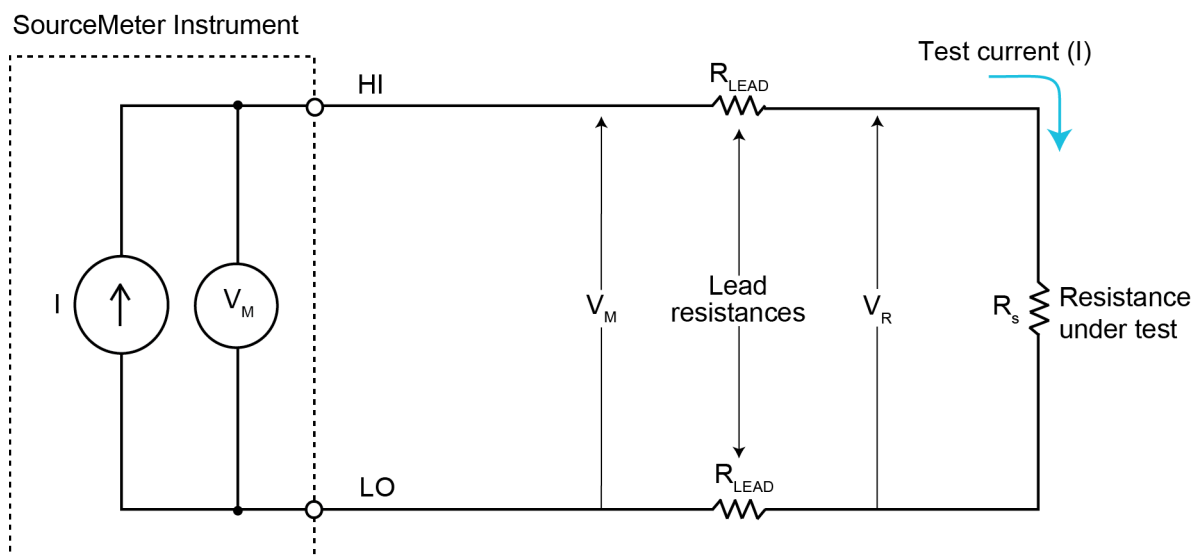
The following topics describe some considerations to be aware of when taking measurements.

2-wire (local) vs. 4-wire (remote)

NOTE

This information is relevant for dc IV measurements only. HV C-V measurements made through the 8020 are 2-wire (local) sense only.

The 2-wire sensing method requires only two test leads. However, as shown in the following figure, test lead resistance can seriously affect the accuracy of 2-wire resistance measurements, particularly when measuring smaller resistance values.

