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Automated Characterization Suite (ACS) Advanced Features

Reference Manual

ACS-908-01 Rev. C November 2023

ACS-908-01C

KEITHLEY
A Tektronix Company

Automated Characterization Suite (ACS)

Advanced Features Reference Manual

These are the original instructions in English.

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Safety precautions

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

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

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

The types of product users are:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The symbol indicates a connection terminal to the equipment frame.

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

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

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

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

Instrumentation and accessories shall not be connected to humans.

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

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

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

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

Safety precaution revision as of June 2018.

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Section 1

Introduction

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Introduction to this documentation

If you have any questions after reviewing this information, 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-tek.

NOTE

When the Series 2600B System SourceMeter® instruments are referenced, it also includes the Series 2600A System SourceMeter instruments.

Reference manual content

This manual contains information about the ACS software. It includes information about how to install, configure, and operate the ACS software and full details of software features such as prober control, wafer setup, summary reports, and building, loading, and executing test projects.

For more information about instruments that can be used with the ACS software, refer to the documentation for each specific Keithley Instruments model:

- Model 4200-SCS Semiconductor Characterization Suite
- Model 4200A-SCS Parameter Analyzer
- Series 2600B System SourceMeter
- Series 2650A High Power System SourceMeter
- Series 2400 SourceMeter
- Series 3700A System Switch/Multimeter
- Model 707A or 707B Switching Matrix
- Model 708A or 708B Switching Matrix
- S500 Integrated Test System

NOTE

When the Model 4200A-SCS is indicated in this manual, it includes both Model 4200A-SCS Parameter Analyzer and the Model 4200-SCS Semiconductor Characterization Suite unless otherwise specified.

You can visit the Keithley Instruments website (tek.com/products/keithley) to search for updated information by model number.

ACS software overview

The Keithley Instruments Automated Characterization Suite (ACS) software supports semiconductor characterization at the cassette, wafer, and device level, using multiple test instruments and automatic parametric testing with semiautomatic and automatic probe stations.

ACS software controls system instruments and hardware connected through the GPIB, LAN, USB, and RS-232 serial port. This includes:

- Models 4200-SCS and 4200A-SCS Parameter Analyzers
- Series 2600B System SourceMeter® instruments
- Series 2400 SourceMeter® instruments
- Model 707A and 707B Switch Matrices
- Series 3700A System Switch/Multimeter instruments

ACS can perform multisite parallel I-V testing using a Series 2600B as the primary instrument. You can have as many as 16 groups of source-measure units (SMUs) on a single GPIB card, for a total of 16 parallel test sites. Each group can support up to 64 Series 2600B instruments, or 128 channels.

NOTE

Contact Keithley Instruments if you need more than 16 parallel sites.

ACS software is supported on the following probers:

- Tokyo Electron Limited (TEL): P8/P12/19S Prober and T78S/80S Prober

NOTE

To make sure that ACS software will properly control the TEL P8 prober, use the following method to configure the settings: On the TEL P8 prober, go to the **Main Menu** > **Diagnostics** > **Adjustments** (enter a password, if necessary) > **HARDWARE OPTIONS** > **GPIB Parameter Settings** > **Output SRQ 47H at the Off Wafer With X, Y, I, J, b**. Then select **Yes**.

- Tokyo Semitsu: Semitsu (TSK) UF200/UF3000/APM60/70/80/90 Prober
- MPI Corporation: SENTIO Prober
- Cascade Microtech: Tesla prober
- Cascade Microtech: 12000/S300/R19S/CM300 Prober

NOTE

If you want to make the ACS prober ignore or execute the Z/D command, open the `.ini` file and make the following changes:: Go to the `C:\ACS\KATS\ACS_setting.ini` file > `[common]` > `chuck_for_move=1 (1 = ignore Z/D; 0 = execute Z/D).`

- Electroglas: EG2X/EG4X Prober

NOTE

Only the EG4X prober supports post-inking in ACS.

- Wentworth Laboratories: Pegasus 300S
- Signatone: CM500 Prober (WL250)
- Suss Micro Tec: A200/PA300 Prober
- Yang: Sagi3 Prober with SRQ check
- Micromanipulator: 8860/P300A Prober
- Semiprobe SPFA Prober
- MJC AP-80 Prober
- Apolloware AP200/AP300 Prober
- Vector Semiconductor AX/VX Series Prober
- HiSOL HSP-300 Prober

ACS testing hierarchy

ACS provides a combined test-execution engine that supports Series 2600B SourceMeter® instruments, Series 2400 SourceMeter® instruments, and Model 4200A-SMU source-measure instruments through interactive test modules (ITMs). An ITM allows you to define a test interactively using the user interface.

A script test module (STM) supports Test Script Processor (TSP®) files. A TSP file customizes tests for a Series 2600B, Series 2400, or Model 3706A Switch/Multimeter instrument. A Python programming language test module (PTM) supports control of any GPIB, LAN, or USB instrument. A script editor is included with ACS for editing STMs and PTMs.

ACS supports semiautomatic and automatic testing, multipattern wafer maps, and Series 2600B multigroup tests and Series 2400 mixed group tests. Common transistor parameter testing (for example, Vds-Id, Vgs-Id, Vg-Ig) and life testing (TDDB, NBTI, HCI) are supported.

NOTE

Another option for test modules is the C Test Module (CTM). The CTM is created using Microsoft Visual C++. This method of test creation is most useful when interfacing with external DLL libraries or when ACS is running directly on a Keithley 4200A-SCS or 4200-SCS. There is no access to LPTLib when this method is used. As a result, this is the most difficult method of test library creation and should be reserved for use in creating drivers for unsupported instruments or incorporating third-party libraries into the ACS environment. Refer to the *ACS Programmer's Manual* (ACS-907-01) for more detail.

ACS organizes tests in the hierarchy below (from the cassette-level down), consistent with semiconductor-wafer organization, allowing for a one-time setup when managing cassette-level tests:

- **Cassette:** Automate multiple wafers tests
- **Wafer:** Define test patterns
- **Pattern:** Multiple sites (nonexclusive) for each pattern
- **Device:** Perform one or more tests (single or multigroup)
- **Subsite:** Perform one or more tests on devices
- **Test:** Four types = ITM, STM, PTM, and CTM

Command line execution

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ACS commands 2-1

ACS commands introduction

You can start and operate ACS using the Microsoft® Windows® Command Prompt app.

To use the command-line execution function:

1. At the Microsoft Windows Start menu, type `cmd` to open a command prompt.
2. Input the command that you want to execute.

Using command lines provides a convenient way for the interaction between ACS and those who also keep a comparatively matched consistency with the S400 or S600 system in operating style and diversification of user interface. The commands you can use at the command prompt are case insensitive and path free. The commands are listed in the following table.

Command list

Commands	Description
`startacs`	Start ACS software
`startauto`	Perform automatic execution
`startktec`	Start KTE conversion tool
`loadprj`	Load an ACS project
`hide`	Hide ACS user interface
`show`	Show ACS user interface

ACS commands

Descriptions of the ACS commands are provided in the following topics.

Start ACS command

Purpose: Start ACS software using Command Prompt.

Format:

```
startacs [-options] [args]
```

NOTE

When you use the `startacs` command, you can specify login options to load after ACS has started. However, you cannot use this command if ACS is already open.

Start ACS command options

Options	Arguments	Example	Description
N/A	N/A	`startacs`	Start ACS in online or offline mode
`-d`	N/A	`startacs -d`	Start ACS in demo mode
`-prj`	project name	`startacs -prj HCI`	Start ACS with a project loaded as the default
`-help`	N/A	`startacs -help`	Show the help information

Here is an example of a command line that opens ACS in demo mode with the project HCI as the default:

```
startacs -d -prj HCI
```

Automatic execution

Purpose: Start ACS software to automatically execute an XML project using Command Prompt.

Format:

```
startauto [-options] [args]
```

NOTE

When you use the `startauto` command, you must make sure that ACS is already open. However, you cannot use this command if ACS is executing a test. Also, for this command to execute, you need to make sure that the Keithley limit file (`.klf`) and the wafer description file (`.wdf`) are identified in the file path (see next table).

Start auto command options

Options	Arguments	Examples	Description
`-l`	Keithley limit file	`startauto -l D :\H.klf`	Start automation with the `H.klf`
`-prj`	project name	`startauto -w D :\a.wdf`	Start automation with a `.wdf` imported
`-lid`	lot ID number	`startauto -lid LOT1`	Start automation with lot LOT1
`-help`	N/A	`startauto -help`	Show the help information for this command

Here is an example of a command line that opens the project HCI, then with a `H.klf` applied and a `.wdf` imported, and then the LOT ID configured with LOT1:

```
startauto -l D:\H.klf -w D :\a.wdf -prj HCI -lid LOT1
```

Start KTE conversion tool

Purpose: Start the KTE conversion tool, which allows you to convert KTE projects to ACS projects using Command Prompt.

Format:

```
startktec
```

Load an ACS project

Purpose: Load an ACS project using Command Prompt.

Format:

```
loadprj [-options] [args]
```

NOTE

When you use the `loadprj` command, you must make sure that ACS is already open and that it is not presently executing a test.

Load project command options

Options	Arguments	Example	Description
N/A	`project name`	`loadprj HCI`	Load a project named HCI.
`-help`	N/A	`loadprj -help`	Show the help information for this command.

Hide the ACS user interface

Purpose: Hide the ACS GUI using Command Prompt.

Format:

```
hide
```

Show the ACS user interface

Purpose: Show the ACS GUI using Command Prompt.

Format:

```
show
```

Section 3

Ultrafast BTI

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Ultrafast BTI Introduction

ACS software contains an optional ultrafast BTI (bias temperature instability) package that can only be used with the Keithley Instruments Model 4200A-SCS Semiconductor Characterization Suite.

NOTE

If you do not have a 4200A-SCS, the ultrafast BTI option is not functional in your version of ACS. For more information about the 4200A-SCS, refer to the documentation that was shipped with your purchase. You can also visit tek.com/keithley (tek.com/products/keithley) to search for updated information by model number.

Ultrafast BTI is a reliability test that uses AC and DC reliability stress and measure techniques (stressing a device and measuring how the device withstands the stress). This technique of stress and measure is done with ultrafast coordination of the Keithley Instruments Series 2600B SourceMeter® instrument, the 4200A-SCS with the Model 4225-PMU Ultra-Fast Pulse Measure Unit, two 4200-SMU Medium Power Source-Measure Units, and two 4225-RPM Remote Preamplifier/Switch Modules that provide the source and measure functions.

Ultrafast BTI general notes

To conduct ultrafast testing, the 4200A-SCS must use a 4225-PMU ultrafast I-V module. Each 4200A-SCS chassis can accommodate up to six 4225-PMU modules to provide up to 12 ultrafast source and measure channels. The 4225-PMU module is the hardware core of the ultrafast I-V measurement capability for characterizing negative bias temperature instability (NBTI) and positive bias temperature instability (PBTI) degradation in microseconds, allowing for accurate lifetime measurements for designed-in reliability that supports modeling for device and circuit design. It integrates a sophisticated two-channel waveform generator with high-speed voltage and current measurement capabilities, a deep measurement buffer, and a real-time test execution engine.

Unlike traditional pulse generation solutions, the 4225-PMU can be programmed to output the complex waveforms required in ultrafast BTI testing. And, unlike traditional arbitrary waveform generators (AWGs), the duration and complexity of the waveform are not limited by bitmap or memory depth. Instead, the 4225-PMU employs a high-level waveform description language that uses the concept of segments, segment libraries, and looping. In addition, the waveform description specifies exactly when measurements must be made during the waveform and the type of measurement to be made.

The following measurement types are supported and multiple measurement types can be linked to form a test sequence:

- Spot
- Step sweep
- Smooth sweep
- Sample

The programmable sample period can be set as fast as five ns, so most measurements will include multiple samples. The real-time test execution engine of the system automatically calculates the mathematical mean of the samples, which reduces the volume of data that must be transferred and parsed during the test. The resulting measurements are streamed back to the high-level test module for near-real-time analysis and test termination.

Each channel of the 4225-PMU combines high-speed voltage outputs (with pulse widths ranging within 20 nanoseconds to DC) with simultaneous current and voltage measurements. With this combination of ultrafast high-speed voltage source and current measurement capabilities, the 4200A-SCS and ACS software tools can be used for a wide range of ultrafast I-V test applications.

The 4225-RPM (Remote Pulse Module) connects to the 4225-PMU and expands the capabilities of the PMU by providing four additional low-current ranges, offering current sensitivity down to tens of picoamps. The 4225-RPM also reduces cable capacitance effects and supports switching automatically between the 4225-PMU, the 4210-CVU, and other source-measure unit (SMU) modules installed in a 4200A-SCS chassis (see the following figure). This allows you to choose the most appropriate instrument for a particular measurement task without recabling.

Figure 1: Model 4225-RPM and Model 4200-SCS backplane

ACS software solution

The ultrafast BTI test software module brings together the measurement capabilities of the 4225-PMU and 4225-RPM through an intuitive interface without compromising test flexibility. It makes it easy to define stress timing, stress conditions, and a wide range of measurement sequences from spot, sweep, and sample tests. The test module allows measurement of recovery effects and degradation. It also offers prestress and poststress measurement options for both single device and multiple device tests that incorporate the DC source-measure units (SMUs) of the 4200A-SCS for high-precision low-level measurements. Note that DC tests are only available for single devices.

When used together, the 4225-PMU and 4225-RPM provide all the tools necessary to perform a range of applications that otherwise cannot be supported in a single instrument chassis, such as:

- Single-pulse charge trapping/high-K dielectric characterization
- Silicon-on-insulator testing
- LDMOS/GaAs isothermal characterization
- Flash RTS ID
- Phase-change random access memory (PCRAM) testing
- Ultrafast NBTI characterization
- Charge pumping measurements
- Thermal impedance characterization
- MEMs capacitor testing
- Random telegraph signal (RTS) CMOS
- Charge-based capacitance measurement (CBCM) materials testing for scaled CMOS, such as high-K dielectrics
- NBTI/PBTI reliability tests

Ultrafast BTI hardware configuration

For enhanced measurement accuracy in ultrafast BTI applications, you can add an optional multimeasurement performance cable (MMPC) kit that connects the 4200A-SCS to a prober manipulator. These kits simplify switching between DC, I-V, C-V, and ultrafast I-V testing configurations and eliminate the need for recabling. They maximize signal fidelity by eliminating the measurement errors that often result from cabling errors. Versions for Cascade Microtech, SUSS MicroTec, Lucas Signatone, and Wentworth Laboratories probers are available. There is also a general-purpose kit for connecting the 4225-PMU to other triaxial and coaxial probe stations.

NOTE

Before you start to configure your testing parameters, make sure that hardware configuration has been run to ensure that connections to the SMU and RPM have been established.

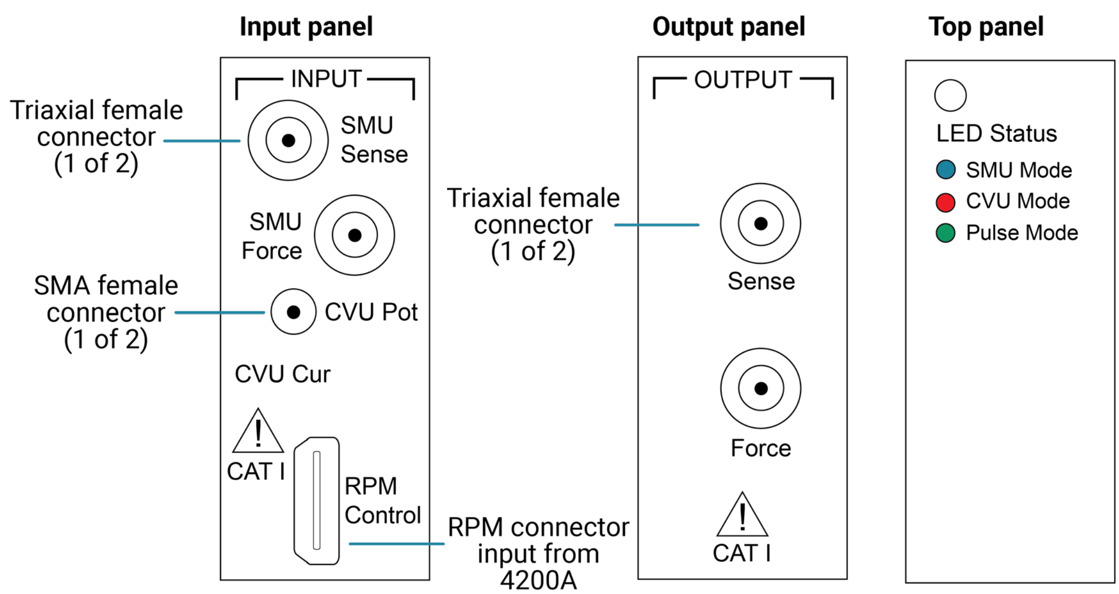
The following table shows the minimum required hardware to use ultrafast BTI with the 4200A-SCS:

Ultrafast BTI minimum hardware requirements		
Quantity	**Part number**	**Name**
One	4225-PMU	Ultra-Fast Pulse Measure Unit
Two	4225-RPM	Remote Preamplifier/Switch Module

The 4225-RPM contains two input and two output TRX connections for the SMU sense and SMU force. It contains one CVU potentiometer SMA connection and one CVU current potentiometer SMA connection. It also contains one RPM control slot for the RPM control cable. The Status LED on the top of the RPM indicates the present measurement state of the RPM (refer to the following figure for more information):

- Blue = SMU/DC
- Red = CV
- Green = Pulse

Figure 2: 4225-RPM panels



The ultrafast BTI coordination of instruments sourcing and measuring time starts at <100 ns and can increase to seconds or hours depending on your application and needs.

Using the 4225-RPM provides you the following timing, measurement, speed, and simplicity features:

- Measure low current (<10 nA resolution and noise)
- Quickly measure low current (at least one reading within 1 μs)
- Visibly measure low current (1 μs off-stress window includes source transitions of rise and fall and settling)
- Easily source waveforms and measure methods
- Provide SMU capability without recabling
- SMUs not connected while pulsing, pulsers not connected (high impedance, low leakage) when performing SMU sweeps

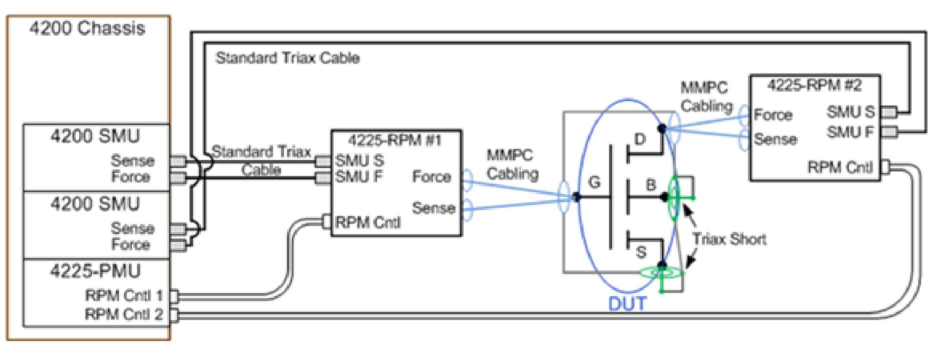
The following details how to connect the 4200-SCS to the 4225-RPM (see the following figure).

When you connect the 4200-SMU to the 4225-RPM, make sure you use the input connections for the SMU sense and force using the standard triaxial cables. For the 4225-PMU, make sure you use the RPM control cables to connect the 4225-RPM. Once you have made those connections, you can make the connections from the 4225-RPM to the DUT using the multimeasurement performance cables (MMPC).

NOTE

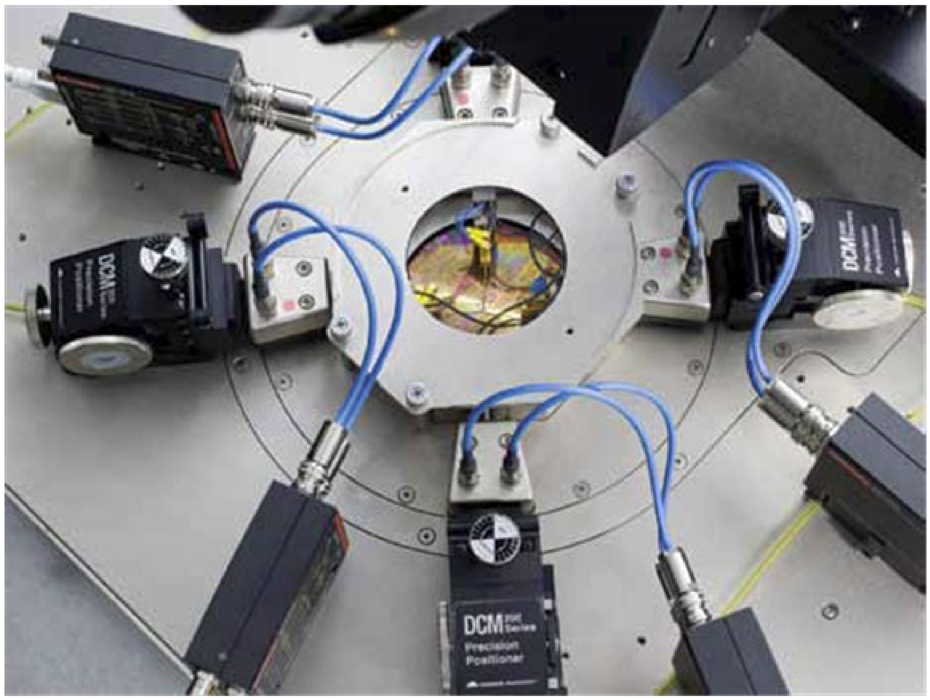
The following figure shows the minimum hardware requirements for the 4225-PMU, the 4200-SMUs, the 4225-RPMs, and the DUT.

Figure 3: Model 4225-RPM detailed diagram to DUT



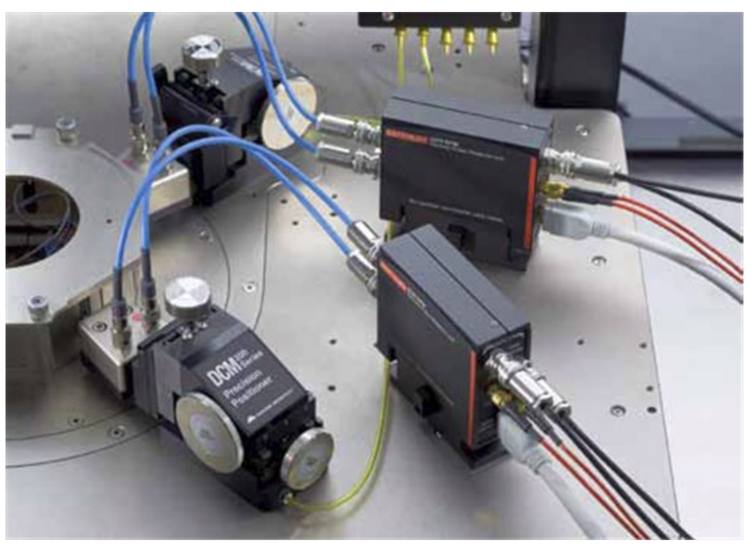
The top-down view of a Cascade Microtech analytical probe station in the following figure illustrates best practices for interconnecting the 4225-RPM to the prober using the blue cables from a MMPC cable kit.

Figure 4: Interconnection for Model 4225-RPM to prober



This close-up of two 4225-RPMs highlights the DC SMU, C-V, and ultrafast I-V cable connections (see the following figure).

Figure 5: Interconnection of two Model 4225-RPMs to prober



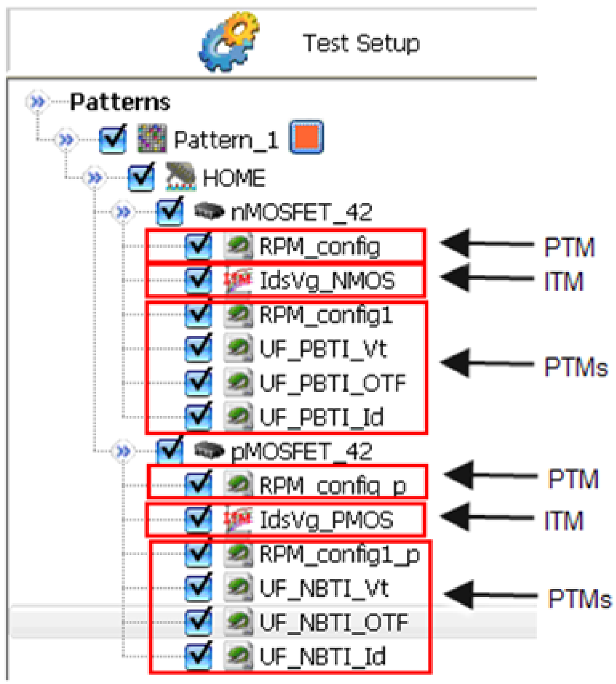
Ultrafast BTI descriptions

The ultrafast BTI project in ACS includes Python test modules (PTMs) and interactive test modules (ITMs) (see the following figure).

NOTE

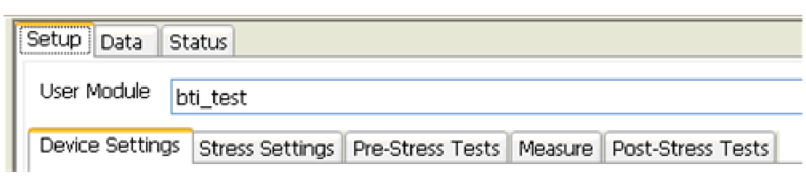
An ITM is used for DC testing.

Figure 6: ACS ultrafast BTI project tree



The ACS user interface for PTMs and ITMs contains three main tabs (Setup, Data, Status) and is like the NBTI project (see the following figure).

Figure 7: Ultrafast BTI Setup tab



For additional information about PTMs, refer to the *Automated Characterization Suite (ACS) Fundamentals Reference Manual* topic “Python language test module (PTM) configuration.” A PTM is defined by the Python programming language. ACS software contains example projects that include ultrafast BTI PTM modules that you can review for more information.

After you create a new ultrafast BTI PTM in the configuration navigator, you must make sure that it is configured correctly for your test requirements:

- **Setup:** Contains five subtabs for test parameter purposes and is the primary interface that allows you to configure an ultrafast BTI test module and display the configuration.
- **Data:** Contains plot and data information of test results which are displayed in spreadsheet format and plot format in real-time test execution.
- **Status:** Contains text of test results based on configured parameters.

The Setup tab contains the following subtabs:

- Device Settings
- Stress Settings
- Pre-Stress Tests
- Measure
- Post-Stress Tests

NOTE

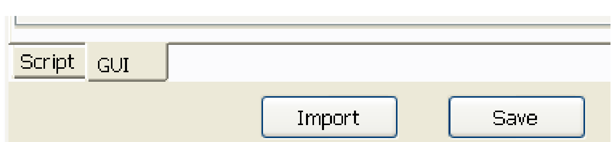
Before you start to configure your testing parameters, run hardware configuration to make sure that connections to the SMU and RPM have been established.

Import a Python file

The Python script file overwrites the present PTM file information that you are viewing in your project folder.

You can select Import or Save at any time (see the following figure).

Figure 8: Import and Save function



To import a Python file:

1. Select **Import**.
2. Select the Python script.
3. Select **Open**.

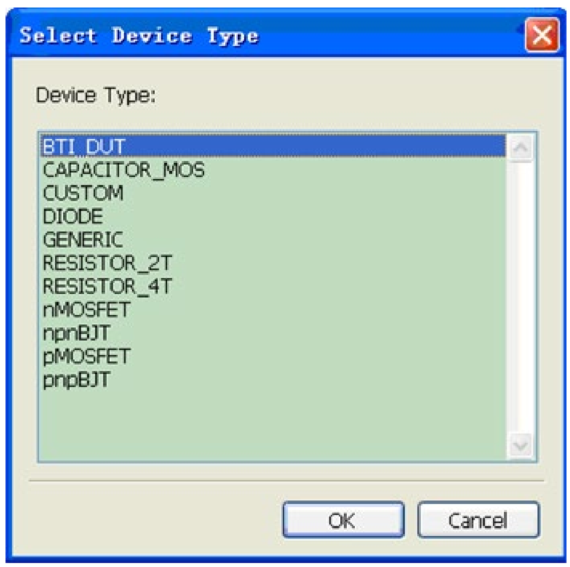
Load a device

On the device level (for example, the `DUT nMOSFET_42`) of the Device Settings tab, you need to add hardware to your test configuration.

To load a device:

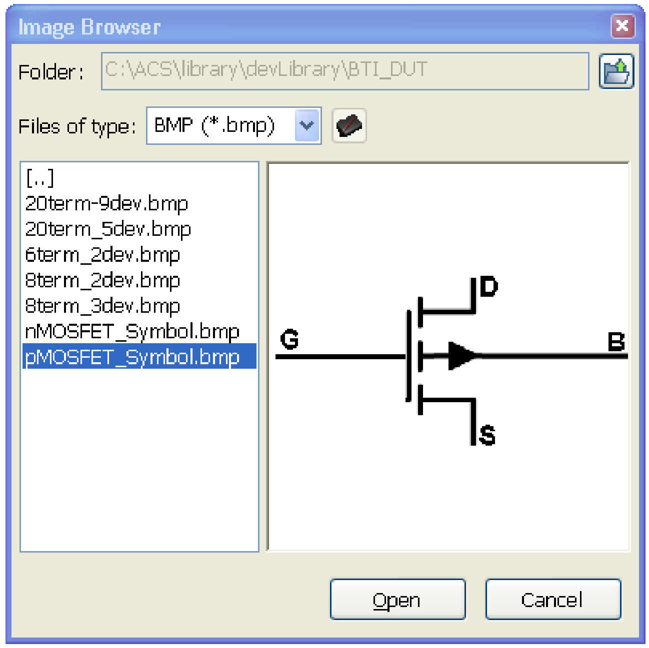
1. Select **Load Device**. The Select Device Type dialog opens (see the following figure).

Figure 9: Select the BTI device



2. Select the device.
3. If available for the selected device, select a graphic for display on the device settings tab.

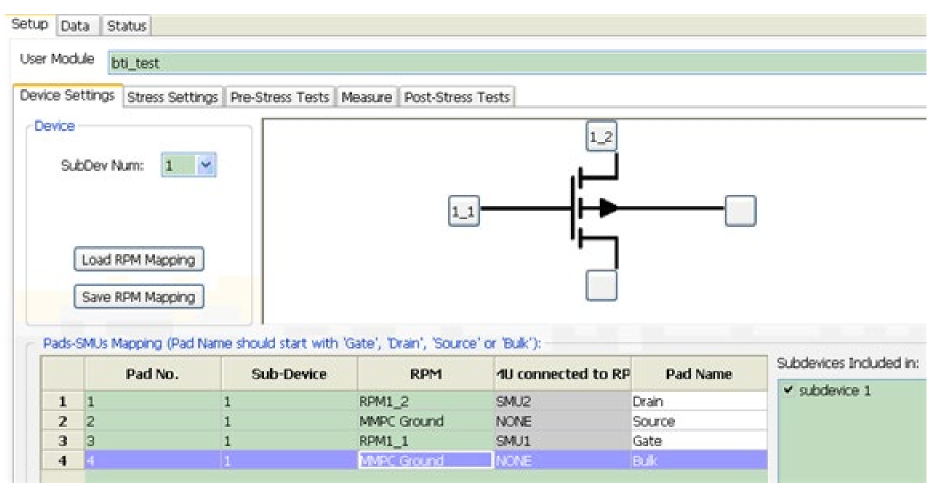
Figure 10: Bitmap device Image Browser



Device Settings tab

In the following figure, two 4225-RPMs are connected to the drain and the gate of the pMOSFET device. The source and bulk of the device are connected with an MMPC Ground.

Figure 11: BTI PTM Device Settings

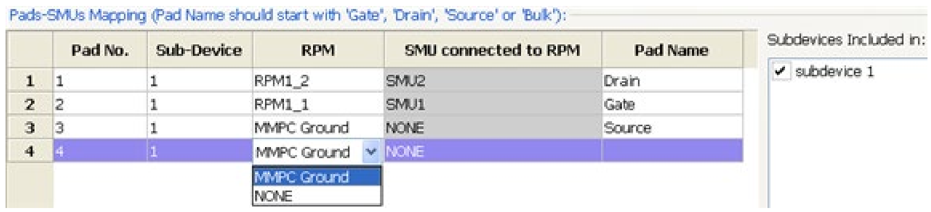


Depending on your configuration and parameters, the following table shows how the Pad Name (type) and the RPM type are configured interchangeably.

Pad Name (type)	RPM type
Drain	RPM
Gate	RPM
Source	RPM, MMPC Ground, NONE
Bulk	RPM, SMU, MMPC Ground, NONE

You can use the list to choose the type of RPM, based on your configuration and the Pad Name (see the following figure).

Figure 12: Pad and SMU mapping settings



If there is only one subdevice when a terminal is connected to the RPM, the SMU connected to the RPM will appear in the SMU connected to RPM column and the SMU test will be available in the pre-stress tests and post-stress tests. If there is more than one subdevice in your configuration settings, the SMU connected to RPM column will not be available and the SMU test will not be available (see the following figure).

Figure 13: More than one subdevice

To save RPM mapping:

1. Select **Save RPM Mapping**.
2. Enter the file name.
3. Select **Save**. The mapping is saved as a `.csv` file.

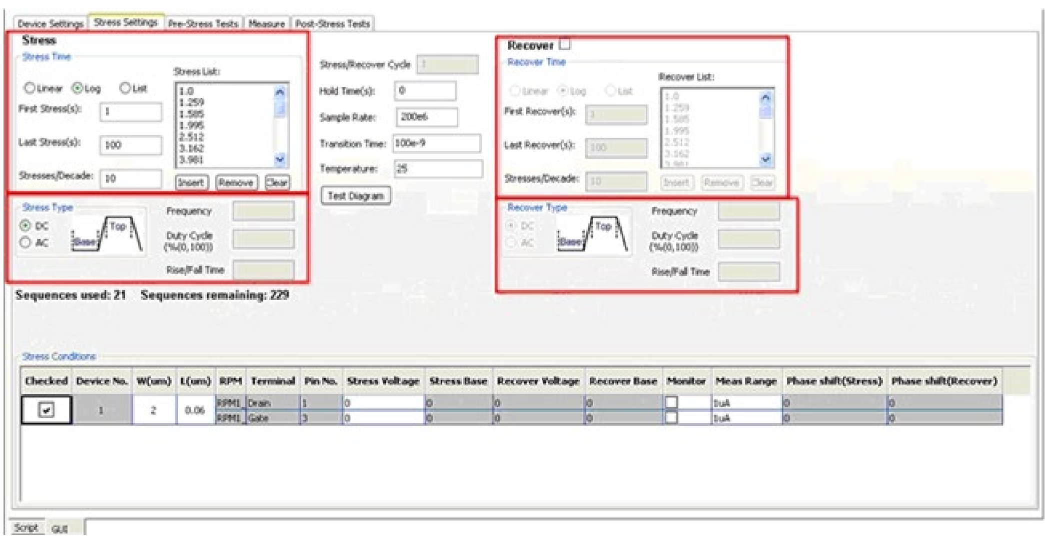
To load RPM mapping:

1. Select **Load RPM Mapping**. The Import RPM Mapping File dialog opens.
2. Navigate to the folder where the ACS projects have been saved.
3. Select the file.
4. Select **Open**.

Stress Settings tab

On the Stress Settings tab, there are different areas that you need to configure for testing parameters (see the following figure):

Figure 14: BTI PTM Stress settings



- **Stress Time:** Establishes the duration of the test; each BTI PTM can have a unique stress time
- **Recover Time:** The Recover function must be selected for this area to be enabled; the Stress Time settings are duplicated when this area is enabled

NOTE

The default function is for the Recover Time area to duplicate the Stress Time settings. You can change the Recover Time settings if needed.

- **Stress Type:** DC and AC are the available types
- **Recover Type:** Identical to Stress Type; DC and AC are the available types
- **Stress Conditions:** Establishes the conditions needed for your test

Stress Time settings

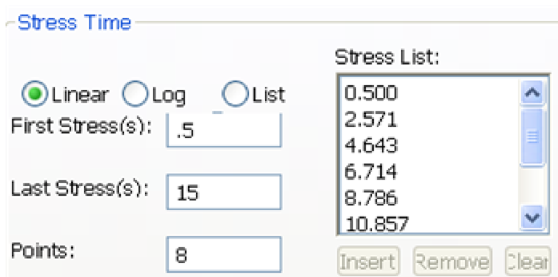
You have the following choices to configure your stress time scale:

- **Linear:** Ensures all stress times are the same
- **Log:** Ensures all stress times increase logarithmically with each cycle
- **List:** Allows you to specify the stress times

If you select Linear, the Stress List options (Insert, Remove, and Clear) will not be active and you must make changes to the edit boxes for your testing needs (see the following figure):

- **First Stress:** Enter the amount of time (seconds) your devices are stressed during first cycle
- **Last Stress:** Enter the total stress time for your entire subsite plan
- **Points:** Enter the number of stress points you want for your test

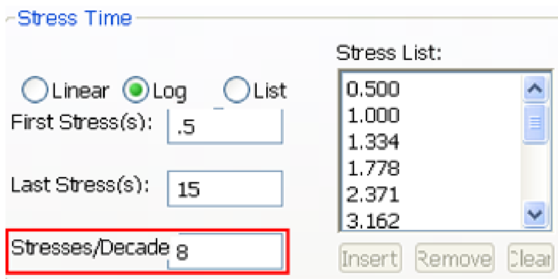
Figure 15: Stress Time Linear settings



If you select Log, the Stress List options (Insert, Remove, and Clear) will not be active and you must make changes to the edit boxes for your testing needs (see the following figure):

- **First Stress:** Enter the amount of time (seconds) your devices are stressed during the first cycle
- **Last Stress:** Enter the total stress time for your entire subsite plan
- **Stresses/Decade:** Enter the number of tests that you want to perform

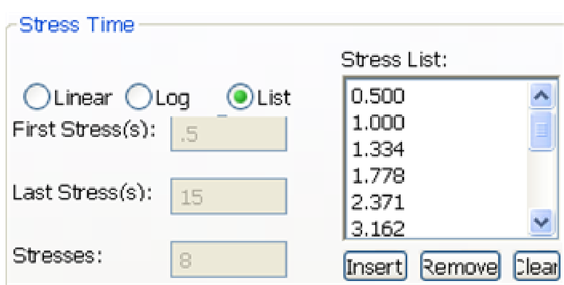
Figure 16: Stress Time Log settings



If you select List, the Stress List options will be active and you can make changes directly in the list (see the following figure):

- **Insert:** Use your keyboard to enter a series of stress times by selecting the function
- **Remove:** Select one of the list items and select Remove to remove that item from the list
- **Clear:** Select to remove the entire Stress List

Figure 17: Stress Time List settings



Stress Type settings

The Stress Type settings available are DC and AC.

NOTE

For the DC type, Frequency, Duty Cycle, and Rise/Fall Time are not functional. These stress type settings are only available in the AC type (see the following figure).

Figure 18: Stress Type settings DC

In the AC type, you see the following functions where you can change the settings based on you testing needs (see the following figure):

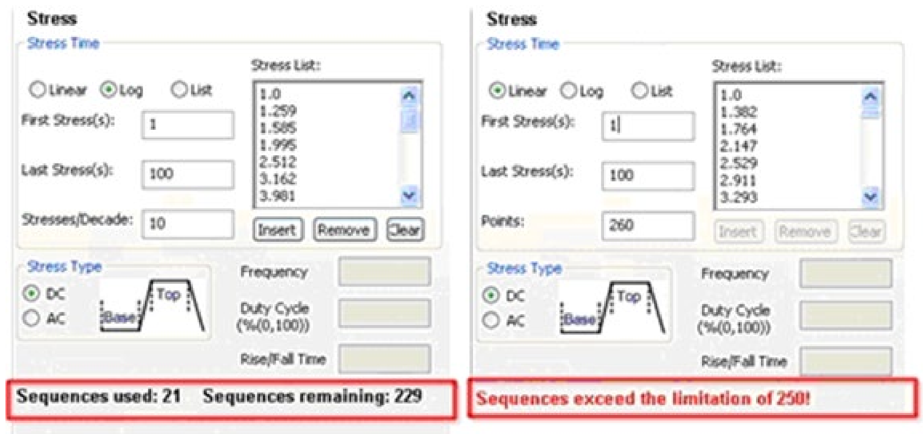
- **Frequency:** Choose an input based on your testing needs (highest frequency available is 10 M)
- **Duty Cycle:** Choose an input based on your testing needs
- **Rise/Fall Time:** Choose and input based on your testing needs

Figure 19: Stress Type settings AC

Stress setting limitation

The Ultrafast BTI module uses a 4225-PMU to generate the waveform and take measurements. According to the 4225-PMU specifications, the test module sets a limitation to the stress time sequences. In the user interface, a note shows how many sequences are used and how many sequences are left. If the stress time exceeds the maximum limits, you see an indication in the user interface (see the following figure).

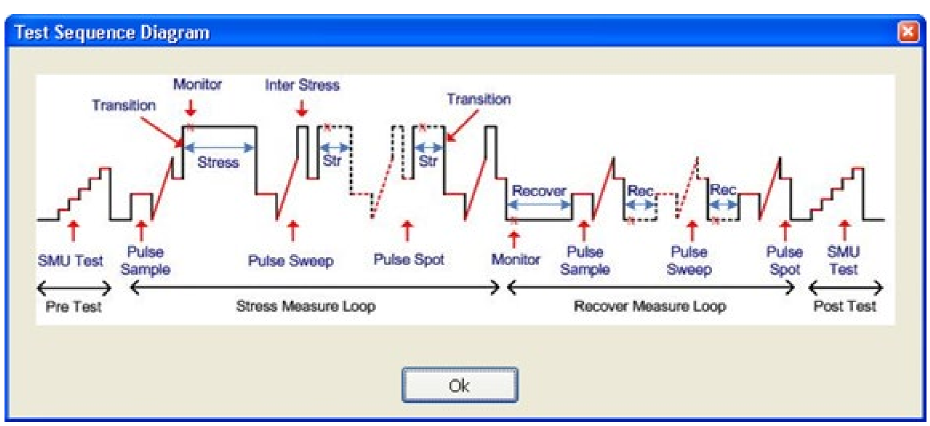
Figure 20: Stress Time sequences



Set the following Stress Time settings and Recover Time settings:

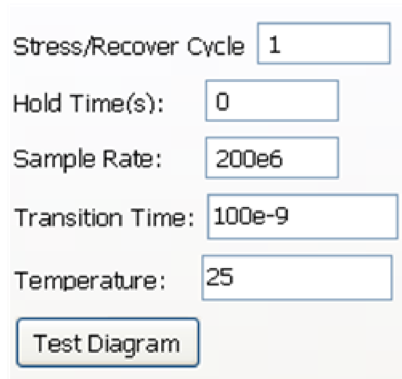
1. If the recover function is enabled, set the stress/recover cycle to the fixed number of times (cycles) that you want the subsite test to execute (256 maximum).
2. Set the hold time as needed to measure the device (DUT) before testing occurs; You can specify 0 to 1000 seconds; default is 0. The hold time should be less than the shortest stress/recover time which allows for monitoring of the stress and is performed in each stress/recover section once monitor is enabled (see the following figure).

Figure 21: Test sequence diagram



3. Set the sample rate for the PMU cards (all cards involved in BTI testing will have the same sampling rate).
4. Set the transition time to the interval between corresponding points on the rising or falling edge of the pulse.
5. The temperature shows the present temperature of the chuck in Celsius.

Figure 22: Stress and Recover settings



The test diagram function in this area is shown in the previous figure. These settings are for global use in the test configuration that will be used in the pre-stress tests, measure, and post-stress tests.

If you select the test diagram function, the dialog opens that defines the type of testing with an example diagram.

Recover Time settings

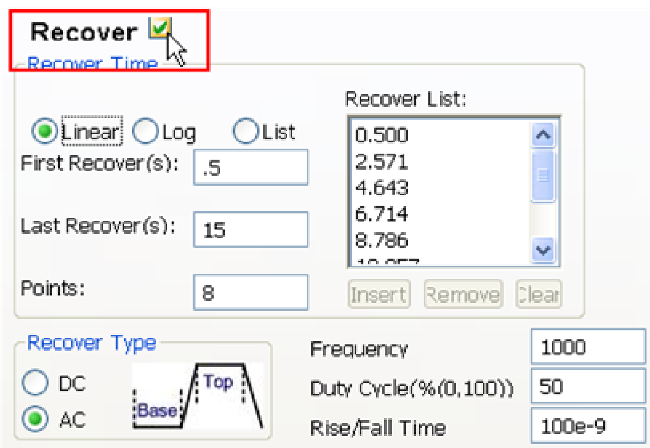
Like the Stress Time Settings, you have three choices to view your recover time scale:

- **Linear:** Ensures all stress times are the same
- **Log:** Ensures all stress times increase logarithmically with each cycle
- **List:** Allows you to specify the stress times

NOTE

However, note that you must select the Recover option for the Recover Time and Recover Type features to be functional, including the Stress/Recover Cycle function mentioned previously (see the following figure).

Figure 23: Stress Settings Recover function



If you select Linear or Log, the Stress List options (Insert, Remove, and Clear) will not be active and you must make changes to the edit boxes for your testing needs.

- **First Stress:** Enter the amount of time (seconds) your devices are stressed during first cycle
- **Last Stress:** Enter the total stress time for your entire subsite plan
- **Points:** Enter the number of stress points you want for your test (128 maximum)
- **Stresses/Decade:** Enter the number of tests that you want performed (128 maximum)

If you select List, the Stress List options will be active and you can make changes directly in the list.

- **Insert:** Use your keyboard to insert a series of stress times by selecting a stress list item
- **Remove:** Select one of the list items and select Remove to remove that item from the list
- **Clear:** Select to remove the entire Stress List

Recover Type settings

The Recover Types available are DC and AC, which are the same as the Stress Types. In the AC type, you will see the Frequency, Duty Cycle, and the Rise/Fall Time available for you to change based on your testing needs.

NOTE

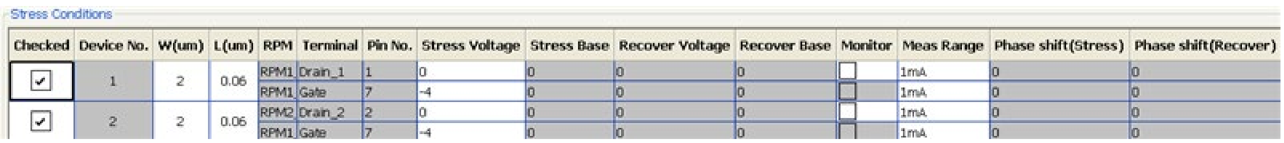
For the dc type, Frequency, Duty Cycle, and Rise/Fall Time are not functional. Depending on your testing needs, the Stress Type and Recover Type (AC or DC) do not have to have identical values or type. In other words, the Stress Type can be AC and your Recover Type can be DC.

Stress Conditions

The Stress Conditions, which are represented in columns, represent the terminals that are connected to the 4225-RPM. You can view and set up the conditions needed for your test:

- **Checked:** You can choose if the device in that row should be tested by selecting or clearing (see the following figure).

Figure 24: Stress Conditions


Stress Conditions

Checked	Device No.	W(um)	L(um)	RPM	Terminal	Pin No.	Stress Voltage	Stress Base	Recover Voltage	Recover Base	Monitor	Meas Range	Phase shift(Stress)	Phase shift(Recover)
✓	1	2	0.06	RPM1	Drain_1	1	0	0	0	0		1mA	0	0
				RPM1	Gate	7	-4	0	0	0		1mA	0	0
✓	2	2	0.06	RPM2	Drain_2	2	0	0	0	0		1mA	0	0
				RPM1	Gate	7	-4	0	0	0		1mA	0	0

- **Device No.:** Indicates the number of the device.
- **W(um):** You can change the width of the device in microns for testing purposes.
- **L(um):** You can change the length of the device in microns for testing purposes.
- **RPM:** You can view the status of module.
- **Terminal:** You can view the area of the RPM that is going to be tested.
- **Pin No.:** Indicates the pin that is tested.
- **Stress Voltage:** You choose the constant high-voltage state to apply.
- **Stress Base:** Only enabled for AC stress; Choose the low voltage to apply.
- **Recover Voltage:** The defined high-voltage state applied.
- **Recover Base:** Only enabled for AC recovery; It displays the defined low voltage state applied.

NOTE

The Stress Voltage is available for all stress types. The Stress Base is enabled for AC stress only. When Recover is enabled, Recover Voltage is available for both AC and DC recovery. Recover Base is only enabled for AC Recover type.

- **Monitor:** If enabled for a terminal, the current of that terminal is measured once at the beginning of each stress/recover loop on a PMU and RPM.

NOTE

The Monitor function will be active if the Stress Type or Recover Type is DC.

- **Meas Range:** You can choose the range of parameters needed based on the device and stress conditions.
- **Phase_shift (Stress):** On the terminal gate is disabled; the shape of the waveform on the gate is the same as graphic in the user interface; the phase shift of the waveform on other terminals will use the waveform on the gate as a reference and will shift to the left side; a valid shift value will fall between 0 to period; ACS will check the input value.
- **Phase_shift (Recover):** Defines the phase shift in Recover phase.

NOTE

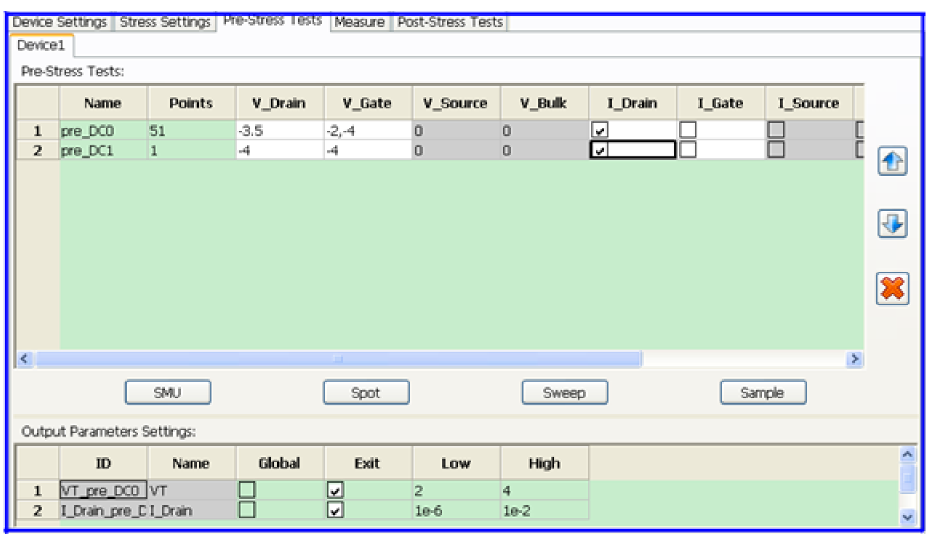
The Phase_shift function will be active if the Stress Type or Recover Type is AC.

Pre-Stress Tests tab

The Pre-Stress Tests tab contains a list of your pre-stress tests and an area for you to set up your Output Parameters Settings. There are also functions that allow you to add different types of tests (see the following figure).

- **SMU:** Measurement of DC; available if one subdevice is connected to RPM
- **Spot:** Measurement that returns one value
- **Sweep:** Measurement that has a starting and stopping point that over a period returns a range of values
- **Sample:** Measurement that allows you to choose when to start measuring and the number of points you want to measure

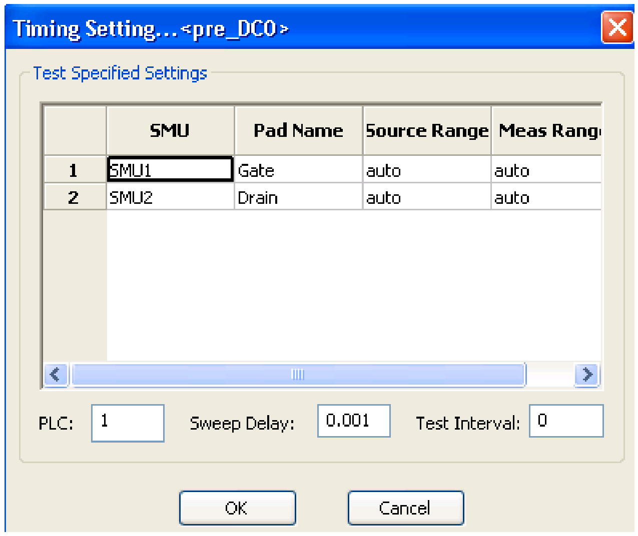
Figure 25: BTI PTM Pre-Stress Tests



You can choose all four tests at once and run your tests or select one at a time.

The SMU test is a DC test and is performed on the SMU. This test is only available if one subdevice is connected. If there is more than one device, the SMU test is not available (see the following figure).

Figure 26: Timing of DC test



The Spot, Sweep, and Sample tests are performed on the PMU that is connected to the RPM.

NOTE

The Spot, Sweep, and Sample tests are available on the Pre-Stress Tests tab, Measure tab, and the Post-Stress Tests tab. All three tests function the same on each tab. For more information and descriptions of each test, continue to the next topic for the Measure tab.

You can change the sequence of the testing by selecting the row of the test and selecting the up or down arrow to the right of the window. You can delete any test by selecting the red X.

NOTE

The SMU test cannot be moved and it will run first before any other tests.

The Pre-Stress Tests Output Parameters Settings options allow you to create global parameters, indicate a low and high variable, and determine if the testing should exit based on the established parameters.

Measure tab

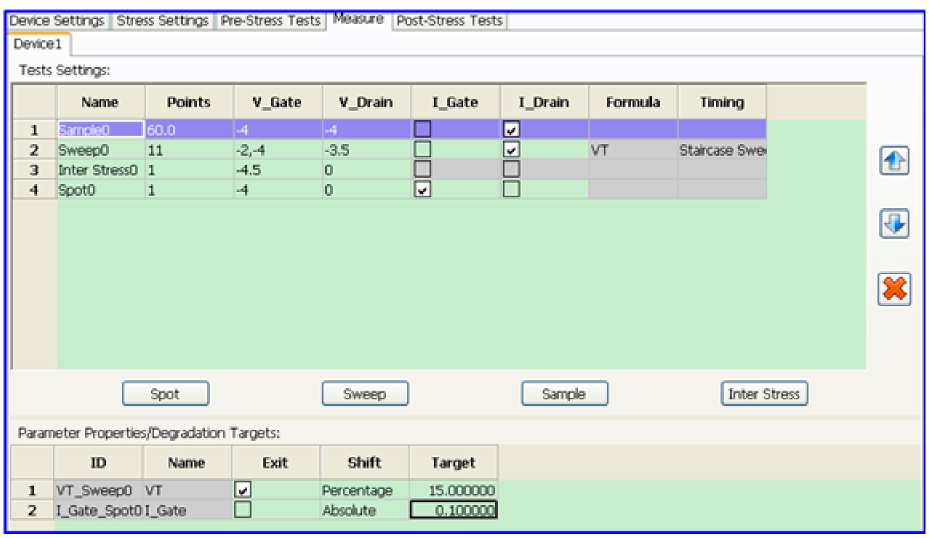
The Measure tab contains a tab for each device that you have configured for testing and an area for you to set up Parameter Properties/Degradation Targets. You also see Tests Settings for the device and four different functions that allow you to add four different types of tests (see the following figure).