Figure 76: Two-wire resistor sensing

I = Current sourced

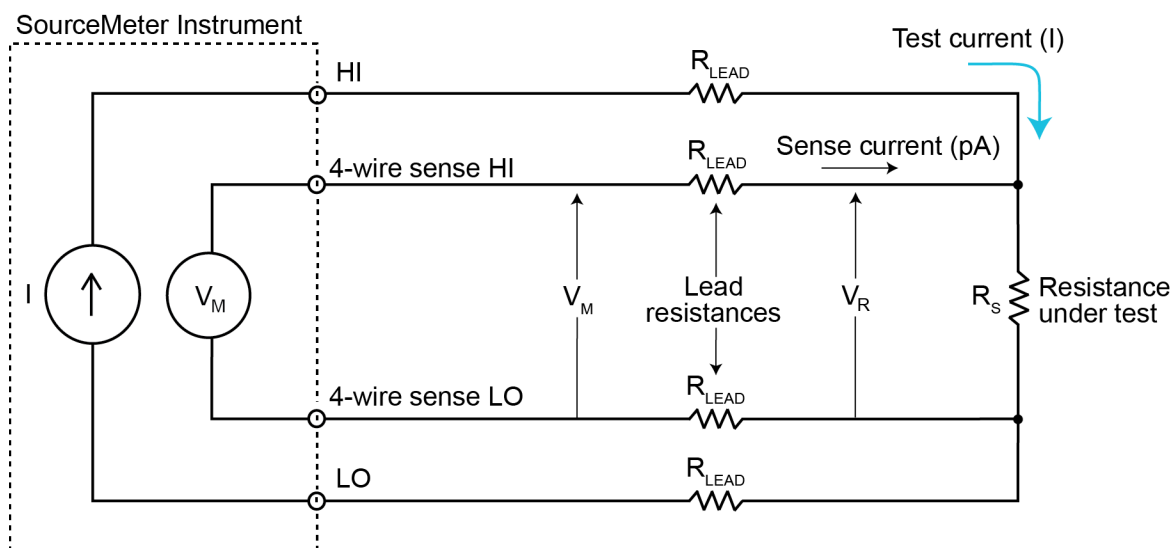
V_M = Voltage measured

V_R = Voltage across resistor

$$\text{Measured resistance} = \frac{V_M}{I} = R_s + (2 \times R_{LEAD})$$

$$\text{Actual resistance} = \frac{V_R}{I} = R_s$$

The 4-wire sensing method, as shown in the following figure, minimizes or eliminates the effects of lead resistance by measuring the voltage across the resistor under test with a second set of test leads. Because of the high input impedance of the voltmeter, the current through the sense leads is negligible, and the measured voltage is essentially the same as the voltage across the resistor under test.

Figure 77: Four-wire resistance sensing

I = Current sourced by SourceMeter
 V_M = Voltage measured by SourceMeter
 V_R = Voltage across resistor

Because sense current is negligible, $V_M = V_R$
 and measured resistance = $\frac{V_M}{I} = \frac{V_R}{I} = R_s$

The 8020 includes 1 M Ω auto-sense resistors between sense Hi and HI and 1 k Ω between sense LO and LO. These resistors ensure that there is always a connection to the sense terminals and that improper connections do not result in unintended output.

NOTE

If you have installed a resistor between nodes 1 and 2 on the 8020 motherboard to suppress device oscillations, remove the sense Hi connection at the device connections panel of the 8020. The SMU will sense voltage at the instrument side of the resistor.

Optimize cables and connections for low current dc measurements

Ensuring proper connections between the instrumentation and the device under test (DUT) is key to optimizing low current dc measurements. Leakage currents are caused by stray resistance paths between instruments and the DUTs. Leakage current can occur through parasitic or nonparasitic leakage paths.

An example of parasitic resistance is the leakage path across the insulator in a coaxial or triaxial cable. An example of nonparasitic resistance is the leakage path through a resistor that is connected in parallel to the DUT.

A driven guard is important for maintaining low-leakage measurements. Each of the HV and 200 V channels of the 8020 brings in the driven guard from each SMU instrument on the triaxial connector inner shell. This driven guard is always enabled and provides a buffered voltage that is at the same level as the HI (or sense HI for remote sense) voltage.

Guard is typically used to drive the guard shields of cables and test fixtures. Guard is extended to a test fixture from the cable guard shield. This is only true for triaxial cable connections. When using coaxial connector cards, such as the 8020-SHV, guard is not carried to the DUT. Therefore, measurements made through coaxial connector cards will include the error due to leakage paths that occur between the connector card and the DUT. For optimal low current dc measurements, triaxial connections are recommended throughout the test system.

Low current dc measurements require additional settling time when performed with the 8020-CVU bias tee option installed. Refer to the Model 8020 specifications for typical settling time values.

Suppress device oscillations for dc and pulsed dc measurements

Power transistors are prone to self-oscillation under forward bias conditions. In such cases, there may be oscillations or ringing in the gate or drain voltage waveforms. This would be visible using an oscilloscope or the Model 2651A high speed A dc when monitoring the drain waveform. These oscillations often result in inconsistent or unrepeatable dc drain voltage and current measurements.