- **Spot:** Measurement that returns one value
- **Sweep:** Measurement that has a starting and stopping point, over a period, which returns a range of values
- **Sample:** Measurement that allows you to choose when to start measuring and the number of points you want to measure
- **Inter Stress:** Unique test inserted between two measurements to allow the DUT time to recover from the previous measurement (contains voltage value that is usually associated with the stress value)

NOTE

The Measure tab does not allow you to run DC tests.

Figure 27: BTI PTM Measure



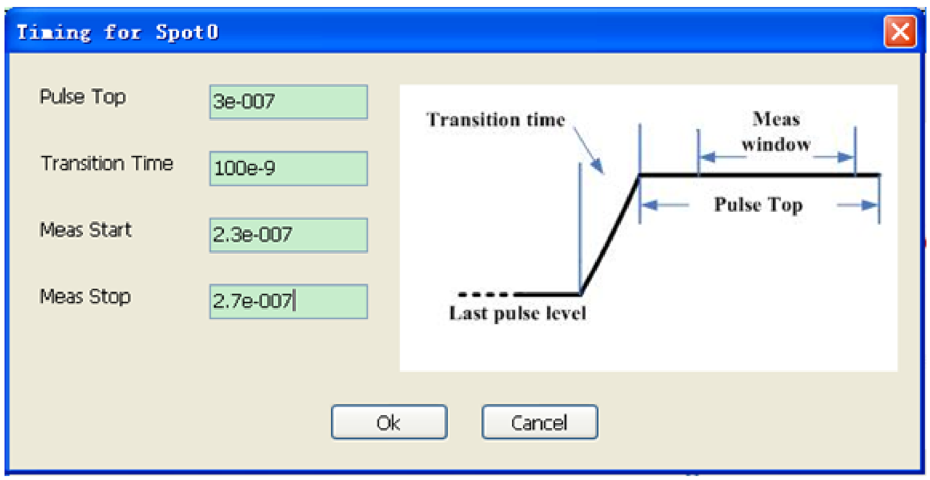
The terminals shown on the user interface represent the terminals connected to the RPM.

Spot test: Spot mean measurement with the PMU. No calculation is provided for the spot test.

Double-click in the Timing column cell of a test to display the Timing dialog of the spot test. A measurement is made during the Meas Window and is defined by Meas Start and Meas Stop values. One current value is returned (see Timing of Spot test (on page 3-26)).

Timing of Spot test

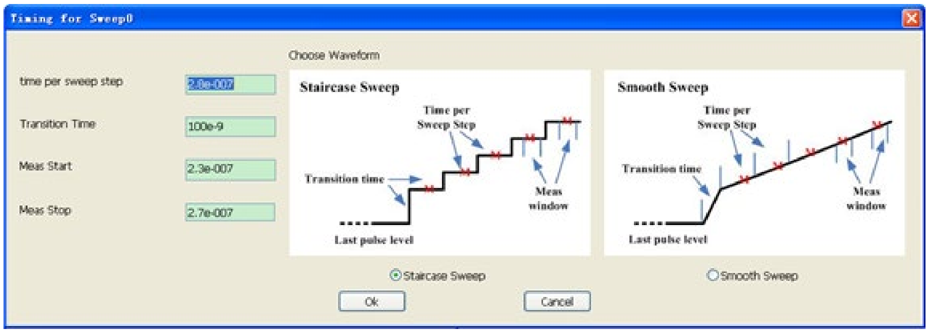
Figure 28: Timing of Spot test



Sweep test: The sequence of spot mean measurement with the PMU. The value of Points is at least two. The Start and Stop voltage value of the sweep terminal are split by a comma. Formulas are available by double-clicking a Formula column cell of a sweep test. Double-click the Timing section to display the Timing of Sweep test (see Timing of Sweep test (on page 3-27)).

Timing of Sweep test

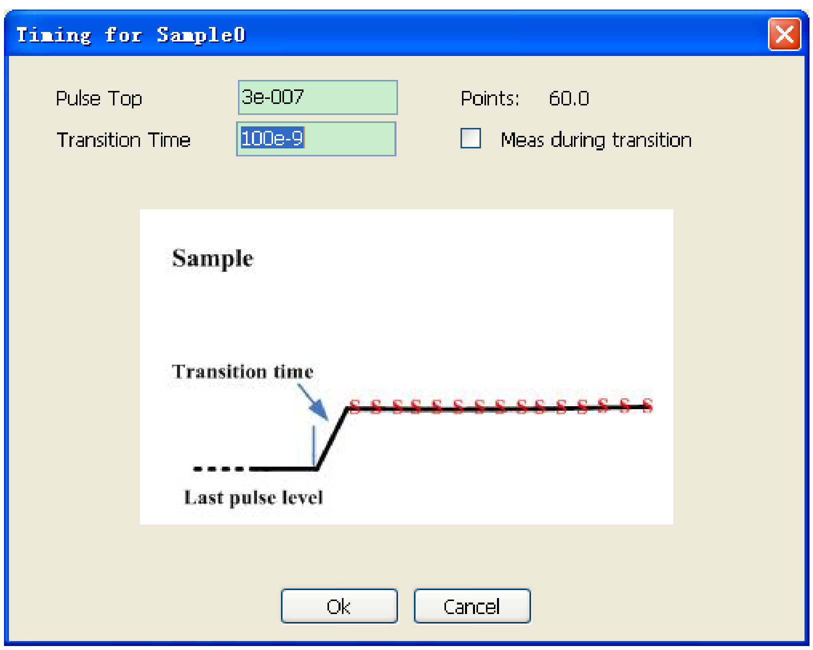
Figure 29: Timing of Sweep test



Timing of Sample test

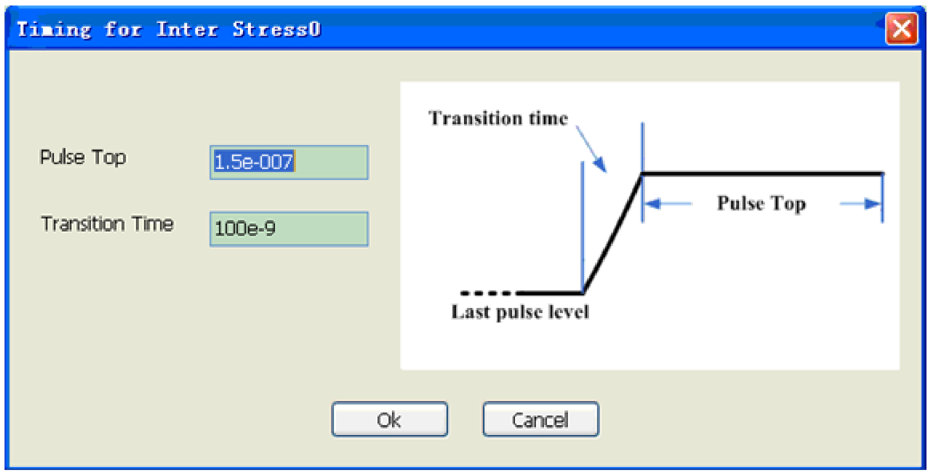
Sample test: Waveform capture measurement is performed. Data is collected at the sample rate. You can choose to measure during the transition time. Once the measurement time is complete, ACS calculates the data and display the points once you set the pulse top value. An example of the Timing for Sample is displayed in the next figure.

Figure 30: Timing of Sample test



Inter Stress: Allows you to define some special voltage status between two tests. Usually, the device will go back to stress condition for a while because in the previous tests the device might recover. No measurement is provided with Inter Stress. As indicated in the test diagram, Inter Stress test will only be applied in the measurement phase after a stress phase. It will not be applied to the recover-measure phase, it cannot be the last test completed, and it cannot be the only test performed (see the following figure).

Figure 31: Timing of Inter Stress



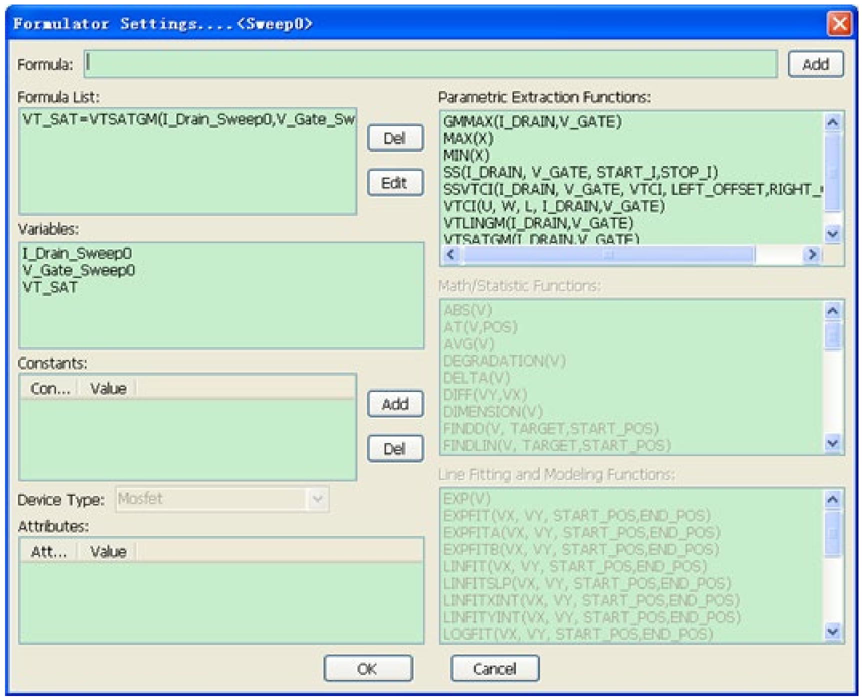
ACS provides basic calculation of Vth, Gm, and subthreshold slope, among others. However, if you double-click a Formula column cell, the Formulator Settings dialog opens. The Formulator is a mathematical test results analysis tool where you can manipulate test data with user-defined formulas. It allows in-test and post-test data computation.

NOTE

Formula is available for sweep test only.

Formulator Settings

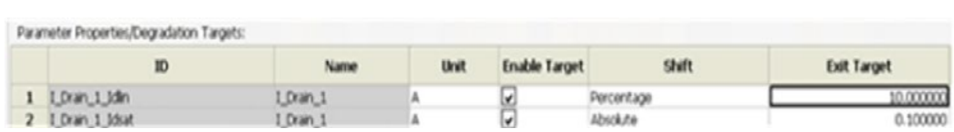
Figure 32: Formulator Settings dialog



Parameter Properties/Degradation Targets

The variables and the measured and calculated results that have only one value appear in this table. The Parameter Properties/Degradation Targets functions determine when to stop a test on a device. The Shift function is from the initial value of a variable and is calculated and compared with the target value. When the target is met, the test on that device is terminated. If Recover is enabled, this section of the user interface is disabled (see the following figure).

Figure 33: Parameter Properties_Degradation Targets functions



Post-Stress Tests tab

Post-Stress Tests are the same as Pre-Stress Tests:

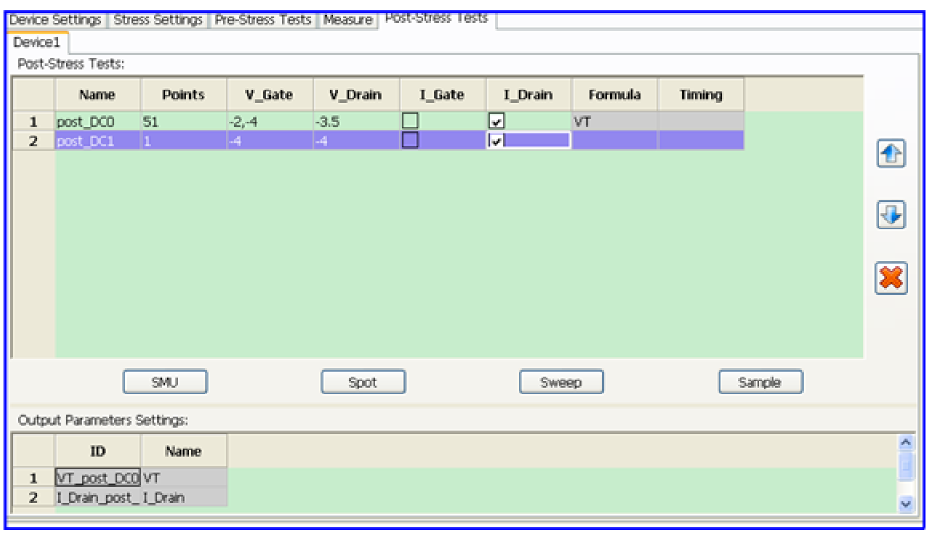
- **SMU:** Measurement of DC; available if one subdevice is connected to RPM
- **Spot:** Measurement that returns one value
- **Sweep:** Measurement that has a starting and stopping point, over a period, which returns a range of values
- **Sample:** Measurement that allows you to choose when to start measuring and the number of points you want to measure

DC testing is permitted; however, DC testing is done after pulse testing has completed.

Refer to Pre-Stress Tests tab (on page 3-23) and Measure tab (on page 3-25) for more information and descriptions of each test.

The only difference is the Output Parameters Settings. The Pre-Stress Tests Output Parameters Settings allow you to create Global parameters, indicate a low and high variable, and if the testing should exit based on the established parameters. The Post-Stress Tests Output Parameters Settings does not allow you to configure these same types of parameters and are for measurement purposes only (see the following figure).

Figure 34: Post-Stress Tests



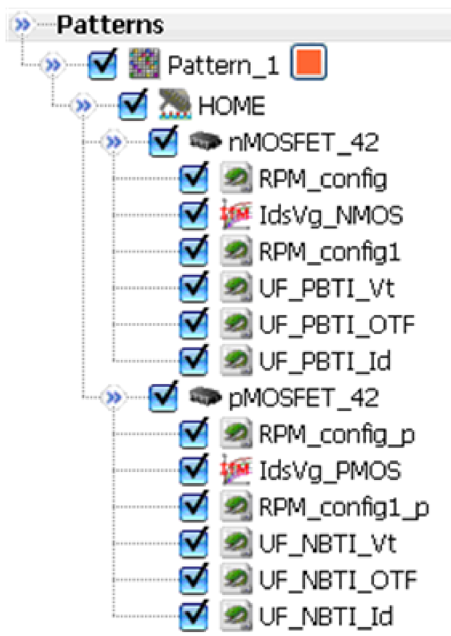
Ultrafast BTI project information

There are two demonstration projects included with your version of ACS software for the ultrafast BTI test:

- `UF_BTI_1DUT` represents a standard 4-terminal device.
- `UF_BTI_nDUTs` is a more complicated device structure that consists of more than one device.

Since positive bias temperature instability (PBTI) tests are usually performed on nMOSFET devices and negative bias temperature instability (NBTI) tests are usually performed on pMOSFET devices, the ACS software package contains tests for both devices (see the following figure).

Figure 35: Ultrafast BTI 1DUT test tree



Tests (or modules) that are under the nMOSFET_42 device are:

- **RPM_config:** PTM test used to turn RPMs to SMU mode so that a SMU test can be performed.
- **IdsVg_NMOS:** ITM test used to get IdVg curve of a device with SMU.
- **RPM_config1:** PTM test used to turn RPMs to PMU mode since BTI tests are all performed with PMU.
- **UF_PBTI_Vt:** PBTI test which contains IdVg test and Vt (threshold voltage) extraction in measurement phase.
- **UF_PBTI_OTF:** On-the-fly PBTI test that extracts the shift of threshold voltage in measurement phase.
- **UF_PBTI_Id:** PBTI test contains sampling on drain current in measurement phase. You can capture the drain current immediately after stress.

Tests under the `pMOSFET_42` device are like the `nMOSFET_42` device, except for the polarity of the voltage.

When a test structure contains more than one device, the devices can have shared or separate device terminals.

In the case of shared terminals, ACS permits a shared gate, source, and bulk. However, it is not possible for devices to have a shared drain. Included with your version of ACS software, you will find a project that provides tests for separate PMOS devices named `PMOS_notshared_Gate` and shared gate PMOS devices named `PMOS_shared_Gate`.

Tests (or modules) that are under the PMOS_shared_Gate device are:

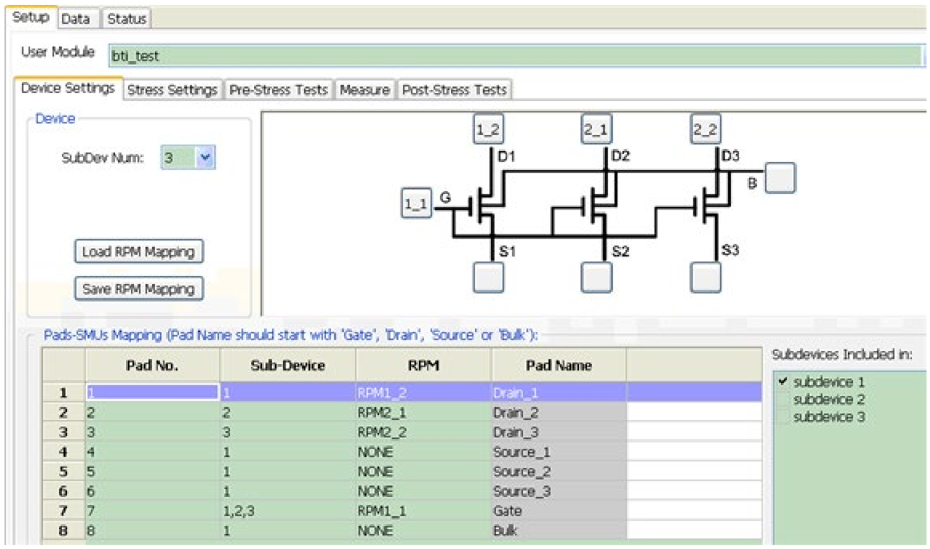
- **RPM_config:** PTM test used to turn RPMs to PMU mode since BTI tests are all performed with PMU.
- **UF_NBTI_S_Vt:** NBTI test, which contains IdVg test and Vt (threshold voltage) extraction in measurement phase.

NOTE

Tests under the `PMOS_notshared_Gate` device are like the `PMOS_shared_Gate` device, except for separate device gates for each device. Also, in either test structure, all testing is accomplished in parallel.

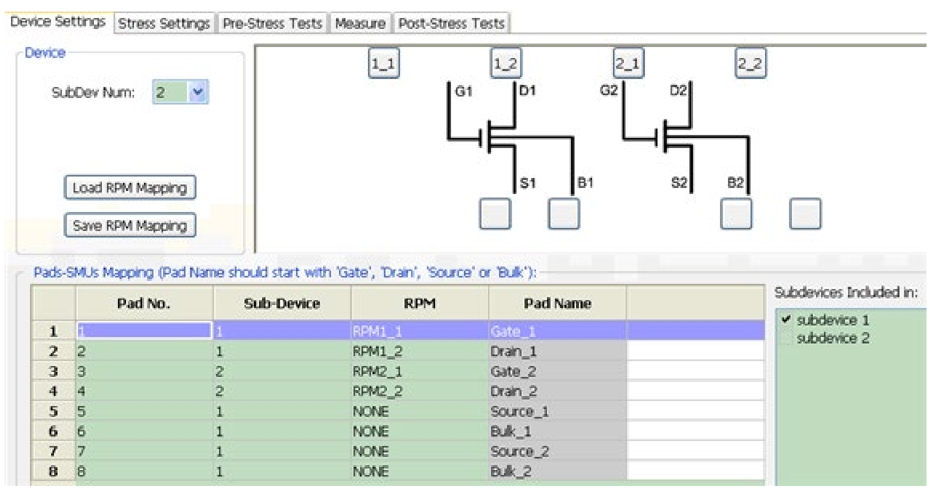
In the next figure, the device graphic shows one gate for three different devices and that there are three different sources and one bulk.

Figure 36: Multiple DUT for shared Device Settings tab



In the next figure, notice that the device graphic shows a separate (not shared) gate for both devices. Also, notice that each device has a separate source and separate bulk.

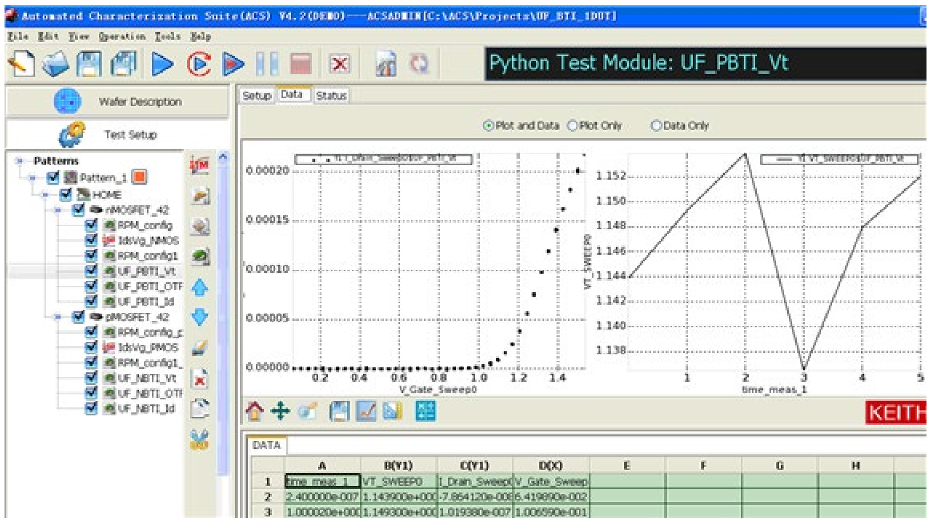
Figure 37: Multiple DUT for not shared Device Settings tab



Ultrafast BTI data

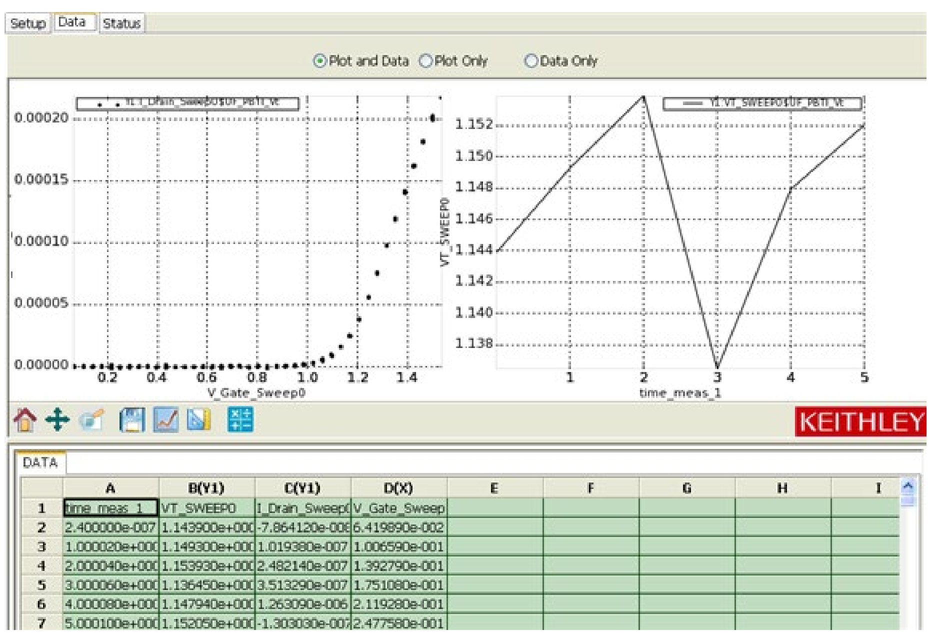
When you perform tests during the ultrafast BTI testing, data is captured and can be viewed on the Data tab (see the following figure).

Figure 38: PTM Data tab GUI



You can use the Plot Only function to view the test results, the Data Only function, or both functions (Plot and Data) simultaneously (see the following figure).

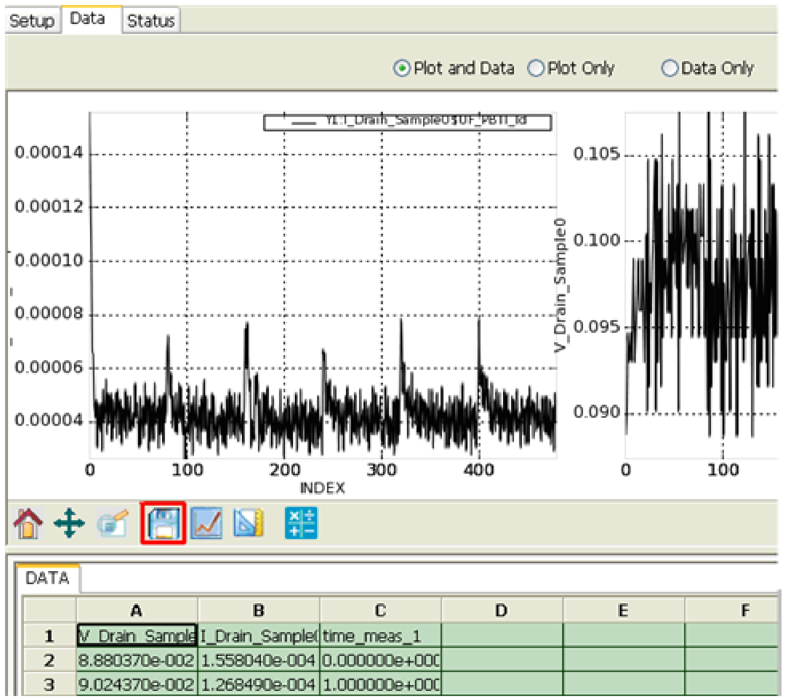
Figure 39: PTM Plot and Data GUI



NOTE

Each module will have test results that you can view. Plus, you can save the results to view the data later (see the following figure).

Figure 40: Save Plot and Data information



Sample projects and test modules

In this section:

Projects and test modules for use cases 4-1
Model 237-HV RTM 4-2
Generic high-voltage capacitance-voltage PTM 4-9
System level compensation 4-24
DC compensation 4-26
Charge pumping test module 4-27
SWEAT test module 4-34
Power supply library 4-37
DC stress-measure loop project 4-40
Pulse stress-measure loop project 4-48
Stress migration project–resistance batch measurement 4-57
Shared stress reliability test application 4-64

Projects and test modules for use cases

The ACS software package provides several sample projects and test modules for special use cases. Theses sample projects or test modules are usually for specific instruments. This section gives a detailed description about these projects:

- Model 237-HV (high-voltage) reliability test modules (RTM)
- High-voltage, high-current, capacitance-voltage (CV) Python-language test module (PTM)
- Charge pumping test module
- SWEAT test module
- Power supply library
- DC stress-measure test module
- Pulse stress-measure loop project
- Stress migration project-resistance batch measurement

Model 237-HV RTM

The Model 237-HV (high-voltage) reliability test module (RTM) is an extended version of the 2600-based RTM module that uses the Model 237-HV source-measure unit (SMU). These test modules extend the voltage range applied to a device under test (DUT). The Model 237 SMU can reach ±1100 volts. These test modules include HV TDDB, HV VRamp, HV JRamp, and HV HCI modules. The test flow and function are the same as the corresponding 2600-based RTM modules. These test modules are in the PTM category, and support two DUTs tested sequentially. For more information about TDDB, VRamp, JRamp, and HCI, refer to the ACS 2600 RTM manual (document number ACS2600RTM-900-01).

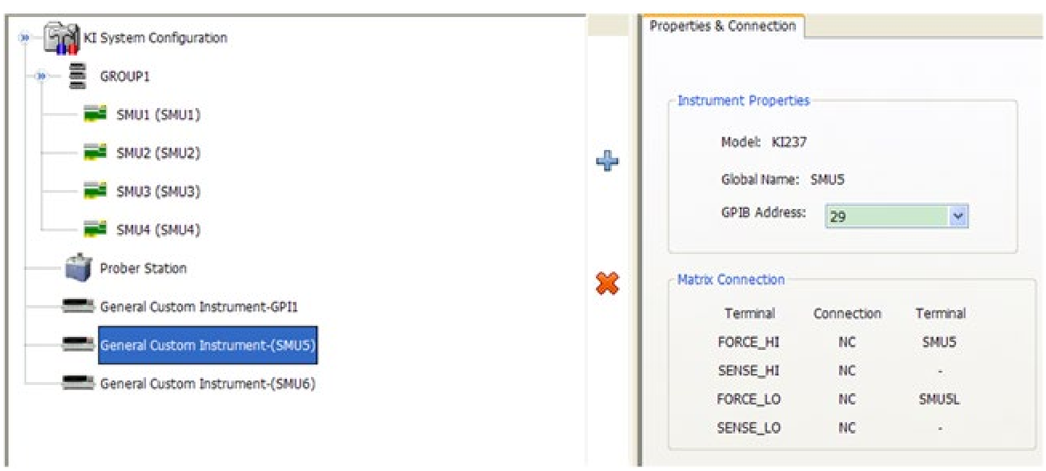
Model 237-HV RTM features:

- Enables ±1100 V bias
- Used with PTM modules
- Sequential execution with two DUTs

Hardware configuration

The Model 237-HV RTM uses the Model 237-HV SMU. This instrument is a general-purpose instrument in the ACS hardware configuration (see the following figure). For details on how to add a general-purpose instrument, refer to *Automated Characterization Suite (ACS) Advanced Features Reference Manual* (document number ACS-908-01).

Figure 41: Add a Model 237-HV SMU



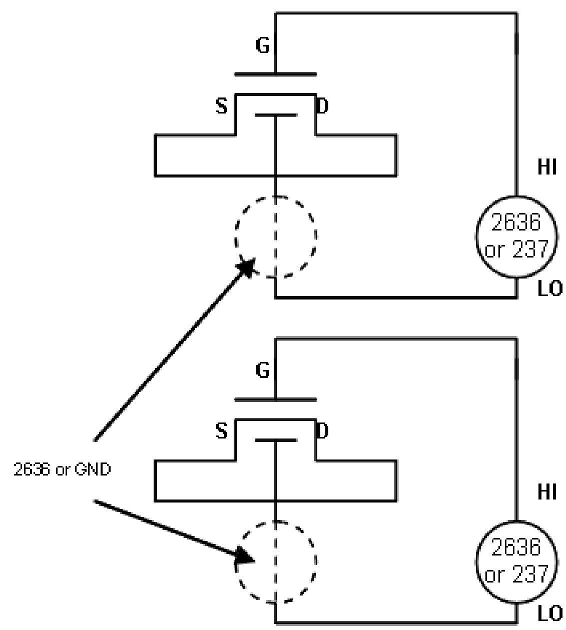
Model 237-HV TDDB

To access the Model 237-HV TDDB module, create a PTM, then import the file from the following location: `C:\ACS\library\pyLibrary\PTMLib\KI237_HV_TDDB.py`.

The differences between the Model 237-HV TDDB module and the TDDB are shown in the following examples:

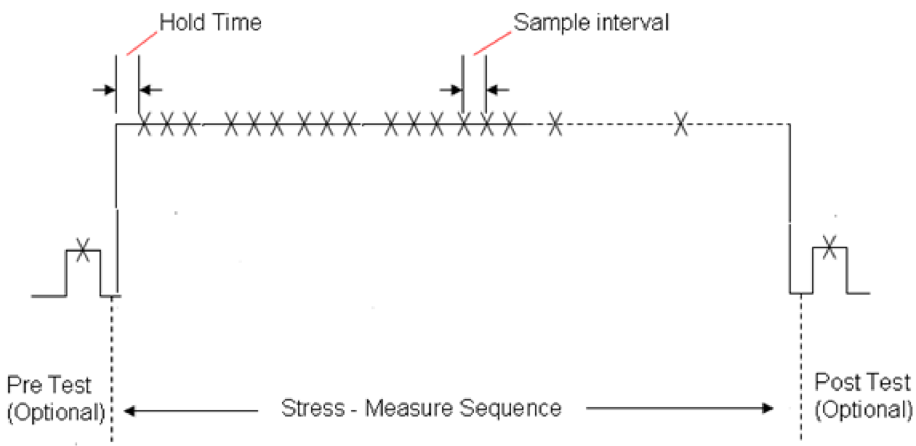
- The Model 237-HV TDDB is for two DUTs tested sequentially (refer to the next figure for the hardware connection).

Figure 42: Model 237-HV hardware connection



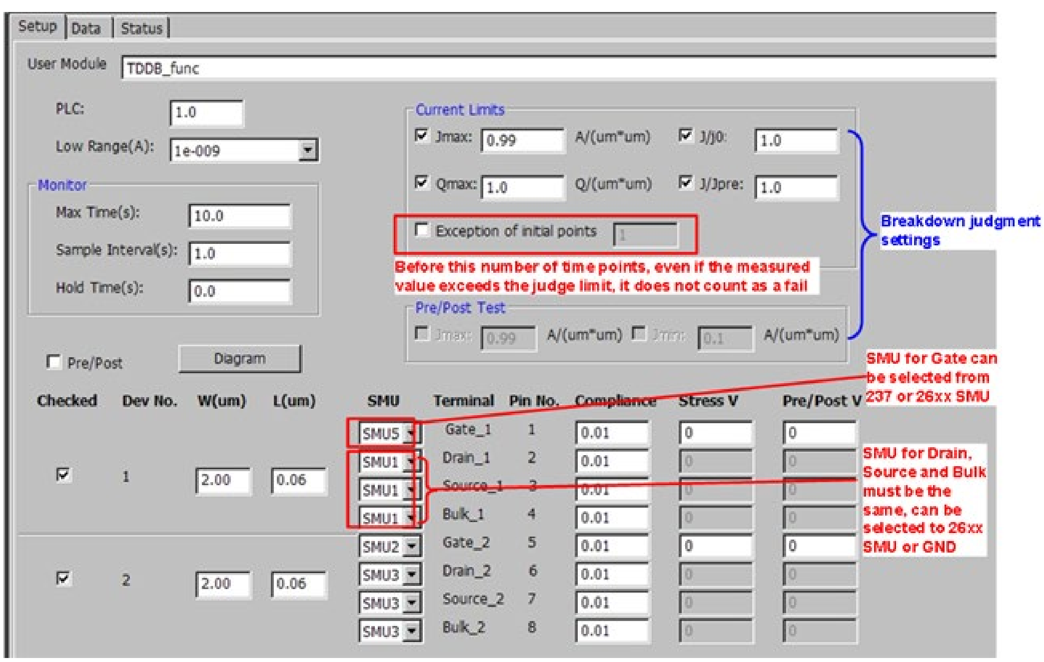
- **Test flow:** The stress is only be applied once, and there is no SILC (stress induced leakage current) test in the Model 237-HV TDDB. The test diagram of the Model 237-HV TDDB is shown in the next figure.

Figure 43: Model 237-HV test diagram



- **Settings:** The Model 237-HV TDDB can be configured for a Max Time stress (for instance, a one-time stress, which does not have an inter-stress measurement, and contains the time span of the Max Time setting). The user interface for setting the time is shown in the next figure.

Figure 44: Model 237-HV TDDB settings GUI



Model 237-HV VRamp

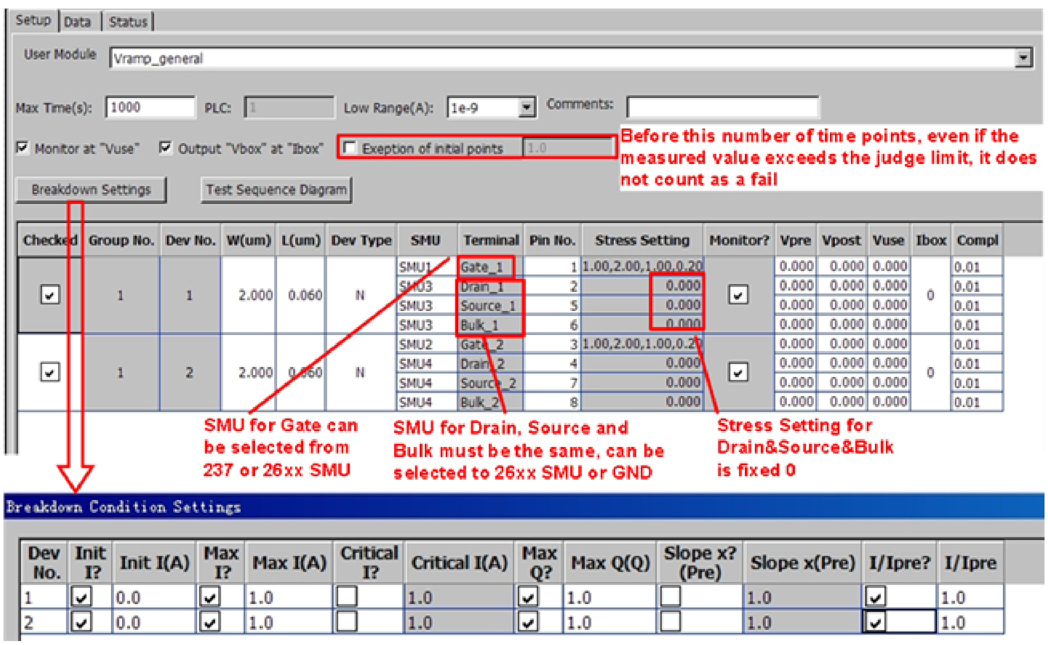
The Model 237-HV VRamp is used with two DUTs in a sequential test.

To access the Model 237-HV VRamp module:

1. Create a PTM.
2. Import the file from `C:\ACS\library\pyLibrary\PTMLib\KI237_HV_Vramp.py`.

The test flow for the Model 237-HV VRamp is the same as the 2600-based-RTM VRamp module (see the next figure).

Figure 45: Model 237-HV VRamp settings



Model 237-HV JRamp

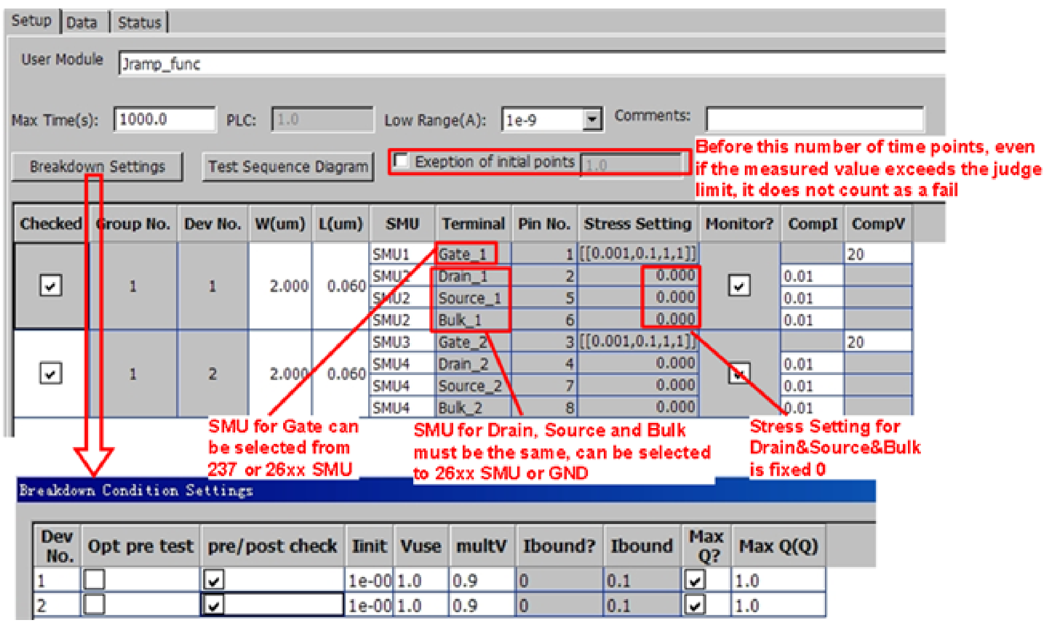
Model 237-HV JRamp is used for sequentially testing two DUTs.

To access to the 237-HV JRamp module:

1. Create a PTM.
2. Import the file from `C:\ACS\library\pyLibrary\PTMLib\KI237_HV_Jramp.py`.

The test flow for the Model 237-HV JRamp is the same as the 2600-based RTM JRamp module (see the next figure):

Figure 46: Model 237-HV JRamp settings



Model 237-HV HCI

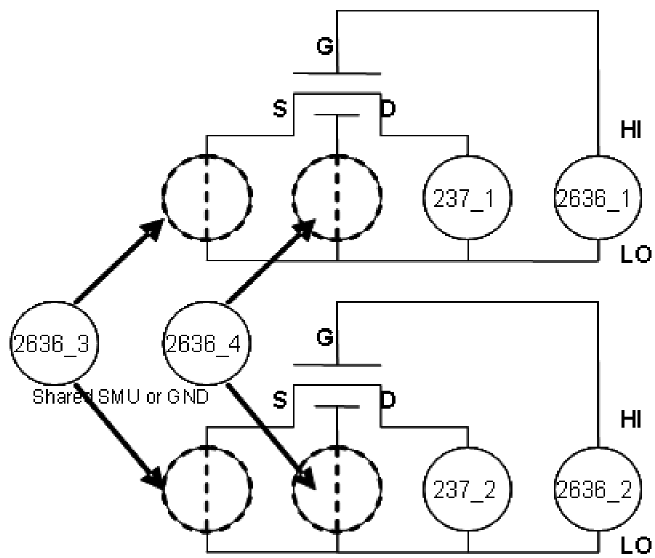
The Model 237-HV HCI is used for two DUTs in a sequential test.

To access to the Model 237-HV HCI module:

1. Create a PTM.
2. Import the file from `C:\ACS\library\pyLibrary\PTMLib\KI237_HV_HCI.py`.

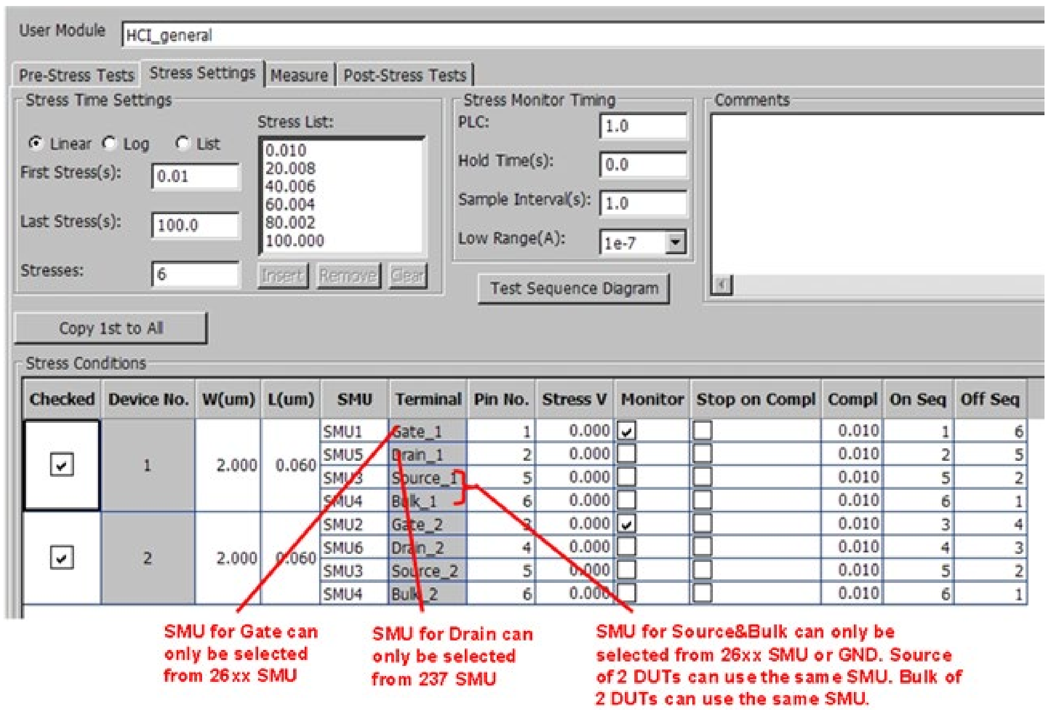
A typical two DUT test connection is shown in the next figure:

Figure 47: Model 237-HV HCI two DUT connection



The test flow and settings for the Model 237-HV HCI are similar to the 2600-based RTM HCI module. The only difference is that in the Model 237-HV HCI, the SMU assignment is at the Stress Settings tab rather than the device level on the configuration navigator. The Stress Settings tab is shown in the next figure:

Figure 48: Model 237-HV HCI settings



Checked	Device No.	W(um)	L(um)	SMU	Terminal	Pin No.	Stress V	Monitor	Stop on Compl	Compl	On Seq	Off Seq
☑	1	2.000	0.060	SMU1	Gate_1	1	0.000	☑	☐	0.010	1	6
				SMU5	Drain_1	2	0.000	☐	☐	0.010	2	5
				SMU3	Source_1	5	0.000	☐	☐	0.010	5	2
				SMU4	Bulk_1	6	0.000	☐	☐	0.010	6	1
☑	2	2.000	0.060	SMU2	Gate_2	3	0.000	☑	☐	0.010	3	4
				SMU6	Drain_2	4	0.000	☐	☐	0.010	4	3
				SMU3	Source_2	5	0.000	☐	☐	0.010	5	2
				SMU4	Bulk_2	6	0.000	☐	☐	0.010	6	1

Generic high-voltage capacitance-voltage PTM

You can make capacitance-voltage measurements using this PTM module.

The following are supported SMUs:

- 4200 SMU
- 2600 SMU
- 2657 SMU

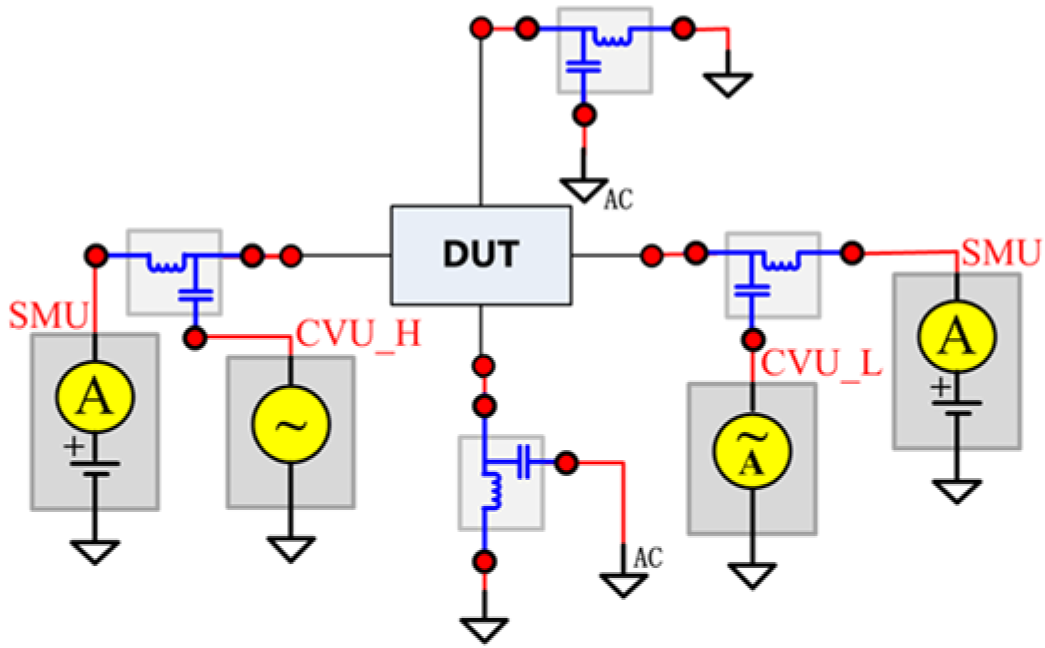
The configuration of this PTM module requires the following setup:

- Model 4200-CVU (to supply AC voltage).
- Model 4205-RBTs (200 V remote bias tee) or 3 kV remote bias tee (up to four bias tees can be used in the configuration).
- Model 8010 Test Fixture or Model 8020 Test Fixture

For supplies of ±200 V or 400 V differential DC bias or sweep voltage, either the 4200 SMU or the 2600 SMU can be used. The 4205-RBTs are connected to the device under test (DUT) through the Model 8010 test fixture.

For supplies of 3 kV DC bias or sweep voltage, the 2657A SMU is needed. The 3 kV remote bias tees are connected to the DUT through the Model 8020 test fixture.

Figure 49: HV_CV measurement hardware connections



NOTE

In the previous graphic, a 4-terminal device is shown. You can also use this test for 2-terminal and 3-terminal devices.

Generic high-voltage capacitance-voltage functions

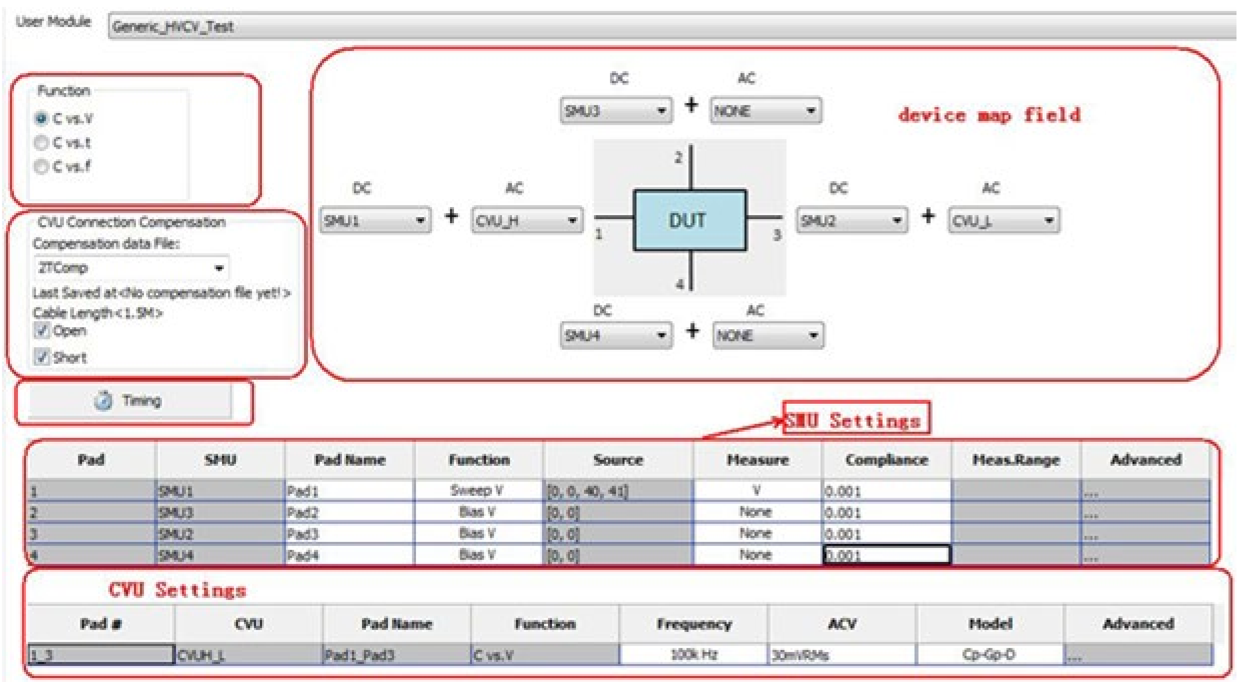
The generic high-voltage high-current PTM library module is in the following directory:

```
C:\ACS\library\pyLibrary\PTMLib\GenericHVCVlib.py
```

To open the module, import the `.py` file to your test.

You can use this module to switch between the functions C vs. V, C vs. t, and C vs. f. The details of these functions are indicated in the following figure. Descriptions follow the figure.

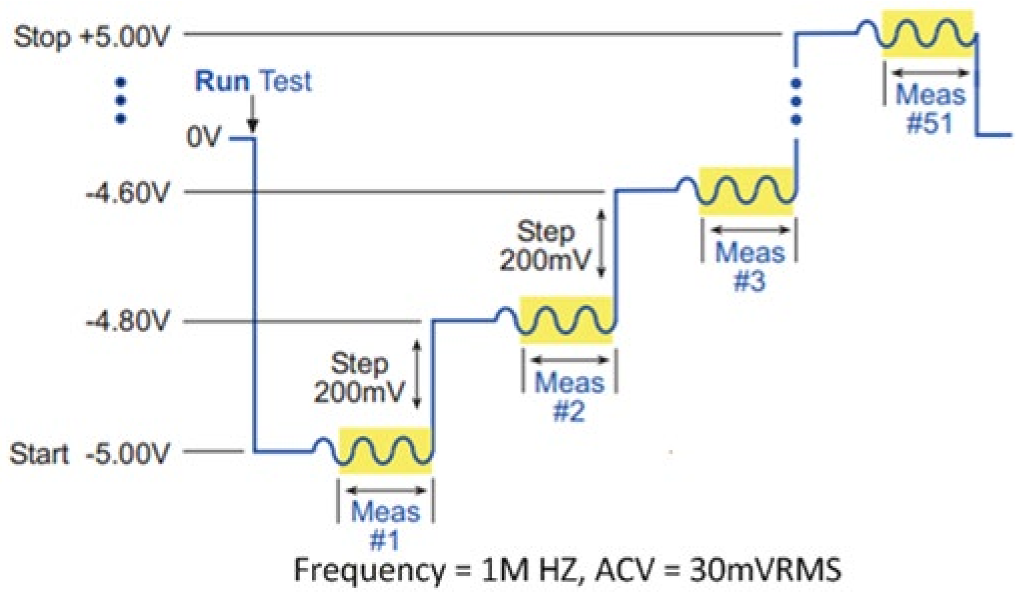
Figure 50: High-voltage capacitance-voltage PTM module GUI



C vs. V

Using a voltage sweep, capacitance is measured at every step of the sweep to generate a Capacitance versus Voltage graph. An example is shown in the following figure.

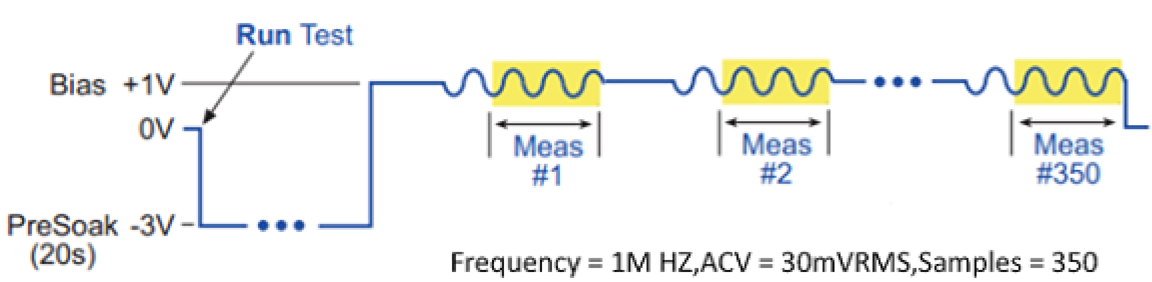
Figure 51: C vs. V waveform example



C vs. t

Performs a specified number of capacitance measurements (Sample Count) at a specified time interval (Measurement Delay) with voltage and frequency held constant. The capacitance versus time measurements is then plotted on a graph. An example is shown in the following figure.

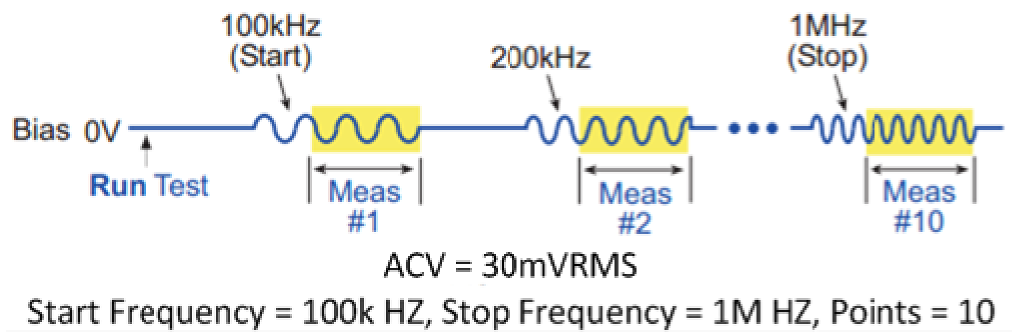
Figure 52: C vs. t waveform example



C vs. f

Using a frequency sweep, capacitance is measured at every frequency point to generate a Capacitance versus Frequency graph. An example is shown in the following figure.

Figure 53: C vs. f waveform example



CVU connection compensation

***In the CVU connection** compensation area:*

- **Compensation data file:** Select the compensation data file to be used. For more information about how to generate a compensation file, refer to "Generate connection compensation data" in the *Automated Characterization Suite (ACS) Fundamental Reference Manual* (document number ACS-914-01)
- **Open:** Enable or disable open compensation for CVU.
- **Short:** Enable or disable short compensation for CVU.

Double-click the cell to display the Timing dialog for the selected function.

Figure 54: C vs. V, C vs. t, and C vs. f Timing dialogs

Measurement Speed: Selects the SMU and CVU measure speed.

- **Fast:** Optimizes speed at the expense of noise performance. It is good for fast measurements where noise and settling time are not concerns.
- **Normal:** The most commonly used setting. It provides a good combination of speed and low noise and is the best setting for most cases.
- **Slow:** Optimizes the low-noise measurements at the expense of speed. If speed is not a critical consideration, it is a good choice when you need the lowest noise and most accurate measurements.
- **Custom:** Allows you to fine-tune the timing parameters to meet a particular need. With Custom, you can configure the integration time and the number of readings to produce a composite setting. The entries in the PLC edit fields control the A/D (analog-to-digital) converter integration time used to measure a signal. A short integration time for each A/D conversion results in a relatively fast measurement speed, at the expense of noise. A long integration time results in a relatively low noise reading, at the expense of speed. The integration time setting is based on the number of power line cycles (NPLCs):
  - For 60 Hz line power, 1.0 PLC = 16.67 ms (1/60 of a second).
  - For 50 Hz line power, 1.0 PLC = 20 ms (1/50 of a second).
- **CV optimized:** This option allows you to select a setting that gives an accurate CV measurement.
- **PLC:** If you selected the Custom measurement Speed mode, you can enter any value between 0.001 NPLC and 25 NPLC. If you selected the **Fast**, **Normal**, **Slow** or **CV optimized** measurement Speed mode, ACS sets the A/D Integration Time correspondingly. The following table summarizes the allowed A/D Integration Time settings for the measurement Speed modes.

Measurement speed	**PLC**
Fast	0.01
Normal	1
Slow	10
Custom	0.001 to 25
CV optimized	10

- **Delay Factor:** After applying a forced voltage or current, a SMU waits for a delay time before making a measurement. The delay time allows for source settling. The default delay time is pre-programmed and range-dependent to allow for the exceptionally long settling times needed at very low current ranges. The applied delay time is a multiple of the default delay time and the value in the Delay Factor edit box specifies this multiple.

  Applied delay time = (Default delay time) x (Delay Factor)

For example, if the default delay time is 1 ms and the Delay Factor is 0.7, the applied delay time is 0.7 ms (1 ms x 0.7).

If you select the Custom measurement speed mode, you can enter a custom Delay Factor of 0 to 100. If you select the **Fast**, **Normal**, **Slow** or **CV optimized** measurement speed mode, the SMU sets an appropriate fixed Delay Factor.

Measurement speed	Delay Factor
Fast	0.7
Normal	1.0
Slow	1.3
Custom	0 to 100
CV optimized	1

- **Filter Factor:** To reduce measurement noise, a SMU applies filtering, which may include averaging of multiple readings to make one measurement. The value entered in the Filter Factor edit box specifies a multiple of this preprogrammed filtering.

  If you select the Custom measurement speed mode, you can enter a Filter Factor value of 0 to 100. If you select the **Fast**, **Normal**, **Slow** or **CV optimized** measurement speed mode, the SMU sets an appropriate fixed Filter Factor.

Measurement speed	Filter Factor
Fast	0.2
Normal	1
Slow	3
Custom	0 to 100
CV optimized	3

Presoak Time (sec): Time in seconds to apply soak voltage.

Measurement Delay (sec): Delay time in seconds before measurement. The delay time allows for source settling.

#Sample (1-10000): Specifies the number of data points to be acquired during the test.

Generic HV CV user interface descriptions

Pad: Cannot be changed here. Pads are fixed and referenced to the diagram in the device map field.

SMU: Cannot be changed here. It can only be assigned in the device map field based on the hardware connection.

Pad Name: The header for the data related to the hardware connection.

Function: The function type for force. Double-click to select one of the following options from the list:

- **C vs. V:** Bias V/Sweep V/List V/GND/Open can be selected, but only one SMU can be set to Sweep V or List V
- **C vs. t:** Only Bias V/GND/Open can be selected
- **C vs. f:** Only Bias V/GND/Open can be selected

Source: The source value of SMU. Double-click the Source cell to display a Settings dialog.

Options for Bias V:

- **Presoak V:** When the test is started and before measurement sequence, the device is stressed at a specified voltage (Presoak V) for a specified period (Presoak Time), as shown in the following figure.
- **Bias Level:** Defines a constant and valid voltage at the terminal.

Figure 55: Bias V settings

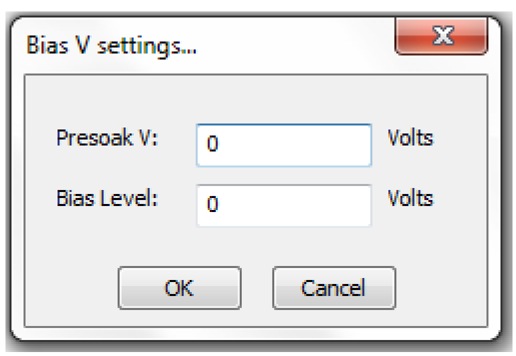
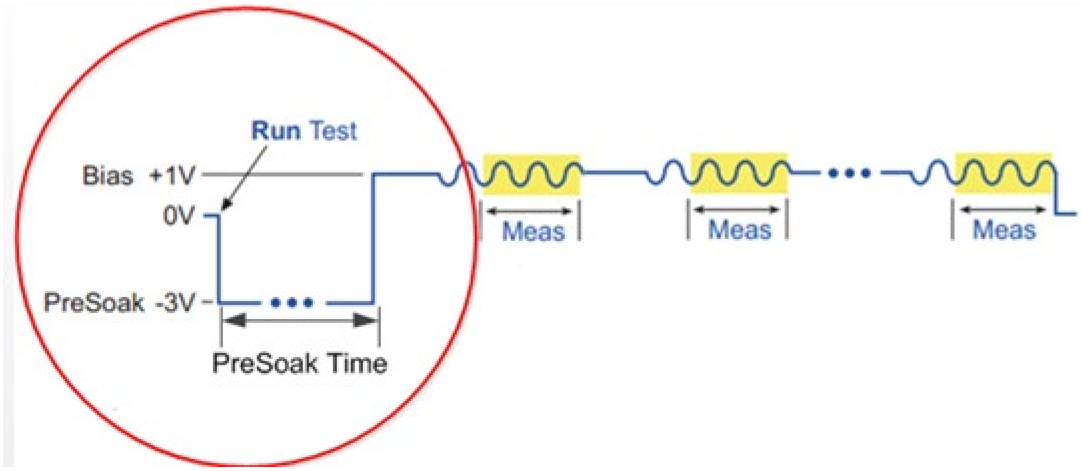


Figure 56: Presoak V and Presoak time



Options for Sweep V:

- **Dual Sweep:** You can set the SMUs in a test to perform a dual sweep. When enabled, the SMU sweeps from Start to Stop, and then continues to sweep from Stop back to Start. When it is disabled, the SMU only sweeps from Start to Stop.

Figure 57: Sweep V settings

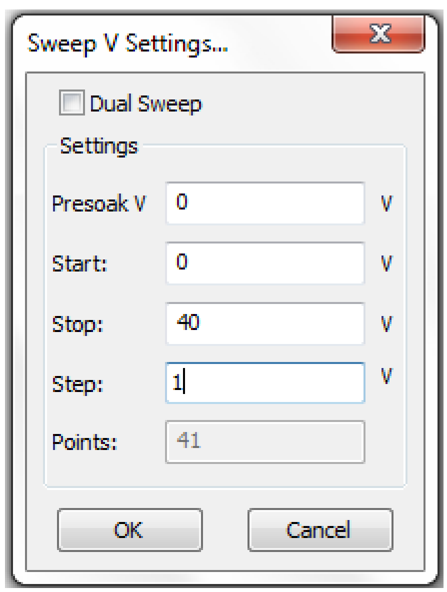
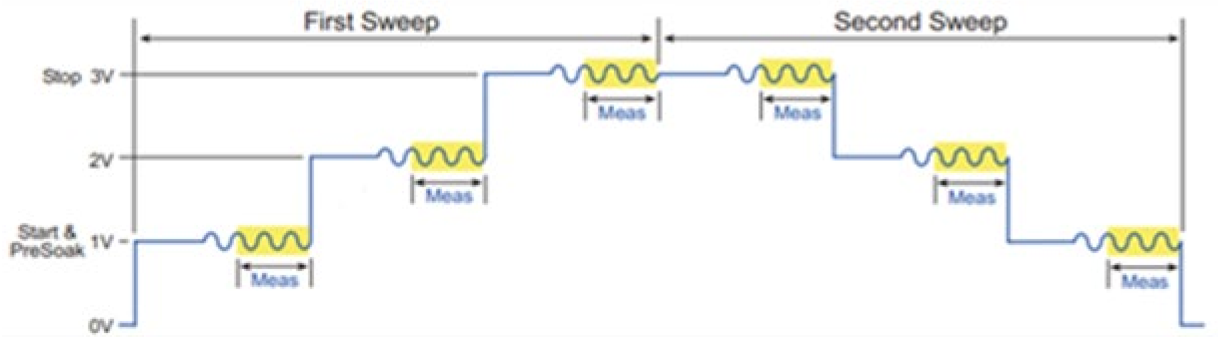


Figure 58: Dual voltage sweep example



- **Presoak V:** When the test is started and before measurement sequence, the device is stressed at a specified voltage (Presoak V) for a specified period (Presoak Time).
- **Start:** The Start edit box specifies the voltage forced for the first data point of the sweep.
- **Stop:** The Stop edit box specifies the voltage forced for the last data point of the sweep.
- **Step:** The Step edit box specifies the size of the voltage increments and determines the calculated Points value
  {Points = integer value of [1 + (Stop − Start)/(Step)]}
- **Points:** Shows the number of data points that are input when a sweep is executed.

Options for **List V**:

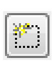
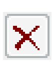
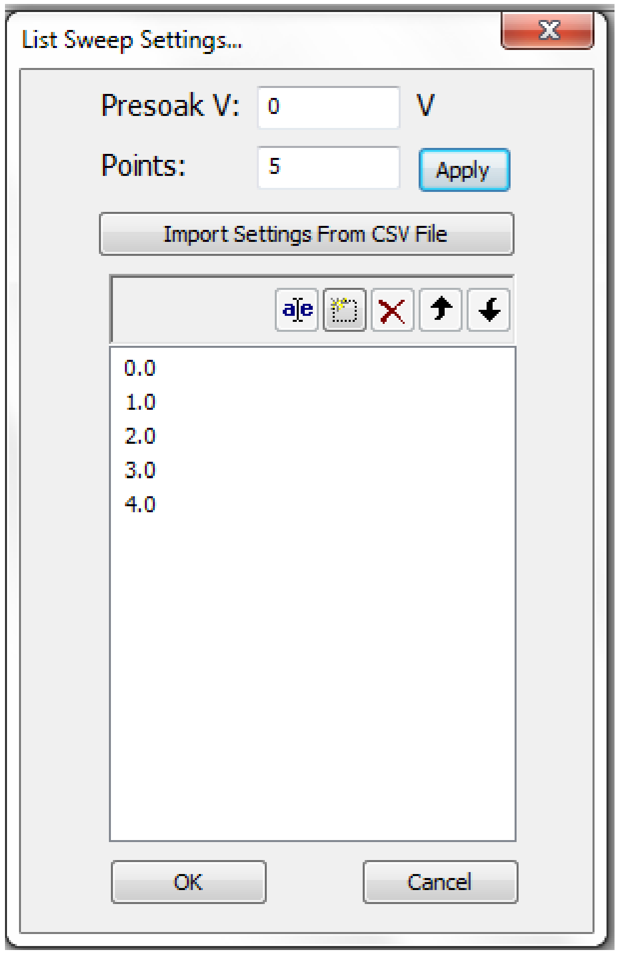
- **Presoak V:** When the test is started and before measurement sequence, the device is stressed at a specified voltage (Presoak V) for a specified period (Presoak Time).
- **Points:** The number of points for the forcing values.
- **Import Settings From CSV File:** Allows you to import and then save a `.csv` file.
- **Edit item** **:** Change the number.
- **New item** **:** Adds a new item.
- **Delete item** **:** Delete the selected item.
- **Move up** **:** Move the selected item up.
- **Move down** **:** Move the selected item down.

Figure 59: List Sweep Settings



Measure: Measures the voltage unit in volts.

Compliance: Enables the test to abort and turn off the SMU output when it reaches the compliance (limit) value. The value is limited by the specifications of the SMU.

Meas.Range: This item is disabled.

Advanced: Double-click the Advanced cell to open a dialog that allows you to set advanced features for this SMU.

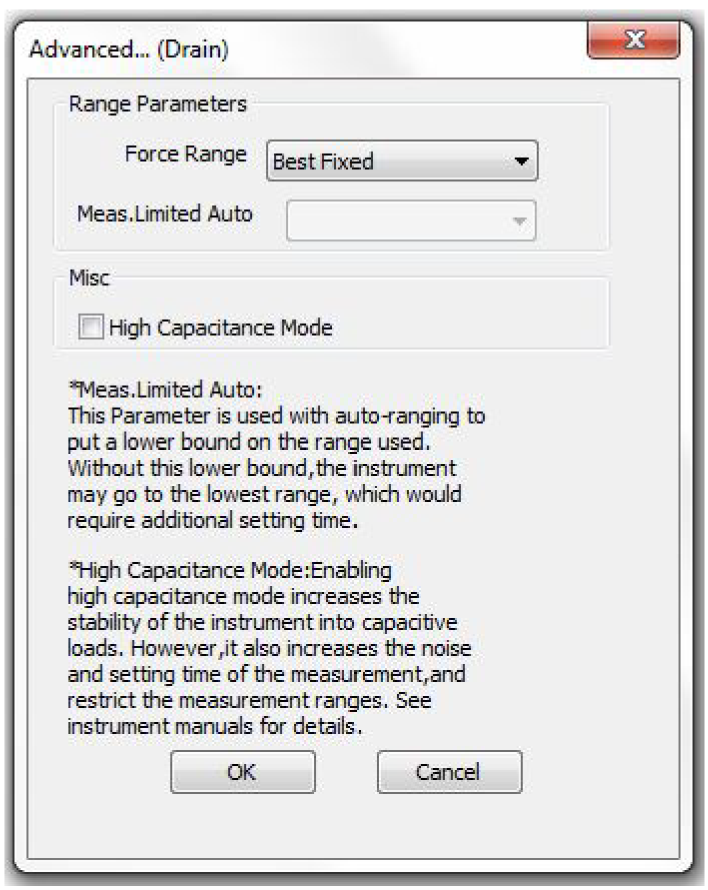
Range Parameters:

- **Force Range:** Specifies the SMU force range used to force voltage, including Best Fixed and numerical range options.
- **Meas. Limited Auto:** This item is disabled.

Misc:

- **High Capacitance Mode:** Sets the SMU to high capacitance mode.

Figure 60: SMU Advanced settings dialog



CVU Settings

Pad #: Changed with ac settings in the device map field accordingly.

CVU: Cannot be changed here. It can only be assigned in the device map field.

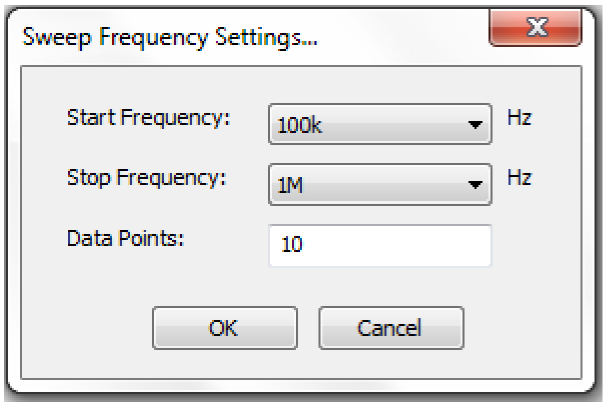
Pad Name: Changed with ac settings in the device map field accordingly.

Function: Changed with the function selected.

Frequency: Test frequency (Hz). A variable that selects the measurement frequency to use.

- In C vs. V and C vs. t, the frequency is biased (10 KHz to 2 MHz)
- In C vs. f, the frequency sweeps up or down

Figure 61: Sweep Frequency Settings



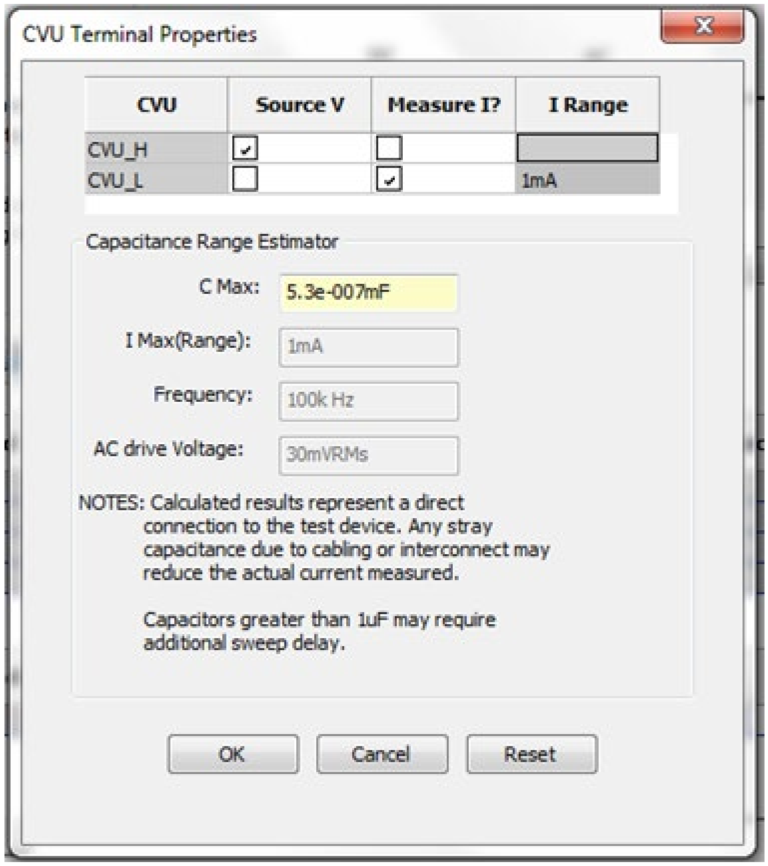
ACV: AC test voltage of CVU (10 mV to 100 mV RMS).

Model: The parameters that can be measured by the 4200-CVU:

- **Cp-Gp-D:** Parallel Capacitance and Conductance and Dissipation Factor.
- **R+jX:** Resistance and Reactance.
- **Z,Theta:** Impedance and Phase Angle.
- **Cs-Rs-D:** Series Capacitance and Conductance and Dissipation Factor.

Advanced CVU Properties

Figure 62: CVU Terminal Properties dialog



- **I Range:** Fixed 1 mA
- **Capacitance Range Estimator:** The capacitance is calculated from the capacitive impedance

The test frequency range is calculated using the following formula:

$$C_{max} \approx \frac{I_{max}}{2\pi f V_{ac}}$$

- **C Max:** The calculated capacitance
- **I Max(Range):** Fixed 1 mA
- **Frequency:** Test frequency, the value changes with the setting in CVU settings user interface accordingly
- **AC drive Voltage:** Measured ac voltage, the value changes with the setting in CVU settings user interface accordingly

Device specific high-voltage capacitance-voltage PTM

The device specific high-voltage capacitance-voltage PTM libraries are in the following directory: `ACS\library\pyLibrary\PTMLib`. They include the following test libraries specific to different devices:

```
Specific_IGBT.py
Specific_nMOSFET.py
Specific_npnBJT.py
Specific_pMOSFET.py
Specific_pnpBJT.py
Specific_nPowerMOSFET.py
Specific_pPowerMOSFET.py
Specific_npnPowerBJT.py
Specific pnpPowerBJT.py
```

Import the `.py` file you need for your test. The device module opens.

Discharge test

The discharge test PTM library module is in the following computer directory: `ACS\library\pyLibrary\PTMLib\Discharge_Test.py`.

This module is optional and is used to safely discharge the bias tee capacitance, especially once each CV test ends in which there is dc bias applied by the Model 2657A. You can import the `.py` file and insert it in the test sequence. This module can discharge bias tees by programming all SMUs to zero volts with 1 mA compliance and turning their outputs on for 1 second then turning off.

This module can be used for both `Generic_HVCV_Test` and device specific PTMs in MultiMode.

System level compensation

The PTM module measure CV compensation (measCVcomp) is used to generate correction factors for system level HVCV compensation. To use this module, first create a PTM and import the `hvcv_genCompData.py` file from this location: `C:\ACS\library\pyLibrary`.

This modules uses the low-voltage CVU as a calibration tool to provide load values for high-voltage CVU characterization.

Open, short, and load devices must be connected to run this procedure. Select a load device with a value close to the capacitance you are measuring. If you are configuring 3-terminal capacitance measurements, use a 1 nF to 2 nF capacitor.

The correction factors generated by this command are saved as calibration constants in this directory: `C:\ACS\compensation\dev_comp.ini`. These calibration constants are used by the `hvcv_test`, `hvcv_sweep`, and `hvcv_3term` modules with the `doComp=2` compensation command input.

Once you have obtained the compensation data, you need to save the information to the following file: `C:\ACS\compensation\dev_comp.ini` for system level compensation. The calibration constants in this file will be used by the `hvcv_test`, `hvcv_sweep`, and `hvcv_3term` modules with the `doComp=1` compensation command input.

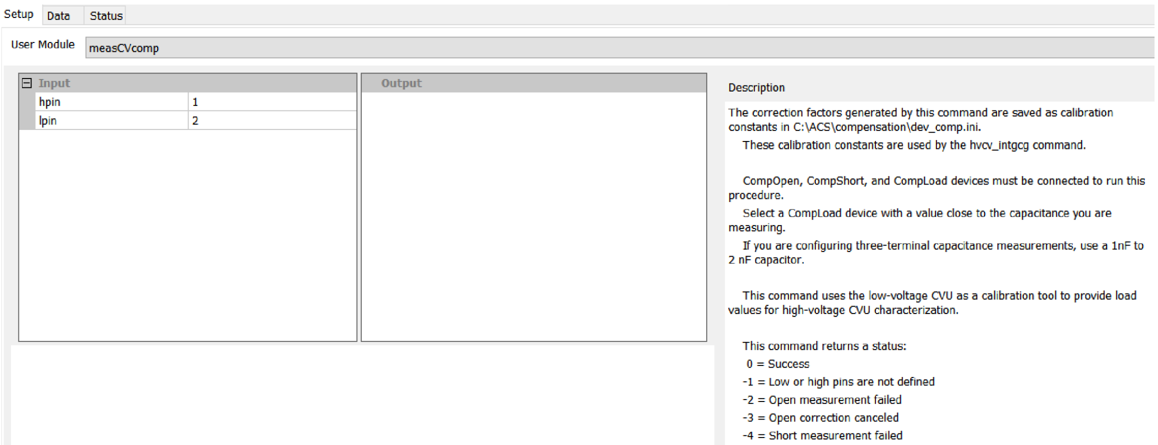
The following is a list of inputs used for this test (see the following figure):

- **high_pin:** CVU_HI terminal pin
- **low_pin:** CVU_LO terminal pin

The following is a list of outputs used for this test:

- **CpCalc:** The corrected parallel capacitance value; should be consistent with low-voltage CVU measurement or the expected or known value
- **GpCalc:** The corrected parallel conductance value; should be consistent with low-voltage CVU measurement or the expected or known value
- **DCalc:** Dissipation factor

Figure 63: ACS measCVcomp PTM settings GUI



DC compensation

This feature adds DC compensation to test the SMU offset current. The SMU:

- Executes the DC compensation at fixture open
- Forces 0 volts
- Measures the offset current at the user-specified range

ACS gets the value and keeps the value as global data, which can be used in 2600-ITM REL function.

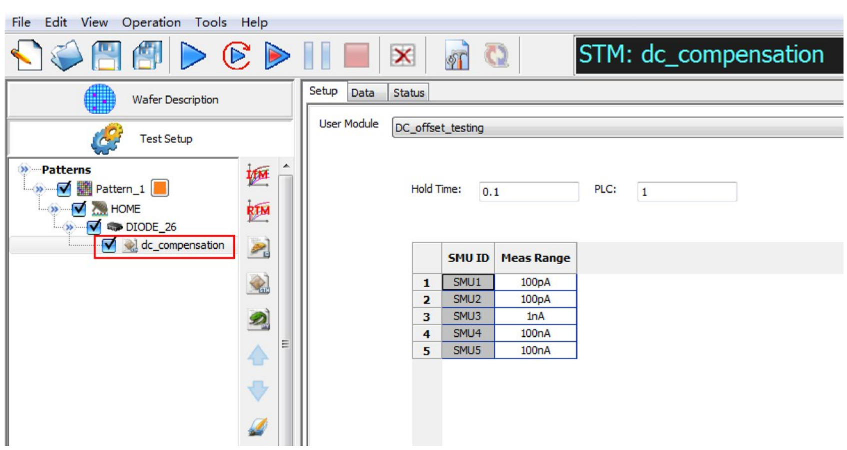
If the hardware connection or SMU configuration has not changed, it is not necessary to run the DC compensation test every time ACS starts. If the hardware configuration changes, you must run the DC Compensation test.

DC compensation saved one offset value and does not store the corresponding measure range value. If you want to change the measure range, you need to repeat the DC Compensation testing.

To use DC compensation:

1. Set flag in `ACS_setting.ini` file: `ACS_DC_Compensation = 1`
2. Open the `DC_Compensation` project and run the test module in the project. ACS gets the SMU offset value and stores the value to a file. The file is the origin source for global data.
3. Open or create a new test project. You can use the REL function in an ITM device or use the SMU offset value in an ITM, STM, PTM, or UAP.

Figure 64: DC Compensation



DC offset test

In the DC Compensation project, there is an STM test to run the DC offset test. This test module lists all the SMUs. You must choose the measure range for each SMU.

When this test module is run, each SMU forces 0 volts, measures the offset current, and posts this offset current to ACS. ACS will get the value of each SMU, store them into a file.

The return data name of this test module:

- "DC_Compensation_SMU1" : The offset current of SMU1
- "DC_Compensation_SMU2" : The offset current of SMU2
- "DC_Compensation_SMU3" : The offset current of SMU3
- ……
- "DC_Compensation_SMU*n*" : The offset current of SMU*n*

DC compensation user access point

You can execute DC compensation when automation starts using UAPs.

To execute DC compensation when automation starts:

1. Add one STM at the automation start UAP level.
2. From `C:\ACS\library\26Library\TSPLib`, import the `DC_offset_testing.tsp` file.

Charge pumping test module

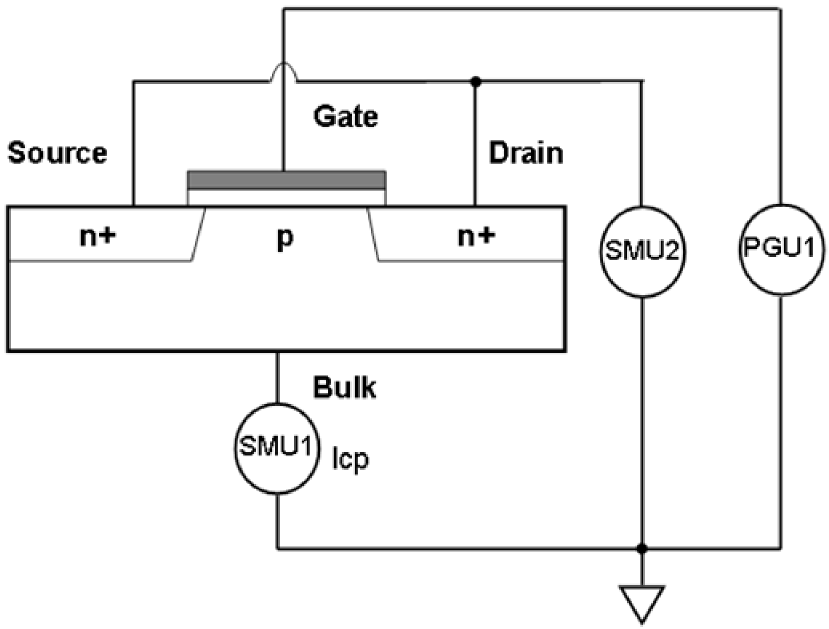
Charge pumping is a measurement technique to evaluate the surface-states at the Si-SiO2 interface of MOSFET devices. This method applies pulse on the gate of the MOSFET and measures the bulk current when the source and drain are biased. The bulk current is generated by the repetitive recombination at the interface traps of the minority carriers with majority carriers when the gate pulses the channel between inversion and accumulation.

The charge pumping test module is a PTM module that uses a Keysight 8110 for waveform generation. It uses square, triangle, and trapezoid pulse methods.

Connection

The gate of the MOSFET is connected to a pulse generator, the source and drain are connected to SMU2, and the bulk is connected to SMU1 for the current measurement.

Figure 65: Charge pumping module instrument connections



The Charge Pumping test module uses the following connections:

- **Pulse Generator:** A Keysight 8110 or 8110A
- **Bulk current measurement:** SMU1
- **Bias on the Source and Drain:** SMU2.

The Keysight 8110 is added to the ACS Hardware configuration as a general-purpose instrument (GPI), as shown in the following two figures.

Figure 66: Customized instrument settings

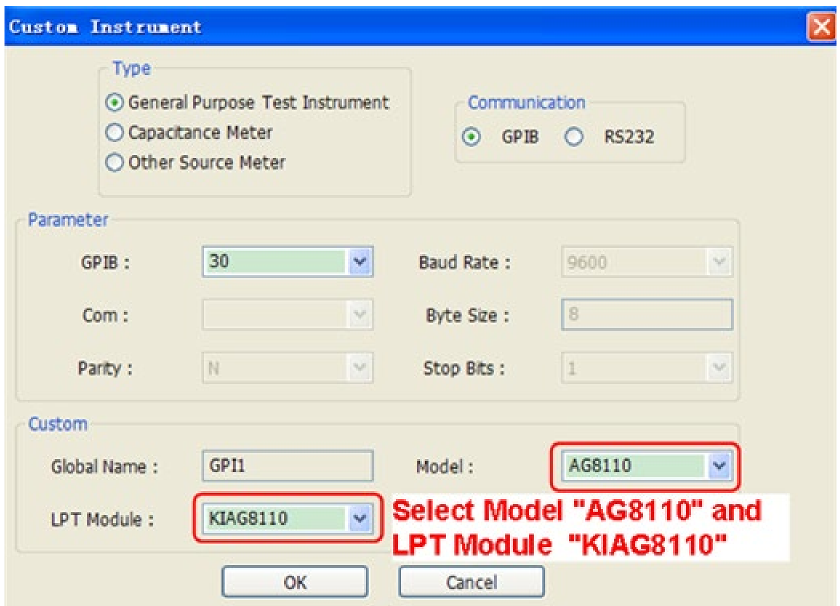
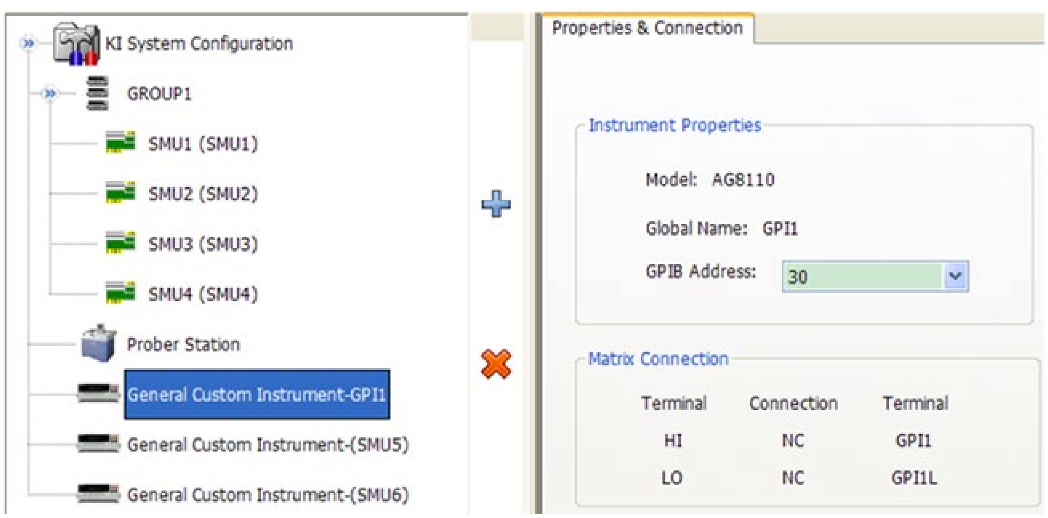


Figure 67: General Custom Instrument Properties and Connection



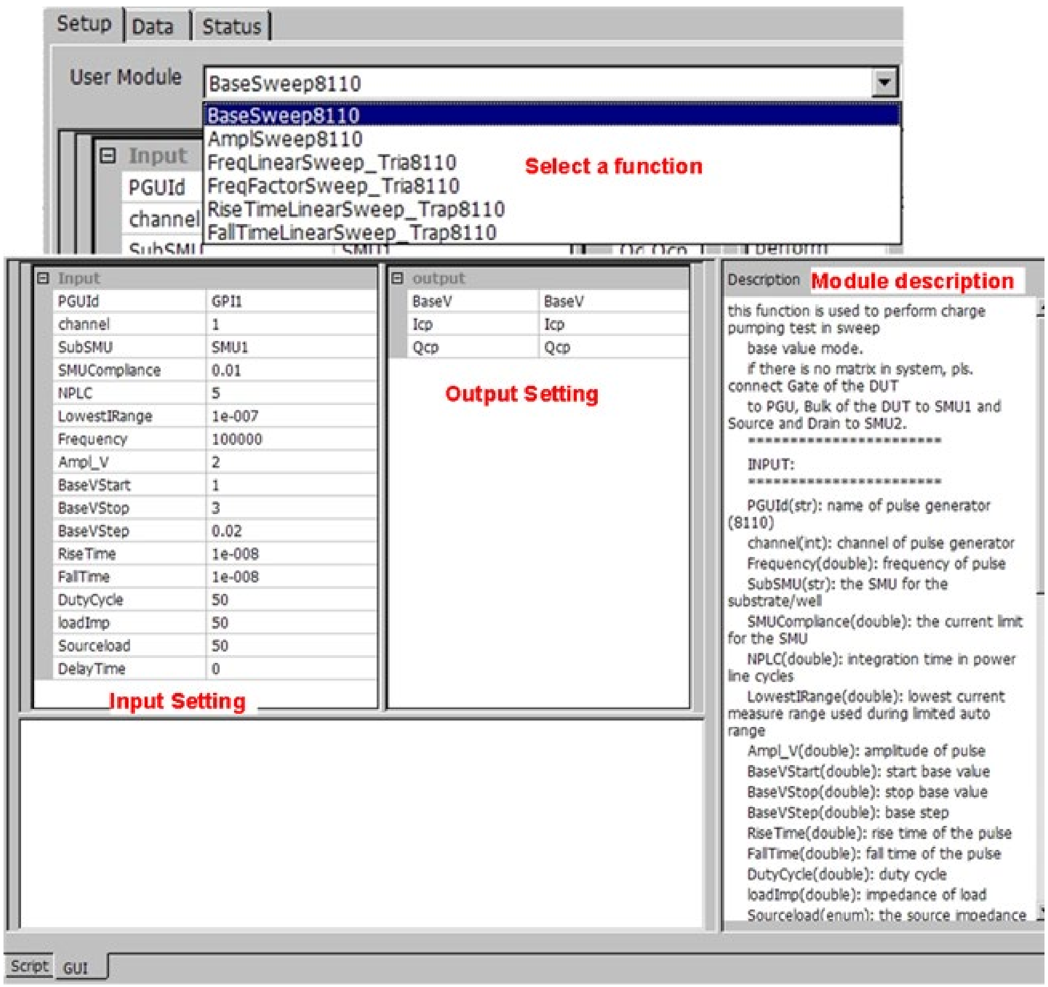
Test module settings

The Charge Pumping Test Module has several functions to achieve different pulse methods. The function can be selected from the User Module menu. The module uses the standard ACS test module user interface, as shown in the following figure.

To access to the Charge Pumping module:

1. Create a PTM.
2. Import the file `C:\ACS\library\pyLibrary\PTMLib\ChargePumping.py`.

Figure 68: Charge pumping settings GUI

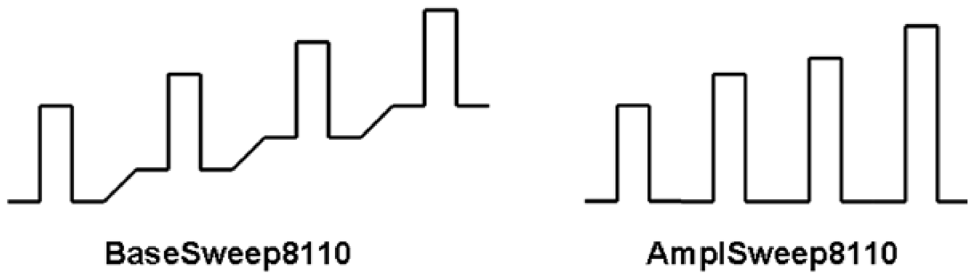


Square pulse method

BaseSweep8110 and AmplSweep8110

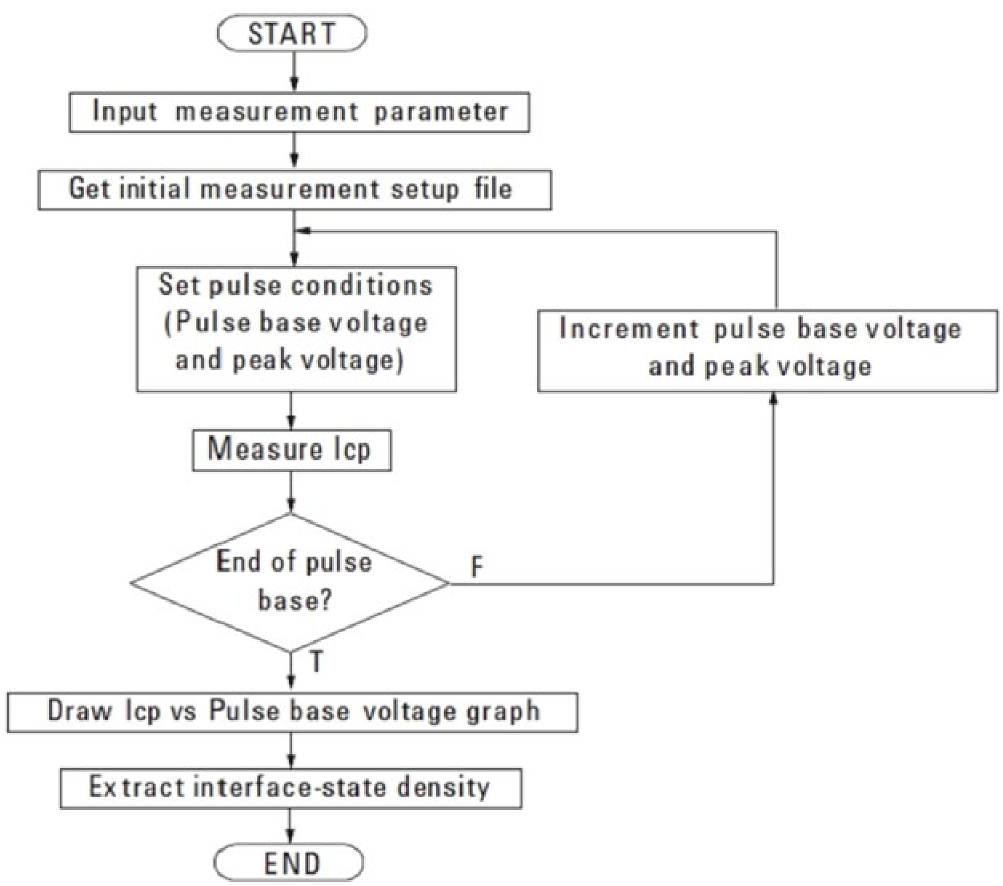
The BaseSweep8110 generates fixed amplitude voltage pulses on top of a linear voltage sweep. The AmplSweep8110 generates voltage pulses with linearly varying amplitude.

Figure 69: Base sweep and amplitude sweep



The test flow is shown in the next figure:

Figure 70: Square pulse method test flow



Triangular pulse method

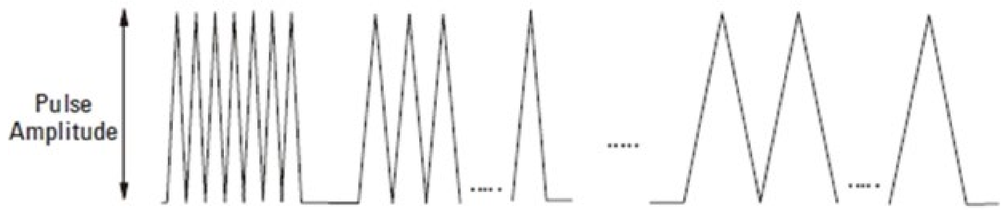
FreqLinearSweep_Tria8110 and FreqFactorSweep_Tria8110

These two modules generate a triangular pulse with an increasing frequency:

FreqLinearSweep_Tria8110 generates pulses with linearly increasing frequency.

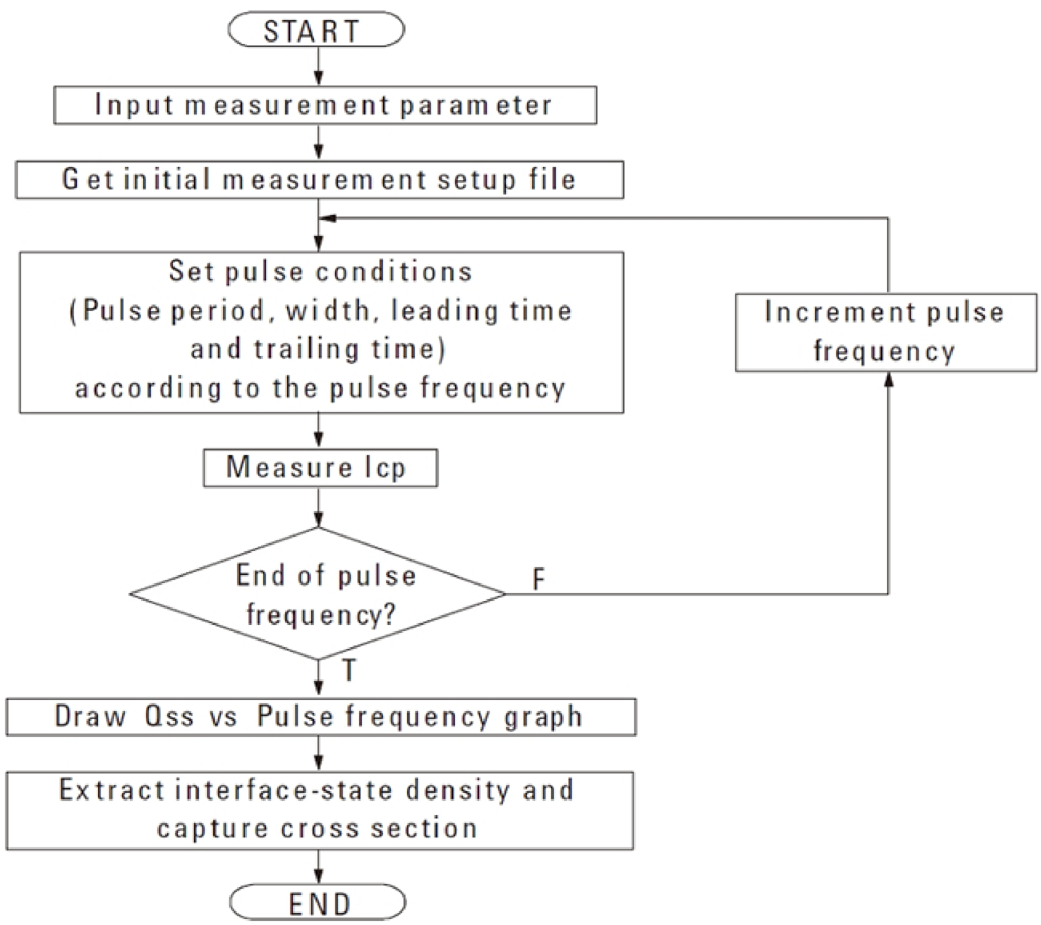
FreqFactorSweep_Tria8110 generates a pulse with an exponentially increasing frequency.

Figure 71: Triangular pulse method



The test flow is shown in the next figure:

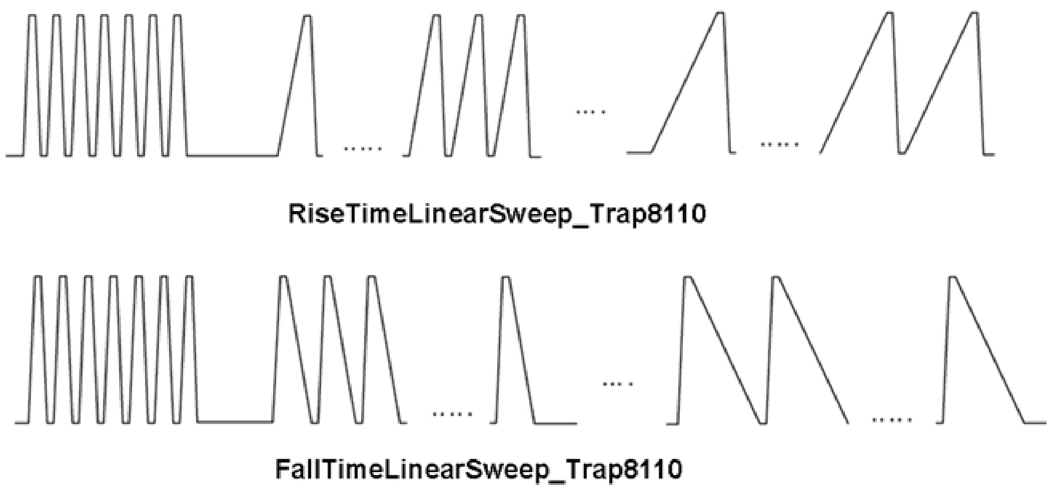
Figure 72: Triangular pulse method test flow



Trapezoidal pulse method

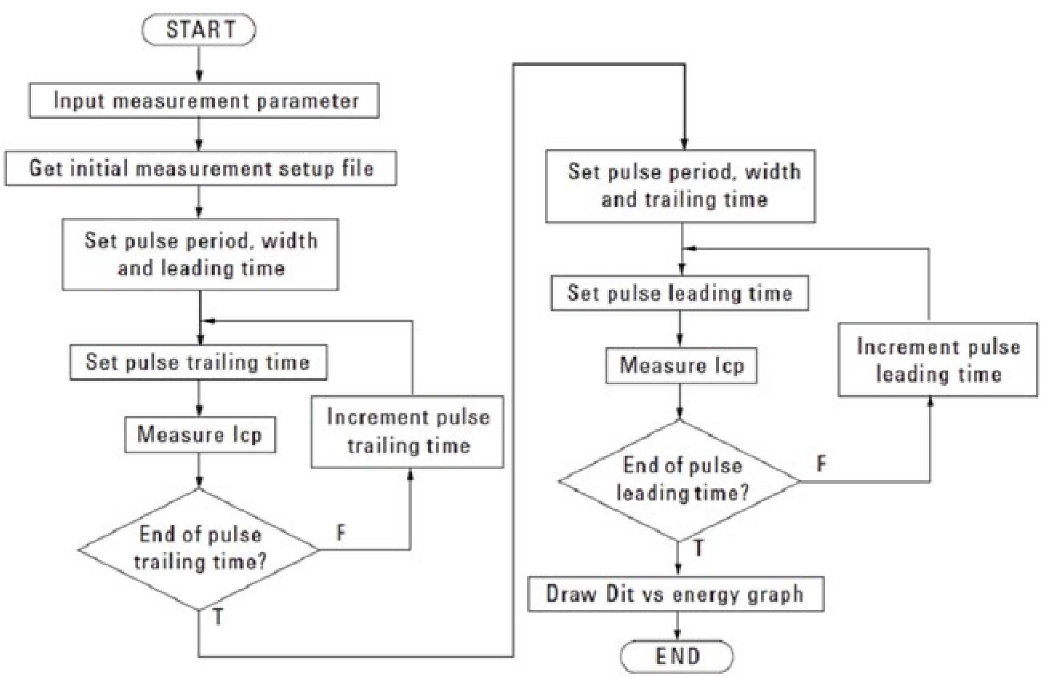
The `RiseTimeLinearSweep_Trap8110` and `FallTimeLinearSweep_Trap8110` modules generate a trapezoidal pulse. `RiseTimeLinearSweep_Trap8110` has a rise time that changes linearly. `FallTimeLinearSweep_Trap8110` has a fall time that changes linearly.

Figure 73: Trapezoidal pulse method



The test flow is shown in the next figure:

Figure 74: Trapezoidal pulse method test flow



SWEAT test module

The standard wafer-level electromigration accelerated test (SWEAT) method is an accelerated electromigration test performed on microelectronic metallization. This highly accelerated test was developed as a method to quickly obtaining a measure of metallization reliability and for providing process control data to the semiconductor manufacturer.

The SWEAT method uses a feedback control loop to adjust the stress current applied to the metallization such that temperature and current density of the structure maintain the target time to failure within a programmed error band.

SWEAT test module process:

SWEAT test module process:	Description
Initial R measurement	Resistance measurement
Phase 1: ramp current until temperature > TCT +50 degrees Celsius	TCT = Chuck temperature as input by you
Phase 2: ramp current until ETF is achieved	ETF = estimated time to failure as input by you
Phase 3: adjust current to keep ETF	Adjust the current as needed
Final R measurement	Resistance measurement

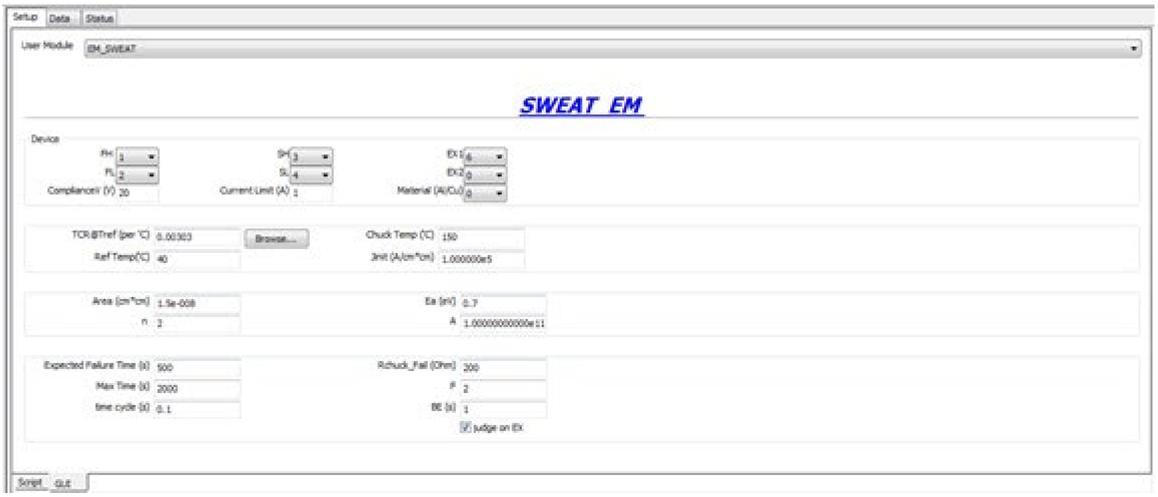
For more details about the procedure for executing the SWEAT algorithm, refer to JEDEC standard JEP119A, *A Procedure for Performing SWEAT*, available at www.jedec.org (jedec.org).

Test module settings

To access the SWEAT test module:

1. Create an STM.
2. Import the file `\\ACS\library\26Library\TSPLib\SWEAT.tsp`. The details are shown in the next figure. Descriptions of the figure contents follow the figure.