To dampen these oscillations and stabilize the gate, some manufacturers recommend adding a resistor in series with the gate terminal (between the device gate and the SourceMeter connected to the gate). See How to insert a series resistor in the 8020 for details.

The device manufacturer may recommend a specific resistance value, or you may determine an appropriate resistance value by trial and error. Typical gate resistor values range from tens to hundreds of ohms.

The 8020 is supplied with a kit of resistors that can be used for this purpose. See the 8020-RES-KIT HV-Rated Resistors document on tek.com/keithley.

NOTE

When series resistors are used to quell device oscillations, 4-wire (remote) sense connections must terminate at the instrument side of the resistor. Therefore, disconnect sense HI at the DUT.

If the device oscillations remain after inserting a series resistor, enable the high-capacitance mode (if available) on the SMU connected to the gate. If high-capacitance mode is enabled, the gate SMU cannot output pulsed dc signals.

Optimize connections for high current dc pulses

NOTE

The 8020 can carry up to 100 A pulses from two Model 2651A SMU instruments.

You can connect two Model 2651A SMU instruments to the 8020, and the SMU instruments are connected in parallel. High current pulses require low-resistance and low-inductance connections to minimize voltage drops and voltage errors in the measurements.

The series resistance of a cable is related to the thickness of the current-carrying conductor; to minimize error due to excessive series resistance, use cables of sufficient thickness. To maximize accuracy of voltage measurements made in a high-current test setup, use 4-wire (remote) sense connections between the high-current SMU instrument and the DUT.

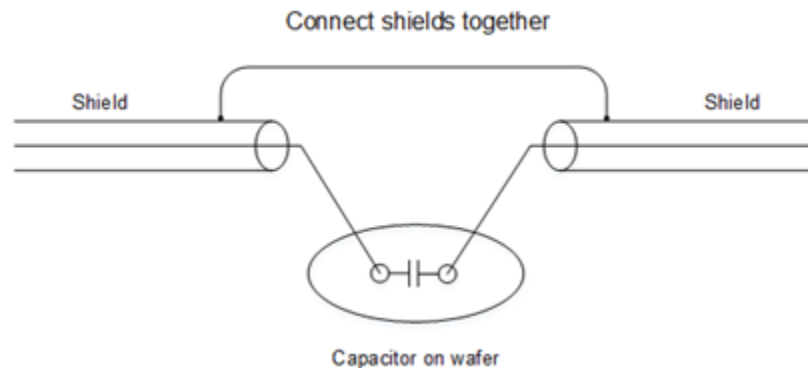
Observe that inductance is related to the loop area between the HI and LO leads of the high-current conductor. The Keithley Model 2651A-KIT cable assemblies are designed to have low-resistance inductance and the cables are recommended whenever the Model 2651A High Power System SourceMeter instrument is used. When coaxial cable is not suitable for the probe station environment, cables with at least a 12 AWG conductor are recommended. You can also twist single conductors for HI and LO to minimize loop area inductance.

There may be some test system geometries in which it may not be possible to overcome the parasitic resistance and inductance (such as probing to vertical devices), and measurement error will result. Excessive inductance may slow the rise time of a pulse and result in inaccurate fast A dc readings on the leading and falling edges of the pulse. For a series resistance error, take note of the maximum voltage that the SMU can tolerate between the force and sense leads. Exceeding this voltage will result in a voltage measurement error. Reduce the test current to stay within the force-sense voltage limitation.

Optimize cables and connections for high-voltage C-V measurements

Successful C-V measurements require a precise coaxial cabling setup. The Model 4210-CVU C-V instrument is a four-terminal instrument that includes remote sense capability. A C-V meter includes an ac voltage source and an ac ammeter. The sense leads are used to maintain the voltage at the device terminals. As with all ac measurements, ensure a connection between the shields of all the terminals at the DUT. The integrity of this connection becomes increasingly important with an increase in the test frequency. The connection between the shields forms an inductive loop that is directly inserted in the measurement path. Connect the cable shields together as close as possible to the DUT to minimize the inductive loop area. See the following illustration for an example.