Figure 75: ACS SWEAT STM settings GUI



The SWEAT user interface inputs:

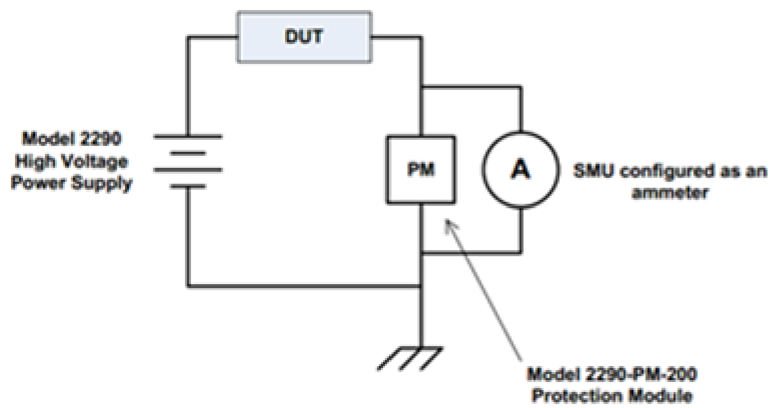
- **FH (Force High):** Choose the device terminal.
- **SH (Sense High):** Choose the device terminal.
- **FL (Force Low):** Choose the device terminal.
- **SL (Sense Low):** Choose the device terminal.
- **EX1 (Extrusion):** Choose the device terminal; if there is no extrusion terminal, select `0`.
- **EX2 (Extrusion):** Choose the device terminal; if there is no extrusion terminal, select `0`.
- **Compliance V:** Voltage compliance. Test stops when compliance is achieved.
- **Current Limit (A):** Maximum current for the test. Test stops when next current achieves this value.
- **Material:** Material (choose 0 for Al and 1 for Cu).
- **TCR@Tref:** The temperature coefficient of resistance at Tref. This can be manually input from the user interface or automatically added using the TCR module test result. To load it manually, select the **Browse** button and load the value from the user data folder `C:\ACS\user_data`.
- **Chuck Temp ('C):** This is the Chuck temperature of the structure before joule heating.
- **Ref Temp ('C):** Reference temperature for TCR. Reference temperature at which TCR is calculated.
- **Jinit (A/cm*cm):** Force current density at the beginning of stress.
- **Area (cm*cm):** Area of the test line. The cross-sectional area of the narrowest region of the test structure.
- **Ea (eV):** Constant 'Ea' in Black's equation; the activation energy of the metallization.
- **n:** Constant 'n' in Black's equation; the current density factor.
- **A:** Constant 'A' in Black's equation; the empirically determined constant.
- **Expected Failure Time:** Expected target failure time. The time it takes for the combined stress of temperature and current density to result in a prescribed increase in resistance of the test structure (definition of failure) as determined by Black's equation.
- **Rchuck_fail (Ohm):** Initial contact check. Before stress begins, R is measured at Chuck temperature. If the measured R is greater than this value, a failure occurs.
- **Max Time (s):** Time limit for the test.
- **F:** In phase 3; R fails when R ≥ (1+F)*R phase3 (where Rphase3 is the R value when entering phase3).
- **time cycle (s):** The time of a stress-measure judge-loop.

- **BE (s):** In phase 3, stress current will be adjusted when calculated time to failure exceeds BE of expected failure time.
- **judge on EX:** When selected, the results of EX1 and EX2 will be taken into judgment.

Power supply library

This module makes simple leakage current measurements on 2-terminal and 3-terminal devices using a Series 2290 high-voltage power supply and a SMU. This module can support the following SMUs for measuring the current through the device: Models 2611A/B 2612A/B, 2635A/B 2636A/B, 4200-SMU, and 4210-SMU. Each SMU should be connected to a Model 2290-PM-200 Protection Module to protect the SMU from high voltage in the event of a device breakdown.

Figure 76: Test connection example

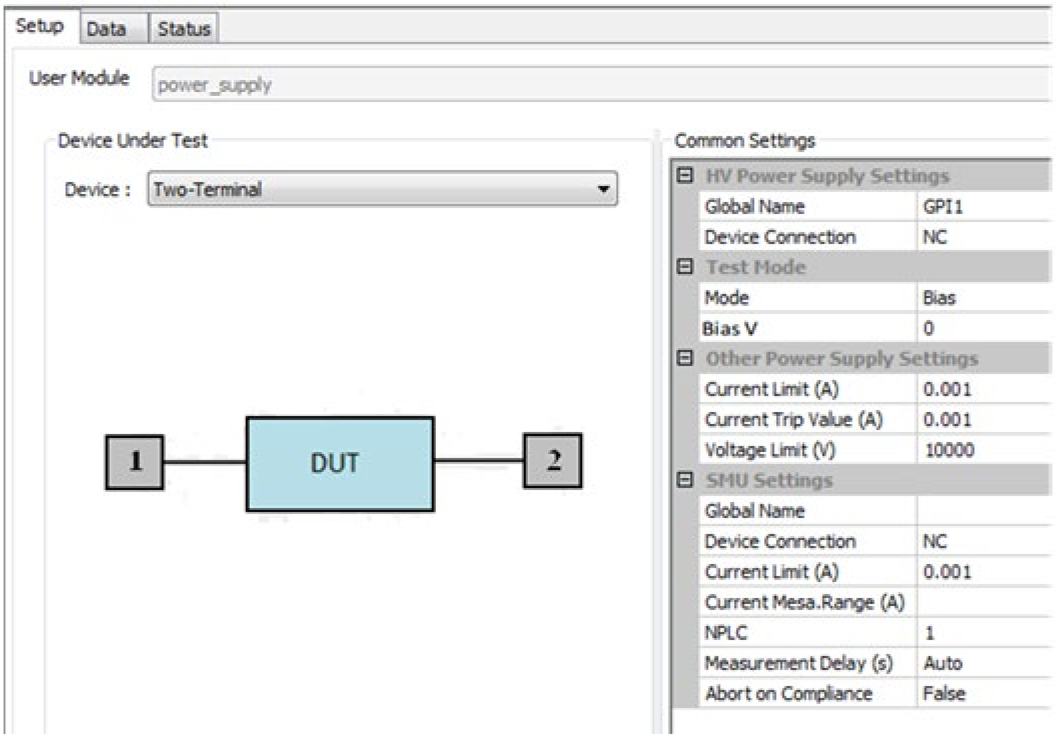


NOTE

The Series 2290 is not detected during the ACS software's hardware scan. You must add it as an external instrument (refer to *Automated Characterization Suite (ACS) Software Reference Manual* topic “Add and delete a PTM-only instrument”).

The power supply library `PowerSupply.py` is in the `C:\ACS\library\pyLibrary\PTMLib folder`. To add the power supply library to your project, insert a PTM and then import this library. For details on importing specific PTM libraries, refer to the *Automated Characterization Suite (ACS) Software Reference Manual* topic "Python Language Test Module (PTM) configuration."

Figure 77: Power supply GUI



Inputs

HV Power Supply Settings

- **Global Name:** GPI1, GPI2, …, GPIn.
- **Device Connection:** List of pins to connect.

Test Mode Settings

- **Mode:** Allows you to select test mode (Bias or Sweeping) from a list.
- **Bias V:** Force value for the bias.
- **Number of Points:** The number of points to sweep.
- **Sweep start V:** Initial force value for the sweep.
- **Sweep stop V:** Final force value for the sweep.

Other Power Supply Settings

- **Current Limit:** The programmed high voltage power supply current limit. The default value is 1 mA. The maximum value depends on the power supply selected in the hardware configuration.
- **Current Trip Value:** The programmed high voltage power supply current trip value. The high voltage output shuts off when the output current exceeds the current trip value. The default value is 1 mA. The maximum value depends on the power supply selected in the hardware configuration.
- **Voltage Limit:** The voltage limit is a protection feature to prevent the output voltage from being set too high or overshooting because of dramatic load changes. The output voltage cannot be set higher than the voltage limit. The default value is the maximum of the power supply.

SMU Settings

- **Global Name:** SMU1, SMU2, …, SMUn
- **Device Connection:** List of pins to connect.
- **Current Limit:** The programmed SMU current limit. The default value is 1 mA. The minimum and maximum values depend on the SMU used.
- **Current Meas.Range:** Specifies the SMU current measure range to use. The Auto option configures the SMU current range for autorange. The default is Auto.
- **nPLC:** Number of power line cycles for integration. The default value is 1.

- **Measurement Delay:** Use to apply a delay before each measurement is made. Use seconds to specify a delay, or set to Auto. If the measure delay is set to Auto, a range-dependent delay is applied each time the instrument performs a current measurement, or after changing current ranges during an autorange measurement. The range-dependent delay varies by SMU model. The Auto setting only can be applied to a 26XX SMU. When the 42XX SMU is used, you must input a specific value. If you use Auto for the 42XX SMU, this delay is disabled by default and measurements are made immediately.
- **Abort on Compliance:** Select one of the following:
  - **False:** The test will not abort when it reaches the programmed current limit of the SMU.
  - **True:** The test will abort when it reaches the programmed current limit of the SMU.

DC stress-measure loop project

The DC stress-measure loop project performs a stress test for device reliability analysis. This project uses a stress-measure subsite loop to control the loop. It contains specific user access points (UAPs) that allow you to save specific data files. You can bypass subsite, device, or testing based on the pass or failure judgment.

The DC stress-measure loop project features:

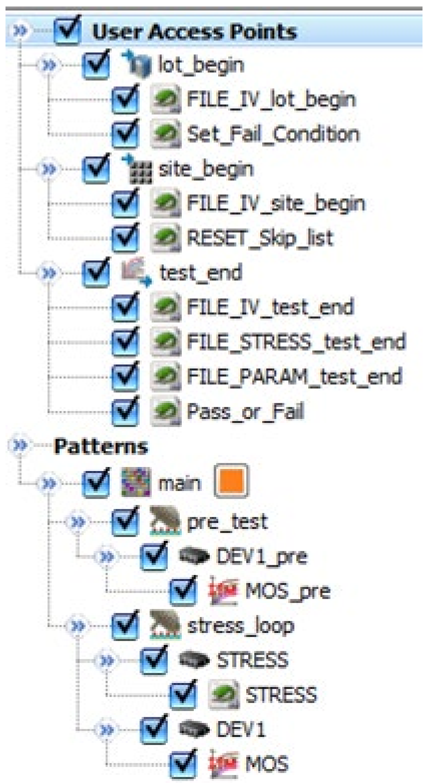
- Complete ACS project with limited configuration navigator settings
- Subsite loop to implement stress-measure for reliability tests
- Simple failure criteria
- PTM for pulse stress

Project settings

To access the DC stress-measure loop project:

1. On the toolbar, select **File**.
2. Select **Open**.
3. Go to the folder `C:\ACS\Projects\DC_Stress_Measure_loop`.
4. Select `DC_Stress_Measure_loop.xml`. The project configuration navigator shown in the following figure is displayed.

Figure 78: DC stress_measure loop project



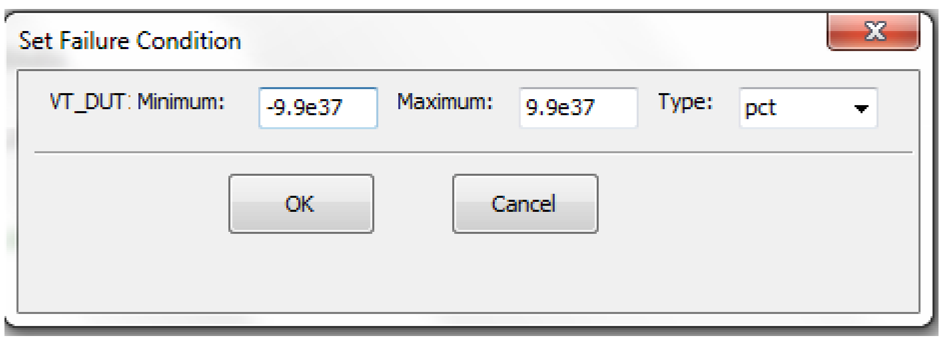
The following are the UAPs in the project configuration navigator:

- **lot_begin UAP**

  FILE_IV_lot_begin module: Creates the used data file directory `Gfdir` where the I-V data is stored. The file is stored in `C:\ACS\user_data` in a folder named with the `LotID_timestamps` or `WaferID_timestamps` (single wafer). For example, for `lot1_20140925153952`, the user data file directory is `C:\ACS\user_data\lot1_20140925153952`.

  Set_Fail_Condition module: Prompts you to set the failure criteria Minimum, Maximum, and Type (Type is either percent or absolute). Selecting **OK** records the setting in the global variable `Vt_DUT1_limit`. Selecting Cancel exits the test and stops the automation. The data evaluation of this failure occurs in the `Pass_or_Fail` in the UAP module `test_end`.

Figure 79: DC stress-measure Set Failure Condition GUI



- **site_begin UAP**

  FILE_IV_site_begin module: Creates a global data file, `Gnewdata`, that is used to record the test results at the end of the test.

  RESET_Skip_list module: Clears the list of subsites, devices, or tests to skip. In the stress-measure loop, if a device, subsite, or test fails, then it is added to the skip list which means that the failed item is not tested for the remainder of the test. However, at the beginning of a new test, or if there are new results, the skip list is reset and all items are tested again.

- **test_end UAP**

  FILE_IV_test_end module: Outputs the I-V test data to the user data file directory created in the UAP Lot Begin module File_IV_lot_begin. The file name format is `WaterID_IVdutid_testmodulename_stresstime.csv`, for example, `test_IV1_MOS_0000010.csv`, DUT ID is the index value in `ACS_dut_id`.

  FILE_STRESS_test_end module: Outputs the data collected during the stress monitoring to the user data file directory created in the UAP Lot Begin module `File_IV_log_begin`. The file name format is `waferID_STR_testmodulename_stresstime.csv`, for example, `test_STR_STRESS_0000010.csv`.

  FILE_PARAM_test_end module: Records the VT, VT_PRE, and VT_POS calculated values to the used data file directory created in the UAP module `File_IV_lot_begin`. The file name format is `waferID_PARAM_DEVdutid_patternID.csv`. For example, for the `test_PARAM_DEV1_main.csv`, DUT ID is the index value in `ACS_dut_id`.

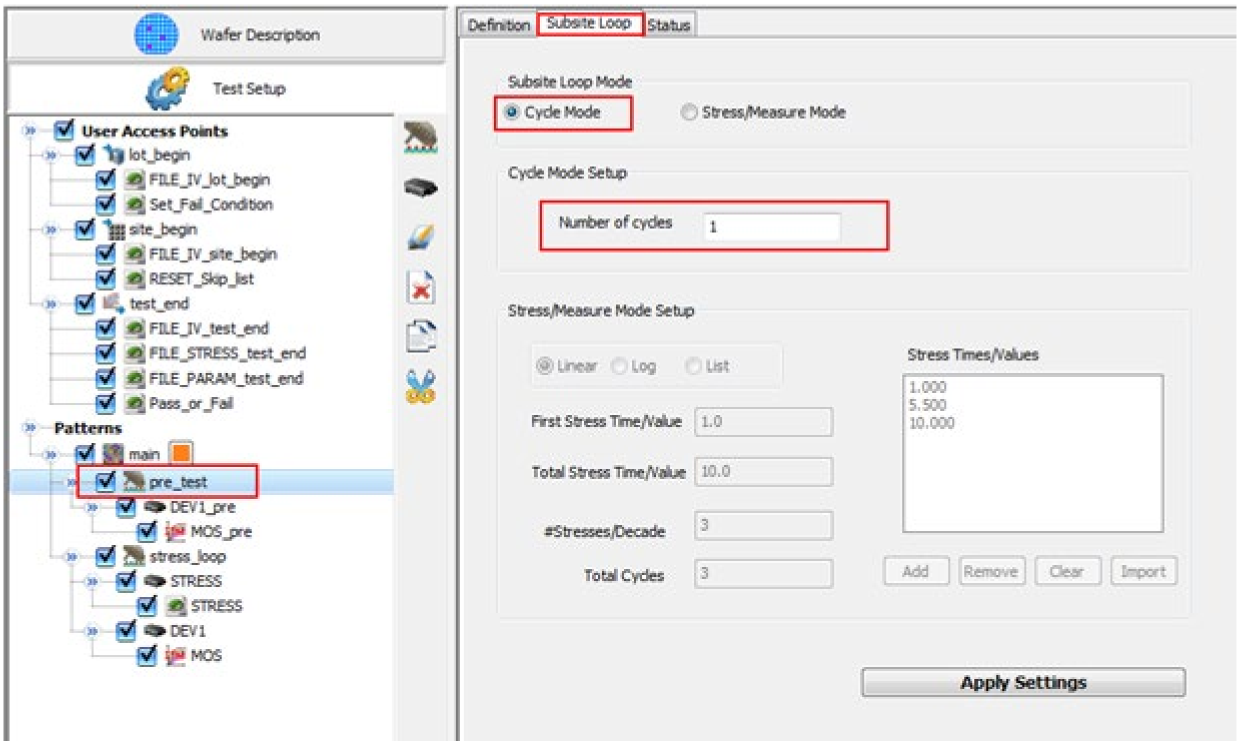
- **Pass_or_Fail module:** Compares the VT_PRE data collected during the MOS-pretest with VT data collected during the stress loop. Minimum and maximum limits are set in the UAP lot_begin module Set-Fail_Condition. If comparison criteria selected in the UAP `Set_Fail_Condition` is abs, when abs (VT - Base_Val4_VT) is out of range [min, max], then the device fails. If comparison criteria selected in the UAP `Set_Fail_Condition` is PCT when 100.0*abs (VT - Base_Val4_VT)/Base_Val4_VT) is out of range [min, max], then the device fails. When the device fails, the `ACS_Disable_DUT_List` is updated. The tests under this DUT node will not run in the ACS platform. If all the DUT nodes under the subsite node fail, the `ACS_Disable_Subsite_List` is updated. The tests under this subsite node will not run in the ACS platform.

Configure the DC stress-measure loop test

Configure the pre-test subsite to generate the pre-test data for comparison:

1. Select the **pre_test** subsite in the project navigator (see the following figure).
2. Select the **Subsite Loop** tab.

Figure 80: Set Subsite Loop for subsite pre_test

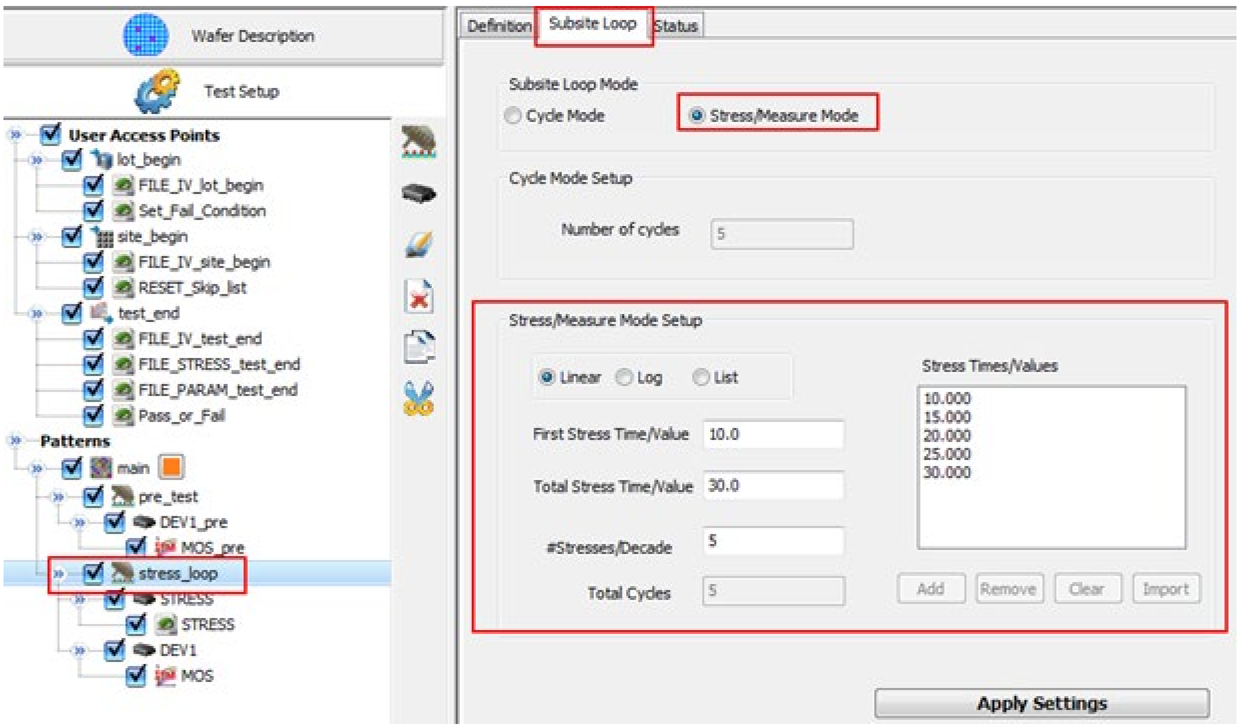


3. Set the Subsite Loop Mode to Cycle Mode.
4. Set the number of cycles to 1 so that the pre-test only executes once.

Configure the stress_loop subsite

The `stress_loop` subsite specifies the values of the stress parameter. The stress parameter is controlled by the STRESS PTM, which is under the `stress_loop` subsite. The sample project uses time as the stress parameter. However, you can write a custom PTM in place of the STRESS PTM that controls another parameter, such as temperature.

Figure 81: Set Subsite Loop for subsite stress_loop



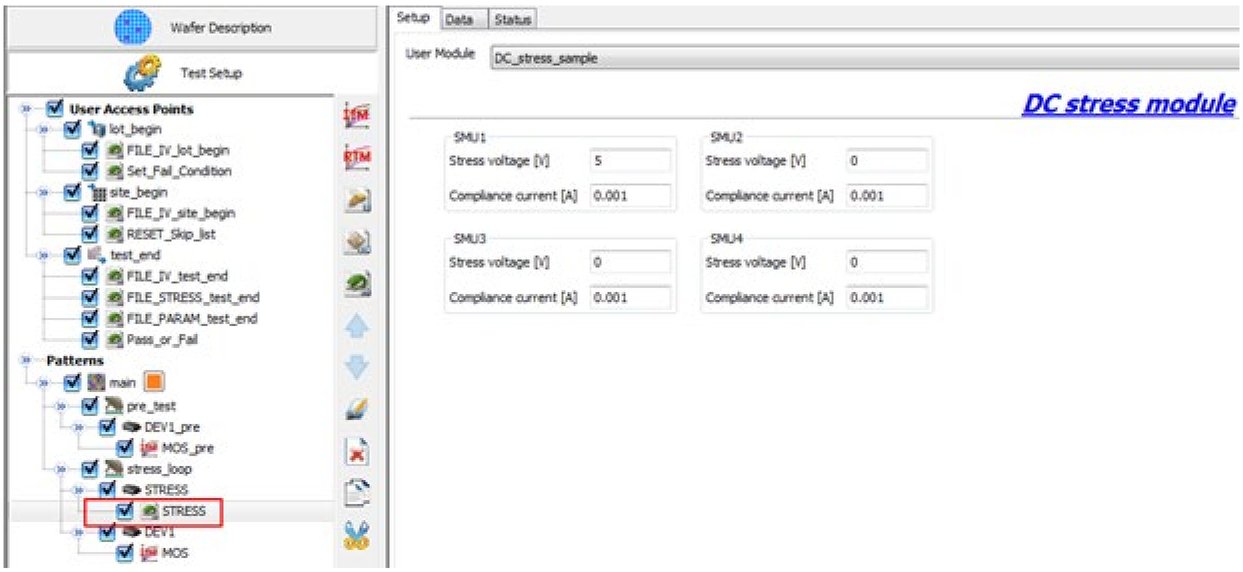
To configure the stress_loop subsite:

1. Set the Subsite Loop Mode to **Stress/Measure Mode**.
2. Configure the Stress/Measure Mode Setup by setting the **First Stress Time/Value**.
3. Configure the **Total Stress Time/Value** and the **#Stresses/Decade** parameters. For example, if the #Stresses/Decade is 5, the project adds five different length/size stresses to the DUT.

Configure the stress voltages

The PTM STRESS subsite is used for the stress-measure loop stress phase.

Figure 82: PTM stress GUI



1. Configure the stress voltages for each SMU in the test.
2. Configure the current limits for each SMU in the test.

During the stress portion of the loop, the SMU will not make any measurement and will essentially behave as a DC power supply.

You also need to configure the measurement portion of the stress-measure loop.

The ITM MOS in the configuration navigator (under DEV1) is for the measure phase of the stress-measure loop.

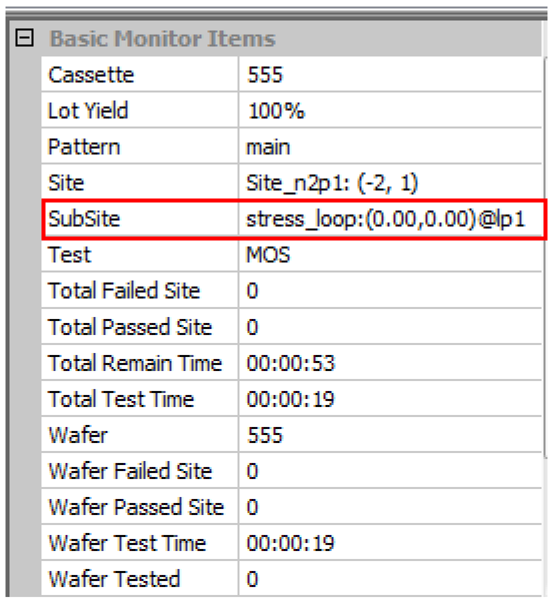
For each SMU in the test, configure the forcing function, forcing mode, source value, compliance, and measure function for the stress loop.

Monitor the DC stress-measure loop test

You should execute this project in Automation mode. For more information about executing projects, refer to *Automated Characterization Suite (ACS) Fundamental Reference Manual* (document number ACS-914-01), "Automation functions."

During automation, you can check the Basic Monitor Items to see the subsite loop that is executing in automation, as shown in the following figure).

Figure 83: DC stress-measure Basic Monitor Items



Basic Monitor Items	
Cassette	555
Lot Yield	100%
Pattern	main
Site	Site_n2p1: (-2, 1)
SubSite	stress_loop:(0.00,0.00)@lp1
Test	MOS
Total Failed Site	0
Total Passed Site	0
Total Remain Time	00:00:53
Total Test Time	00:00:19
Wafer	555
Wafer Failed Site	0
Wafer Passed Site	0
Wafer Test Time	00:00:19
Wafer Tested	0

Test flow

The following figure shows the basic test and stress flow in this project using an example where you can specify a list of five stress times.

Figure 84: Basic test and flow of DC stress_measure project

- For loop 1, a DC stress voltage is applied by the SMUs for 10 seconds.
- For loop 2, a DC stress voltage is applied by the SMUs for 5 seconds.
- For loop 3, a DC stress voltage is applied by the SMUs for 5 seconds.
- For loop 4, a DC stress voltage is applied by the SMUs for 5 seconds.
- For loop 5, a DC stress voltage is applied by the SMUs for 5 seconds.

Test result data

The DC stress-measure loop project saves and displays data the same as other ACS projects. You can:

- Define a data plot on the data tab of each test
- Set the automation real-time plot for the test and see the data results of the plot in real time

The test results are saved to `C:\ACS\Projects\DC_Stress_Measure_loop` and can be saved to the file types `.kdf`, `.db`, or `.csv`. A customized test result file is specified in UAP `lot_begin`.

Pulse stress-measure loop project

This project is only available when ACS is installed on a Keithley Model 4200A-SCS.

The Pulse stress-measure loop project performs a stress test for device reliability analysis. This project uses a stress-measure subsite loop, and to stress and measure different devices using different tests.

Since different tests are used for stress, or measure, the recovery time for the device is introduced in the loop. This project is for a use case where the device under test (DUT) does not have much sensitivity to the recovery time; however, you may need to evaluate changes in the characteristics after different stresses have been applied (for example, dc, or Pulse, and different waveforms).

The pulse stress-measure loop project features:

- Complete ACS project with limited configuration navigator settings
- Subsite loop to implement stress-measure for reliability tests
- Simple exit criteria
- PMU for pulse stress (for example, waveform files can be used to define a customized stress for each loop)

Example connection of DUT

The following DUT connections are examples of how to use the pulse stress-measure loop project for testing.

Figure 85: Single DUT test with two RPMs

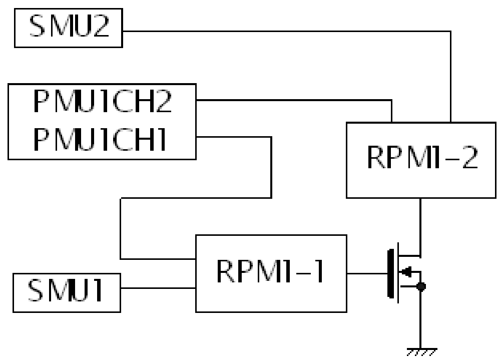


Figure 86: Two DUTs with two RPMs

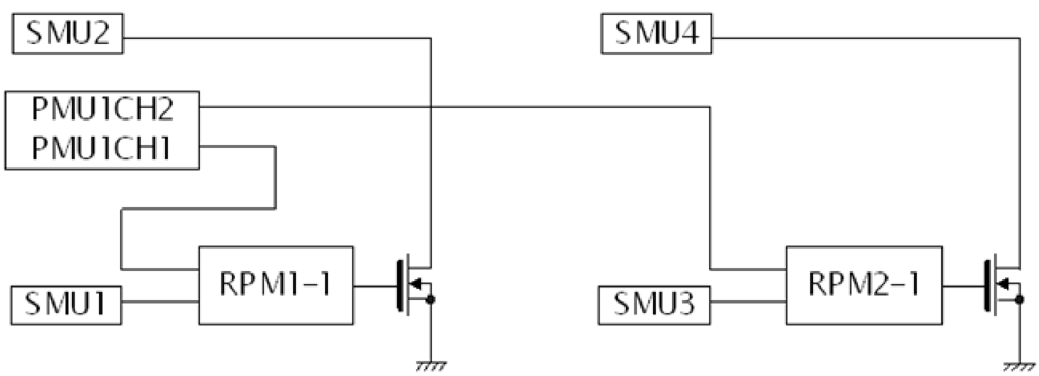
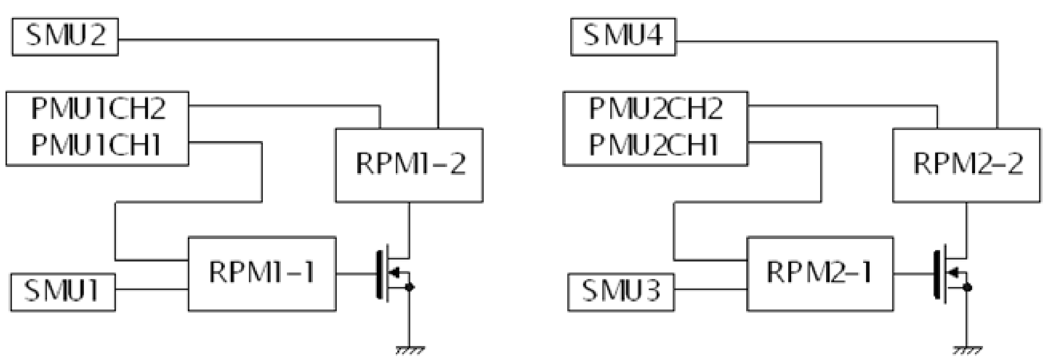


Figure 87: Two DUTs with four RPMs

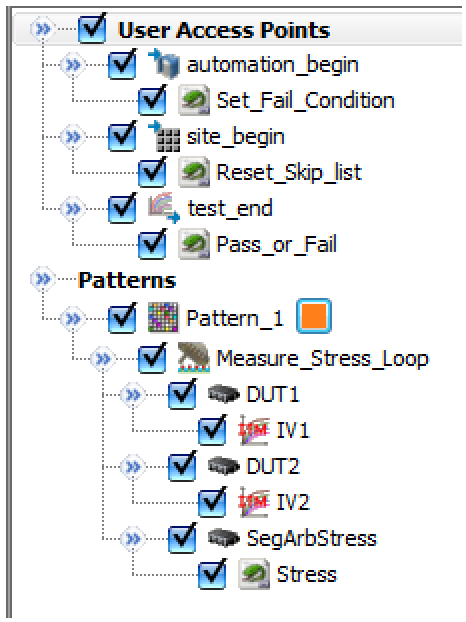


Project settings

To access the Pulse stress-measure loop project:

1. On the toolbar, select **File**.
2. Select **Open**.
3. Go to the folder `C:\ACS\Projects\Pulse_Stress_Measure_Loop`.
4. Select the file `Pulse_Stress_Measure_Loop.xml`.

Figure 88: Pulse stress-measure loop project

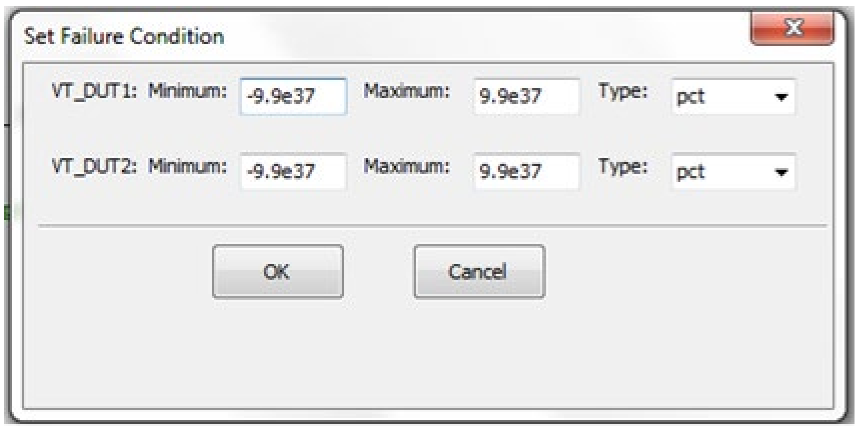


The following are the UAPs in the project configuration navigator:

- **automation_begin**

  Set_Fail_Condition module: Prompts you to set the failure criteria Minimum, Maximum, and Type (Type is either percent or absolute). Selecting OK records the setting in the global variable `Vt_DUT1_limit`. Selecting Cancel exits the test and stops the automation. The data evaluation to this failure occurs in the `Pass_or_Fail` Test End UAP module.

Figure 89: Set Failure Condition GUI



- **site_begin**

  RESET_Skip_list module: Clears the list of subsites, devices, or tests to skip. In the stress-measure loop, if a device, subsite, or test fails, then it is added to the skip list which means that the failed item is not tested for the remainder of the test. However, at the beginning of a new test, or if there are new results, the skip list is reset and all items are tested again.

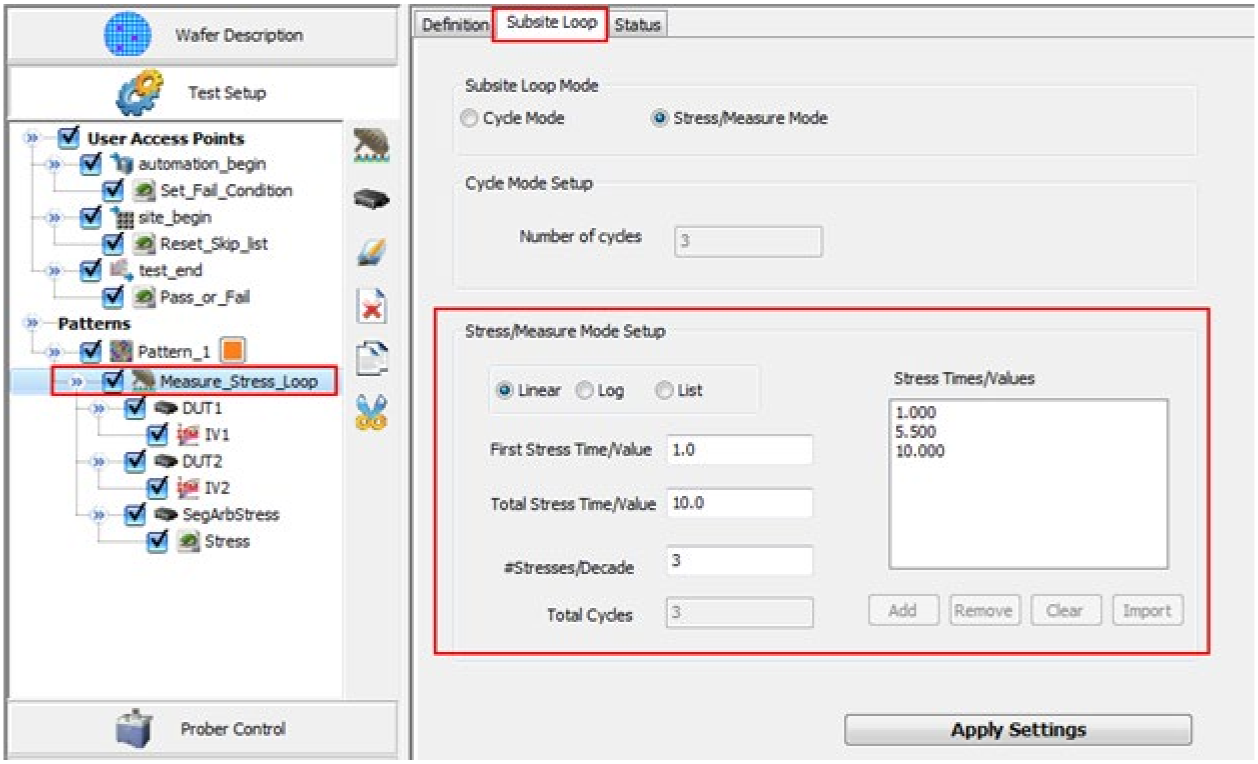
- **test_end**

  Pass_or_Fail module: Compares the `VT_PRE` data collected during the MOS-pretest with VT data collected during the stress loop. Minimum and maximum limits are set in the UAP lot_begin module Set-Fail_Condition. If comparison criteria selected in the UAP Set_Fail_Condition is abs, when abs (VT - Base_Val4_VT) is out of range [min, max], then the device fails. If comparison criteria selected in the UAP Set_Fail_Condition is pct when 100.0*abs (VT - Base_Val4_VT)/Base_Val4_VT) is out of range [min, max], then the device fails. When the device fails, the ACS_Disable_DUT_List is updated. The tests under this DUT node will not run in the ACS platform. If all the DUT nodes under the subsite node fail, the ACS_Disable_Subsite_List will be updated. The tests under this subsite node will not run in the ACS platform.

  When the test ends for the first subsite loop, it is recorded for the first measurement value as the base value for comparison. At the end of each test, the test determines whether the result is out of the limit value that is set in the automation_begin UAP Set_Fail_Condition. If it is out of limits, the DUT is marked as failed and will exit the stress-measure loop. The other DUT will continue the loop until it reaches the maximum loop number or it fails.

Set the Subsite Loop for subsite `Measure_Stress_loop` (see the following figure).

Figure 90: Set Subsite Loop for subsite Measure_Stress_Loop



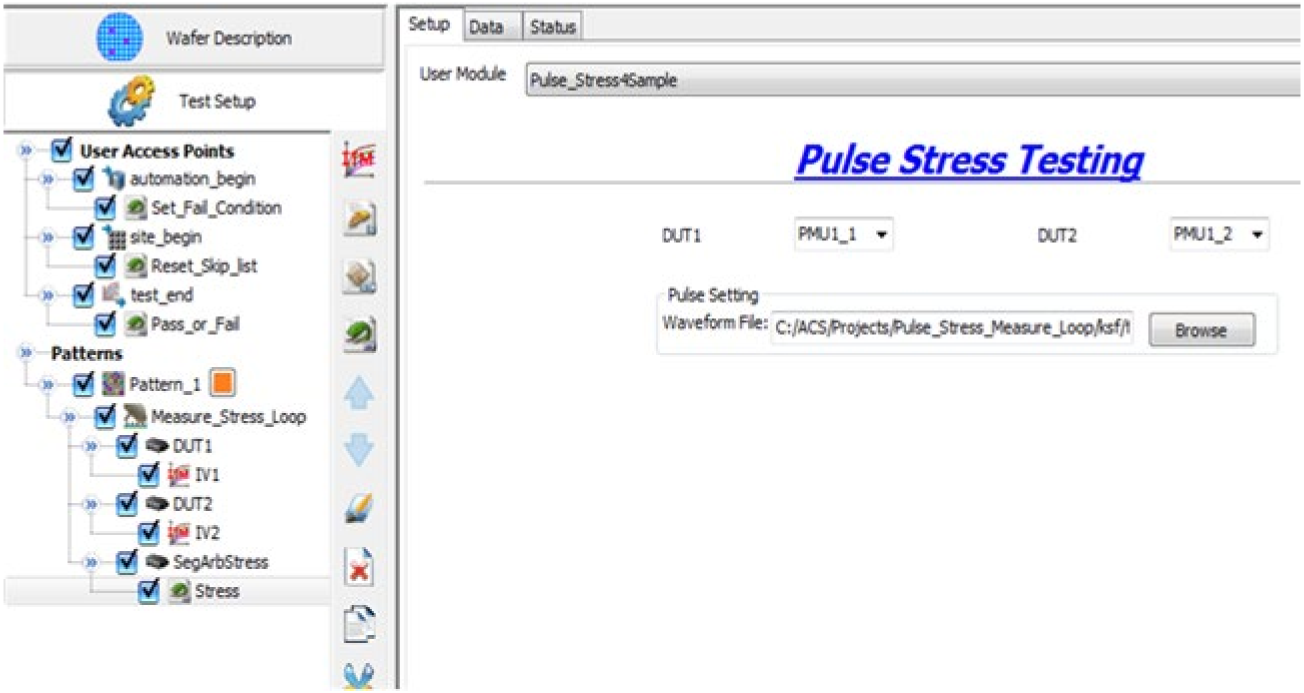
In the previous figure, the Stress/Decade is three. This means that the project will add three different types of stress to the DUT.

Choose the test for each DUT (for example, for DUT1 and DUT2).

IV1 and IV2 are the tests for DUT1 and DUT2, respectively. You can add any test to these two devices. These are the measure phases of the stress-measure loop.

Choose the stress waveform. The PTM Stress under device `SegArbStress` is for the stress phase. The following is an example setting for the two DUTs with two RPMs. This means that the stress terminal for DUT1 is `PMU1_1`, and the stress terminal for DUT2 is `PMU1_2`.

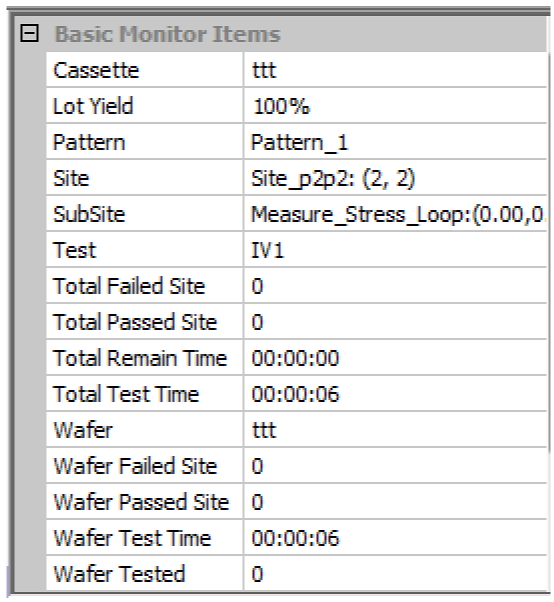
Figure 91: PTM stress on two DUTs



Select the Browse button to add a waveform. The waveform is read from the waveform `.ksf` file. The `.ksf` file is created by KPulse. For example, the Segment ARB waveform in this sample project is in `file1.ksf`.

You should execute this project in Automation mode. During automation, you will know which subsite loop is executing in automation by using the Basic Monitor Items (see the following figure):

Figure 92: Pulse stress-measure Basic Monitor Items



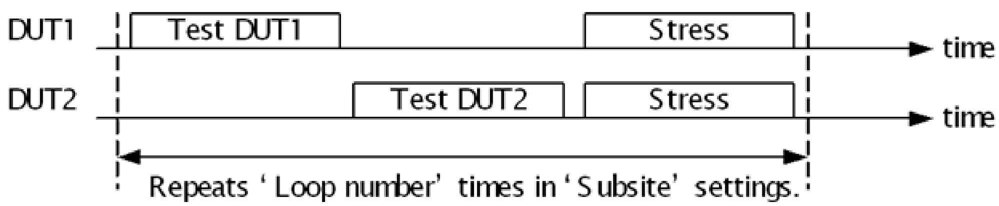
Test flow

The following figure shows the basic test and stress flow in this project. The flow is:

1. ACS executes all DUT1 tests.
2. ACS executes all DUT2 tests.
3. When all testing is complete, ACS forces stress (pulse or DC voltage, depending on the settings) to one or both DUTs.

During the stress, ACS makes measurements and the PMU functions as a pulse generator or a DC power supply.

Figure 93: Basic test and flow of the project



Stress is applied and calculated during every loop:

1. Uses the Segment ARB waveforms, which are read from the waveform `.ksf` file.
2. Determines `ACS_Stress_Duration` of every loop.
3. Calculates pulse cycles and uses the smallest integer greater than or equal to `ACS_Stress_Duration` or period as pulse cycles.
4. Applies the stress during each loop, which is the same number of Segment ARB waveforms to pulse cycles.

Test result data

The Pulse stress-measure loop project saves the same type of data as any another ACS project. You can define a data plot on the data tab of each test (for example, IV1 and IV2 in this project). You can also set the automation real-time plot for these two tests and see the data results of the plot in real time. The test results can be saved to the file types `.kdf`, `.db`, or `.csv`.

Stress migration project–resistance batch measurement

Stress migration, also called stress voiding or stress-induced voiding, describes the movement of metal atoms under the influence of mechanical stress gradients. This causes the resistance of the metal line to rise and form a void, which may cause electrical failures. Usually the mechanical stress is caused by a thermal process.

The stress migration project can make batch resistance measurements to multiple DUTs. The test project itself does not provide stress, so there needs to be another procedure used to achieve the stress process. The test project can display the test results as defined with a failure or pass in real time. This project is in a `.csv` file, which makes it convenient for editing. The project is generated by importing the `.csv` test plan file. By importing the file, it simplifies the procedure so that you do not have to create your own project. You can edit the `.csv` file for your test plan.

Stress migration project features:

- A complete ACS project generated by importing test plan file in an easy to modify `.csv` test plan format
- Batch resistance measurements
- A real-time test result display that allows you to exit the project if the test fails

Instrument connection

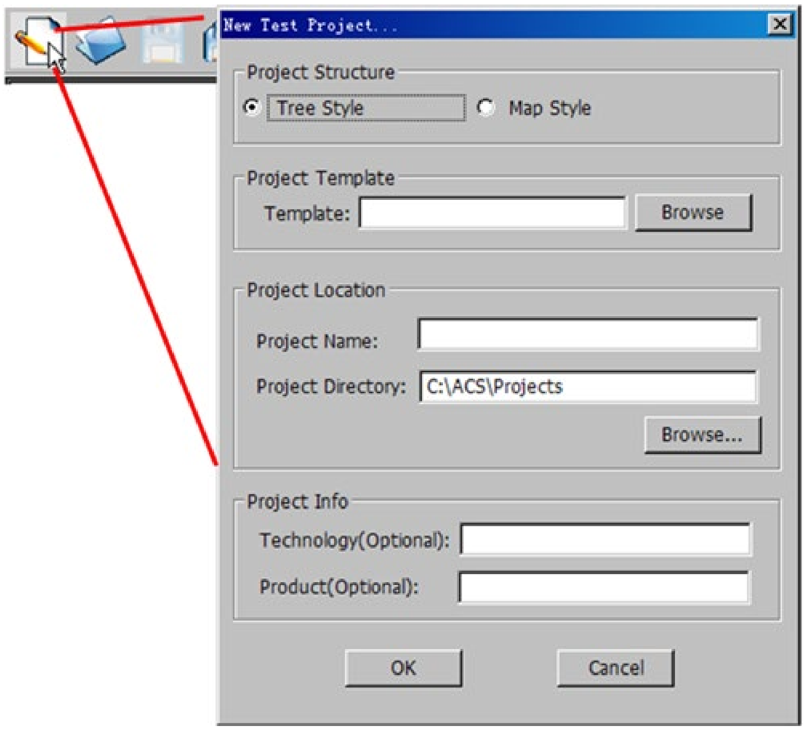
The instruments should all be Series 2600, 2600A, or 2600B in a single GPIB or ethernet group, which are connected in a daisy chain by TSP-Link. The automatically generated project will only select Group 1. You can manually adjust groups after the project is generated. The connection between a SMU terminal and DUT is defined in the test plan `.csv` file.

Test flow and settings

To create a Stress Migration test project:

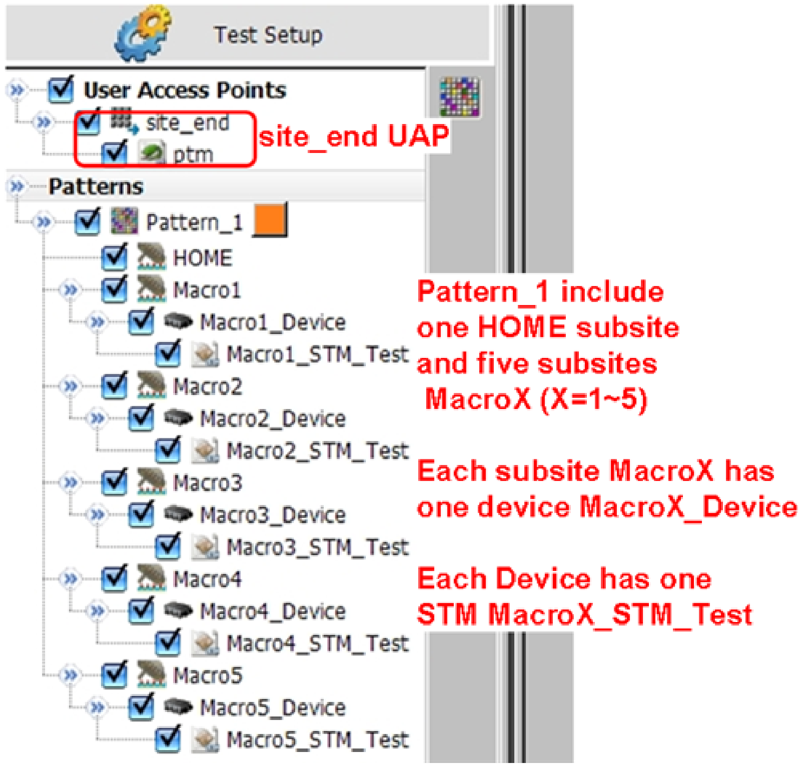
1. Select New ACS project.
2. Define the Project Name (see the following figure).

Figure 94: New ACS project



3. To import the test plan file, select **File > Import > Test Plan File (*.csv)**.
4. Go to `\ACS\Projects\StressMigration` and select `SM_input_format.csv`.
5. From the **please select the import mode** list:
   - To replace the existing file in the configuration navigator: Select **Refresh**.
   - To add modules in the configuration navigator: Select **Append**. If the names of the modules appended already exist, the appended modules are given new names.
6. Configuration navigator:

Figure 95: Test tree



Project explanations from the configuration navigator:

- **site_end UAP:** If there are consecutive site failures, a dialog box opens to let you choose to continue testing or exit. Failure conditions are defined in the test plan `.csv` file as "x_test."
- **Pattern_1:** Has one HOME subsite and five subsites (for example, Macro1_Device - Macro5_Device).
  - Each subsite MacroX has one device, `MacroX_Device`.
  - Each MacroX_Device has one STM, `MacroX_STM_Test`.
  - In each `MacroX_STM_Test`, each `R_meas` function call performs one resistance measurement.

Test plan

The contents of the test plan `.csv` file (`SM_input_format.csv`) is listed in the following table.

Column names	**Comments**
Macro Name	The subsite name in the subsite definition tab.
X(μm)	The subsite X position in subsite definition tab.
Y(μm)	The subsite Y position in subsite definition tab.
Test Structure Name	The device name (DevName) in the generated STM script.
terminal	The resistor measurement mode (ResMode) in the generated STM script (four terminal or two terminal).
Ground Rule(GR)	Y: Enable gnd (ground) connection. N: Disable gnd connection. If the enable and the F +, F - , S +, S - cells are blank, the terminals are assigned as gnd (KI_GND).
Force (A)	The force current value applied to the ForceHi terminal. If the cell is blank, the force function will be voltage force. The Force (A) and Force (V) should not both be blank.
Force (V)	The force voltage value applied to the ForceHi terminal.
Clamp	The compliance value. Current Compliance for voltage force function, and voltage Compliance for current force function.
Output	Output information.
x_test	Failed site threshold. After this number of sites fails, ACS displays a dialog for you to choose whether to continue or exit.
F +	The SMU number of force Hi SMU (for example, 4 stands for SMU4).
S +	The SMU number of sense Hi SMU.
F -	The SMU number of force Lo SMU.
S -	The SMU number of sense Lo SMU.
Expected R (Ohm)	Expected resistance.
Shift range (%)	The pass shift range. If abs (RValue-ExpectedR) < ExpectedR*ShiftRange*100%. the test will pass, otherwise it will fail.
Description (based on documentation)	The description of the structure on this row.

When you import the test plan `.csv` file, ACS also generates an STM (`MacroX_STM_Test`). The STM script structure is shown in the following figure.

Figure 96: The generated STM script

Each STM test module includes the following parts:

- Output definition
- Instrument presets
- `R_meas` call function to measure resistance.
- Reset instruments

The definition of `R_meas` is:

```
R_meas (DevName, ResMode, ForceVIMode, FHiSMU, FLoSMU, SHiSMU, SLoSMU, ForceValue,
    ComplValue, NPLC, RstFlag, OutputOffFlag, ExpRValue, ShiftRange, vHi_value,
    vLo_value, iHi_value, iLo_value, R_value)
```

The parameters in the function correspond to the SM_input_format.csv file and are defined as follows:

- **DevName:** Test structure name
- **ResMode:** Terminal (zero for 4-terminal devices; one for 2-terminal devices)
- **ForceVIMode:** If the cell in Force (A) column is blank and the cell in Force (V) column has a value, ForceVIMode is assigned to 0 which represents voltage force function and current measurement. If the cell in Force (A) column has value and the cell in Force (V) column is blank, ForceVIMode is assigned to 1 which represents current force function and voltage measure.
- **FHiSMU:** F+
- **FLoSMU:** F-
- **SHiSMU:** S+
- **SLoSMU:** S-
- **ForceValue:** Force (A) when ForceVIMode is equal to 1; Force (V) when ForceVIMode is equal to 0
- **ComplValue:** Current value in compliance
- **ExpRValue:** Resistance value expected
- **ShiftRange:** Percent of the shift range for the resistance value. For example, if the absolute value of (RValue-ExpRValue) is lower than (ExpRValue*ShiftRange*100%), the test will pass, if it is not lower, it will fail. Therefore, the RValue is the actual measured resistance value.