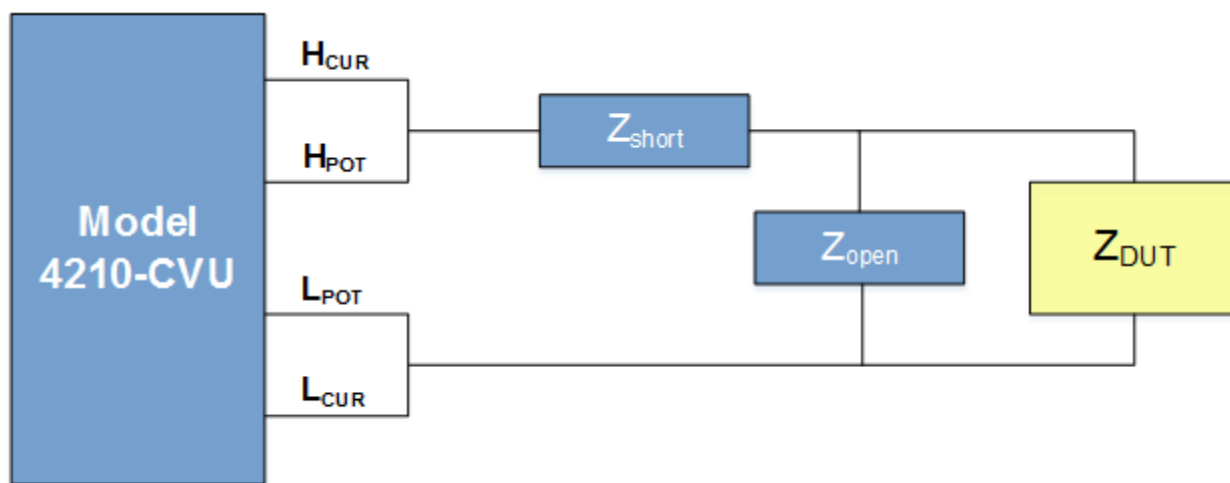
Figure 78: Inductive loop formed by connected shields



NOTE

The 8020 4-wire measurements for the C-V instrument are terminated at the instrument panel. From the instrument panel out to the DUTs, the C-V measurement is a 2-wire measurement. Do not connect the sense Hi and sense LO terminals to the DUTs.

Stray capacitance, resistance, and inductance in the test setup cause measurement errors. These errors will vary with setup and their impact varies with frequency. To remove these errors from the measurement, perform connection compensation. See the next figure that shows the parasitic elements in a typical test circuit and the simplified model used to derive the device impedance.

Figure 79: Parasitics and model to derive impedance

Small capacitance measurements are high impedance and are particularly affected by the stray capacitance in the test setup. During open compensation, stray capacitance is measured so that it may be removed from the calculation of the DUT capacitance. Perform open compensation by removing the DUT connection. This can be done by lifting the probes on a probe station or by removing or disconnecting the DUT. Carefully, remove the DUT connection without altering the connection to the test instrument. For example, the distance between the instrument terminals should remain the same. Run the open compensation routine in ACS Basic (Versions 2.1 and higher) and it will measure impedance across the frequency to capture the stray capacitance.

Larger capacitance measurements are low-impedance and are particularly affected by the stray series resistance and test setup inductance. Short compensation measures the stray resistance and inductance as a function of test frequency. Perform short compensation by shorting-out the C-V instrument terminals at the DUT. Carefully short out the device terminals without altering the connections to the test instrument, including the distance between the test instrument leads. Run the short compensation routine in ACS Basic (Versions 2.1 and higher) and it will measure impedance across the frequency to capture the stray capacitance.