The following parameters are additional settings. The default values are set to be commonly used values:

- **NPLC:** Measurement speed setting. 0.001(fast) to 25(slow). Default value is 1.
- **RstFlag:** To flag if reset SMUs after one R_meas function. (1: reset; 0: not to reset) Default value is 0.
- **OutputOffFlag:** To flag if turn SMUs output off after one test. (1: turn off; 0: not to turn off) Default value is 0.

The others are output parameters to save measurement results:

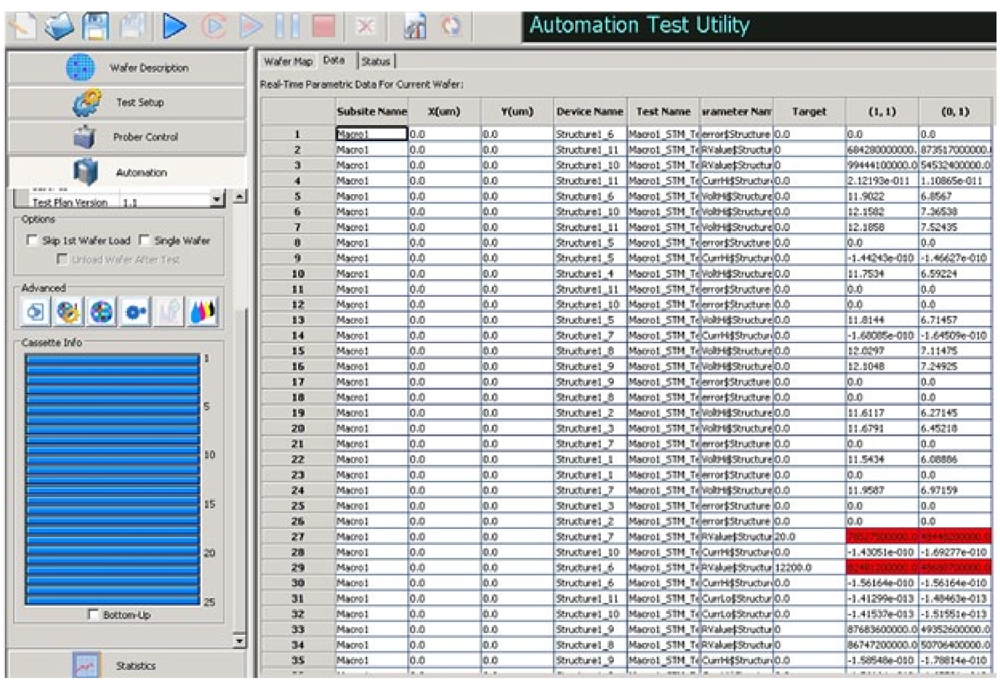
- **vHi_value:** Voltage value measured at SHiSMU for 4-terminal devices or FHiSMU for 2-terminal devices.
- **vLo_value:** Voltage value measured at SLoSMU for 4-terminal devices or FLoSMU for 2-terminal devices.
- **iHi_value:** Current value measured at FHiSMU.
- **iLo_value:** Current value measured at FLoSMU.
- **R_value:** Calculate from the above values. R = abs(vHi-vLo/iHi).

Automation

In this Stress Migration project, the generated `site_end` UAP implements the function that has the same Test Structure failure for the `x_test`. The message "Consecutive failure condition happens, do you want to exit" is displayed. You can choose to exit the project or continue testing. The `x_test` parameters are defined in the `SM_input_format.csv` file. For more information on how to set up the automation function, refer to the *Automated Characterization Suite (ACS) Fundamental Reference Manual* (document number ACS-914-01) “ACS Automation.”

In the Automation Data tab, the failed test is highlighted in red (see the following figure):

Figure 97: Automation Data tab



Error code

In the output, `error$StructureName` indicates the error code of the test, as shown in the following table.

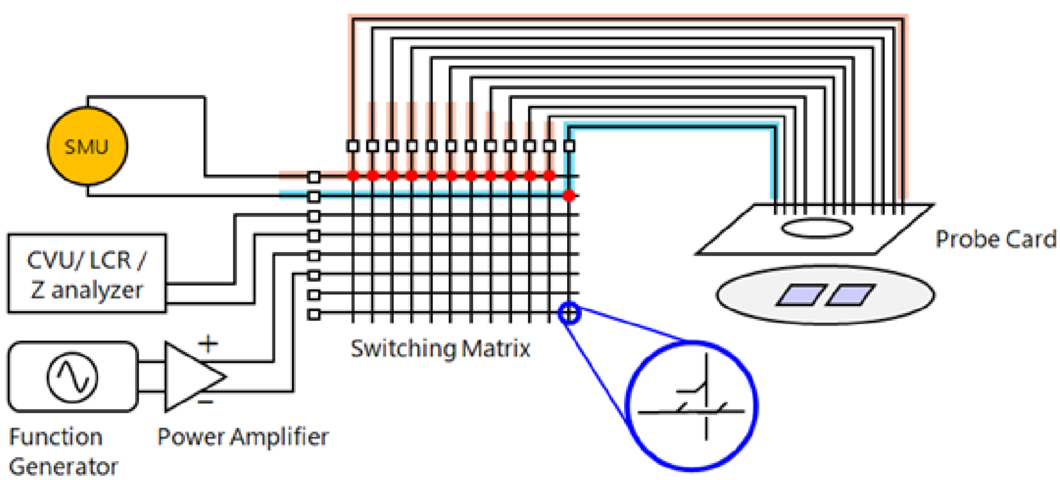
Error value	Description
`-10100`	Indicates that ResMode and ForceVIMode are not 0 or 1. When ForceVIMode is 0, ForceValue > 200 or ComplValue > 0.1. When ForceVIMode is 1, ForceValue >0.1 or ComplValue >200 NPLC < 0.001 or NPLC > 25 RstFlag is not 0 or 1 OutputoffFlag is not 0 or 1
`-10200`	FHiSMU, FLoSMU, SHiSMU, SLoSMU are not set to the correct SMU number.

Shared stress reliability test application

ACS software provides libraries and functions to support the shared stress reliability test application.

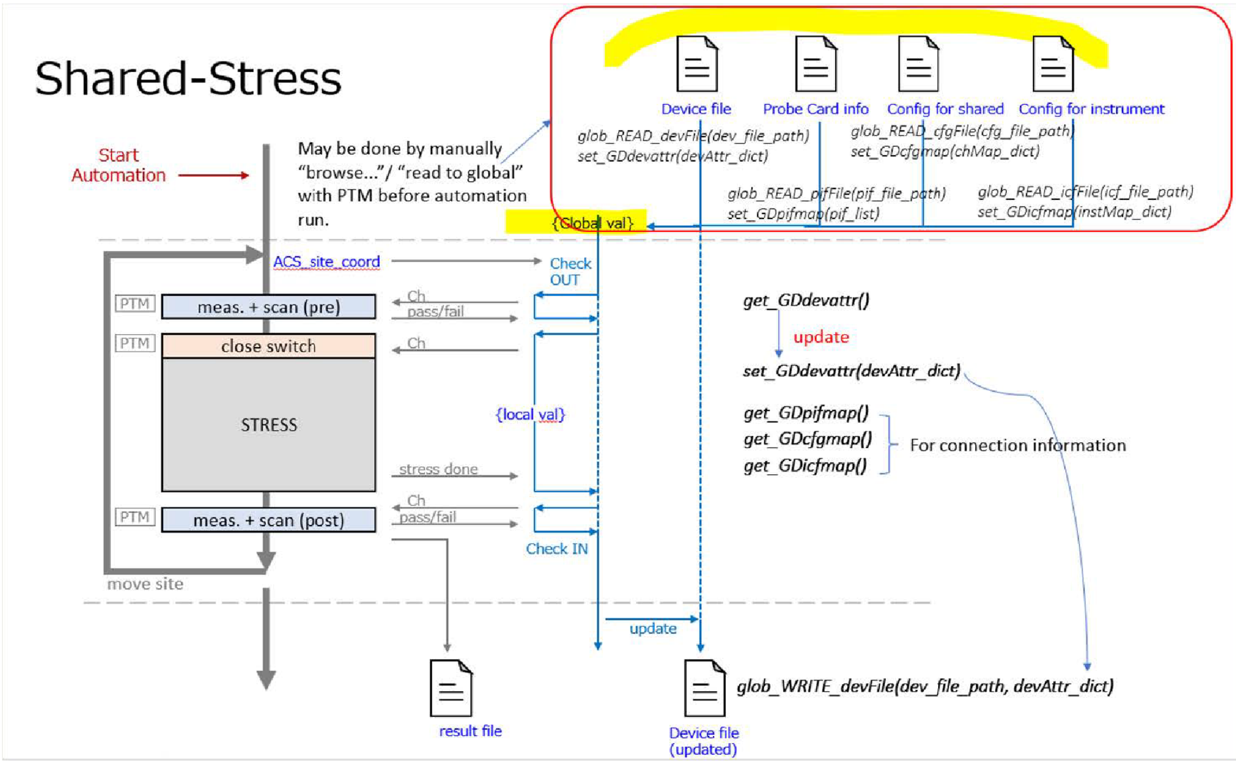
The shared stress reliability tests typically use a SMU with the option to also use a CVU/LCR/Z analyzer, function generator, power amplifier, switching matrix, and a probe card. A typical hardware configuration of the shared stress reliability test is shown in the following figure.

Figure 98: Typical hardware configuration of a shared stress reliability test



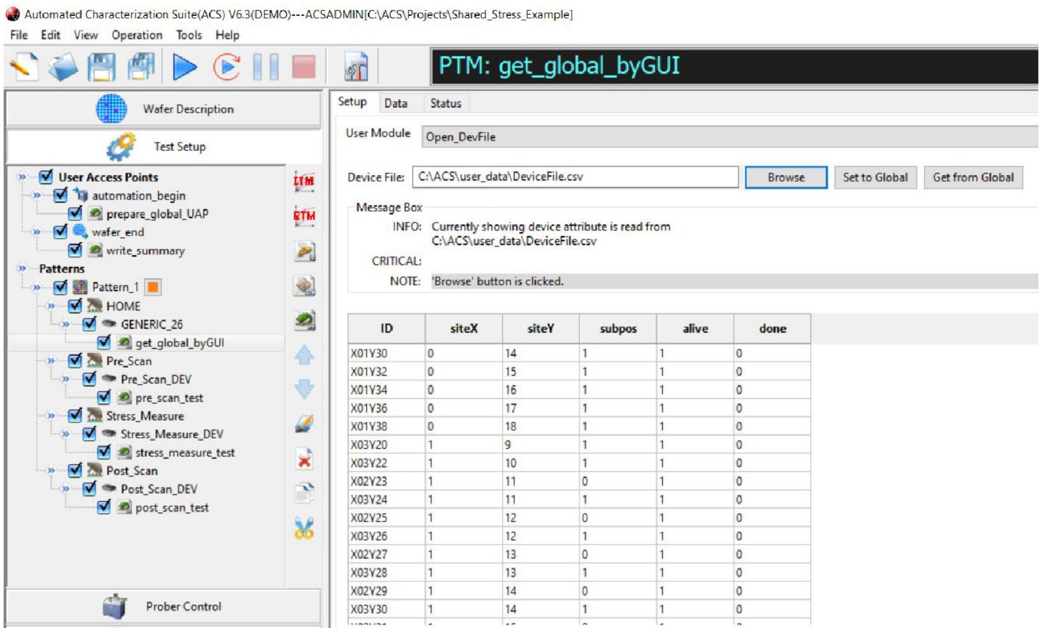
The following figure shows the use case of the shared stress test application.

Figure 99: Use case and procedure of the shared stress reliability test



A demonstration project of the shared stress reliability test is provided in the software with the name `Shared_Stress_Example`, as shown in the following figure. This project contains the UAP and PTM modules that perform the shared stress reliability application.

Figure 100: Demonstration project Shared_Stress_Example



Shared_stress_app library

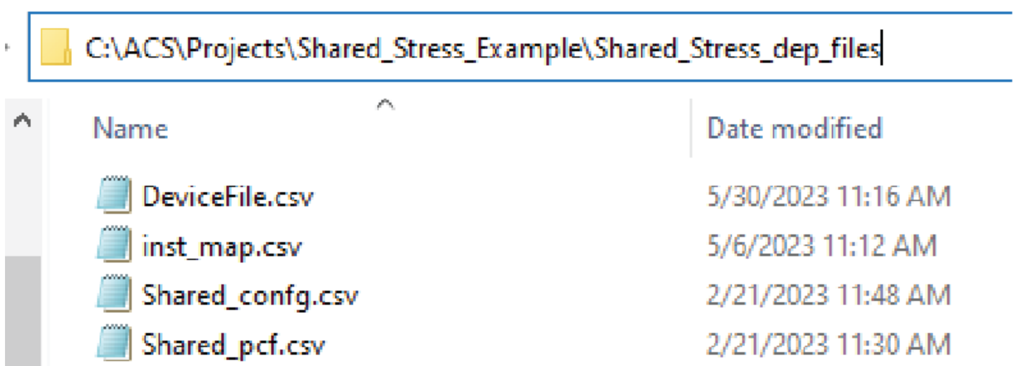
A library `Shared_Stress_app.py` is provided in the folder `C:\ACS\library\pyLibrary\PTMLib` with modules that read the shared stress reliability configuration information files. You can load the library to set up a PTM, for example, `PTM get_global_byGUI` in the demonstration project `Shared_Stress_Example` as shown in the previous demonstration project.

You can read the configuration files stored under path `ACS_proj_path\Shared_Stress_dep_file` as shown in the following figure, show the information on the GUI for confirmation, and set the information to global data. Also, you can get information from global data and check it on the GUI.

NOTE

The UAP `prepare_global_UAP` should be run first before running the PTM `get_global_byGUI`. The PTM `get_global_byGUI`. should not be selected when running automation.

Figure 101: Path of configuration files



The library *Shared_Stress_app.py* contains four modules to read different information files:

- `Open_DevFile`
- `Open_icfFile`
- `Open_CfgFile`
- `Open_PifFile`

Open_DevFile

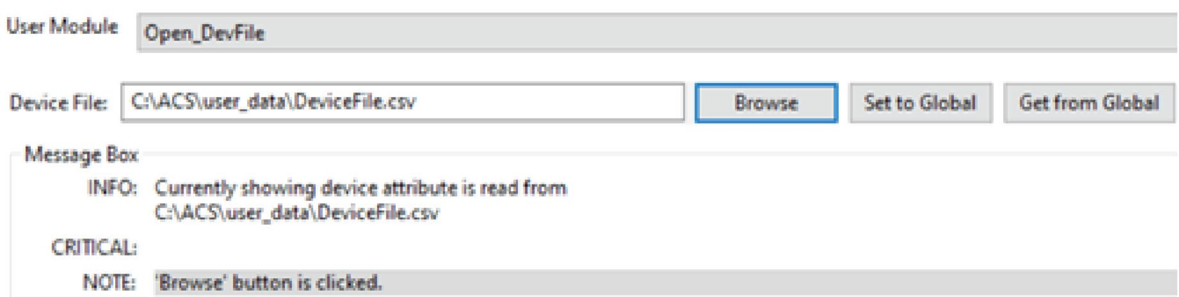
This module can read the device information file, for instance, the `DeviceFile.csv`, and display the information on the GUI. You can also set the information to global data by clicking **Set to Global**, see the following figure. You can also read the device information from global data and display it on the GUI to confirm by clicking **Get from Global**.

Browse: Normally device information is stored under the `ACS_proj_path\Shared_Stress_dep_file`. You can select the file, and the information will be displayed in the table below for confirmation, as shown in the following figure.

Set to Global: Click to set the information displayed in the table to the global data.

Get from Global: Click to get device information from the global data and display it in the table for confirmation, as shown in the following figure.

Figure 102: Opening the device configuration file



ID	siteX	siteY	subpos	alive	done
X01Y30	0	14	1	1	0
X01Y32	0	15	1	1	0
X01Y34	0	16	1	1	0
X01Y36	0	17	1	1	0
X01Y38	0	18	1	1	0
X03Y20	1	9	1	1	0
X03Y22	1	10	1	1	0
X02Y23	1	11	0	1	0
X03Y24	1	11	1	1	0
X02Y25	1	12	0	1	0
X03Y26	1	12	1	1	0
X02Y27	1	13	0	1	0
X03Y28	1	13	1	1	0
X02Y29	1	14	0	1	0
X03Y30	1	14	1	1	0

Device Information File

The following information identifies the attributes in the device information file with an explanation of each one:

- **ID**: Name of device.
- **siteX**: X coordinates of site device location.
- **siteY**: Y coordinate of site device location.
- **subpos**: Sub position of the device.
- **alive**: Situation status of the device; 1 for alive; 0 for not alive.
- **done**: Test status of the device; 1 for done; 0 for not done.

Open_icfFile

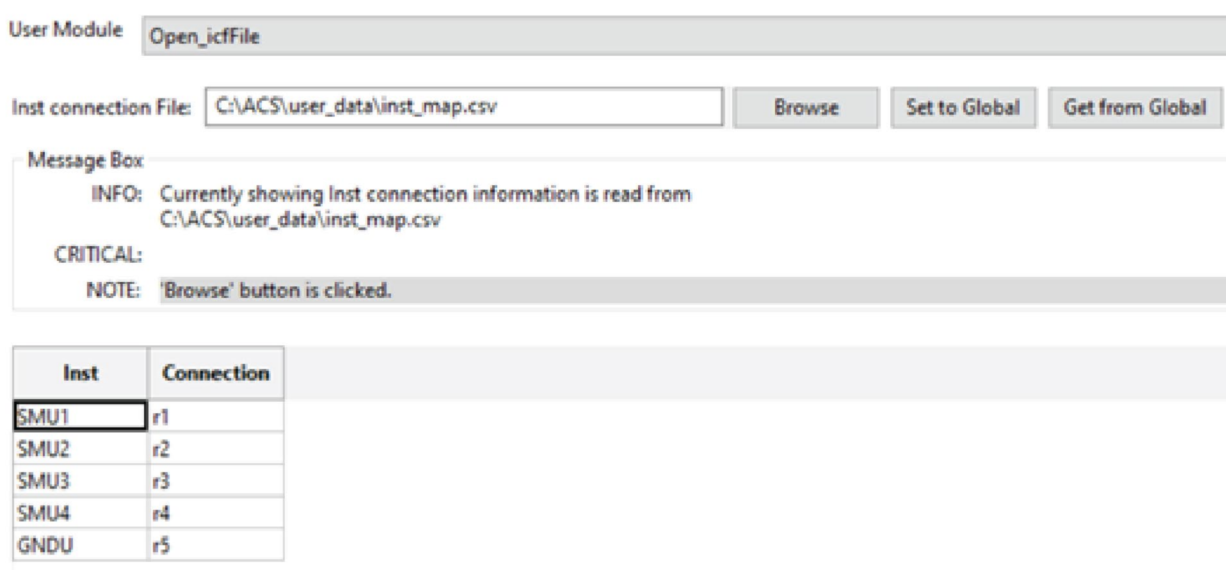
This module can read the instrument configuration file like `inst_map.csv` and display the information on the GUI for you to confirm. You can set the information to global data by clicking **Set to Global**. You can also read the instrument configuration information from global data and display it on the GUI to confirm by clicking **Get from Global**.

Browse: Normally the instrument configuration file is stored under `ACS_proj_path\Shared_Stress_dep_file`. You can select the file, and the information will be displayed in the table below for confirmation.

Set to Global: Click to set the information displayed in the table into global data.

Get from Global: Click to get the instrument configuration information from global data and display it in the table below for confirmation.

Figure 103: Opening the instrument configuration file



Channel Configuration File

The following information identifies the attributes in the device information file with an explanation of each one:

- **Inst:** Instrument name.
- **Connection:** Channel connected to the instrument. The `r` numbers, such as `r1` and `r2`, indicate the row or backplane on the matrix. The integer number represents the channel ID defined in the channel configuration file.

Open_CfgFile

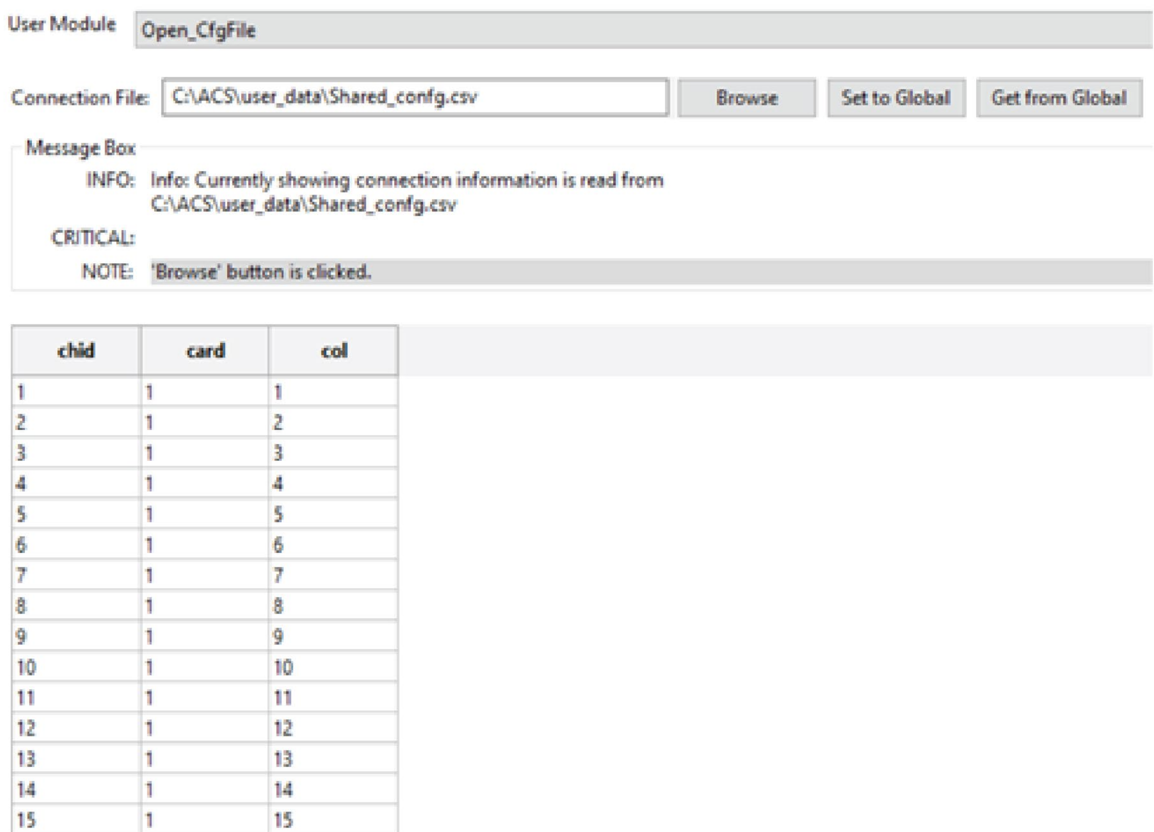
This module can read the channel configuration file like `Shared_config.csv` and displays the information on the GUI for you to confirm. You can set the information to global data by clicking **Set to Global**. You can also read the channel configuration information from global data and display it on the GUI to confirm by clicking **Get from Global**.

Browse: Normally the channel configuration file is stored under `ACS_proj_path\Shared_Stress_dep_file`. You can select the file, and the information will be displayed in the table below for confirmation.

Set to Global: Click to set the information displayed in the table into global data.

Get from Global: Click to get the channel configuration information from global data and display it in the table below for confirmation.

Figure 104: Opening the channel configuration file



Channel Configuration File

The following information identifies the settings in the device information file GUI with an explanation of each one:

- **chid**: Channel id.
- **card**: Card number on which the channel is defined.
- **col**: Column number of which the channel is defined.

Open_PifFile

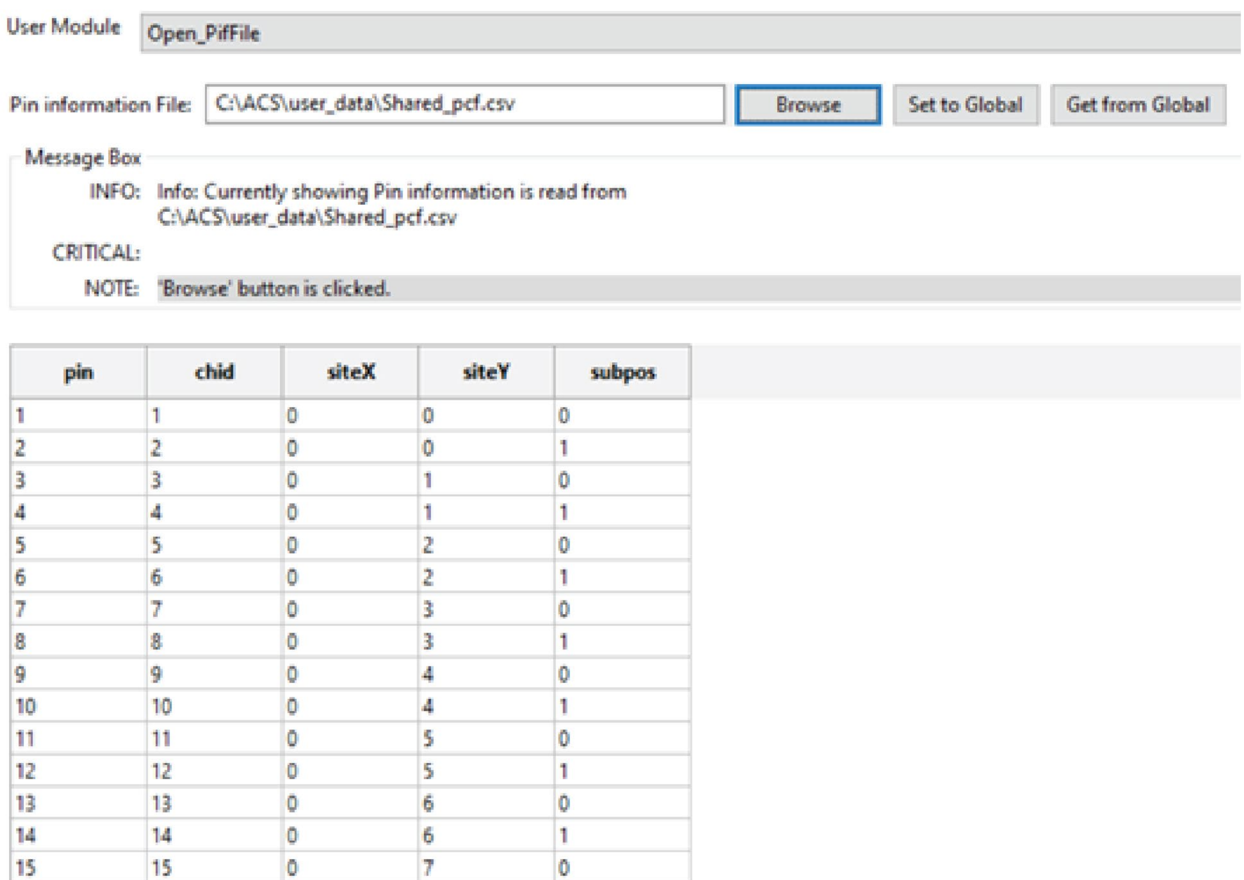
This module can read the pin configuration file like `Shared_pcf.csv` and display the information on the GUI for you to confirm. You can set the information to global data by clicking **Set to Global**. You can also read the pin configuration information from global data and display it on the GUI to confirm by clicking **Get from Global**.

Browse: Normally the pin configuration is stored under `ACS_proj_path\Shared_Stress_dep_file`. You can select the file, and the information will be displayed in the table below for confirmation.

Set to Global: Click to set the information displayed in the table into global data.

Get from Global: Click to get the pin configuration information from global data and display it in the table below for confirmation.

Figure 105: Opening the pin configuration file



pin	chid	siteX	siteY	subpos
1	1	0	0	0
2	2	0	0	1
3	3	0	1	0
4	4	0	1	1
5	5	0	2	0
6	6	0	2	1
7	7	0	3	0
8	8	0	3	1
9	9	0	4	0
10	10	0	4	1
11	11	0	5	0
12	12	0	5	1
13	13	0	6	0
14	14	0	6	1
15	15	0	7	0

Pin Configuration File

The following information identifies the attributes in the device information file with an explanation of each one:

- **pin**: Pin number.
- **chid**: Channel id connected to the pin.
- **siteX**: X coordinate of site that the pin is in.
- **siteY**: Y coordinate of site that the pin is in.
- **subpos**: Sub position of the pin.

Shared_Stress_Demo library

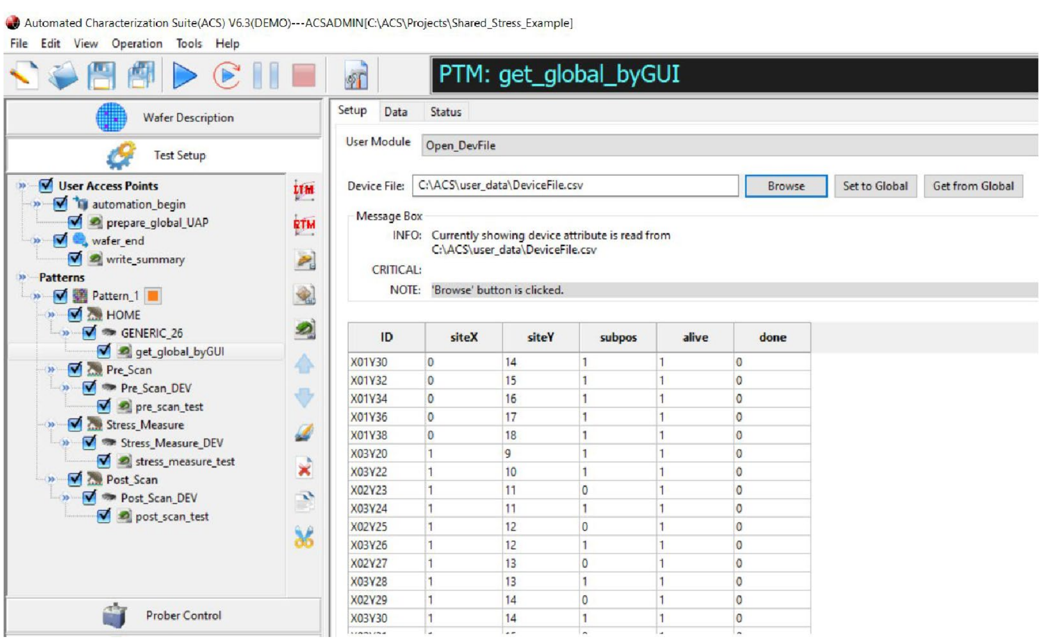
The shared library `Shared_Stress_Demo.py` is in the folder `C:\ACS\library\pyLibrary\PTMLib`. It contains the following template test modules:

- `Pre-Measure`
- `Stress-Measure`
- `Post-Measure`
- `Prepare_Global_All`
- `Write_Summary`

You can create more test routines based on these template test modules. For specific information on how to create a test module, refer to "Creating PTM or STM test libraries and modules" in the *ACS Programmer's Manual*, document number ACS-907-01.

These modules are loaded and used to set up a PTM `pre_scan_test`, `stress_measure_test`, and a `post_scan_test` in the demonstration project `Shared_Stress_Example`. See the following figure.

Figure 106: Demonstration project Shared_Stress_Example



ID	siteX	siteY	subpos	alive	done
X01Y30	0	14	1	1	0
X01Y32	0	15	1	1	0
X01Y34	0	16	1	1	0
X01Y36	0	17	1	1	0
X01Y38	0	18	1	1	0
X03Y20	1	9	1	1	0
X03Y22	1	10	1	1	0
X02Y23	1	11	0	1	0
X03Y24	1	11	1	1	0
X02Y25	1	12	0	1	0
X03Y26	1	12	1	1	0
X02Y27	1	13	0	1	0
X03Y28	1	13	1	1	0
X02Y29	1	14	0	1	0
X03Y30	1	14	1	1	0

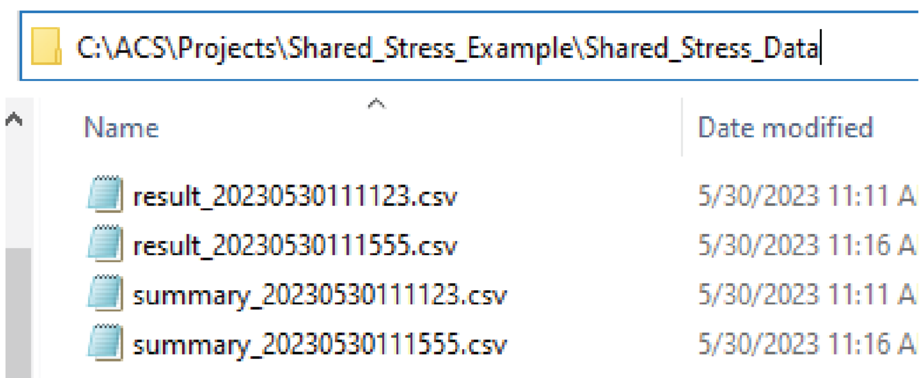
The library also contains a module named `Prepare_Global_All` that prepares global data at the beginning of the test flow and a `Write_Summary` module that creates a summary file at the end of the test flow. In the demonstration project, `Shared_Stress_Example`, these modules are used in the `automation_begin` UAP `prepare_global_UAP` and `wafer_end UAP write_summary`, as shown in the previous figure demonstration project `Shared_Stress_Example`.

Pre_Measure

Template test module for Pre_Measure. You can extend the example code adding more pre-measurement routines as needed such as IV, CV, and temperature measurements.

Also, Pre_Measure will create a raw data file and log data real-time. The raw data file will be saved in the path `ACS_proj_path\Shared_Stress_Data` as shown in the following figure. The naming rule is `result_automationStartTime.csv`.

Figure 107: Result and summary data files



Stress_Measure

Template test module for Stress_Measure. You can extend the example code adding more pre-measurement routines as needed such as IV, CV, and temperature measurements.

Post_Measure

Template test module for Post_Measure. You can extend the example code adding more pre-measurement routines as needed such as IV, CV, and temperature measurements.

Prepare a global test

The Prepare_Global_All module reads the configuration files located at ACS_proj_path\Shared_Stress_dep_files and writes the information into global data. The module also prepares global test information such as test start time, configuration file path, and data file.

dev_file: File of device attributes. Example: DeviceFile.csv

pif_file: File of pin configuration. Example: Shared_pcf.csv

cfg_file: File of channel configuration. Shared_confg.csv

icf_file: File of instrument configuration. Example: inst_map.csv

In the demonstration project, this module is used in automation_begin UAP: prepare_global_UAP.

Write summary file

The Write_Summary module writes the summary file of the test data and saves the file in the computer directory ACS_proj_path\Shared_Stress_Data, as shown in Pre_Measure (on page 4-76).

The file naming convention is summary_ followed by the automation start time (this is a .csv file).

In the demonstration project, this module is used in the wafer_end UAP write_summary.

shared_stress_lib library

The `shared_stress_lib.py` library is located at `C:\ACS\library\pyLibrary\ptmlpt`. The library contains commands used to manage global data of different attributes and configuration information for the Shared Stress Reliability test application. This includes device attributes, instrument configuration, channel configuration, and pin configuration.

These commands can be used in development of PTMs and UAPs for the Shared Stress Reliability test application. Brief descriptions of the commands are provided in the following tables.

get_GDdevattr(global_dict)

Function	Retrieves the global data for the device attributes
	`global_dict`: Global dictionary for current scope
Example	`devattr_dict = get_GDdevattr(globals().copy())`

set_GDdevattr(devAttr_dict)

Function	Sets the global data for the device attributes
Example	`set_GDdevattr(devattr_dict)`

get_GDinstmap(global_dict)

Function	Retrieves the global data for the instrument configuration `global_dict:` Global directory for current scope
Example	`instMap_dict = get_GDinstmap(globals().copy())`

set_GDinstmap(instMap_dict)

Function	Sets the global data for the instrument configuration
Example	`set_GDinstmap(instMap_dict)`

get_GDcfgmap(global_dict)

Function	Retrieves the global data for the channel configuration `global_dict`: Global dictionary for current scope
Example	`cfgMap_dict = get_GDcfgmap(globals().copy())`

set_GDcfgmap(global_dict)

Function	Sets the global data for the channel configuration
Example	`set_GDcfgmap(cfgMap_dict)`

get_GDpifmap(global_dict)

Function	Retrieves the global data for the pin configuration `global_dict`: Global dictionary for current scope
Example	`pifMap_list = get_GDpifmap(globals().copy())`

set_GDpifmap(pifMap_list)

Function	Sets the global data for the channel configuration
Example	`set_GDpifmap(pifMap_list)`

Programming examples

The following examples help explain usage of the global data management commands in PTM and in UAP development.

Shared_Stress_Demo.py

```
from Keithley import *
import os
import time
import copy
import math
import random
from ACS_PostData import *
from ACS_Global import *
import shared_stress_lib
set_globals(shared_stress_lib, "shared_stress_lib", locals().copy())
```

This first code portion imports `shared_stress_lib` and sets all current variables, `(locals.copy())`, into `shared_stress_lib`.

NOTE

The code above must be included to use the global data management commands in the library.

```
#define gloabl variable and update it in code realtime if needed.
G_devattr_dict ={}
G_instmap_dict = {}
G_chmap_dict ={}
G_pif_list ={}
G_testinfo_dict = {}
```

This portion of the code declares the global variables in the test execution library, which can make the `get_GDxxx(globals().copy())` function to operate closer to real-time. The global variables set both before the test and inside the test modules can be accessed.

```
def Post_Measure(v_check_post=10, hi_limit=1e-09, lo_limit=0, acs_site_coord='',
   Channel='Channel', Post_Current='Post_Current', Alive='Alive', Done='Done'):
    global G_devattr_dict
    global G_testinfo_dict
    #currently probed ACS_site_coord
    if ACS_run_mode == "manual":
        if "[" in acs_site_coord or "(" in acs_site_coord:
            site_coord = eval(acs_site_coord)
        else:
            tmp = acs_site_coord.split(",")
            site_coord = (int(tmp[0]), int(tmp[1]))
        DprbDEVs = util_SHARED_PROBING_DEVID(site_coord)
    else:
        DprbDEVs = util_SHARED_PROBING_DEVID(ACS_site_coord) # acs global
   ACS_site_coord
    DeffDEVs = util_SHARED_EFFECTIVE_DEVID(DprbDEVs)
    if len(DeffDEVs["$ID_List"])==0:
        shared_stress_lib.util_logInfo("Post_Measure:  Length of DeffDEVs is 0.
   Please double check device file to see if all the probed devices are alive and
   not done.")
        return
    G_testinfo_dict = shared_stress_lib.get_GDtestinfo(globals().copy())
    G_testinfo_dict["TEST_INFO"]["v_check_post"] = v_check_post
    shared_stress_lib.set_GDtestinfo(G_testinfo_dict)
    postmeas_smu = "SMU1"
    #scan
    test_phase = "Post"
    result = []
    G_devattr_dict = shared_stress_lib.get_GDdevattr(globals().copy())
    for sID in DeffDEVs["$ID_List"]:
        iCH = DeffDEVs[sID]['chid']
        util_SHARED_CLOSE_CH(MTRX1, postmeas_smu, [iCH])
        #measurement done by premeas_smu
        curr = util_SHARED_PREPOST_MEAS(pre_or_post="post")
        if abs(curr) > hi_limit:
            DprbDEVs[sID]["alive"] = 0
        DprbDEVs[sID]["done"] = 1
        G_devattr_dict[sID] = copy.copy(DprbDEVs[sID])
        result.append(",".join(["Post", str(sID), "%g"%curr]))
    # write data + update global
    if len(result)>0:
        util_Write_Data([",".join(["Test_Phase", "ID", "Current"])])
        util_Write_Data(result)
    shared_stress_lib.set_GDdevattr(G_devattr_dict)
    G_testinfo_dict = shared_stress_lib.get_GDtestinfo(globals().copy())
```

```
    shared_dep_folder = G_testinfo_dict["PATH"]["shared_dep_folder"]
    dev_file_path = os.path.join(shared_dep_folder, 'DeviceFile.csv')
    shared_stress_lib.glob_WRITE_devFile(dev_file_path, G_devattr_dict)
```

The global variable `G_devattr_dict` is updated in real-time. To retrieve the global value in the next test, or UAP, you call the `get_GDxxx()` function through the parameter `globals().copy()`. Always call `get_GDxxx` with input parameter `globals().copy()`. In this way, `get_GDxxx` will find the value from the global pool in the present name space.

Prepare the global UAP

```
from ACS_Global import *
import Shared_Stress_Demo
set_globals(Shared_Stress_Demo, "Shared_Stress_Demo", locals().copy())
Shared_Stress_Demo.Prepare_Global_All(dev_file='DeviceFile.csv',
   pif_file='Shared_pcf.csv', cfg_file='Shared_confg.csv', icf_file='inst_map.csv')
```

Similar as in PTM libraries, these lines are essential to underlie the global data management.

These lines of code transfer all the current variables through `locals().copy()` into `Shared_Stress_Demo` space. In `Shared_Stress_Demo.py`, similar lines are used to transfer `locals().copy()` into the next space `Shared_Stress_lib` as mentioned in the `Share_Stress_Demo.py` example.

Note that `locals()` in UAP here contains global data of PTM also, because ACS platform will set all the global data of PTM into UAP space when the test flow runs.

Test module templates

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Zener test module templates.. 5-13
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Introduction

ACS enables you to import or export a test plan for a project to the subsite level or device level. A test plan consists of all the tests and settings under a certain subsite level or device level in the configuration navigator. If you import or export a subsite or device node, all the tests and settings under the subsite or device are added or saved. Additionally, ACS provides preset test plans as test module templates that represent most semiconductor device tests and power device tests.

Import and export a test plan

The import and export functions are accessible by right-selecting any pattern, subsite, or device level node in the configuration navigator.

ACS has preset test plans for many semiconductor device parametric tests. These preset test plans are in the following computer directory: `\ACS\Test Module Template\`. If you want a device level test plan, you need to import it from the device folder. If you want a subsite level test plan, you need to import it from the subsite folder.

The device folder contains high voltage capacitance test modules for several semiconductor devices and has five test module templates for a Vds reliability test. The Test module templates for device test plans (on page 5-3) lists all the high voltage capacitance measurements in this folder. Also, the subsite folder contains parametric tests for many semiconductor devices from which you can choose.

You can export a subsite level or a device level test plan. When you export a subsite or device level test plan, you are exporting all the tests and settings in the subsite or device level in the configuration navigator. Once the test plan has been exported, it can be imported to another project.

To import a test plan:

1. Right-click the pattern, subsite, or device node.
2. Select **Import**. The Import dialog is displayed.
3. Select the `.xml` file test plan to add to the configuration navigator. The imported test plan is added to the configuration navigator as a new device or a new subsite, depending on the type you choose. The imported subsite, device, and test is named with a suffix `_PxSSy`, `_PxSSyDz`, and `_PxSSyDzTm`, respectively, as an indication of the position in the configuration navigator. `_PxSSyDzTm` means *pattern x*, *subsite y*, *device z* and *test m* in the configuration navigator.

To export a test plan:

1. Right-click the pattern, subsite, or device node.
2. Select **Export**. The KATS - Export dialog is displayed.
3. In the Device field, enter a name.
4. In the Location field, select the location to which the file will be exported.
5. To export all the present test data, select **Include Test Data**.
6. Select **Ok**.

Test module templates for device test plans

ACS provides semiconductor device parametric tests, including those for high voltage capacitance (HVCV) measurements, in the computer directory `\ACS\Test Module Template\device`. The following table lists the tests.

Semiconductor device parametric tests

Device	Device test plan	Tests
IGBT	IGBT_HVCV	Cce, Cgc, Cge, Cies, Coes, Cres
nMOSFET	nMOSFET_HVCV	Cds, Cgd, Cgs, Ciss, Coss, Crss
pMOSFET	pMOSFET_HVCV	Cds, Cgd, Cgs, Ciss, Coss, Crss
nPowerMOSFET	nPowerMOSFET_HVCV	Cds, Cgd, Cgs, Ciss, Coss, Crss
pPowerMOSFET	pPowerMOSFET_HVCV	Cds, Cgd, Cgs, Ciss, Coss, Crss
npnBJT	npnBJT_HVCV	Ccb, Cce, Ceb, Cibo, Cobo
pnpBJT	pnpBJT_HVCV	Ccb, Cce, Ceb, Cibo, Cobo
npnPowerBJT	npnPowerBJT_HVCV	Ccb, Cce, Ceb, Cibo, Cobo
pnpPowerBJT	pnpPowerBJT_HVCV	Ccb, Cce, Ceb, Cibo, Cobo

Test module templates for subsite test plans

ACS provides semiconductor device parametric tests that are in the directory `\ACS\Test Module Template\subsite`.

The following tables list the subsite test plans for common semiconductor devices and the available tests for each test plan. The subsite test plans with a `_26xxB` suffix include tests based on an ITM for the Models 26xxB and 265xA instruments. The subsite test plans with a `_MixedSMUs` suffix include tests based on a general PTM or mixed SMU pulse PTM. The two types of PTM are for mixed use for Model 26xxB, 265xA, 24xx, and 42xx SMUs.

Subsite test plans

Device	Subsite test plan	Tests
Diode	Diode_26xxB	DynamicZ, Spot_IfdVfd, Spot_IrdVrd, Spot_VbrIrd, Spot_VfdIfd, Spot_VrdIrd Sweep_IfdVfd, Sweep_IrdDVrd
Diode	Diode_MixedSMUs	DynamicZ, Spot_IfdVfd, Spot_IrdVrd, Spot_VbrIrd, Spot_VfdIfd, Spot_VrdIrd Sweep_IfdVfd, Sweep_IrdVrd
Zener	Zener_26xxB	BVZ, IR, VF
Resistor (2W)	Resistor_26xxB	Spot_IV_2SMU, Spot_VI_2SMU, Sweep_IV_2SMU, Sweep_VI_2SMU
Resistor (2W)	Resistor_MixedSMUs	BVCBO, BVCEI, BVCEO, BVCEV, HFE_SW, IBCO, IBEO, IbIcVbe, IbVbe, ICBO, ICEO, ICEV, IcVcb, IcVce_BiasIb, IcVce_BiasVb, IcVce_StepIb, IcVce_StepVb, VBCO, VCE
npnBJT	npnBJT_26xxB	BVCBO, BVCEI, BVCEO, BVCEV, BVEBO, BVECO, HFE_SW, IBCO, IBEO, IbIcVbe, IbVbe, ICBO, ICEO, ICEV, IcVcb, IcVce_BiasIb, IcVce_BiasVb, IcVce_StepIb, IcVce_StepVb, IEBO, IECO, IeVeb, VBCO, VCE
npnBJT	npnBJT_MixedSMUs	BVCBO, BVCEI, BVCEO, BVCEV, HFE_SW, IBCO, IBEO, IbIcVbe, IbVbe, ICBO, ICEO, ICEV, IcVcb, IcVce_BiasIb, IcVce_BiasVb, IcVce_StepIb, IcVce_StepVb, VBCO, VCE
pnpBJT	pnpBJT_26xxB	BVCBO, BVCEI, BVCEO, BVCEV, BVEBO, BVECO, HFE_SW, IBCO, IBEO, IbIcVbe, IbVbe, ICBO, ICEO, ICEV, IcVcb, IcVce_BiasIb, IcVce_BiasVb, IcVce_StepIb, IcVce_StepVb, IEBO, IECO, IeVeb, VBCO, VCE
pnpBJT	pnpBJT_MixedSMUs	BVCBO, BVCEI, BVCEO, BVCEV, BVEBO, BVECO, HFE_SW, IBCO, IBEO, IbIcVbe, IbVbe, ICBO, ICEO, ICEV, IcVcb, IcVce_BiasIb, IcVce_BiasVb, IcVce_StepIb, IcVce_StepVb, IEBO, IECO, IeVeb, VBCO, VCE
npnPowerBJT	npnPowerBJT_26xxB	BVCBO, BVCEO, BVEBO, HFE, ICBO, ICEO, ICES, ICEV, IcVce_StepIb, IcVce_StepVbe, IEBO, VbeON, VbeSAT, VceSAT, VCESUS
npnPowerBJT	npnPowerBJT_MixedSMUs	IcVce_StepIb_MIX, IcVce_StepVbe_MIX, VceSAT_MIX

pnpPowerBJT	pnpPowerBJT_26xxB	BVCBO, BVCEO, BVEBO, HFE, ICBO, ICEO, ICES, ICEV, IcVce_StepIb, IcVce_StepVbe, IEBO, VbeON, VbeSAT, VceSAT, VCESUS
pnpPowerBJT	pnpPowerBJT_MixedSMUs	IcVce_StepIb_MIX, IcVce_StepVbe_MIX, VceSAT_MIX
TRIAC	TRIAC_26xxB	IDRM, IGT, IHneg, IHpos, ILneg, ILpos, IRRM, VGT, VTneg, VTpos
IGBT	IGBT_26xxB	BVCES, ICES, IcON, IcVce_StepVge, IcVge, IGESF, IGESR, VceSAT, VF, VgeON, VGETH
IGBT	IGBT_MixedSMUs	IcVce_StepVge_MIX, IcVge_MIX, VceSAT_MIX
nPowerMOSFET	nPowerMOSFET_26xxB	BVDSS, GFS, IdON, IDSS, IdVd_StepVg, IdVg_StepVd, IGSSF, IGSSR, RdsON, VdsON, VgsON, VGSTH, VSD
nPowerMOSFET	nPowerMOSFET_MixedSMUs	IdON_MIX, IdVd_StepVg_MIX, RdsOn_MIX, VgsON_MIX
pPowerMOSFET	pPowerMOSFET_26xxB	BVDSS, GFS, IdON, IDSS, IdVd_StepVg, IdVg_StepVd, IGSSF, IGSSR, RdsON, VdsON, VgsON, VGSTH, VSD
pPowerMOSFET	pPowerMOSFET_MixedSMUs	IdON_MIX, IdVd_StepVg_MIX, RdsOn_MIX, VgsON_MIX
nMOSFET	nMOSFET_26xxB	BVDSS, BVDSV, BVGDO, BVGDS, BVGSO, IDL, IDS_ISD, IdVd_BiasVg, IdVd_StepVg, IdVg_BiasVd, IdVg_StepVd, IdVg_StepVsub, IGL, IgVg, ISL, Vtci, Vtext, Vtext_llsq
nMOSFET	n_MixedSMUs	BVDSS, BVDSV, BVGDO, BVGDS, BVGSO, IDL, IDS_ISD, IdVd_BiasVg, IdVd_StepVg, IdVg_BiasVd, IdVg_StepVd, IdVg_StepVsub, IGL, IgVg, ISL, Vtci, Vtext
pMOSFET	pMOSFET_26xxB	BVDSS, BVDSV, BVGDO, BVGDS, BVGSO, IDL, IDS_ISD, IdVd_BiasVg, IdVd_StepVg, IdVg_BiasVd, IdVg_StepVd, IdVg_StepVsub, IGL, IgVg, ISL, Vtci, Vtext, Vtext_llsq
pMOSFET	p_MixedSMUs	BVDSS, BVDSV, BVGDO, BVGDS, BVGSO, IDL, IDS_ISD, IdVd_BiasVg, IdVd_StepVg, IdVg_BiasVd, IdVg_StepVd, IdVg_StepVsub, IGL, IgVg, ISL, Vtci, Vtext

Diode test module template

The diode tests in the subsite test plan module template are used to test parameters of a diode, such as the forward voltage and current, reverse voltage and current, I-V curve, and dynamic impedance. The TSP files are used with a Series 2600B instrument to create Test Script files based on the Series 2600B LPT library.

DynamicZ

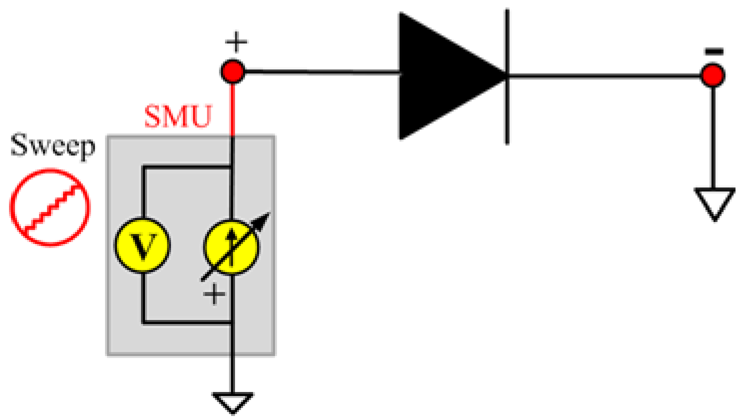
Module name: DynamicZ

DUT: Diode

Function: Measures the Dynamic Impedance based on two forward voltage measurements or two reverse voltage measurements: DynamicZ = (v2 − v1) / (I2 − I1)

Pin connections: Uses one SMU to force the forward current. Connect the other terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 108: Diode DynamicZ pin connections



Spot_IfdVfd

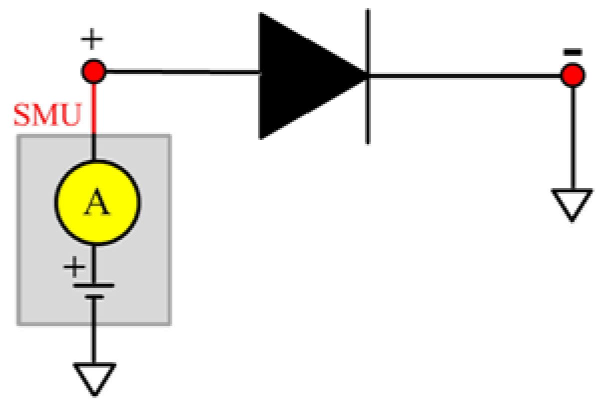
Module name: Spot_IfdVfd

DUT: Diode

Function: Measures the forward current of a diode at a specified forward voltage.

Pin connections: The P terminal forces a forward voltage. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 109: Diode Spot_IfdVfd pin connections



Spot_IrdVrd

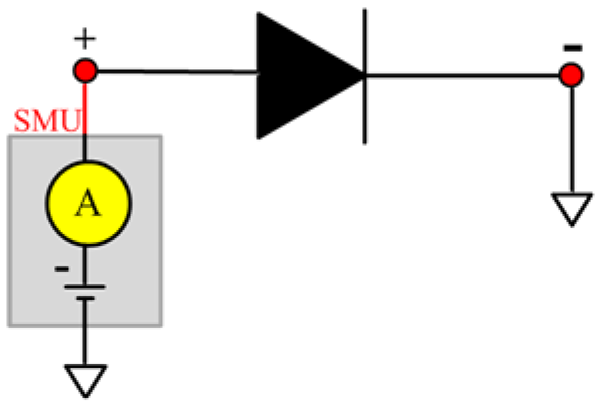
Module name: Spot_IrdVrd

DUT: Diode

Function: Measures the leakage current of a diode at a specified reverse voltage.

Pin connections: Force a reverse voltage or zero voltage to terminal P. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 110: Diode Spot_IrdVrd pin connections



Spot_VbrIrd

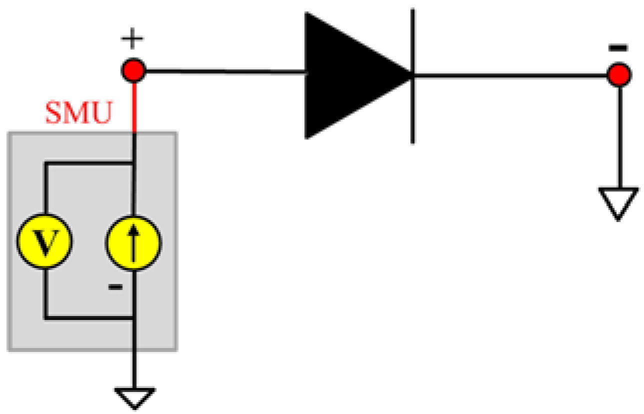
Module name: Spot_VbrIrd

DUT: Diode

Function: Measures the breakdown voltage of a diode at a specified reverse current.

Pin connections: Force a reverse current to the P terminal. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 111: Diode Spot_VbrIrd pin connections



Spot_VfdIfd

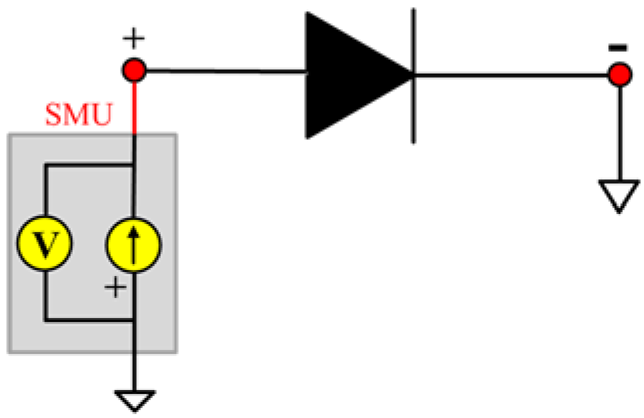
Module name: Spot_VfdIfd

DUT: Diode

Function: Measures the forward voltage of a diode.

Pin connections: Uses one SMU to force forward current to the P terminal. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 112: Diode Spot_VfdIfd pin connections



Spot_VrdIrd

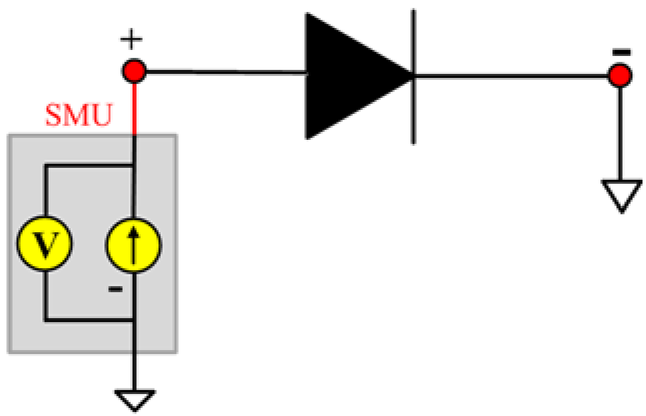
Module name: Spot_VrdIrd

DUT: Diode

Function: Measures the reverse voltage of a diode at a specified reverse current.

Pin connections: Force a reverse current to the P terminal. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 113: Diode Spot_VrdIrd pin connections



Sweep_IfdVfd

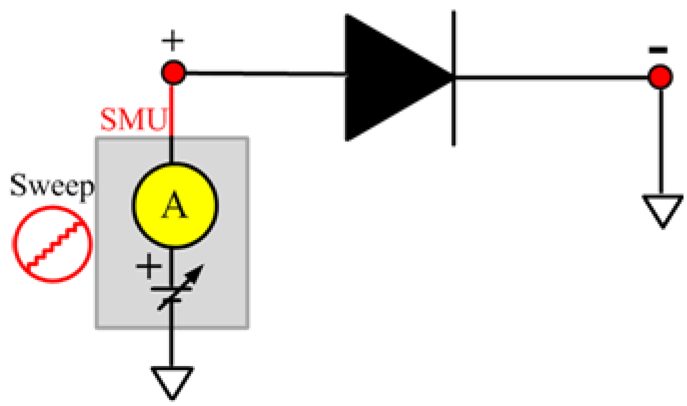
Module name: Sweep_IfdVfd

DUT: Diode

Function: Measures the forward current with a forward voltage sweep to indicate a forward I-V characteristic of a diode.

Pin connections: Apply a forward voltage sweep to terminal P. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 114: Diode Sweep_IfdVfd pin connections



Sweep_IrdVrd

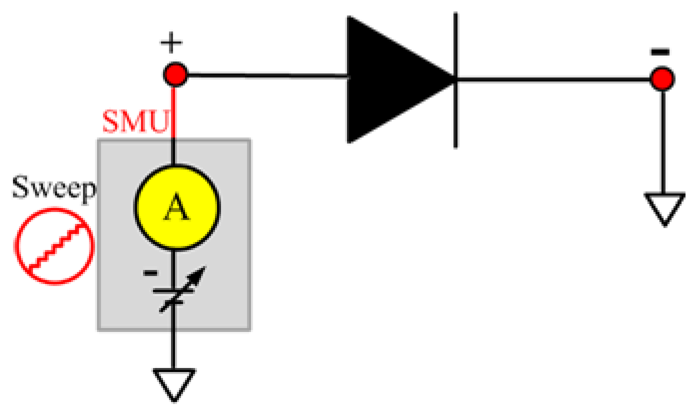
Module name: Sweep_IrdVrd

DUT: Diode

Function: Measures the reverse current with a reverse voltage sweep to indicate the reverse I-V characteristics of a diode.

Pin connections: Apply a reverse voltage sweep to the P terminal. Connect the N terminal to GND or use a SMU to supply a zero-voltage bias.

Figure 115: Diode Sweep_IrdVrd pin connections



Zener test module templates

The Zener parametric test module templates test parameters of a Zener diode, including leakage, on-state, and breakdown properties.

BVZ

Module name: BVZ

Module type: ITM

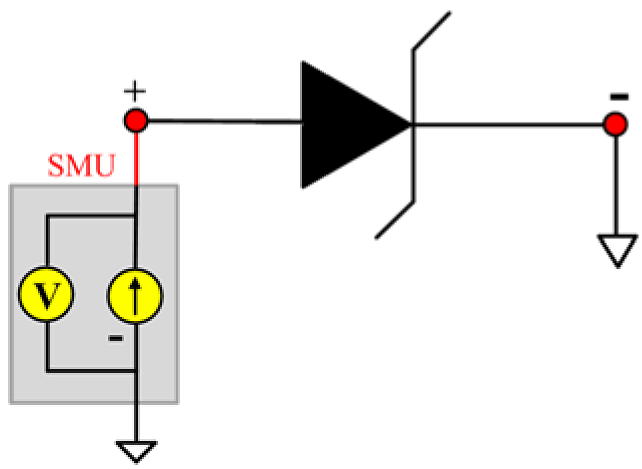
Instrument: Keithley Instruments Series 2600B

DUT: Two-terminal Zener diode

Function: Measures the regulator voltage from the cathode to anode at the maximum rated current that is given in the datasheet.

Pin connections: Use a SMU to apply a negative current (IZM) and make voltage measurements from the anode to the cathode. Connect the cathode to GND or use a SMU to supply a zero-voltage bias.

Figure 116: Zener BVZ pin connections



IR

Module name: IR

Module type: ITM

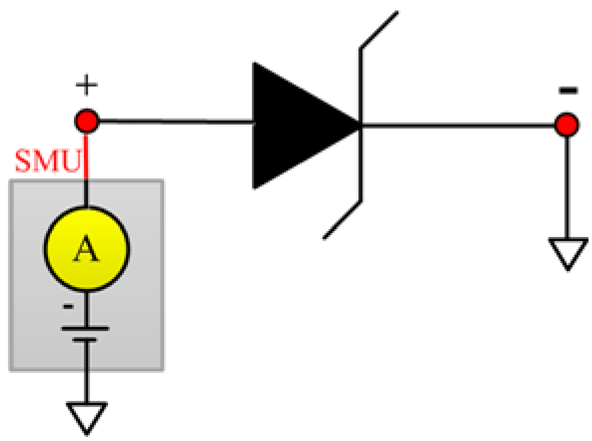
Instrument: Keithley Instruments Series 2600B

DUT: Two-terminal Zener diode

Function: Measures the reverse leakage current at a specific reverse voltage from the cathode to anode that is given in the datasheet.

Pin connections: Use a SMU to apply a negative voltage and make a current measurement from anode to cathode. Connect the cathode to GND or use a SMU to supply a zero-voltage bias.

Figure 117: Zener IR pin connections



VF

Module name: VF

Module type: ITM

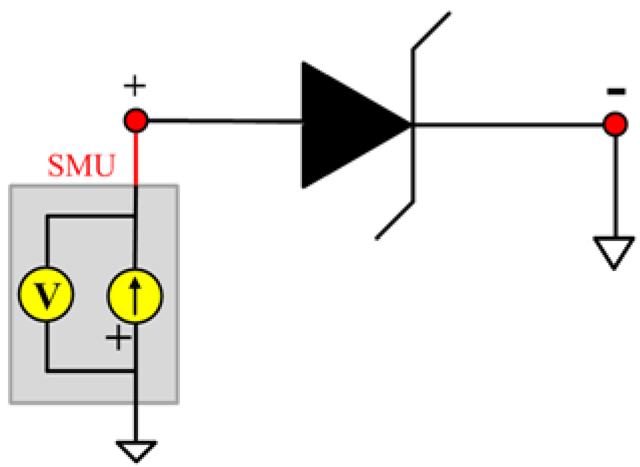
Instrument: Keithley Instruments Series 2600B

DUT: Two-terminal Zener diode

Function: Measures the forward voltage at a specific forward current from the anode to cathode.

Pin connections: Use a SMU to apply positive current and make a voltage measurement from the anode to the cathode. Connect the cathode to GND or use a SMU to supply a zero-voltage bias.

Figure 118: Zener VF pin connections



Two-terminal resistor test module templates

The two-terminal resistor test module templates are used to test parameters of two-terminal resistors, such as resistance (source V measure I or source I measure V, 2-wire, or 4-wire). This library is used with a Series 2600B instrument to create Test Script Processor files based on the Series 2600B LPT library.

Spot_IV_2SMU

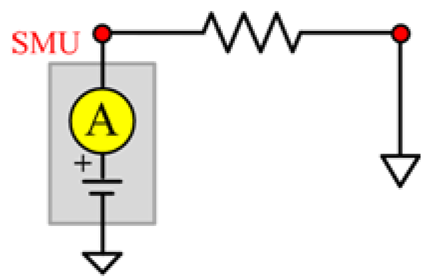
Module name: Spot_IV_2SMU

DUT: Two-terminal generic device

Function: Measures the current at a specified voltage to determine the resistance.

Pin connections: Ensure that you set the sense mode of the SMU in the software toolbar (Tools > Preferences). If remote sense mode is used, which corresponds to four-wire measurement instruments, connect the Sense High lead of the SMU closer to the device than the Force High lead.

Figure 119: Two-terminal Spot_IV_2SMU pin connections



Spot_VI_2SMU

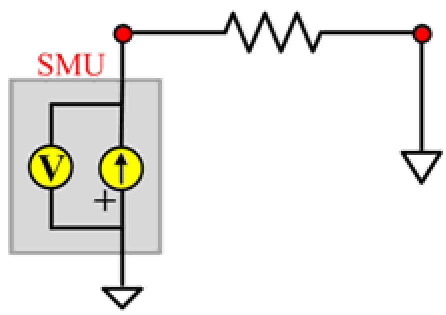
Module name: Spot_VI_2SMU

DUT: Two-terminal generic device

Function: Measures the voltage at a specified current to determine the resistance.

Pin connections: Ensure that you set the sense mode of the SMU in the software toolbar (Tools > Preferences). If remote sense mode is used, which corresponds to four-wire measurement instruments, connect the Sense High lead of the SMU closer to the device than the Force High lead.

Figure 120: Two-terminal resistor spot_VI_2SMU pin connections



Sweep_IV_2SMU

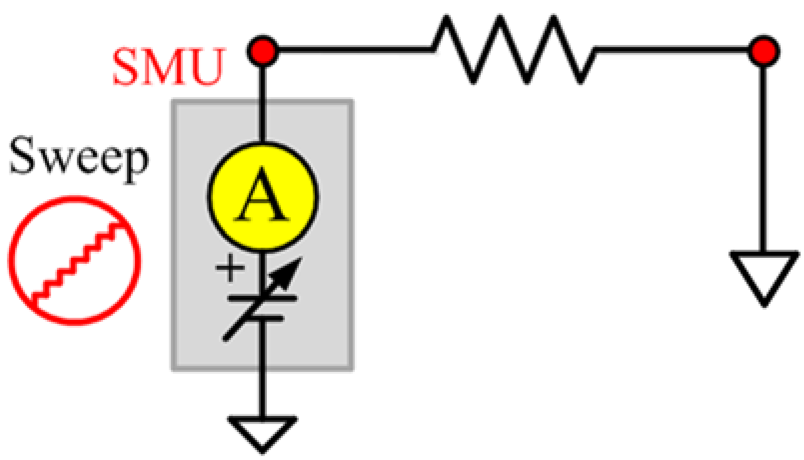
Module Name: Sweep_IV_2SMU

DUT: Two-terminal generic device

Function: Measures the current reading during a voltage sweep and use the values to calculate the resistance.

Pin connections: Ensure that you set the sense mode of the SMU in the software toolbar (Tools > Preferences). If remote sense mode is used, which corresponds to four-wire measurement instruments, connect the Sense High lead of the SMU closer to the device than the Force High lead.

Figure 121: Two-terminal resistor sweep IV 2SMU pin connections



Sweep_IV_2SMU ITM

Module type: ITM

Instrument: Keithley Instruments Series 2600B, Model 4200A-SMU

Figure 122: Two-terminal resistor Sweep_IV_2SMU 2600B ITM settings

Device Num	SMU	Pad	Function	Force Range	Source	Measure	Compliance	Meas Range	Limits Auto
1	SMU1	Pos	Sweep V	auto	Linear:[0.1, 1, 21, 0]	I+V	0.1	auto	
	SMU2	Neg	Bias V	auto	0	None	0.1		

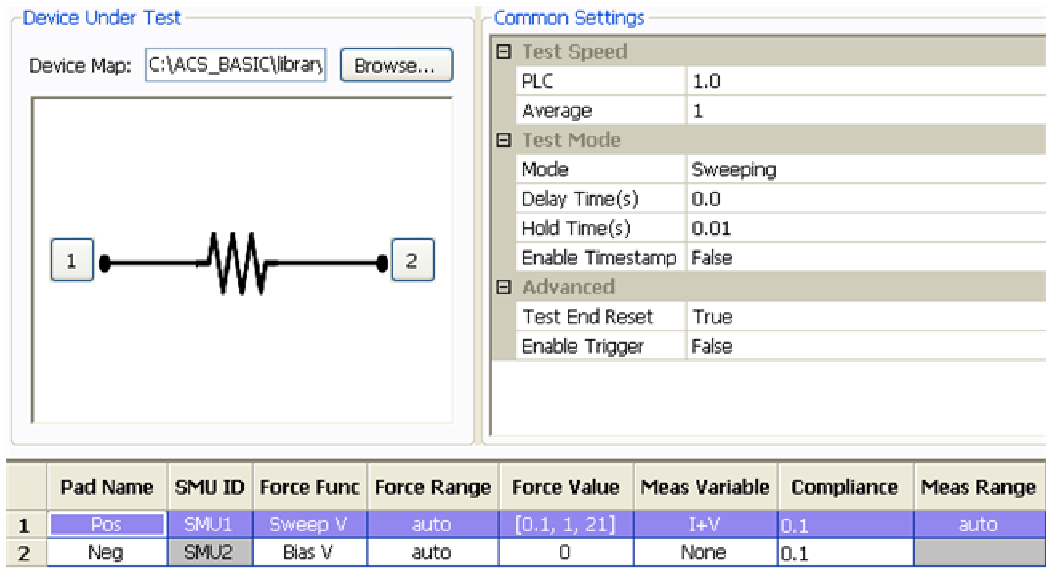
Figure 123: Two-terminal resistor sweep IV 2SMU 4200 ITM setting

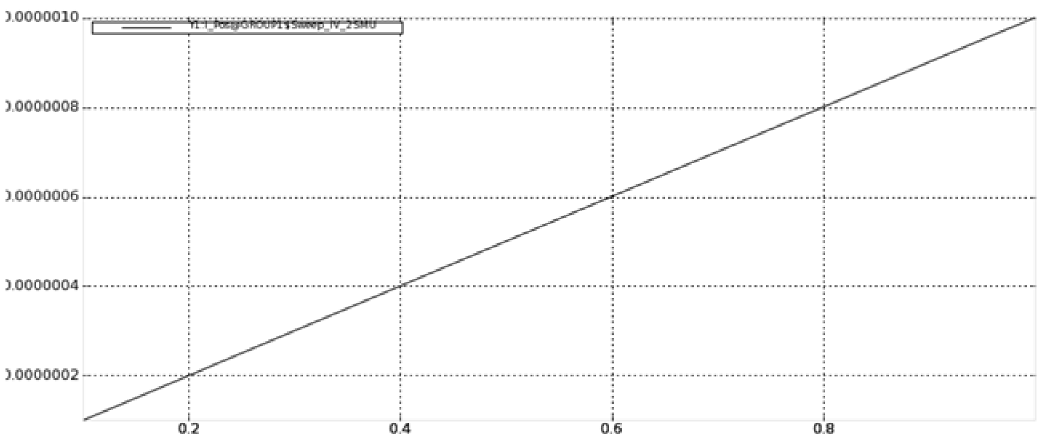
Device Num	SMU	Pad	Function	Force Range	Source	Measure	Compliance	Meas Range	Limits Auto
1	SMU1	Pos	Sweep V	auto	Linear:[0, 1, 21, 0]	I+V	0.1	auto	
	SMU2	Neg	Bias V	auto	0.0	None	0.1		

Sweep_IV_2SMU General Test Module

Module type: General Test Module

Instrument: Keithley Instruments Series 2400 SMU





Sweep_VI_2SMU

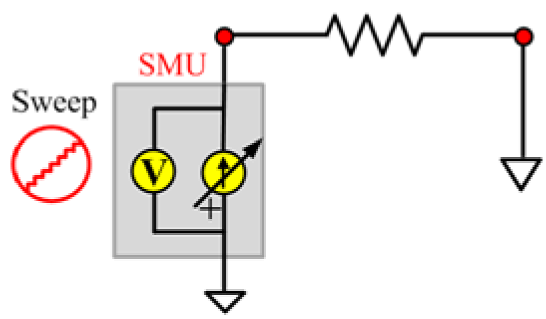
Module name: Two-terminal resistor Sweep_VI_2SMU

DUT: Two-terminal generic device

Function: Measures the voltage during a current sweep and use the values to calculate the resistance.

Pin connections: Ensure that you set the sense mode of the SMU in the software toolbar (Tools > Preferences). If remote sense mode is used, which corresponds to four-wire measurement instruments, connect the Sense High lead of the SMU closer to the device than the Force High lead.

Figure 124: Two-terminal resistor sweep VI 2SMU pin connections



npnBJT test module templates

This npnBJT parametric test module templates are used to test parameters of npn-type power BJTs, including leakage, breakdown, gain, on-state, and characteristic curves.

BVCBO

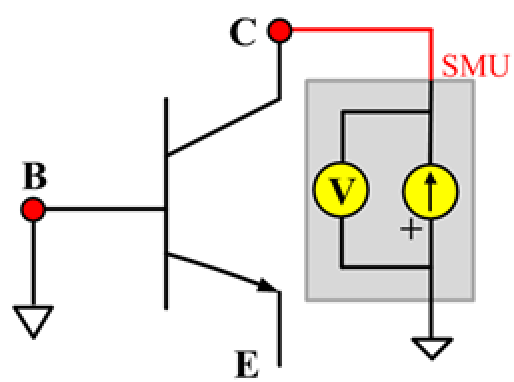
Module name: BVCBO

DUT: Three-terminal BJT

Function: Measures the collector-base breakdown voltage of the BJT, with the emitter open.

Pin connections: Use one SMU to force a reverse current to the collector. Open the circuit to the emitter or use a SMU to supply a zero-current bias. Connect the base to GND or use a SMU to supply a zero-voltage bias.

Figure 125: Three-terminal npnBJT BVCBO pin connections



BVCEI

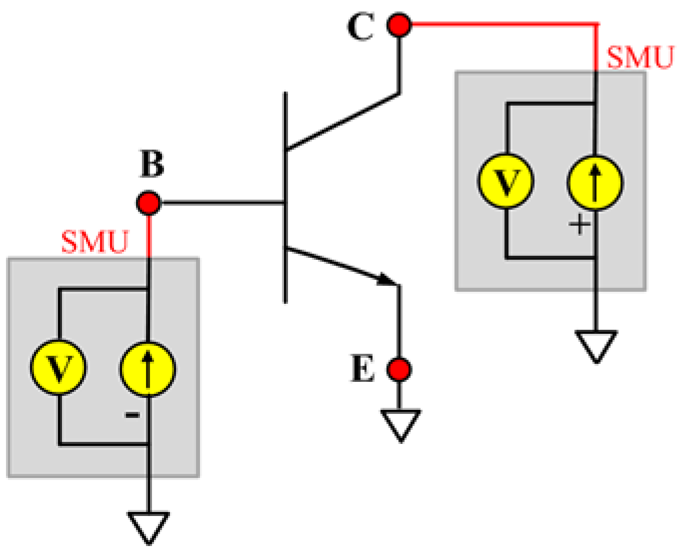
Module name: BVCEI

DUT: Three-terminal npnBJT

Function: Measures the collector-emitter breakdown voltage of the npnBJT with a bias base-forced current.

Pin connections: Use a SMU to force current to the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 126: Three-terminal npnBJT BVCEI pin connections



BVCEO

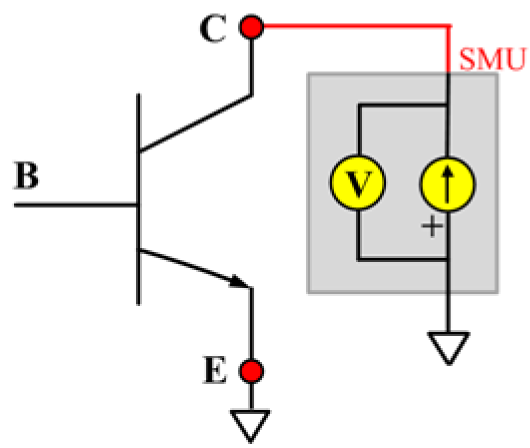
Module name: BVCEO

DUT: Three-terminal npnBJT

Function: Measures the collector-emitter breakdown voltage, with the base opened.

Pin connections: Use a SMU to force current to the collector. Open the circuit to the base or use a SMU to supply a zero-current bias to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 127: Three-terminal npnBJT BVCEO pin connections



BVCEV

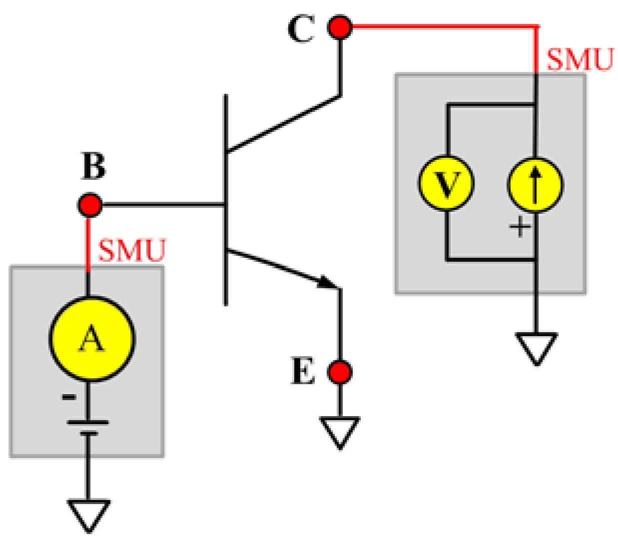
Module name: BVCEV

DUT: Three-terminal npnBJT

Function: Measures the collector-emitter breakdown voltage with a biased base.

Pin connections: Use a SMU to force voltage to the base. Use a SMU to force current to the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 128: Three-terminal npnBJT BVCEV pin connections



BVEBO

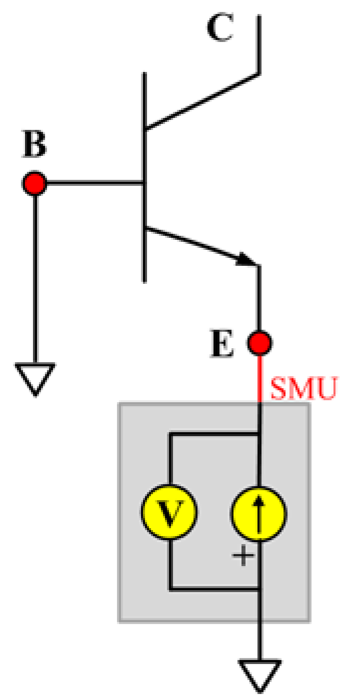
Module name: BVEBO

DUT: Three-terminal npnBJT

Function: Measures the emitter-base breakdown voltage of the npnBJT with the collector opened.

Pin connections: Use a SMU to force current to the emitter. Connect the base to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 129: Three-terminal npnBJT BVEBO pin connections



BVECO

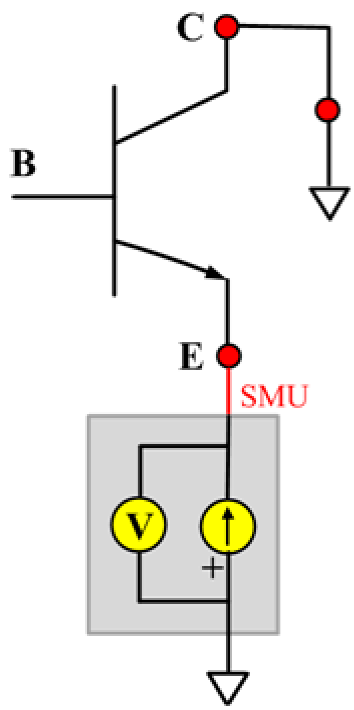
Module name: BVECO

DUT: Three-terminal npnBJT

Function: Measures the emitter-collector breakdown voltage of the npnBJT with the base opened.

Pin connections: Use a SMU to force current to the emitter. Connect the collector to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 130: Three-terminal npnBJT BVECO pin connections



HFE

Module name: HFE_SW

DUT: Three-terminal npnBJT

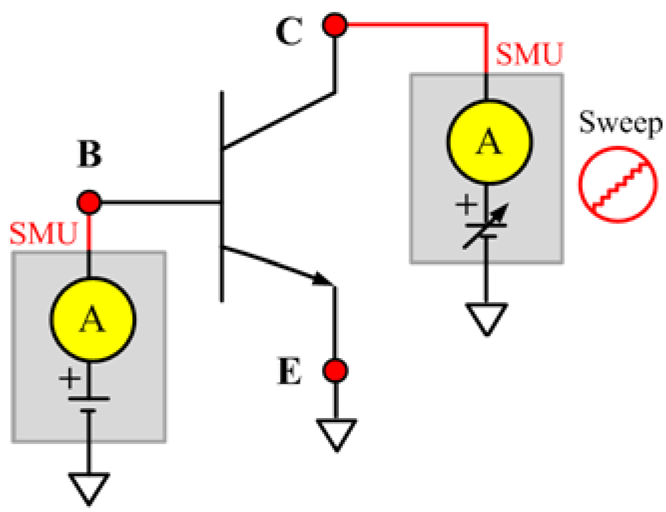
Function: Measures the collector current, base current, and dc current gain based on the collector sweep voltage.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias the base.

HFE= Ic/Ib:

- Force CollectorV sweep
- Measure Ib and Ic
- Check for measurement problems
- Calculate HFE(= Ic/Ib)

Figure 131: Three-terminal npnBJT HFE SW pin connections



IBCO

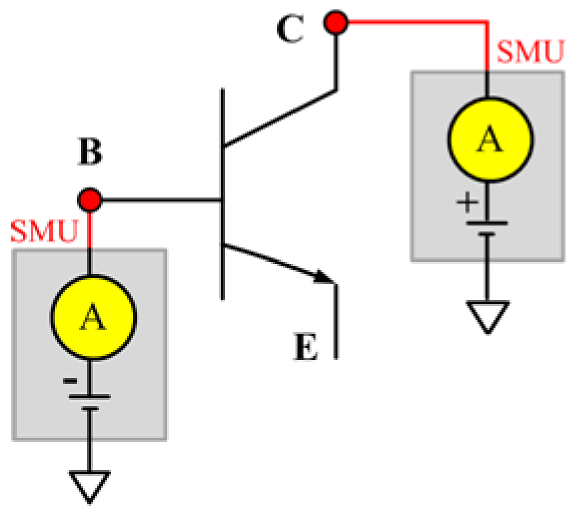
Module name: IBCO

DUT: Three-terminal npnBJT

Function: Measures the base-collector current with the emitter opened.

Pin connections: Use a SMU to force voltage to the base. Connect the collector to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 132: Three-terminal npnBJT IBCO pin connections



IBEO

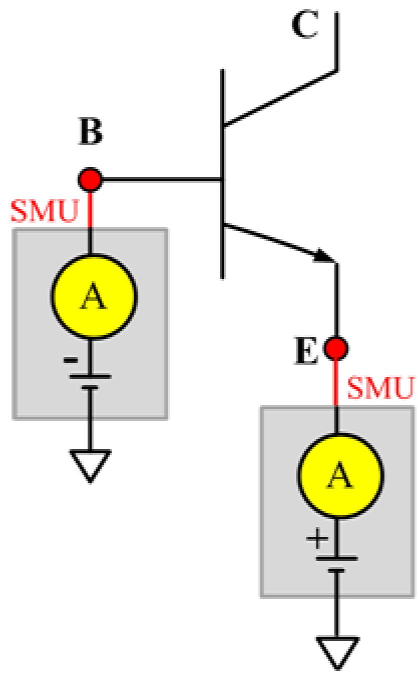
Module name: IBEO

DUT: Four-terminal npnBJT

Function: Measures the base-emitter current with the collector opened.

Pin connections: Use a SMU to force voltage to the base. Connect the collector to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 133: Three-terminal npnBJT IBEO pin connections



IbIcVbe

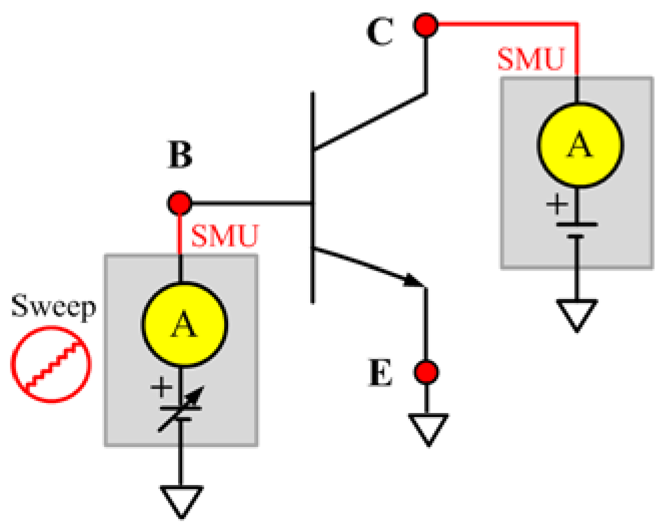
Module name: IbIcVbe

DUT: Three-terminal npnBJT

Function: Measures the base current and collector current of the npnBJT by sweeping a specified base voltage and measures the Ib-Vbe and IcVbe curves and the Gummel plot if the axis properties of result have changed (logarithm instead of right-angle coordinate).

Pin connections: Use a SMU to apply a voltage sweep to the base. Use a SMU to bias the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 134: Three-terminal npnBJT IbIcVbe pin connections



IbVbe

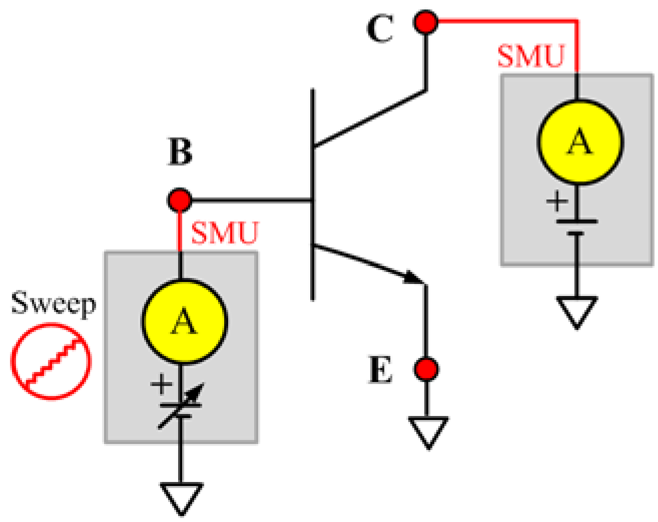
Module name: IbVbe

DUT: Three-terminal npnBJT

Function: Measures the base current of the npnBJT by sweeping a specified base voltage and measures the Ib-Vbe curve.

Pin connections: Use a SMU to apply a voltage sweep to the base. Use a SMU to bias the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 135: Three-terminal npnBJT IbVbe pin connections



ICBO

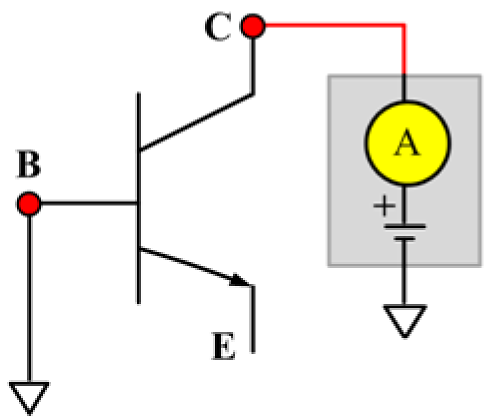
Module name: ICBO

DUT: Three-terminal npnBJT

Function: Measures the collector-base cut off current with the emitter opened.

Pin connections: Use a SMU to force voltage to the collector. Connect the base to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 136: Three-terminal npnBJT ICBO pin connections



ICEO

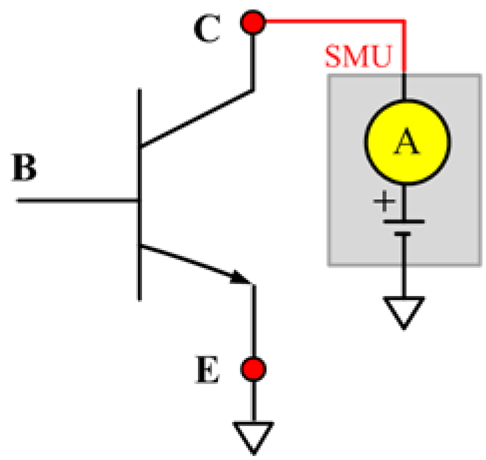
Module name: ICEO

DUT: Three-terminal npnBJT

Function: Measures the collector-emitter cut off current with the base opened.

Pin connections: Use a SMU to force voltage to the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 137: Three-terminal npnBJT ICEO pin connections



ICEV

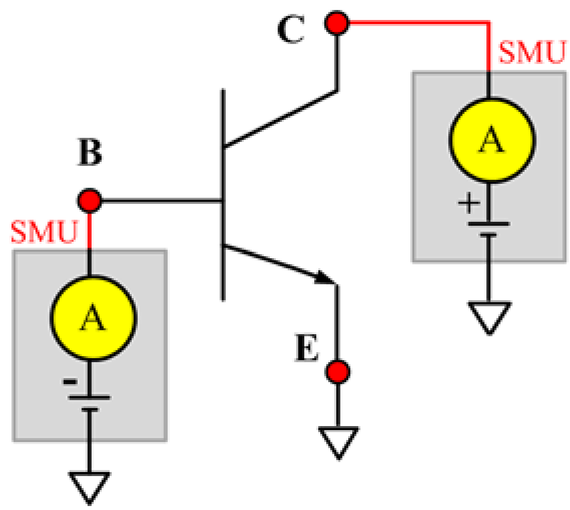
Module name: ICEV

DUT: Three-terminal npnBJT

Function: Measures the collector-emitter cut off current with a bias base voltage.

Pin connections: Use a SMU to force voltage to the base and the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 138: Three-terminal npnBJT ICEV pin connections



IcVcb

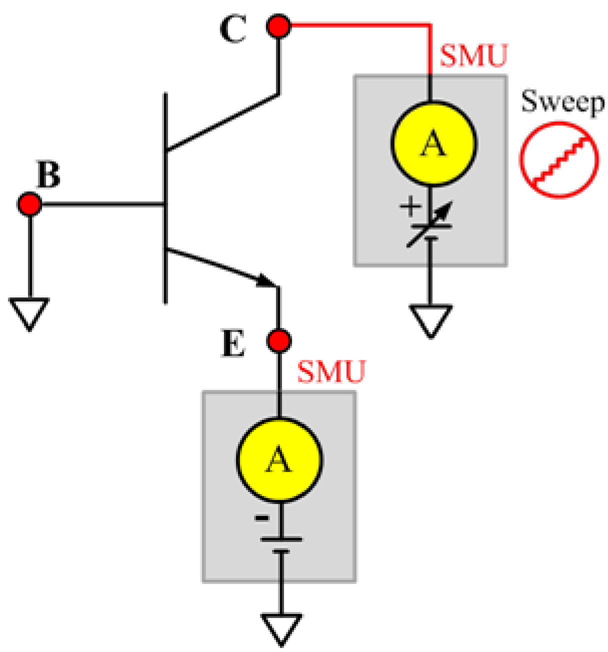
Module name: IcVcb

DUT: Three-terminal npnBJT

Function: Measures the collector current of the npnBJT by sweeping a specified collector voltage.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias the emitter. Connect the base to GND or use a SMU to supply a zero-voltage bias.

Figure 139: Three-terminal npnBJT IcVcb pin connections



IcVce_BiasIb

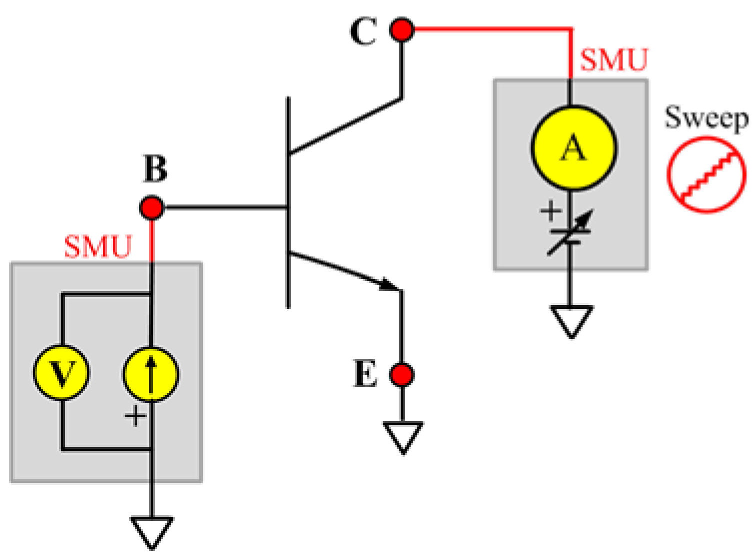
Module name: IcVce_BiasIb

DUT: Three-terminal npnBJT

Function: Measures the collector current based on a base step current and a collector sweep voltage, and a series of IcVce curves with a base current step.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias the current to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 140: Three-terminal npnBJT IcVce_BiasIb pin connections



IcVce_BiasVb

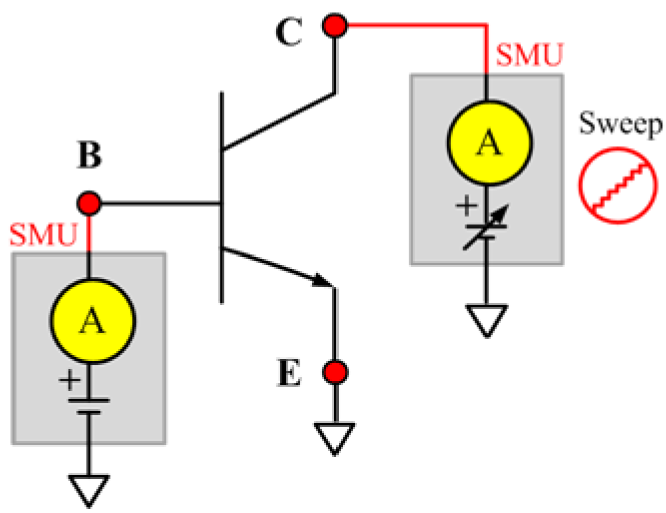
Module name: IcVce_BiasVb

DUT: Three-terminal npnBJT

Function: Measures the collector current based on the collector sweep voltage and a fixed based voltage and measures a series of IcVce curves with a fixed base voltage.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to supply a zero-voltage bias to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 141: Three-terminal npnBJT IcVce_BiasVb pin connections



IcVce_StepIb

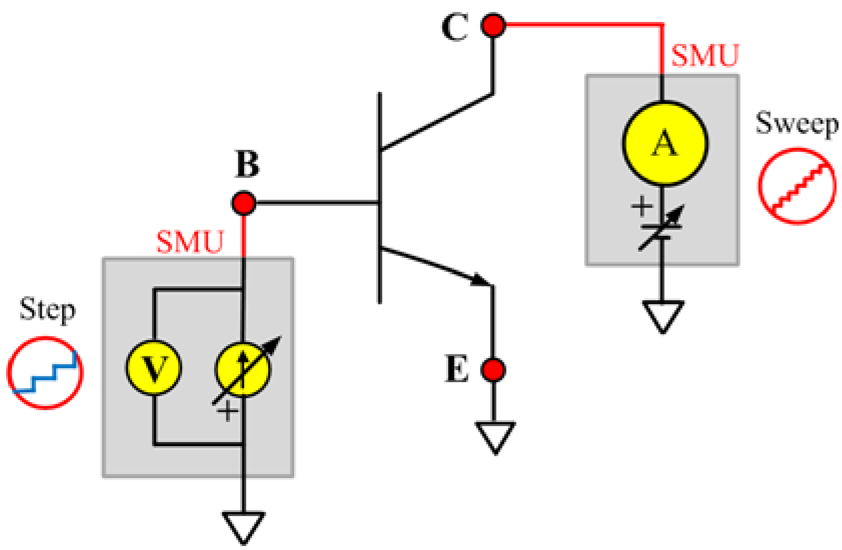
Module name: IcVce_StepIb

DUT: Three-terminal npnBJT

Function: Measures the collector current based on the base step current and the collector sweep voltage and measures a series of IcVce curves with a base current step.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to apply a step current to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 142: Three-terminal npnBJT IcVce_StepIb pin connections



IcVce_StepVb

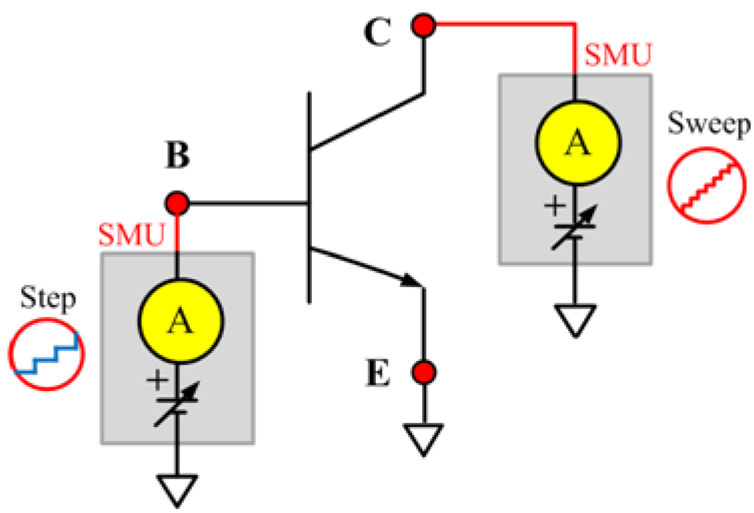
Module name: IcVce_StepVb

DUT: Three-terminal npnBJT

Function: Measures the collector current based on the base step and the collector sweep voltage and measures a series of IcVce curves with a base voltage step.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to apply a step voltage to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 143: Three-terminal npnBJT IcVce_StepVb pin connections



IEBO

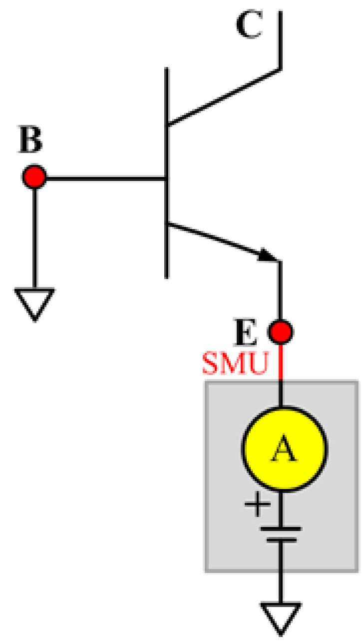
Module name: IEBO

DUT: Three-terminal npnBJT

Function: Measures the emitter-base cut off current with the collector opened.

Pin connections: Use a SMU to force voltage to the emitter. Connect the base to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 144: Three-terminal npnBJT IEBO pin connections



IECO

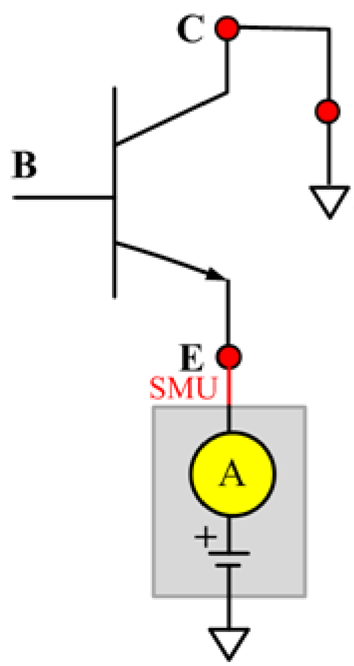
Module name: IECO

DUT: Three-terminal npnBJT

Function: Measures the emitter-collector current with the base opened.

Pin connections: Use a SMU to force voltage to the emitter. Open the circuit to the collector or use a SMU to supply a zero-voltage bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 145: Three-terminal npnBJT IECO pin connections



IeVeb

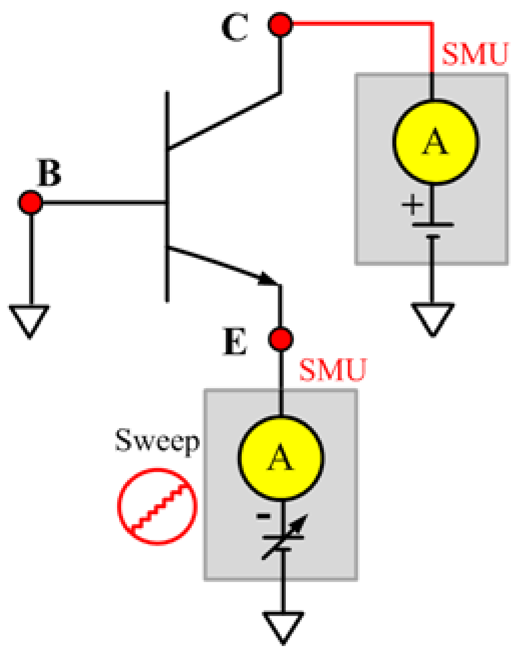
Module name: IeVeb

DUT: Three-terminal npnBJT

Function: Measures the emitter current of the npnBJT with a specified sweeping emitter voltage and measures the IeVeb curves.

Pin connections: Use a SMU to apply a sweep voltage to the emitter. Use a SMU to apply biased voltage to the collector. Connect the base to GND or use a SMU to supply a zero-voltage bias.

Figure 146: Three-terminal npnBJT IeVeb pin connections



VBCO

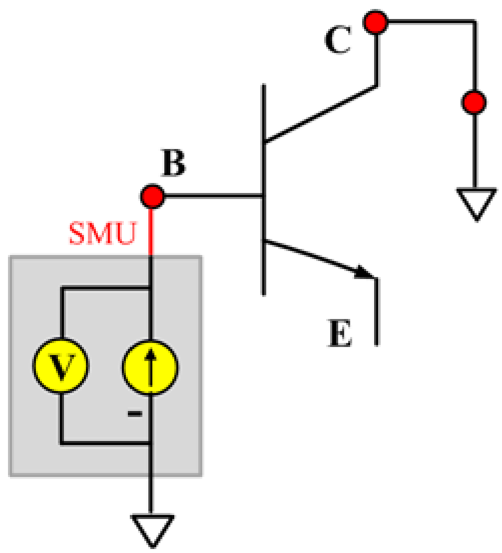
Module name: VBCO

DUT: Three-terminal npnBJT

Function: Measures the base-collector voltage of the npnBJT with the emitter opened.

Pin connections: Use a SMU to apply a biased current to the base. Connect the collector to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 147: Three-terminal npnBJT VBCO pin connections



VCE

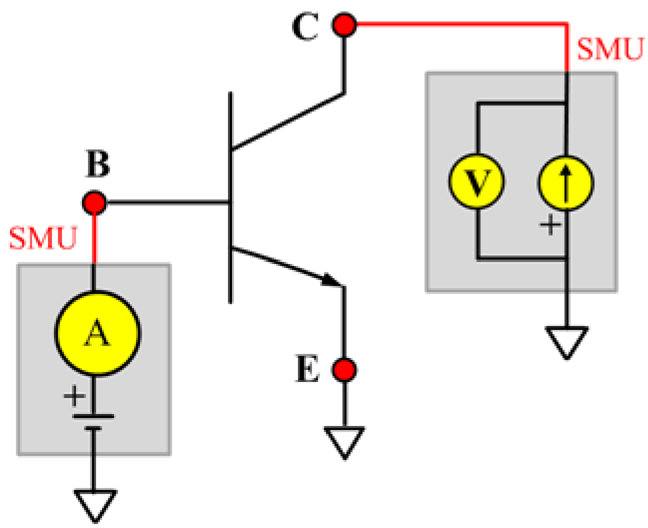
Module name: VCE

DUT: Three-terminal npnBJT

Function: Measures the collector-emitter voltage of the npnBJT device.

Pin connections: Use a SMU to apply a biased current to the collector. Use a SMU to apply a biased voltage to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 148: Three-terminal npnBJT VCE pin connections



Ccb

Description:

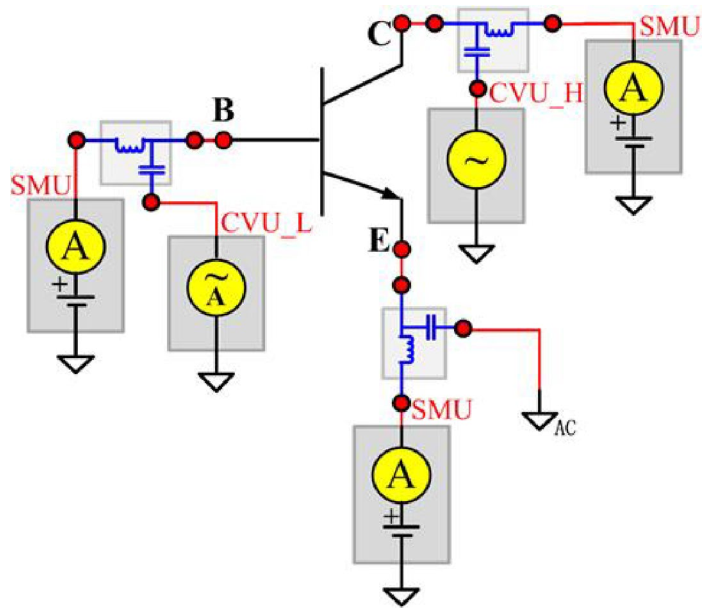
Module name: Ccb

DUT: Three-terminal npnBJT

Function: Measures the capacitance between the collector and base terminals with the emitter terminal connected to the ac guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the AC guard of a three-terminal bridge through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias.

Figure 149: Three-terminal npnBJT Ccb pin connections



Cce

Description:

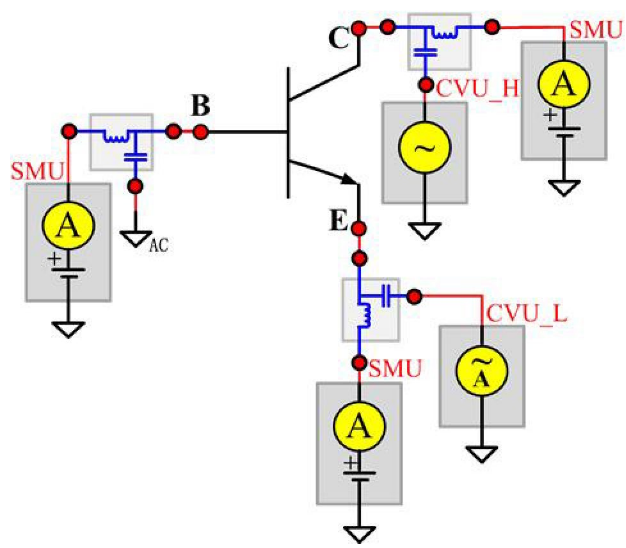
Module name: Cce

DUT: Three-terminal npnBJT

Function: Measures the capacitance between the collector and emitter terminals with the base terminal connected to the ac guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias.