When performing C-V measurements with the 8020-CVU option, short and open compensation help to cancel the impact of the capacitance, resistance, and inductance of the bias tees from the device measurement.

Perform open and short compensation whenever the test setup changes. This includes cabling and adapter changes, as well as changes to the bias tee configurations. High-capacitance, low-impedance devices are especially susceptible to inductance in the test system. Cable movement or changes may affect the test system inductance and can therefore impact measurement accuracy. In these cases, perform short compensation more often. For measurements of three-terminal devices, such as MOSFETs, note that each capacitance measurement type (C_{iss} , C_{oss} , C_{rss} , C_{gs} , and C_{ds}) requires its own open and short connection compensations. ACS basic software version 2.1 and later contains built-in compensation routines that permit you to save the compensation data for each of these measurements. Therefore, you can perform the complete open and short compensation routines for all measurements.

The Model 4210-CVU C-V instrument also includes cable length compensation for its supplied coaxial cables that allows it to compensate for phase errors in the cables up to the point at which the 4-wire measurement point ends.

Frequently asked questions

In this section:

Why does my instrument generate an interlock error	8-1
Why are my dc current measurements unstable?	8-2
Can I break the parallel connection of the high-current SMUs?	8-2
Can I operate the 8020 with the top cover off?	8-3
Why is the pulse rising edge so slow for my SMU?	8-3
Why don't I get a signal at the output? My measurements appear to be an open circuit	8-4
Why are my contact check measurements failing when the SMUs are connected to the high voltage and 200 V channels?	8-4
Why is the high current LO terminal not connected to the Common LO terminal of the 8020?	8-4

Why does my instrument generate an interlock error

The interlock error on the SMU instrument indicates that the interlock circuit has been disengaged and that either the interlock signals from the SMU instruments have not been correctly connected or that a user access point is open.

The top cover of the 8020 high-power interface panel contains two switches that control the interlock of the Model 2657A and Series 2600A SourceMeter instruments. Removing the top cover opens the switches and disengages the interlock. Lifting one end of the top cover will also disengage the switch installed at that end.

Additionally, the 8020 contains an interlock out connection on the instrument connections panel where a user-supplied normally-open switch must be connected. The normally-open switch is intended to be connected to a test fixture, on the enclosure of a semiconductor prober or device handler, or on the doors of a test-equipment rack.

When all these switches are closed, both interlock LEDs on the 8020 are lit. Make sure the interlock cables (part number CA-558-2) are properly connected between the instruments and the 8020-interface panel. Also, make sure that the interface panel top cover is fully closed, and that any user access points connected to the Interlock Out connector on the 8020 are closed.

The interlock is designed so that it can be used with two or more 8020 units. For more information on how the interlock works with more than one 8020 unit in a test configuration, see [Connect two 8020 units](#) (on page 2-7) and [Connect multiple 8020 units](#) (on page 2-9).

For additional information on interlocks, see [Connect the instrument and output interlocks](#) (on page 2-3) topic. Also, refer to the appropriate manual for your SMU instruments.

Why are my dc current measurements unstable?

Several factors contribute to unstable current measurements. Such factors vary based on whether the measurement is for low current or high current measurements.

For low current measurements, triaxial cabling and connections enable shielded cables and guarding to the DUT, which are important for low current measurements. Read more about this topic in [Optimize cables and connections for low current dc measurements](#) (on page 7-3).

For high current measurements, noisy measurements could be a symptom of device oscillation (see How do I remedy oscillation at the DUT? for more details) or a result of improper timing between pulses at different device terminals. When testing transistors, ensure that either the gate or drain is stable before turning on the pulse to the other terminal. For example, make sure that the gate has fully turned on before starting the drain pulse. Otherwise, changes to the gate voltage during turn-on can present a modulated signal in the drain voltage waveform.

Can I break the parallel connection of the high-current SMUs?