Figure 150: Three-terminal npnBJT Cce pin connections



Ceb

Description:

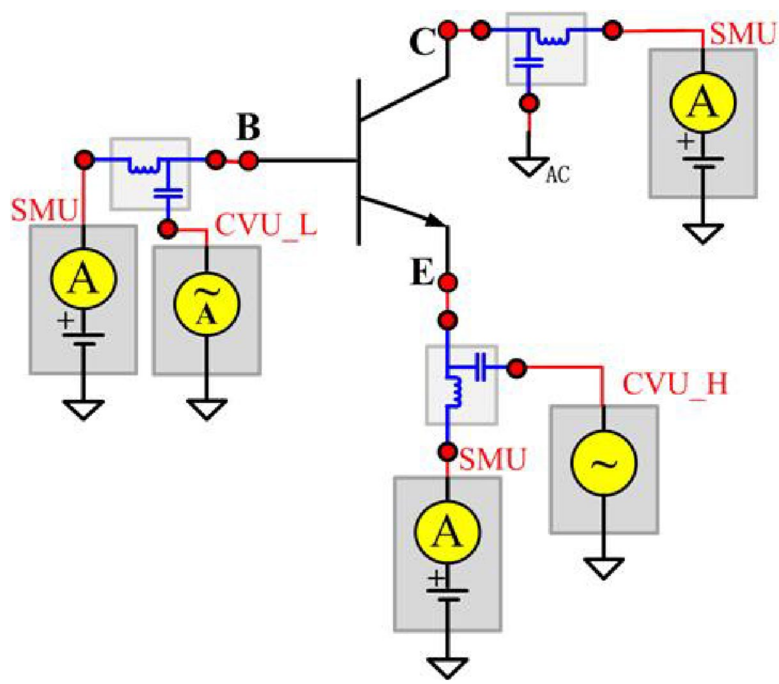
Module name: Ceb

DUT: Three-terminal npnBJT

Function: Measures the capacitance between the emitter and base terminals with the collector terminal connected to the ac guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 151: Three-terminal npnBJT Ceb pin connections



Cibo

Description:

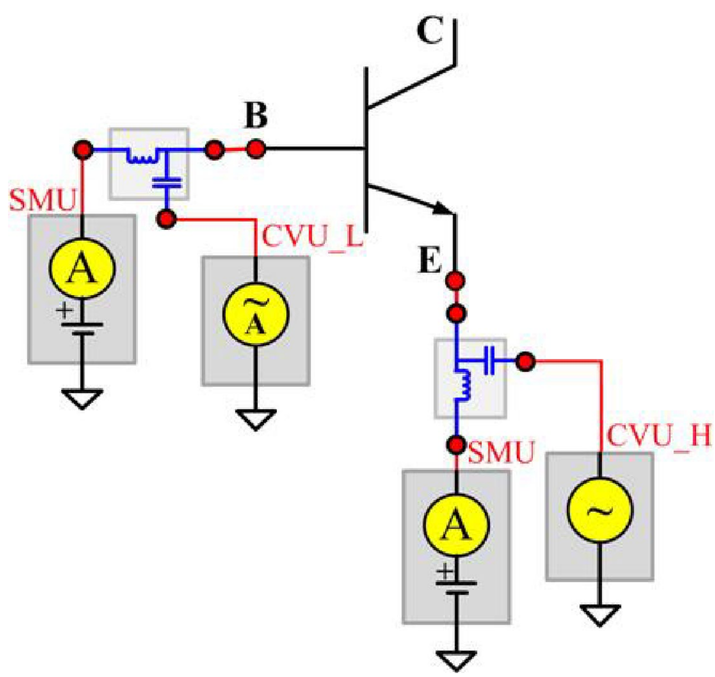
Module name: Cibo

DUT: Three-terminal npnBJT

Function: Measures the capacitance between the input terminals (base and emitter) with the collector terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the AC guard of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 152: Three-terminal npnBJT Cibo pin connections



Cobo

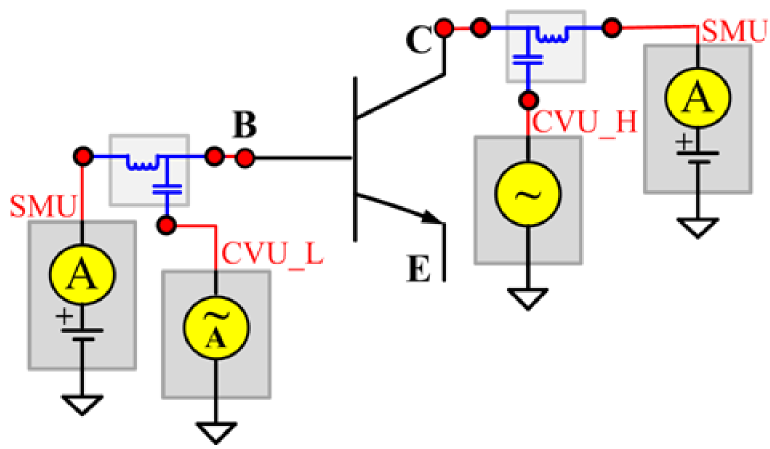
Module Name: Cobo

DUT: Three-terminal npnBJT

Function: Measures the capacitance between the output terminals (base and collector) with the emitter terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Open the circuit to the emitter.

Figure 153: Three-terminal npnBJT Cobo pin connections



pnpBJT test module template

The pnpBJT device parametric test module template is used to test parameters of a pnp-type BJT, including leakage, breakdown, gain, on-state, and characteristic curves.

BVCBO

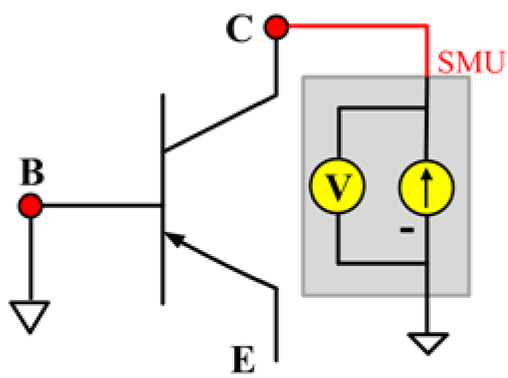
Module name: BVCBO

DUT: Three-terminal BJT

Function: Measures the collector-base breakdown voltage of the BJT with the emitter open.

Pin connections: Use one SMU to force a reverse current to the collector. Open the circuit to the emitter or use a SMU to supply a zero-current bias. Connect the base to GND or use a SMU to supply a zero-voltage bias.

Figure 154: pnpBJT and pnpPowerBJT BVCBO pin connections



BVCEI

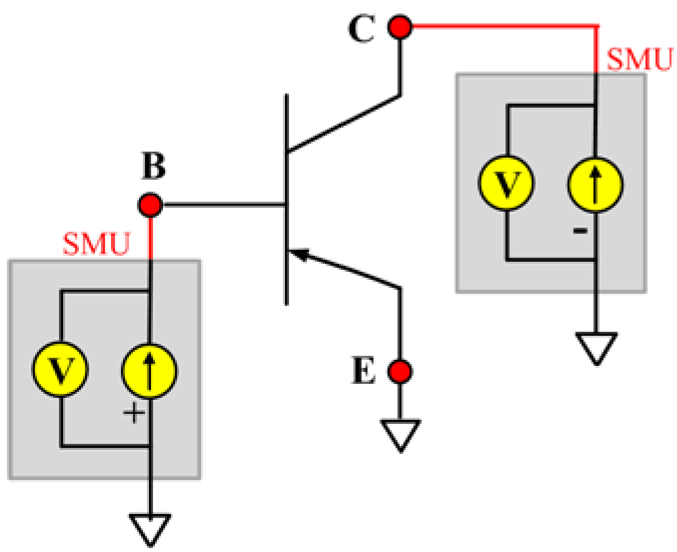
Module name: BVCEI

DUT: Three-terminal pnpBJT

Function: Measures the collector-emitter breakdown voltage of the pnpBJT device with a bias base-forced current.

Pin connections: Use two SMUs to force current to the base and collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 155: Three-terminal pnpBJT BVCEI pin connections



BVCEO

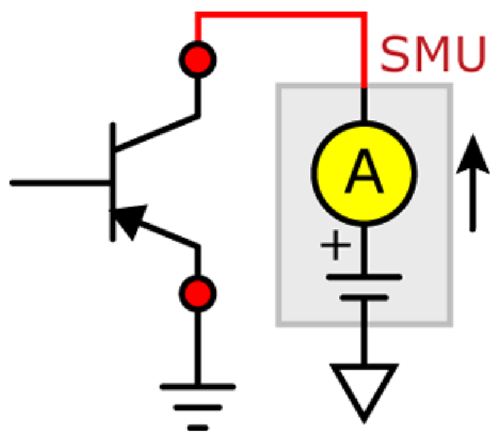
Module name: BVCEO

DUT: Three-terminal pnpBJT

Function: Measures the collector-emitter breakdown voltage with the base opened.

Pin connections: Use a SMU to force current to the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 156: Three-terminal pnpBJT BVCEO pin connections



BVCEV

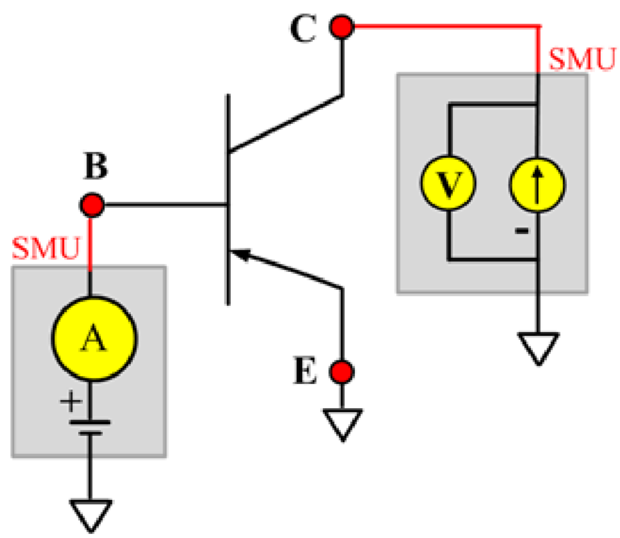
Module name: BVCEV

DUT: Three-terminal pnpBJT

Function: Measures the collector-emitter breakdown voltage with the base forced with a voltage bias.

Pin connections: Use two SMUs to force voltage to the base and collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 157: Three-terminal pnpBJT BVCEV pin connections



BVEBO

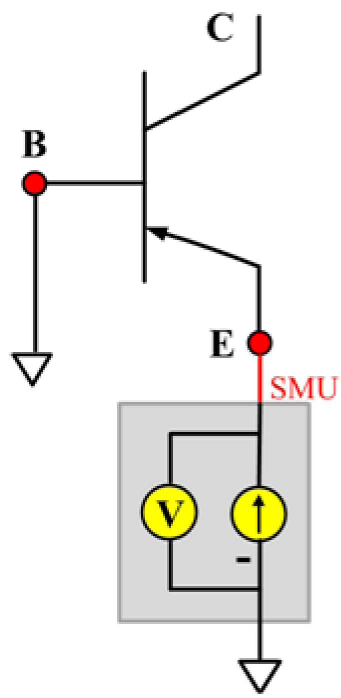
Module name: BVEBO

DUT: Three-terminal pnpBJT

Function: Measures the emitter-base breakdown voltage of the pnpBJT device with the collector opened.

Pin connections: Use a SMU to force current to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 158: Three-terminal pnpBJT BVEBO pin connections



BVECO

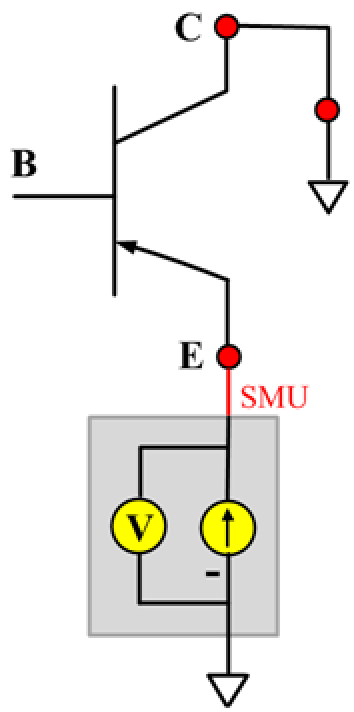
Module name: BVECO

DUT: Three-terminal pnpBJT

Function: Measures the emitter-collector breakdown voltage of the pnpBJT device with the base opened.

Pin connections: Use a SMU to force current to the emitter. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the collector to GND or use a SMU to supply a zero-voltage bias.

Figure 159: Three-terminal pnpBJT BVECO pin connections



HFE

Module name: HFE

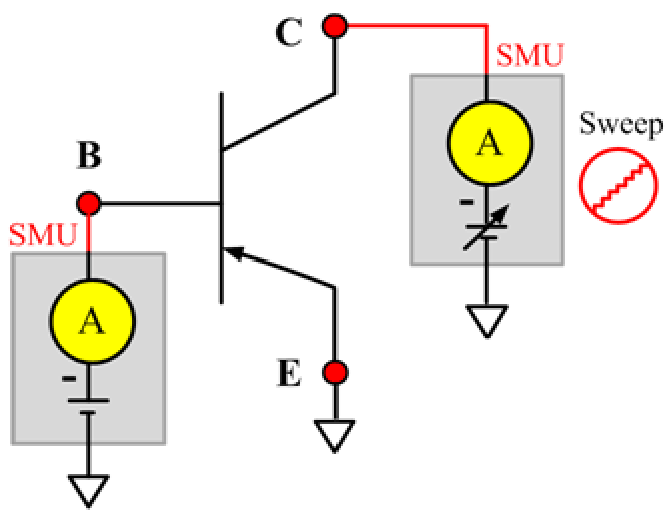
DUT: Three-terminal pnpBJT

Function: Measures the collector current, base current, and dc current gain based on the collector sweep voltage.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

- Force CollectorV sweep
- Measure Ib and Ic
- Check for measurement problems
- Calculate HFE= Ic/Ib

Figure 160: Three-terminal pnpBJT HFE sweep pin connections



IBCO

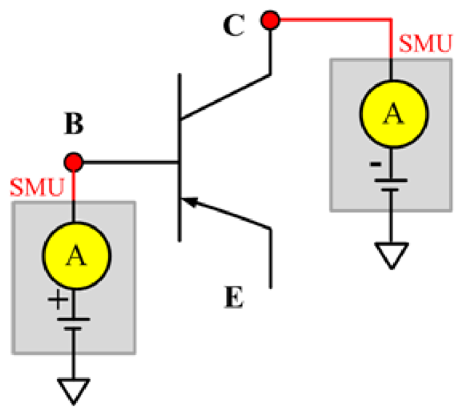
Module name: IBCO

DUT: Three-terminal pnpBJT

Function: Measures the base-collector current with the emitter opened.

Pin connections: Use a SMU to force voltage to the base. Connect the collector to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 161: Three-terminal pnpBJT IBCO pin connections



IBEO

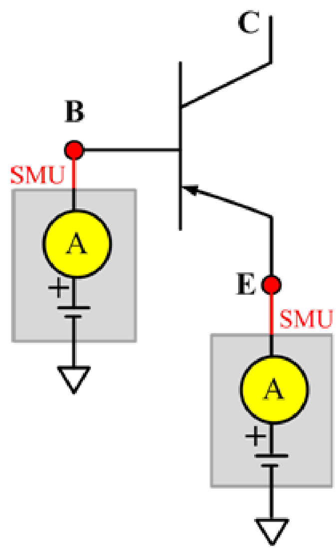
Module name: IBEO

DUT: Three-terminal pnpBJT

Function: Measures the base-emitter current with the collector opened.

Pin connections: Use a SMU to force voltage to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 162: Three-terminal pnpBJT IBEO pin connections



IbIcVbe

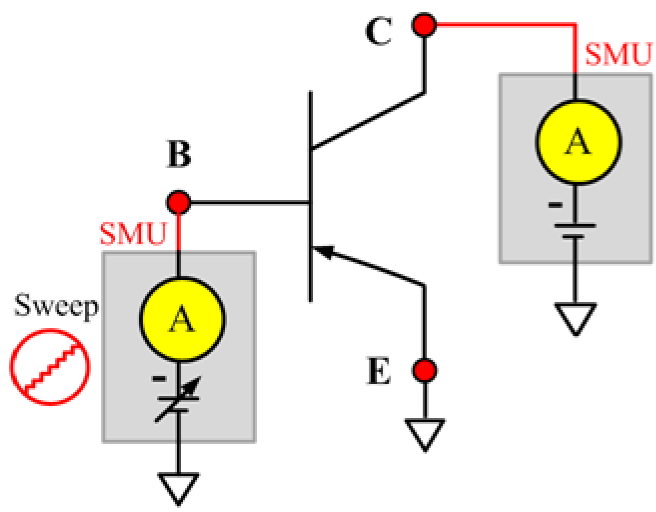
Module name: IbIcVbe

DUT: Three-terminal pnpBJT

Function: Measures the base current and collector current of the pnpBJT device with a specified base voltage sweep, measures the IbVbe and IcVbe curves, and measures the Gummel plot if the axis properties of the data plot have changed (the logarithm instead of right-angle coordinate.

Pin connections: Use a SMU to apply a sweep voltage to the base. Use a SMU to bias the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 163: Three-terminal pnpBJT IbIcVbe pin connections



IbVbe

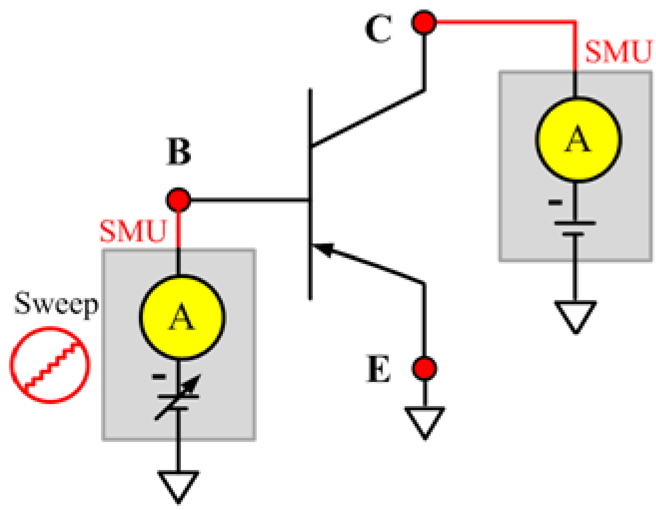
Module name: IbVbe

DUT: Three-terminal pnpBJT

Function: Measures the base current of the pnpBJT device with a specified base voltage sweep and measures the IbVbe curve.

Pin connections: Use a SMU to apply a sweep voltage to the base. Use a SMU to bias the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 164: Three-terminal pnpBJT IbVbe pin connections



ICBO

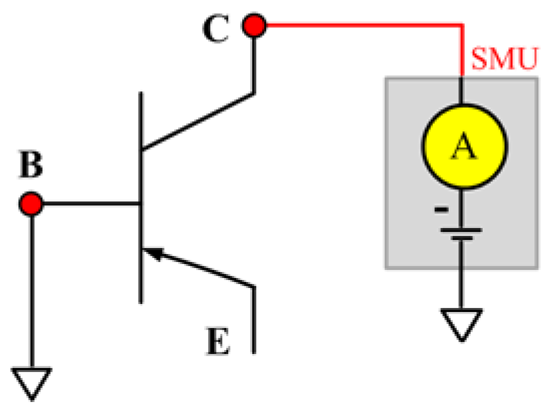
Module name: ICBO

DUT: Three-terminal pnpBJT

Function: Measures the collector-base cut-off current with the emitter opened.

Pin connections: Use a SMU to force voltage to the collector. Connect the base to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 165: Three-terminal pnpBJT ICBO pin connections



ICEO

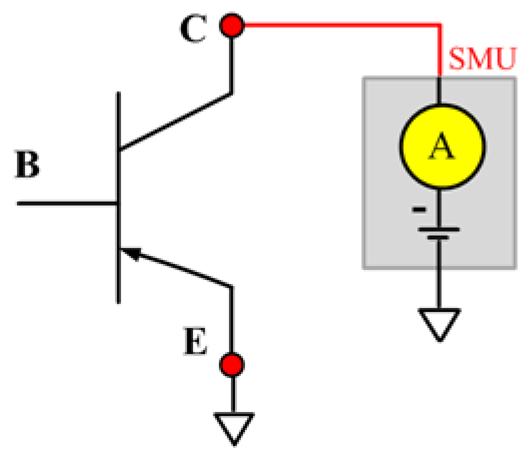
Module name: ICEO

DUT: Three-terminal pnpBJT

Function: Measures the collector-emitter cut-off current with the base opened.

Pin connections: Use a SMU to force voltage to the collector. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 166: Three-terminal pnpBJT ICEO pin connections



ICEV

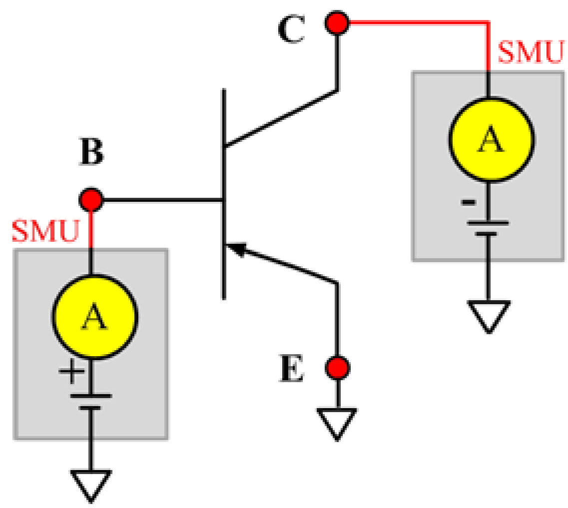
Module name: ICEV

DUT: Three-terminal pnpBJT

Function: Measures the collector-emitter cut off current with the base voltage biased.

Pin connections: Use two SMUs to force voltage to the base and collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 167: Three-terminal pnpBJT ICEV pin connections



IcVcb

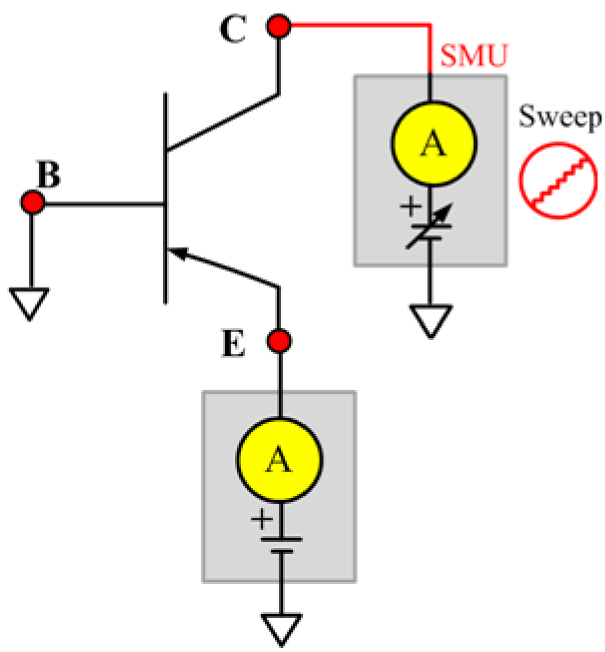
Module name: IcVcb

DUT: Three-terminal pnpBJT

Function: Measures the collector current of the pnpBJT device with a specified collector voltage sweep.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias the emitter. Connect the base to GND or use a SMU to supply a zero-voltage bias.

Figure 168: Three-terminal pnpBJT IcVcb pin connections



IcVce_BiasIb

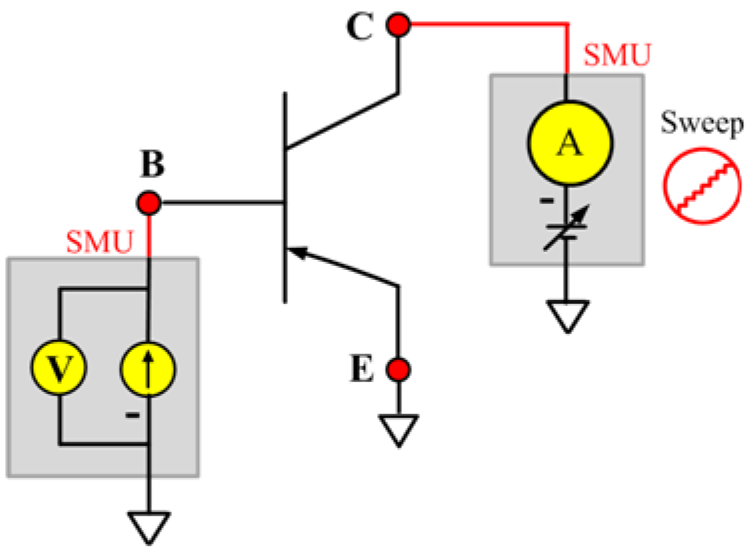
Module name: IcVce_BiasIb

DUT: Three-terminal pnpBJT

Function: Measures the collector current based on the base bias current and collector sweep voltage and measure the IcVce curve.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias current to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 169: Three-terminal pnpBJT IcVce_BiasIb pin connections



IcVce_BiasVb

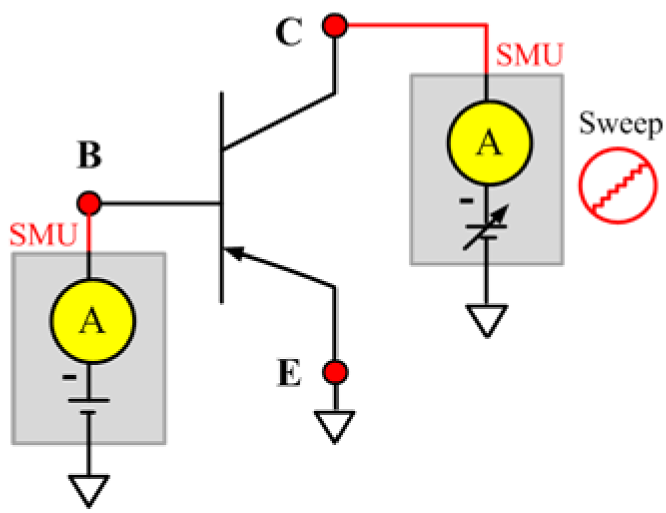
Module name: IcVce_BiasVb

DUT: Three-terminal pnpBJT

Function: Measures the collector current based on the base bias voltage and the collector sweep voltage and measures the IcVce curve.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to bias voltage to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 170: Three-terminal pnpBJT IcVce BiasVb pin connections



IcVce_StepIb

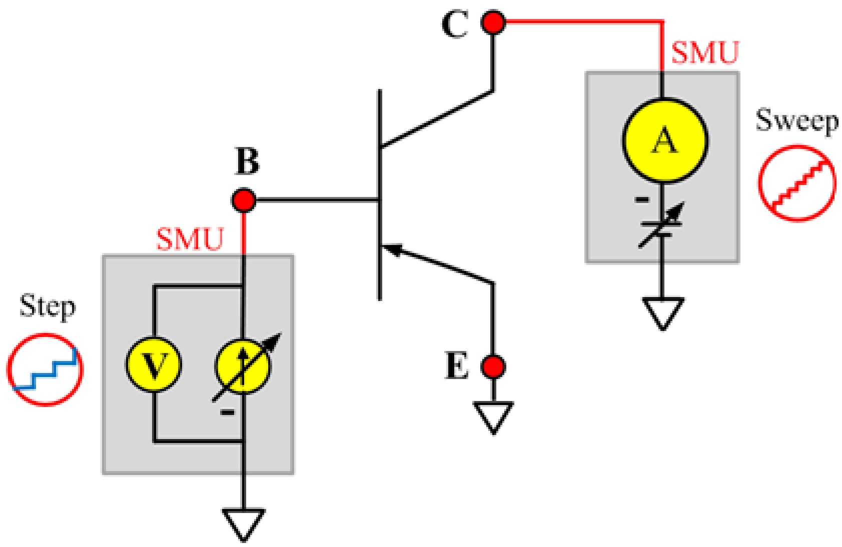
Module name: IcVce_StepIb

DUT: Three-terminal pnpBJT

Function: Measures the collector current based on the base step current and the collector sweep voltage and measures the series of IcVce curves with a base current step.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to step current to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 171: Three-terminal pnpBJT IcVce StepIb pin connections



IcVce_StepVb

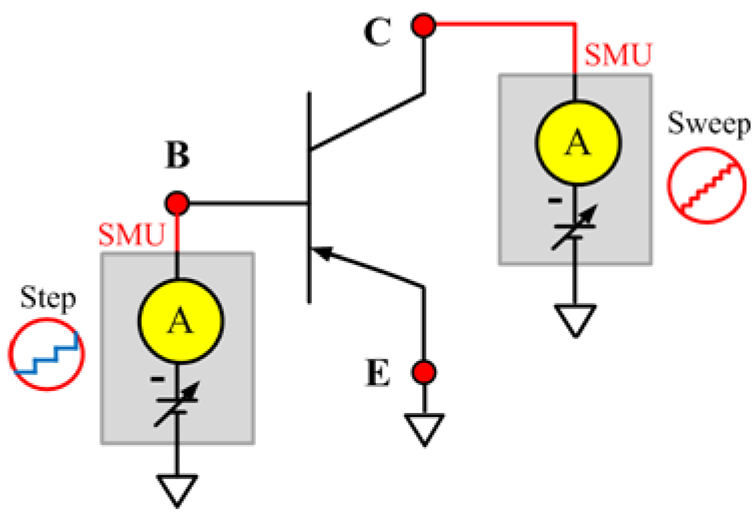
Module name: IcVce_StepVb

DUT: Three-terminal pnpBJT

Function: Measures the collector current based on base step and the collector sweep voltage and measures the series of IcVce curves with at base voltage step.

Pin connections: Use a SMU to apply a sweep voltage to the collector. Use a SMU to apply a step voltage to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 172: Three-terminal pnpBJT IcVce_StepVb pin connections



IEBO

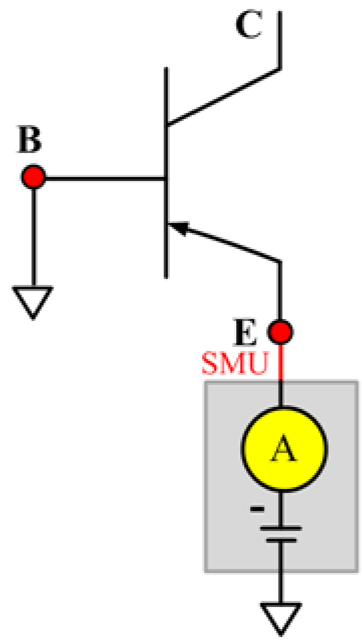
Module name: IEBO

DUT: Three-terminal pnpBJT

Function: Measures the emitter-base cut off current with the collector opened.

Pin connections: Use a SMU to force voltage to the emitter. Connect the base to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 173: Three-terminal pnpBJT IEBO pin connections



IECO

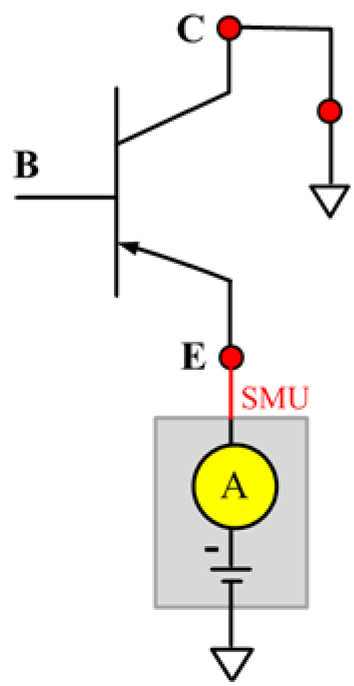
Module name: IECO

DUT: Three-terminal pnpBJT

Function: Measures the emitter-collector current with the base opened.

Pin connections: Use a SMU to force voltage to the emitter. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the collector to GND or use a SMU to supply a zero-voltage bias.

Figure 174: Three-terminal pnpBJT IECO pin connections



IeVeb

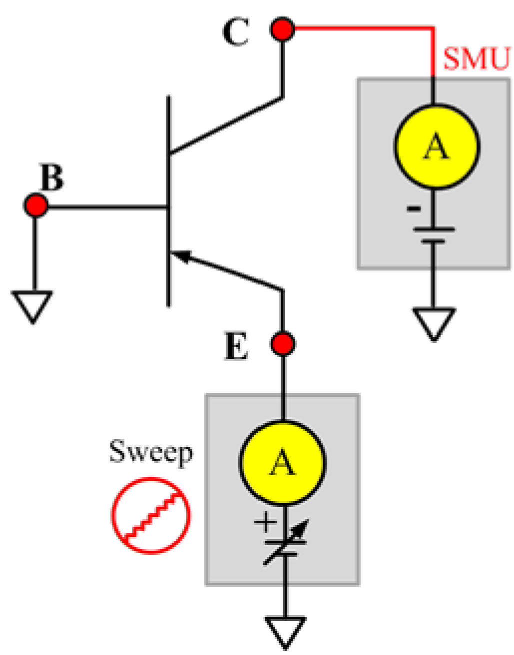
Module name: IeVeb

DUT: Three-terminal pnpBJT

Function: Measures the emitter current based on the emitter voltage sweep and measures the IeVeb curves.

Pin connections: Use a SMU to force voltage to the emitter. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the collector to GND or use a SMU to supply a zero-voltage bias.

Figure 175: Three-terminal pnpBJT IeVeb pin connections



VBCO

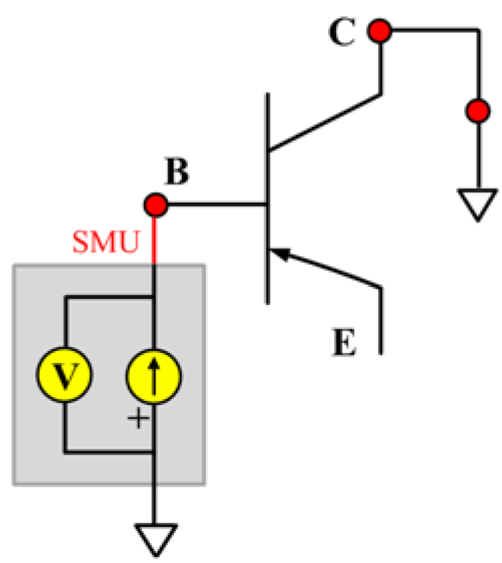
Module name: VBCO

DUT: Three-terminal pnpBJT

Function: Measures the base-collector voltage of the pnpBJT device with the emitter opened.

Pin connections: Use a SMU to apply a bias current to the base. Open the circuit to the emitter or use a SMU to supply a zero-current bias. Connect the collector to GND or use a SMU to supply a zero-voltage bias.

Figure 176: Three-terminal pnpBJT VBCO pin connections



VCE

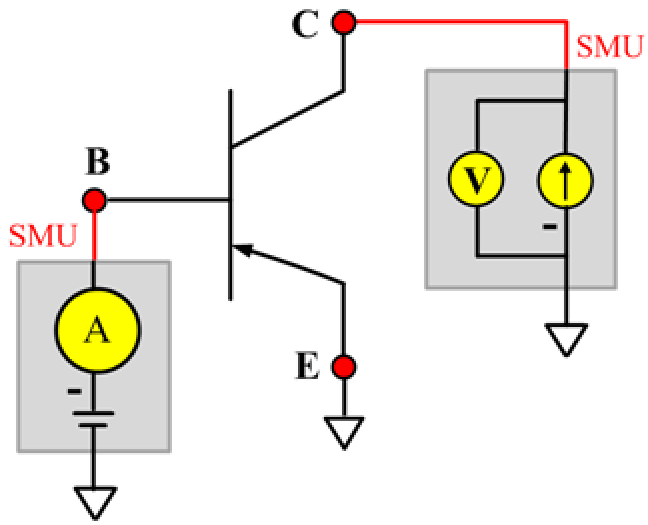
Module name: VCE

DUT: Three-terminal pnpBJT

Function: Measures the collector-emitter voltage of the pnpBJT device.

Pin connections: Use a SMU to apply bias current to the collector. Use a SMU to apply bias voltage to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 177: Three-terminal pnpBJT VCE pin connections



Ccb

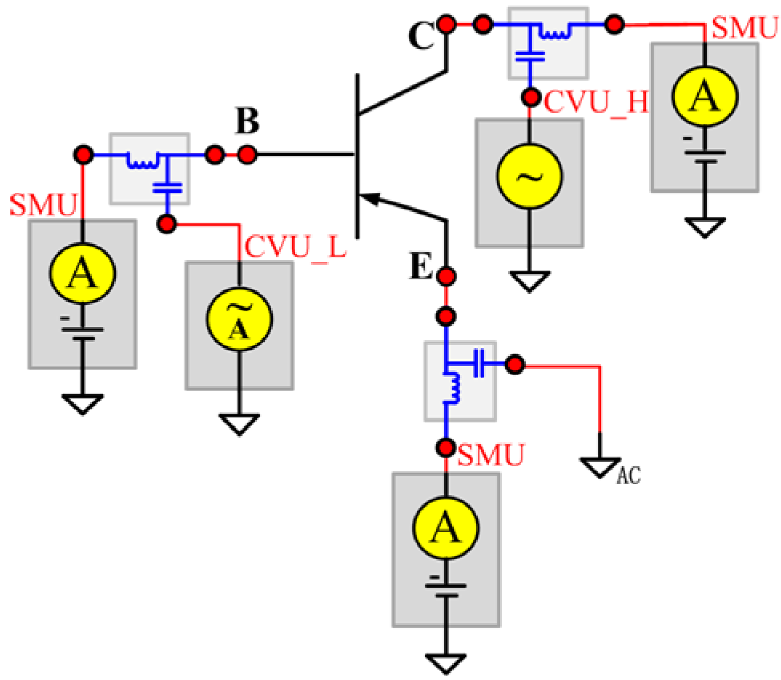
Module Name: Ccb

DUT: Three-terminal pnpBJT

Function: Measures the capacitance between the Collector and Base terminals with the Emitter terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias.

Figure 178: Three-terminal pnpBJT Ccb pin connections



Cce

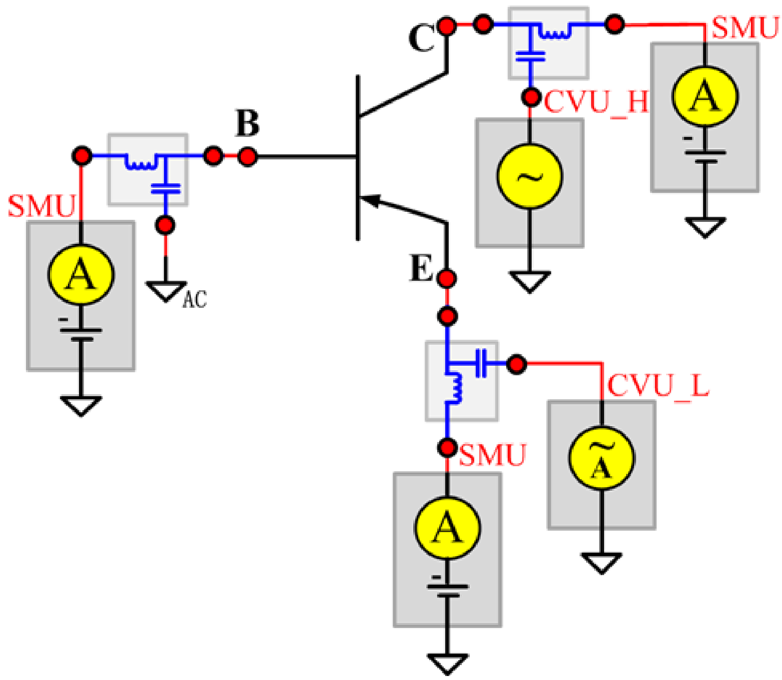
Module Name: Cce

DUT: Three-terminal pnpBJT

Function: Measures the capacitance between the collector and emitter terminals with the base terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias.

Figure 179: Three-terminal pnpBJT Cce pin connections



Ceb

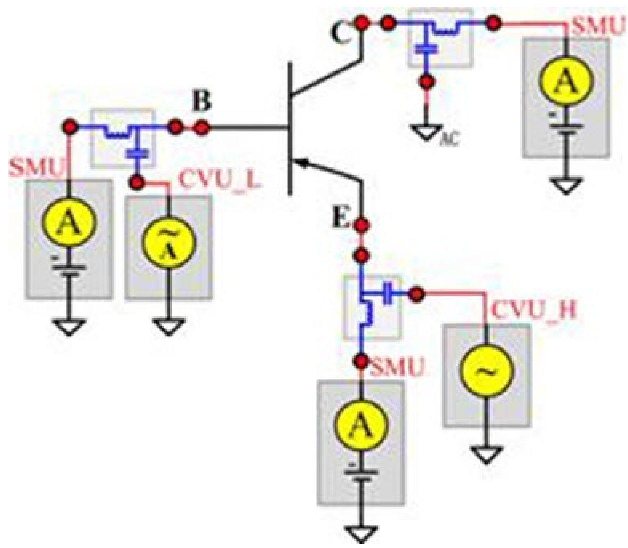
Module Name: Ceb

DUT: Three-terminal pnpBJT

Function: Measures the capacitance between the emitter and base terminals with the collector terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 180: Three-terminal pnpBJT Ceb pin connections



Cibo

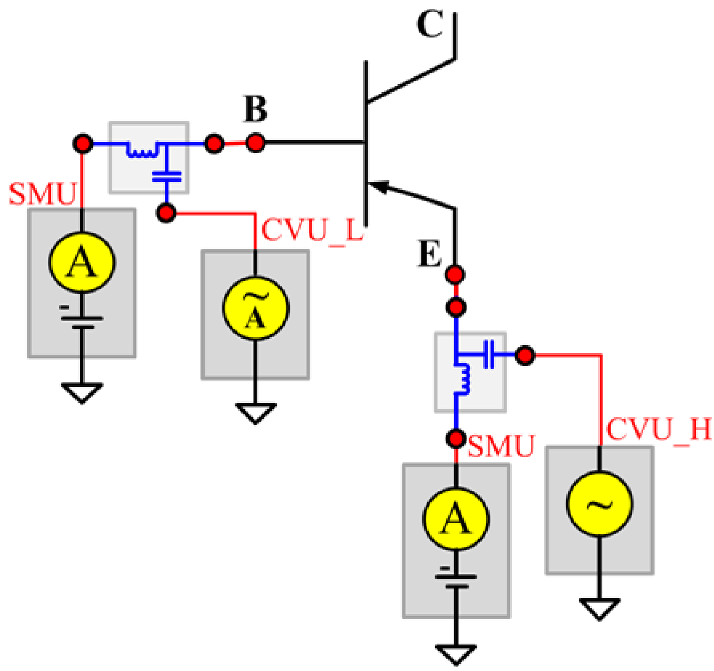
Module Name: Cibo

DUT: Three-terminal pnpBJT

Function: Measures the capacitance between the input terminals (base and emitter) with the collector terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 181: Three-terminal pnpBJT Cibo pin connections



Cobo

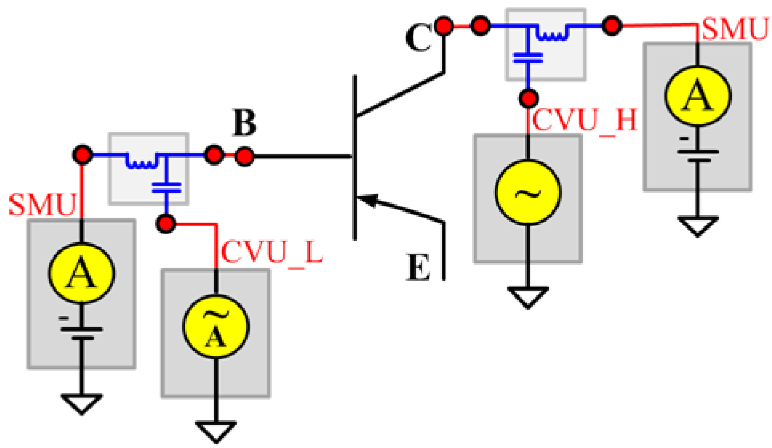
Module Name: Cobo

DUT: Three-terminal pnpBJT

Function: Measures the capacitance between the output terminals (base and collector) with the emitter terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Open the circuit to the emitter.

Figure 182: Three-terminal pnpBJT Cobo pin connections



npnPowerBJT library

This npnPowerBJT parametric test module template is used to test parameters of a npn-type power BJT, including leakage, breakdown, gain, on-state, and characteristic curves.

BVCBO

Module name: BVCBO

Module type: ITM

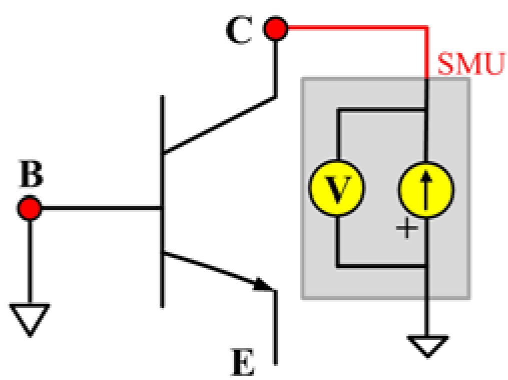
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-base breakdown voltage with the emitter opened. The voltage is measured with a specific collector current that is given in the datasheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the base. Connect the base to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the emitter or use a SMU to supply a zero-current bias.

Figure 183: npnPowerBJT BVCBO pin connections



BVCEO

Module name: BVCEO

Test type: ITM

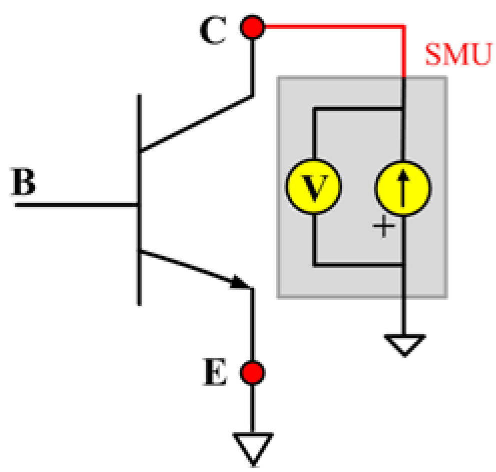
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter breakdown voltage with the base opened. The voltage is measured with a specific collector current that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to emitter. Connect the emitter to GND or use a SMU to supply a zero-current bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 184: npnPowerBJT BVCEO pin connections



BVEBO

Module name: BVEBO

Test type: ITM

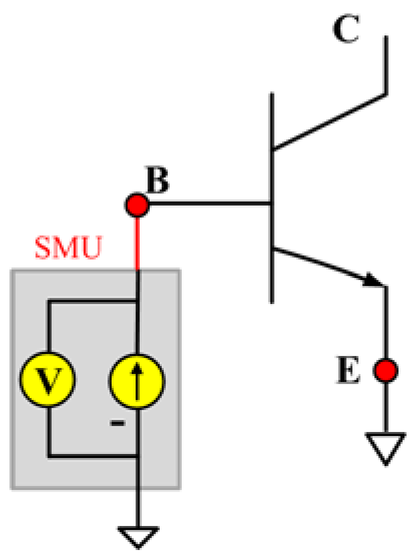
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the emitter-base breakdown voltage with the collector opened. The voltage is measured with a specific base current or emitter current in reverse direction that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the base to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 185: npnPowerBJT BVEBO pin connections



HFE

Module name: HFE

Test type: ITM

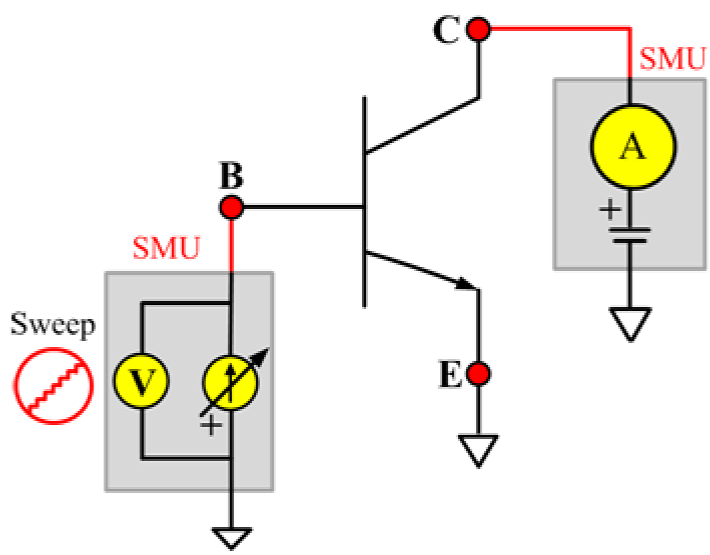
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter static forward current transfer ratio with the output voltage (Vce) held constant (HFE = Ic/Ib).

Pin connections: Use one SMU to apply voltage bias and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply a sweep current to the base.

Figure 186: npnPowerBJT HFE pin connections



ICBO

Description:

Module name: ICBO

Module type: ITM

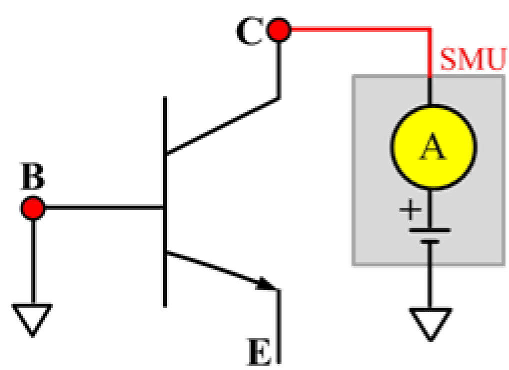
Instrument: KI2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-base cut-off current. Measures the current on the collector with a reverse bias on the collector-base and with the emitter opened.

Pin connections: One SMU is used. The SMU applies voltage and takes current measurements from the collector to base. The emitter is opened or has no current bias from a SMU.

Figure 187: npnPowerBJT ICBO pin connections



ICEO

Module name: ICEO

Module type: ITM

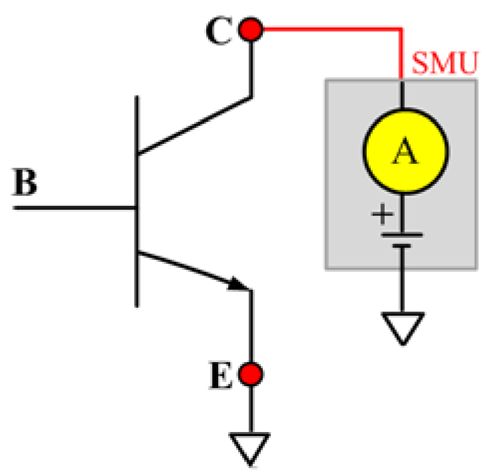
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter cut-off current with the base opened.

Pin connections: Use a SMU to force voltage and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 188: npnPowerBJT ICEO pin connections



ICES

Module name: ICES

Test type: ITM

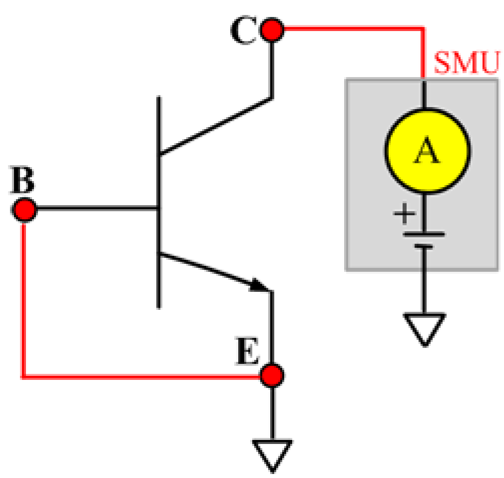
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter cut-off current with the base short-circuited to the emitter.

Pin connections: Use a SMU to force voltage and make a current measurement from the collector to the emitter. Short the base to the emitter or use a SMU to supply a zero-voltage bias.

Figure 189: npnPowerBJT ICES pin connections



ICEV

Module name: ICEV

Test type: ITM

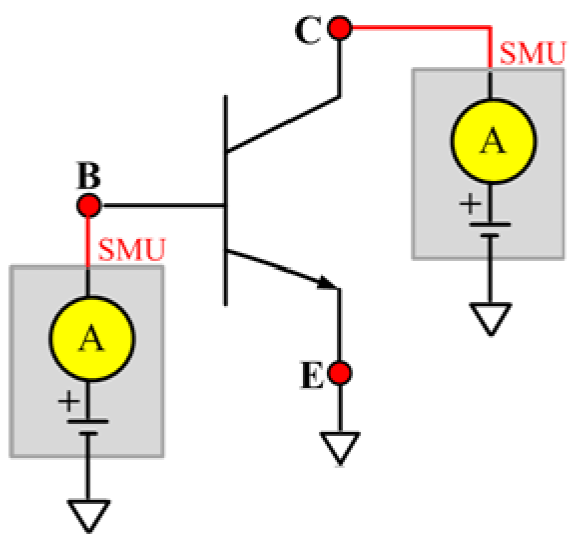
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter cut-off current with a reverse bias on the emitter-base.

Pin connections: Use a SMU to force voltage and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use another SMU to bias the base with a specified voltage.

Figure 190: npnPowerBJT ICEV pin connections



IcVce_StepIb

Module name: IcVce_StepIb

Module type: ITM

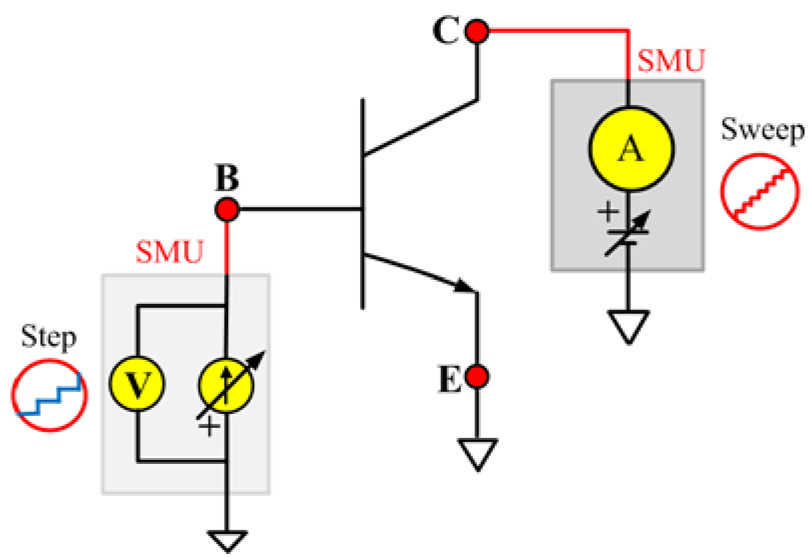
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter output characteristic curve with a current step at the base.

Pin connections: Use one SMU to apply a voltage sweep and make a current measurement from collector to emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply a current step to the base.