No. The parallel connection of the high-current channel is fixed within the 8020 high-power interface panel. The two SMU instruments are connected in parallel to allow you to achieve up to 100 A pulse. This connection cannot be reconfigured.

Can I operate the 8020 with the top cover off?

The top cover of the 8020 high-power interface panel isolates the operator from hazardous voltages and charge sources that are potentially present on the high voltage and 200 V channels, including the integrated bias tees of the 8020-CVU bias tee option.

The interlock circuitry of the 8020 high-power interface panel is designed to be engaged when the top cover is installed. If the top cover is off, the interlock is disengaged and any SourceMeter instruments (SMUs) with outputs that are configured for high voltage will not turn on.

WARNING

Opening the top cover and disengaging the interlock does not necessarily discharge the capacitors of the 8020-CVU bias tee(s). Always perform the [Discharge bias tee and system capacitance](#) (on page 5-10) procedure after removing the top cover of the 8020. Some of these procedures may expose you to hazardous voltages, that if contacted, could cause personal injury or death. Use appropriate safety precautions when working with hazardous voltages.

Low voltage SMUs may still operate with the top cover off and without the interlock connected. For example, the Model 2651A will still operate if the output enable function is not activated. Additionally, the Models 2611A, 2612A, 2635A, 2636A, and 42x0-SMU will operate if they are programmed to the 20 V range or lower.

For additional information on interlocks, see [Connecting the output interlock](#) (on page 2-3) topic. Also, refer to the appropriate manual for your SMU instruments.

Why is the pulse rising edge so slow for my SMU?

For the high voltage and 200 V channels, there are two reasons for degraded pulses or rise time through the 8020:

1. For pulsed dc sourcing and measurement with a SMU instrument on the high voltage and 200 V channels, install a short or resistor in the dc path (between nodes 1a and 2) on the 8020-motherboard assembly. This is necessary whether the 8020-CVU option is installed.
2. The overcurrent protection on the 8020 connector cards slows the rise time of pulses from the SMU. This overcurrent protection is designed to protect sensitive equipment at the device interface from transient overcurrent conditions due to rapid change in device impedance or discharge of system capacitance. For pulsed dc sourcing and measurement with a SMU instrument, bypass the overcurrent protection by installing the 10 A fuse. The connector cards for the 8020 are supplied with the overcurrent protection bypassed.

Why don't I get a signal at the output? My measurements appear to be an open circuit.

Be sure to install a short or a resistor between nodes 1 and 2 on the 8020-motherboard assembly so that there is continuity between the instrument panel and the 8020 device connections panel.

Why are my contact check measurements failing when the SMUs are connected to the high voltage and 200 V channels?

The high voltage and 200 V channels include a 1 k Ω resistor in series with the sense HI lead. This additional series resistance will cause the contact check operation to fail. When using the 8020, it is best to disable the contact check feature on the high voltage and 200 V SMU instruments.

Why is the high current LO terminal not connected to the Common LO terminal of the 8020?

The high current that flows through the high current LO terminal could cause perturbations in the voltage at the LO terminal of the 200 V SMU channels. To prevent perturbations and the errors that these may cause in the measurement of 3-terminal devices such as MOSFETs and IGBTs, the 8020 isolates the force leads of the high-current channel. Additionally, this isolation makes it possible to optimize the path for high current by keeping lower resistance. If there are limited contacts to the DUT, the LO and sense LO of the gate SMU can be connected to the sense LO terminal of the high-current channel for MOSFETs and IGBT, as there is minimal current flowing through the gate terminal. For BJTs, there must be a separate LO connection for the SMU instrument that connects to the base terminal.

Specifications are subject to change without notice.
All Keithley trademarks and trade names are the property of Keithley Instruments.
All other trademarks and trade names are the property of their respective companies.

Keithley Instruments • 28775 Aurora Road • Cleveland, Ohio 44139 • 1-800-833-9200 • tek.com/keithley