Figure 191: npnPowerBJT IcVce_StepIb pin connections



IcVce_StepVbe

Module name: IcVce_StepVbe

Test type: ITM

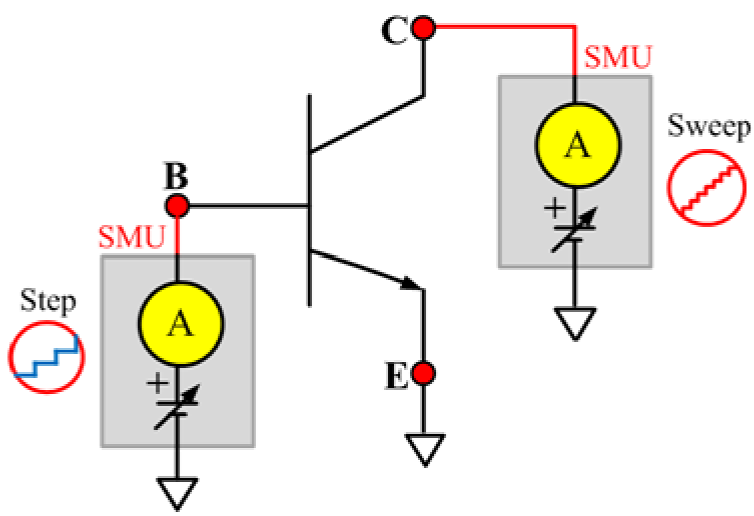
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter output characteristic curve with a voltage step at the base.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from collector to emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply a voltage step to the base-emitter junction.

Figure 192: npnPowerBJT IcVce_StepVbe pin connections



IEBO

Module name: IEBO

Test type: ITM

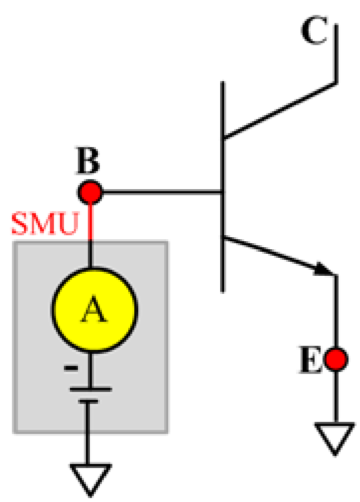
Instrument: Keithley Instruments Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the emitter-base cut-off current. Measures the current on the emitter with reverse bias on the emitter-base and with the collector opened.

Pin connections: Use a SMU to force voltage and make a current measurement from the base to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the collector or use a SMU to supply a zero-current bias.

Figure 193: npnPowerBJT IEBO pin connections



VbeON

Module name: VbeON

Test type: ITM

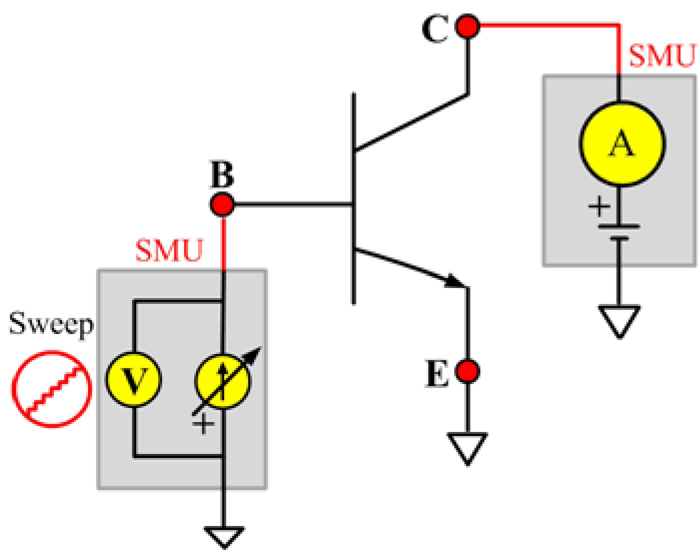
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the on voltage of the base-emitter when the BJT is in the active region. The voltage is measured with the base-emitter forward biased and the collector-emitter voltage higher than the VceSAT.

Pin connections: Use a SMU to apply a current sweep and make a voltage measurement from the base to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply voltage bias to the collector.

Figure 194: npnPowerBJT VbeON pin connections



VbeSAT

Module name: VbeSAT

Test type: ITM

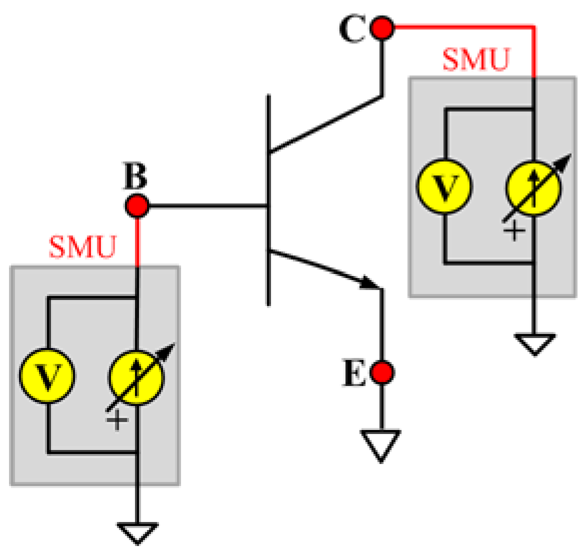
Instrument: Keithley Instruments Models 2651A, Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the base-emitter saturation voltage. The voltage is measured at a specific base current and a collector current that is given in the data sheet to ensure that both the emitter-base and collector-base junctions are forward biased.

Pin connection: Use a SMU to force current and make a voltage measurement from the base to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use one SMU to apply current bias to the collector.

Figure 195: npnPowerBJT VbeSAT pin connections



VceSAT

Module name: VceSAT

Test type: ITM

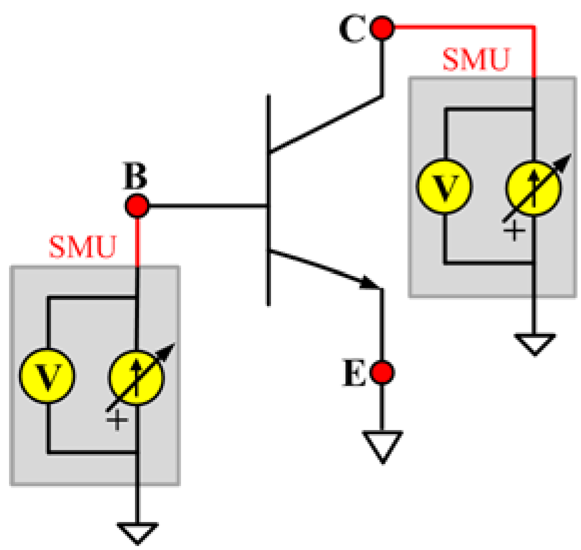
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter saturation voltage. The voltage is measured at a specific base current and collector current that is given in the data sheet to ensure that both the emitter-base and collector-base junctions are forward biased.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply a current bias to the base.

Figure 196: npnPowerBJT VceSAT pin connections



VCESUS

Module name: VCESUS

Test type: ITM

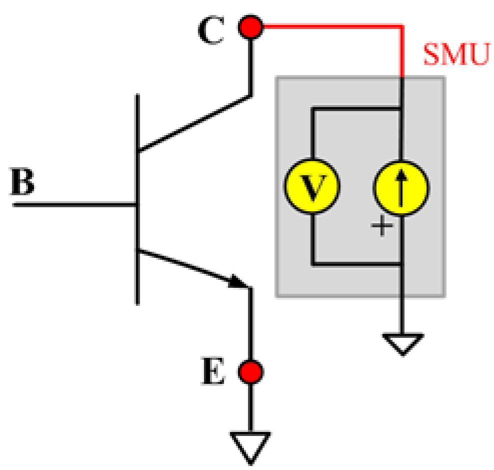
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter sustaining voltage with the base opened. The voltage is measured at a specific collector current that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Open the circuit to the base or use a SMU to supply a zero-current bias.

Figure 197: npnPowerBJT VCESUS pin connections



VceSAT_MIX

Module name: VceSAT_MIX

Module type: PTM

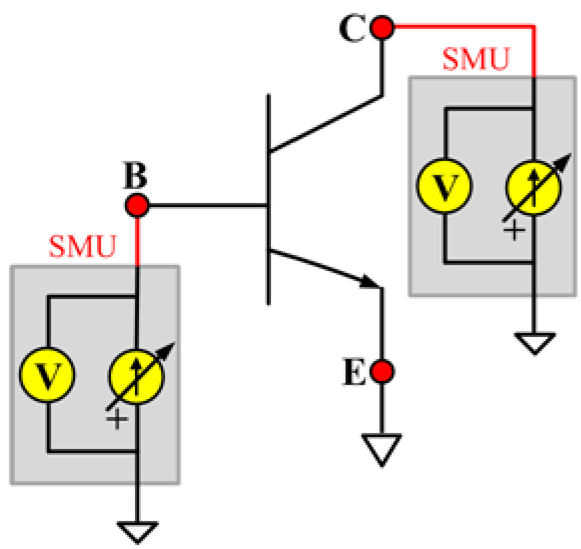
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter saturation voltage. The voltage is measured at a specific base current and collector current that is given in the data sheet to ensure that both the emitter-base and collector-base junctions are forward biased.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply current bias to the base.

Figure 198: npnPowerBJT VceSAT_MIX pin connections



IcVce_StepIb_MIX

Module name: IcVce_StepIb_MIX

Test type: PTM

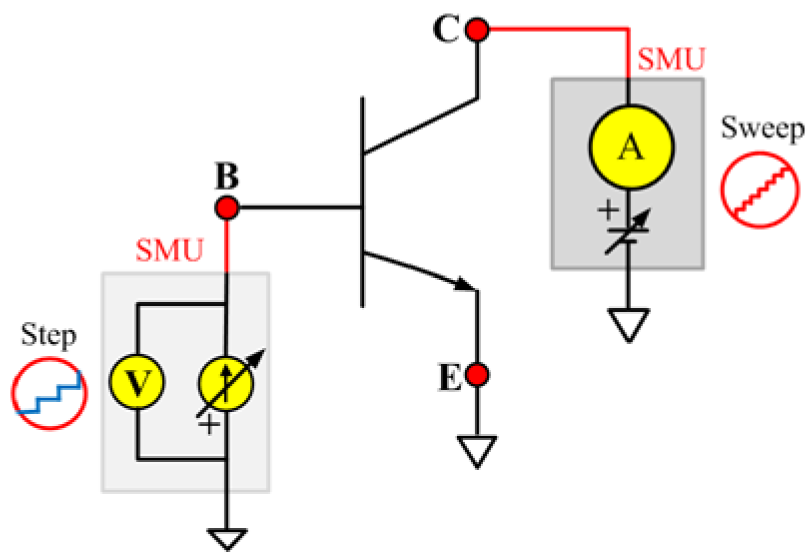
Instrument: Keithley Instruments Model 2657A, and Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter output characteristic curve with a current step at the base.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply current step to base.

Figure 199: npnPowerBJT IcVce_StepIb_MIX pin connections



IcVce_StepVbe_MIX

Module name: IcVce_StepVbe

Module type: PTM

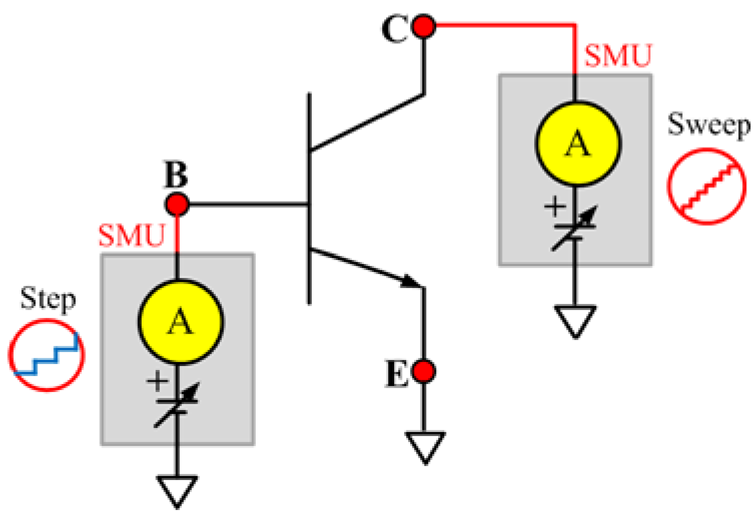
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal npnPowerBJT

Function: Measures the collector-emitter output characteristic curve with a voltage step on the emitter-base junction.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply a voltage step to the base-emitter junction.

Figure 200: npnPowerBJT IcVce_StepVbe_MIX pin connections



Ccb

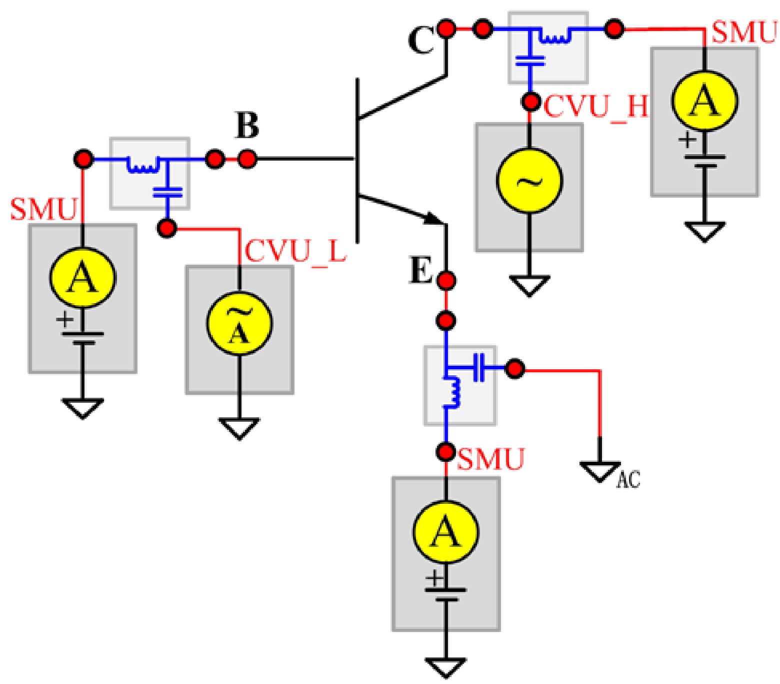
Module Name: Ccb

DUT: Three-terminal npnPowerBJT

Function: Measures the capacitance between the Collector and Base terminals with the Emitter terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias.

Figure 201: Three-terminal npnPowerBJT Ccb pin connections



Cce

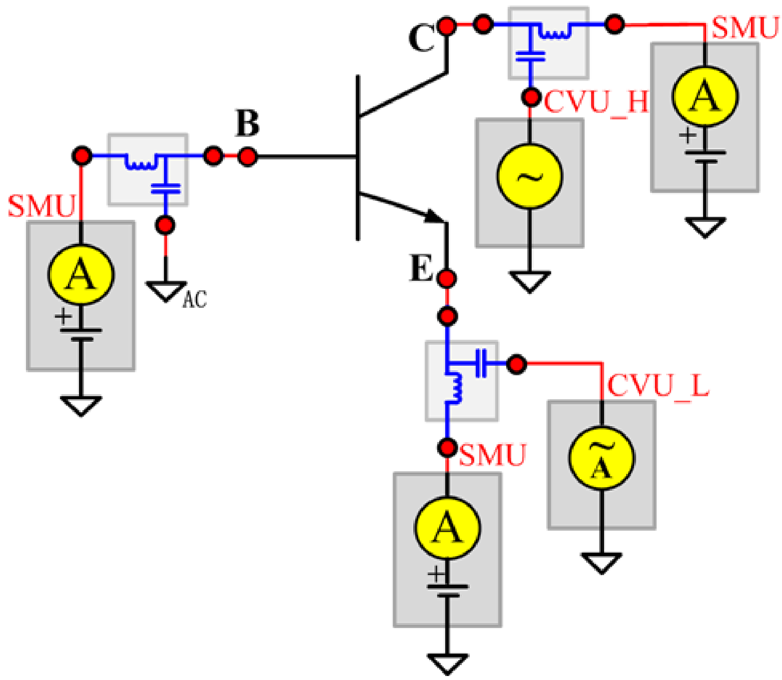
Module Name: Cce

DUT: Three-terminal npnPowerBJT

Function: Measures the capacitance between the collector and emitter terminals with the base terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias.

Figure 202: Three-terminal npnPowerBJT Cce pin connections



Ceb

Description:

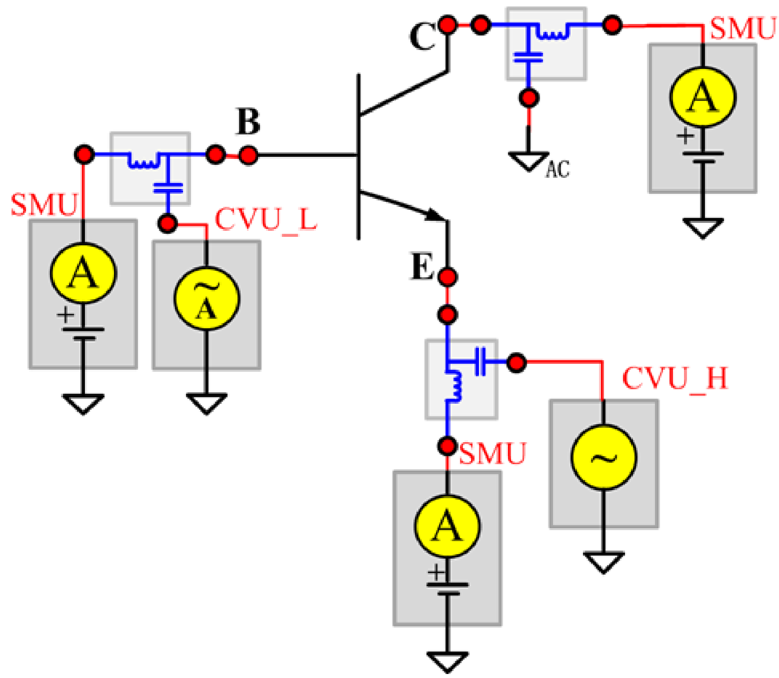
Module Name: Ceb

DUT: Three-terminal npnPowerBJT

Function: Measures the capacitance between the emitter and base terminals with the collector terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 203: Three-terminal npnPowerBJT Ceb pin connections



Cibo

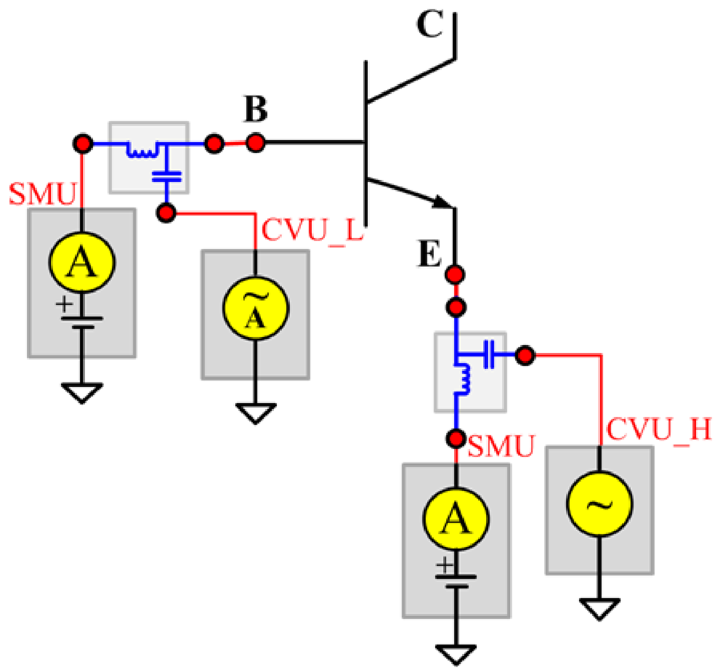
Module Name: Cibo

DUT: Three-terminal npnPowerBJT

Function: Measures the capacitance between the input terminals (base and emitter) with the collector terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 204: Three-terminal npnPowerBJT Cibo pin connections



Cobo

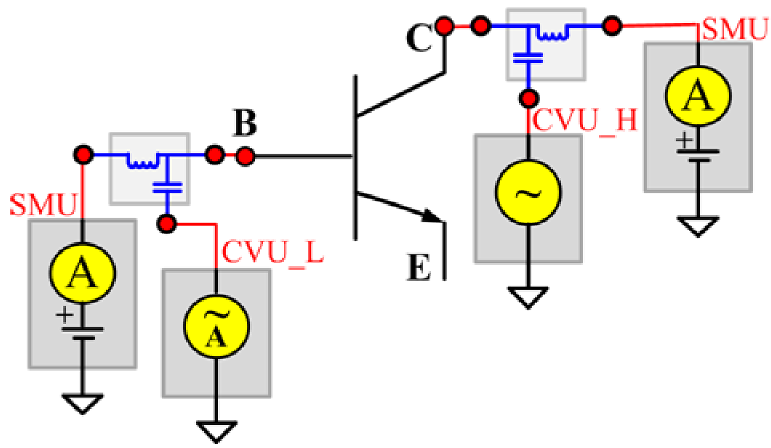
Module Name: Cobo

DUT: Three-terminal npnPowerBJT

Function: Measures the capacitance between the output terminals (base and collector) with the emitter terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Open the circuit to the emitter.

Figure 205: Three-terminal npnPowerBJT Cobo pin connections



pnpPowerBJT test module template

The pnpPowerBJT parametric test module template is used to test parameters of a pnp-type power BJT, including leakage, breakdown, gain, on-state and characteristic curves.

BVCBO

Module name: BVCBO

Test type: ITM

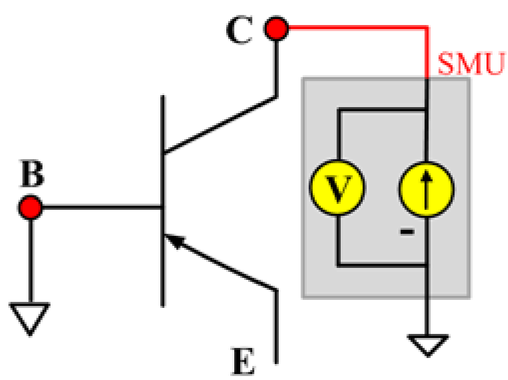
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector base breakdown voltage with the emitter opened. The voltage is measured with a specific collector current that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to base. Open the circuit to the emitter or use a SMU to supply a zero-current bias. Connect the base to GND or use a SMU to supply a zero-voltage bias.

Figure 206: pnpBJT and pnpPowerBJT BVCBO pin connections



BVCEO

Module name: BVCEO

Test type: ITM

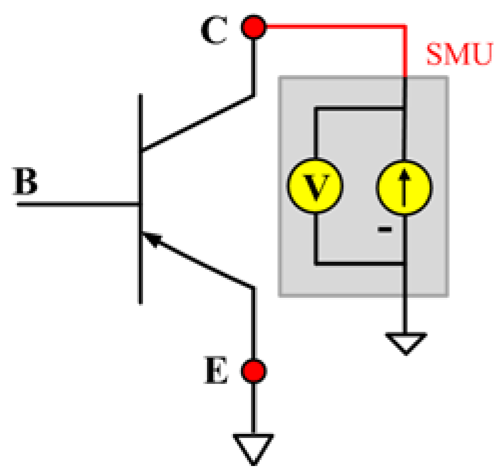
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter breakdown voltage with the base opened. The voltage is measured with a specific collector current that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to emitter. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 207: pnpPowerBJT BVCEO pin connections



BVEBO

Module name: BVEBO

Test type: ITM

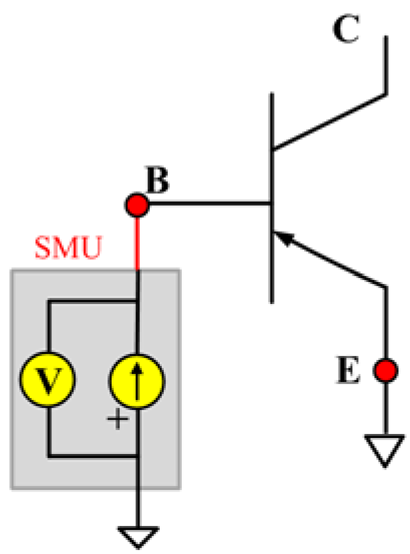
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the emitter-base breakdown voltage with the collector opened. The voltage is measured with a specific base current or emitter current in a reverse direction that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the base to the emitter. Open the circuit to the collector or use a SMU to supply a zero-current bias. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 208: pnpPowerBJT BVEBO pin connections



HFE

Module name: HFE

Module type: ITM

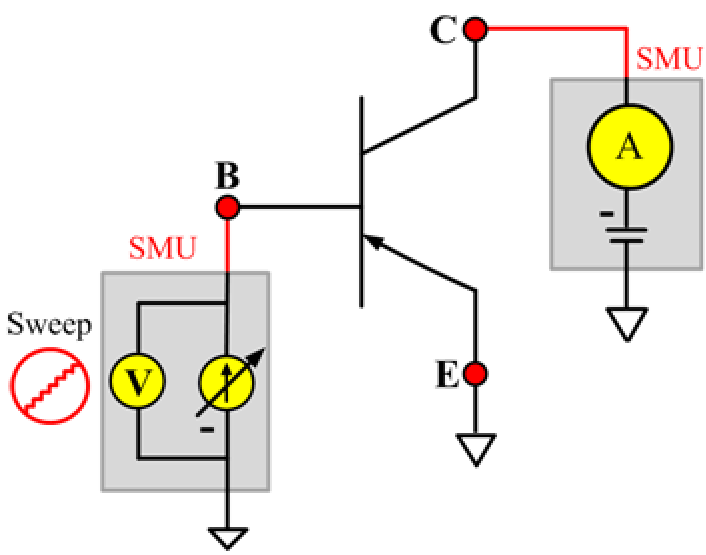
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter static forward current transfer ratio with the output voltage (Vce) held constant (HFE = Ic/Ib).

Pin connections: Use a SMU to apply voltage bias and make current measurements from the collector to the emitter. Use another SMU to apply a current sweep at the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 209: pnpPowerBJT HFE pin connections



ICBO

Description:

Module name: ICBO

Module type: ITM

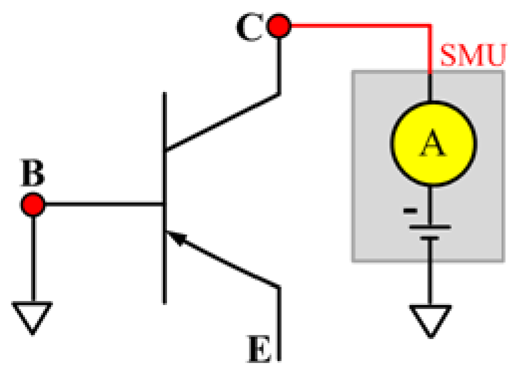
Instrument: KI2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-base cut-off current. Measures the current on the collector by reverse biasing the collector-base and with the emitter opened.

Pin connections: One SMU is used. The SMU applies voltage and takes current measurements from the collector to base. The emitter is open.

Figure 210: pnpPowerBJT ICBO pin connections



ICEO

Module name: ICEO

Test type: ITM

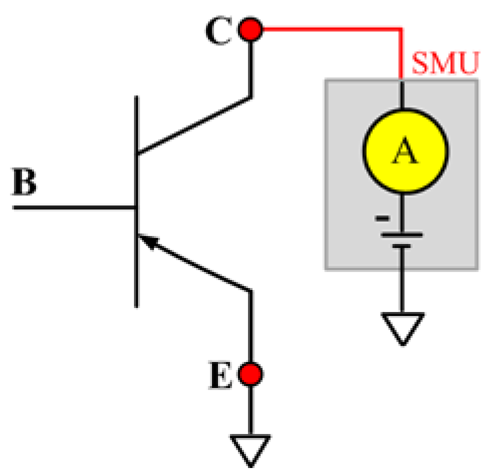
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter cut-off current with the base opened.

Pin connections: Use a SMU to force voltage and make a current measurement from the collector to the emitter. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 211: pnpPowerBJT ICEO pin connections



ICES

Module name: ICES

Test type: ITM

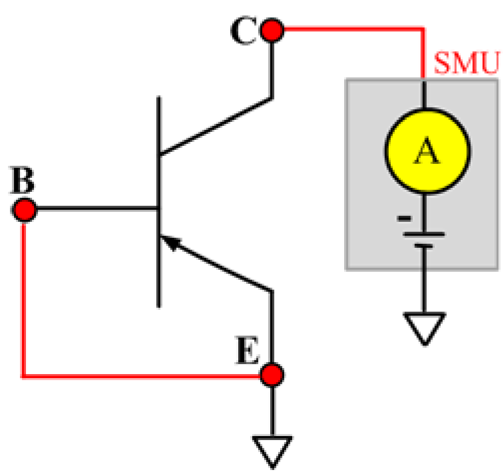
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter cut-off current with the base shorted to the emitter.

Pin connections: Use a SMU to force voltage and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Short the base to the emitter or use a SMU to supply a zero-voltage bias.

Figure 212: pnpPowerBJT ICES pin connections



ICEV

Module name: ICEV

Test type: ITM

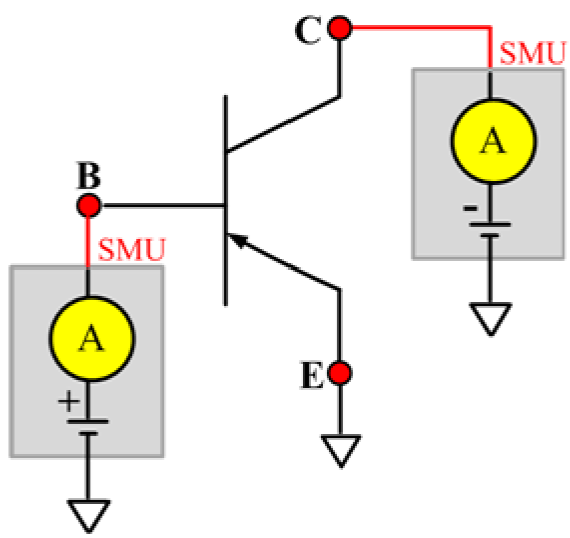
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter cut-off current with reverse biasing at the emitter-base junction.

Pin connections: Use a SMU to force voltage and make a current measurement from the collector to the emitter. Use a SMU to bias the base with a specified voltage. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 213: pnpPowerBJT ICEV pin connections



IcVce_StepIb

Module name: IcVce_StepIb

Test type: ITM

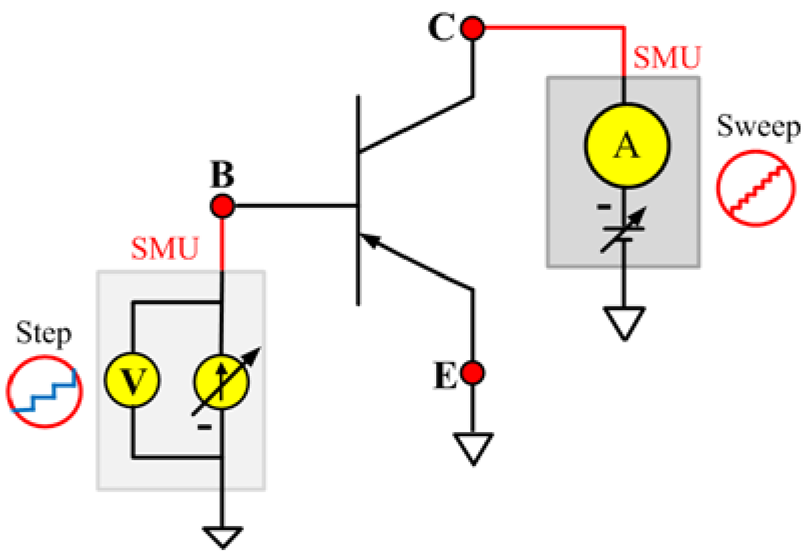
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter output characteristic curve with the current step at the base.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from the collector to the emitter. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 214: pnpPowerBJT IcVce_StepIb pin connections



IcVce_StepVbe

Module name: IcVce_StepVbe

Test type: ITM

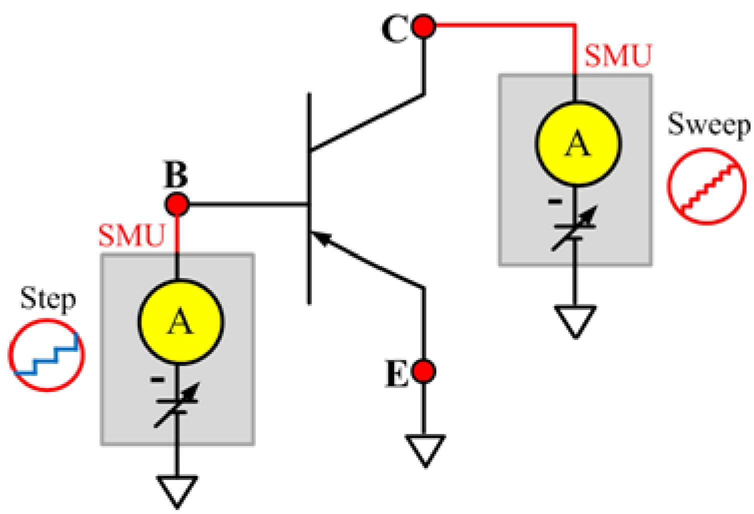
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter output characteristic curve with a current step at the base.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from the collector to the emitter. Use another SMU to apply a current step to the Base-Emitter junction. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 215: pnpPowerBJT IcVce_StepVbe pin connections



IEBO

Module name: IEBO

Test type: ITM

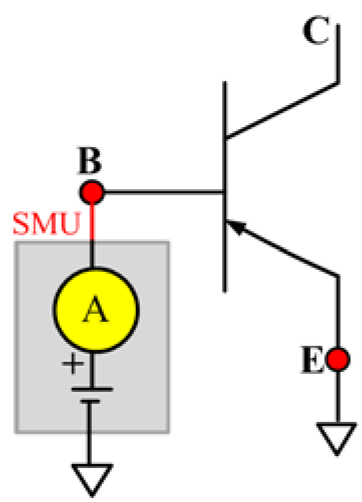
Instrument: Keithley Instruments Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the emitter-base cut-off current. Measures the current on the emitter by reverse biasing the emitter-base junction with the collector opened.

Pin connections: Use a SMU to force voltage and make a current measurement from the base to emitter. Open the circuit to the collector or use a SMU to supply a zero-current bias. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 216: pnpPowerBJT IEBO pin connections



VbeON

Module name: VbeON

Test type: ITM

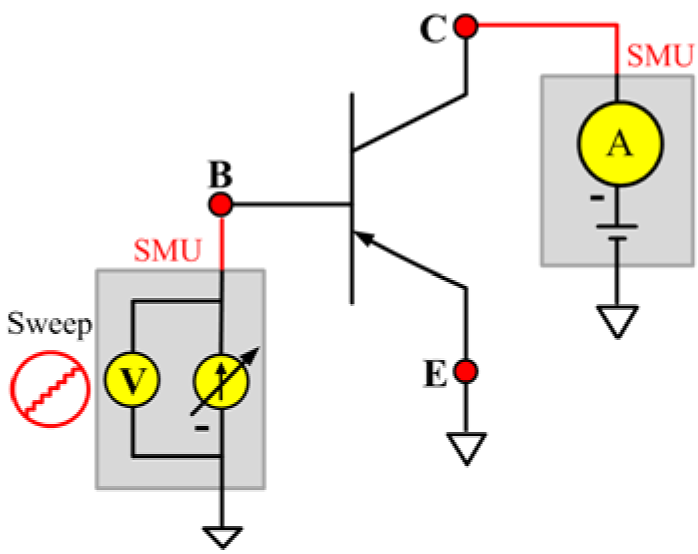
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the base-emitter junction on voltage when the BJT is in an active region. The voltage is measured with the base-emitter junction forward biased and the collector emitter voltage higher than the VceSAT.

Pin connections: Use a SMU to apply a sweep current and make a voltage measurement from base to emitter. Use another SMU to apply a voltage bias to the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 217: pnpPowerBJT VbeON pin connections



VbeSAT

Module name: VbeSAT

Module type: ITM

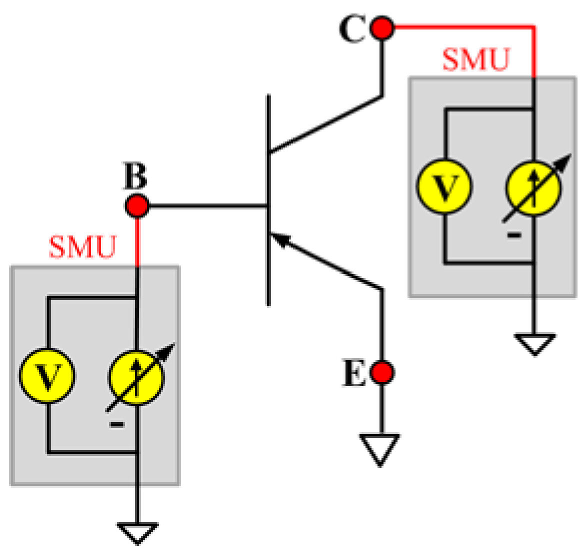
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the base-emitter saturation voltage. The voltage is measured at a specific base current and collector current that is given in the data sheet to ensure that both the emitter-base and collector-base junctions are forward biased.

Pin connection: Use a SMU to force current and make a voltage measurement from the base to emitter. Use a SMU to apply a current bias to the collector. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 218: pnpPowerBJT VbeSAT pin connections



VceSAT

Module name: VceSAT

Module type: ITM

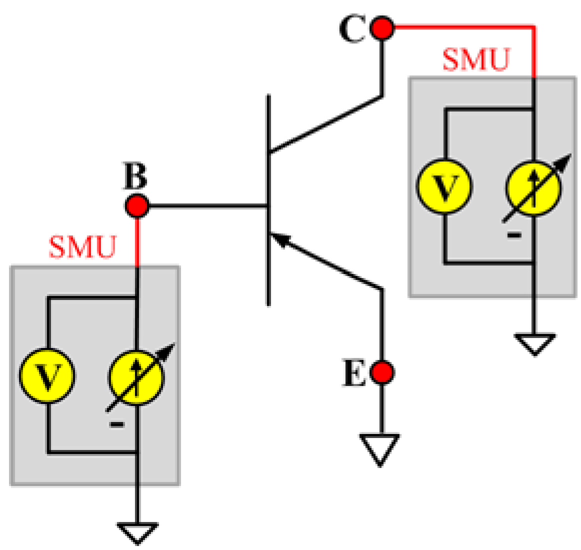
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter saturation voltage. The voltage is measured at a specific base current and collector current that is given in the data sheet to ensure that both the emitter-base and collector-base junctions are forward-biased.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the emitter. Use another SMU to apply current bias to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 219: pnpPowerBJT VceSAT pin connections



VCESUS

Module name: VCESUS

Module type: ITM

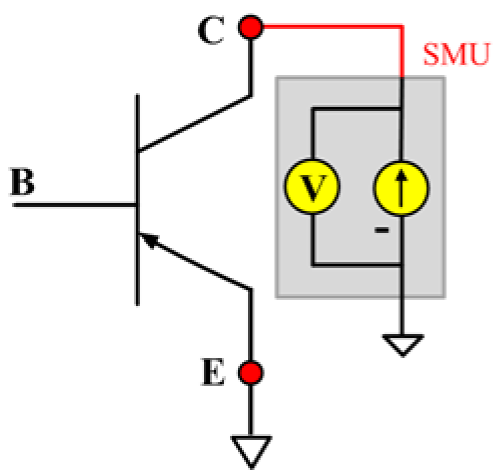
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter sustaining voltage with the base opened. The voltage is measured at a specific collector current that is given in the datasheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to emitter. Open the circuit to the base or use a SMU to supply a zero-current bias. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 220: pnpPowerBJT VCESUS pin connections



VceSAT_MIX

Module name: VceSAT_MIX

Module type: PTM

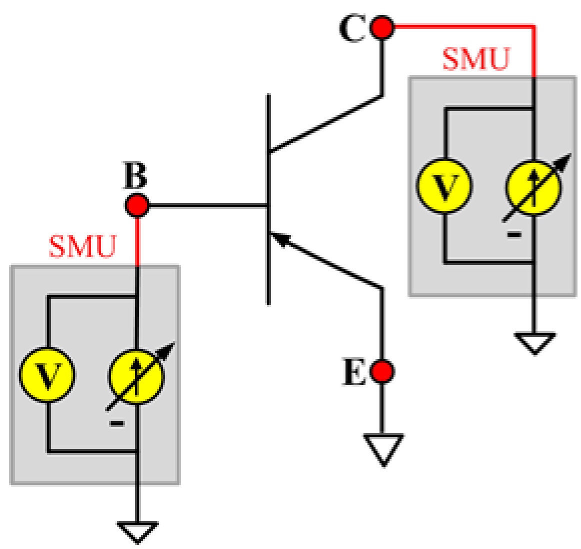
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter saturation voltage. The voltage is measured at a specific base current and at the collector current that is given in data sheet to ensure that both the emitter-base and collector-base junctions are forward biased.

Pin connection: Use a SMU to force current and make a voltage measurement from the collector to emitter. Use another SMU to apply current bias to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 221: pnpPowerBJT VceSAT_MIX pin connections



IcVce_StepIb_MIX

Module name: IcVce_StepIb_MIX

Module type: PTM

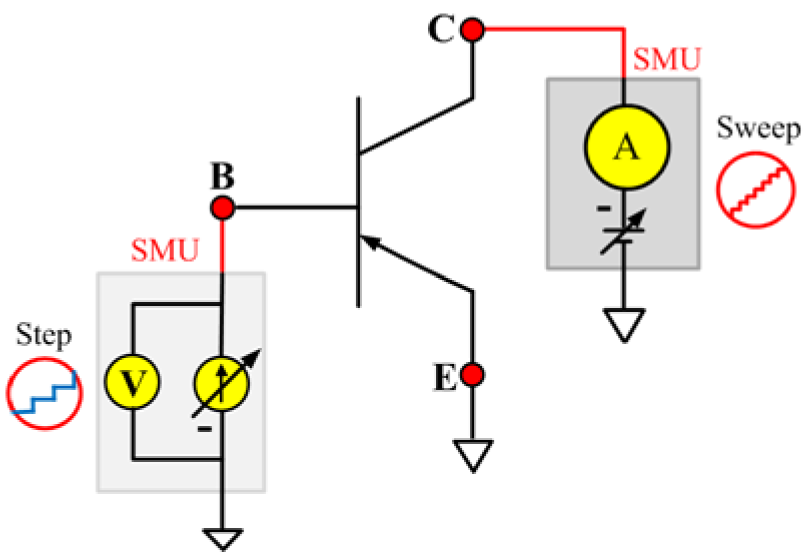
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter output characteristic curve with a current step at the base.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from the collector to the emitter. Use another SMU to apply a current step to the base. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 222: pnpPowerBJT IcVce_StepIb_MIX pin connections



IcVce_StepVbe_MIX

Module name: IcVce_StepVbe_MIX

Module type: PTM

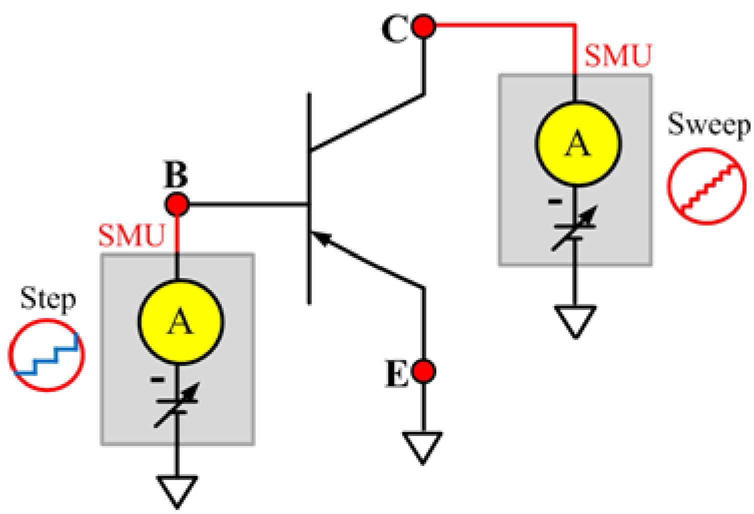
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal pnpPowerBJT

Function: Measures the collector-emitter output characteristic curve with a voltage step on the emitter-base junction.

Pin connections: Use a SMU to apply a voltage sweep and make a current measurement from the collector to the emitter. Use a SMU to apply a voltage step to the base-emitter junction. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 223: pnpPowerBJT IcVce_StepVbe_MIX pin connections



Ccb

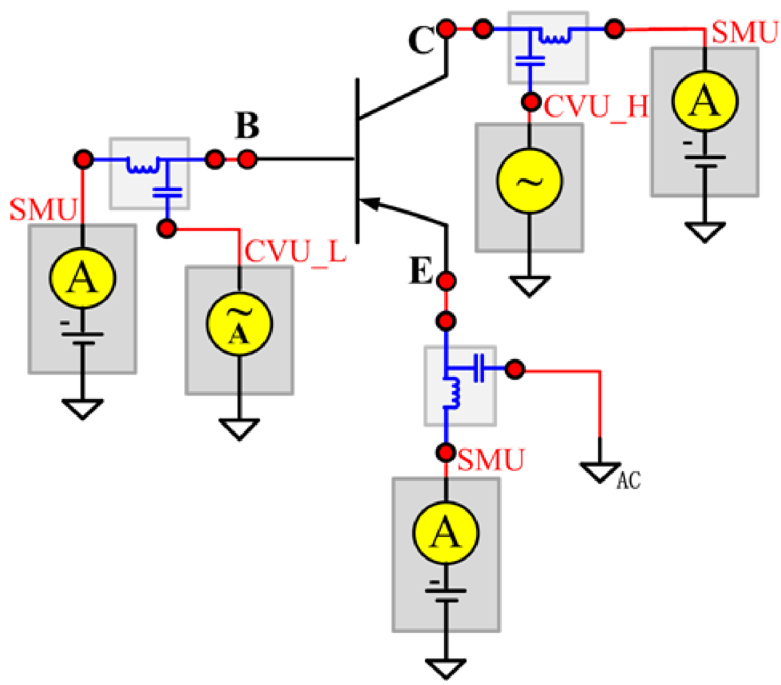
Module Name: Ccb

DUT: Three-terminal pnpPowerBJT

Function: Measures the capacitance between the Collector and Base terminals with the Emitter terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias.

Figure 224: Three-terminal pnpPowerBJT Ccb pin connections



Cce

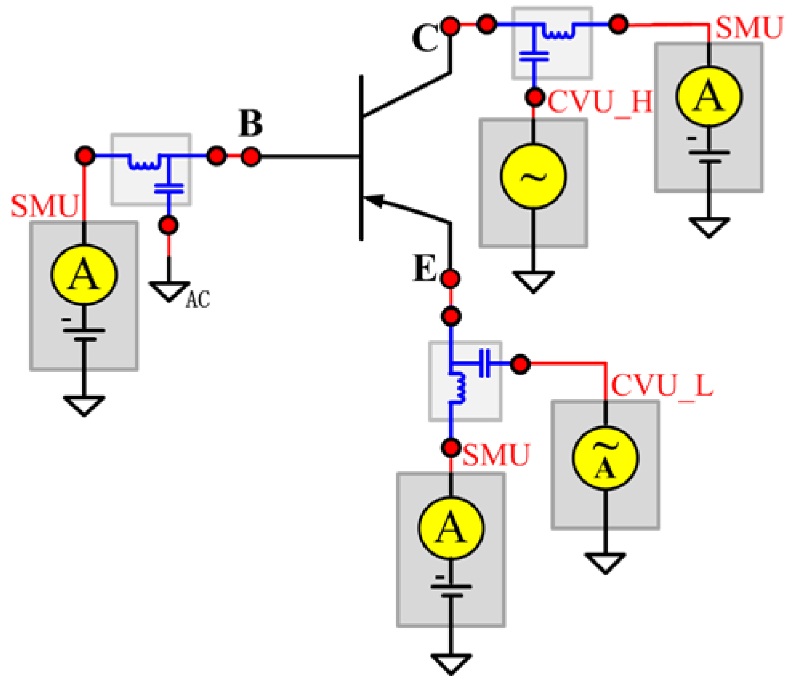
Module Name: Cce

DUT: Three-terminal pnpPowerBJT

Function: Measures the capacitance between the collector and emitter terminals with the base terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias.

Figure 225: Three-terminal pnpPowerBJT Cce pin connections



Ceb

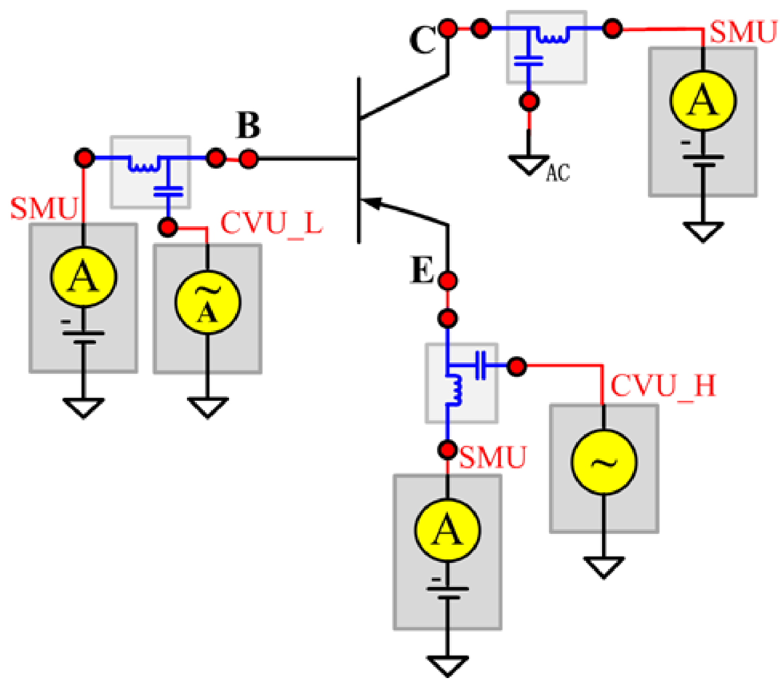
Module Name: Ceb

DUT: Three-terminal pnpPowerBJT

Function: Measures the capacitance between the emitter and base terminals with the collector terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 226: Three-terminal pnpPowerBJT Ceb pin connections



Cibo

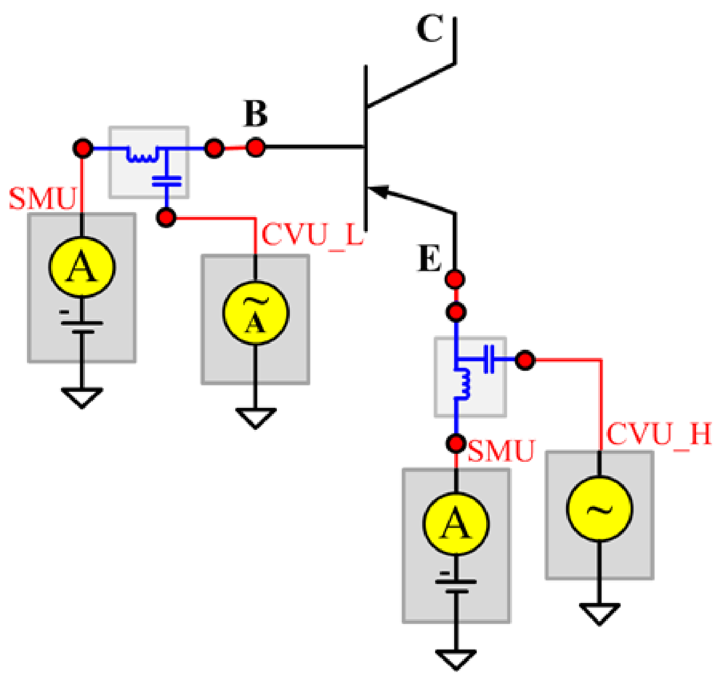
Module Name: Cibo

DUT: Three-terminal pnpPowerBJT

Function: Measures the capacitance between the input terminals (base and emitter) with the collector terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 227: Three-terminal pnpPowerBJT Cibo pin connections



Cobo

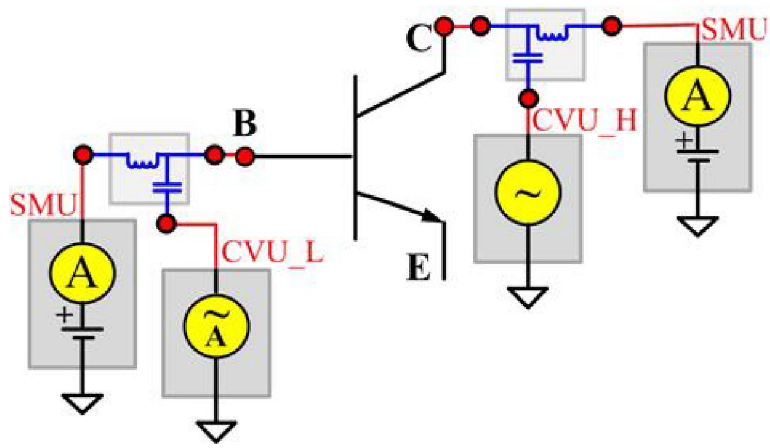
Module Name: Cobo

DUT: Three-terminal pnpPowerBJT

Function: Measures the capacitance between the output terminals (base and collector) with the emitter terminal open.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias. Open the circuit to the emitter.

Figure 228: Three-terminal pnpPowerBJT Cobo pin connections



TRIAC test module templates

The TRIAC parametric test module templates are used to test parameters of a TRIAC device, including leakage, on-state, trigger, latch and hold properties.

IDRM

Module name: IDRM

Module type: ITM

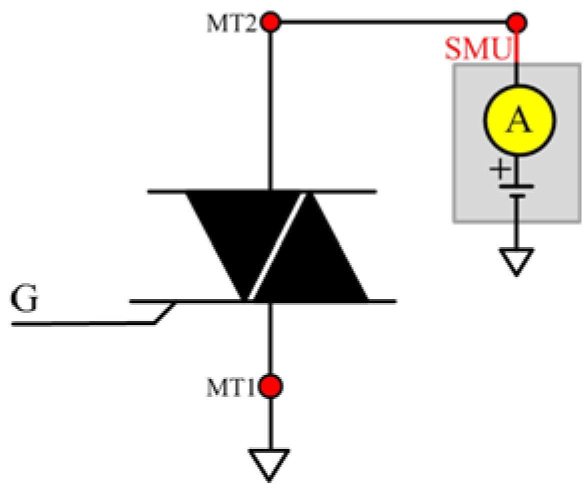
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal TRIAC

Function: Measures the peak repetitive blocking current. Measures the maximum instantaneous value of the off-state current that results from the application of repetitive peak off-state voltage.

Pin connections: Use the Model 2657A to apply voltage and measure current between terminals MT2 (or A2) to MT1 (or A1). Open the circuit to the gate or use a SMU to supply a zero-current bias.

Figure 229: TRIAC IDRM pin connections



IGT

Module name: IGT

Module type: ITM

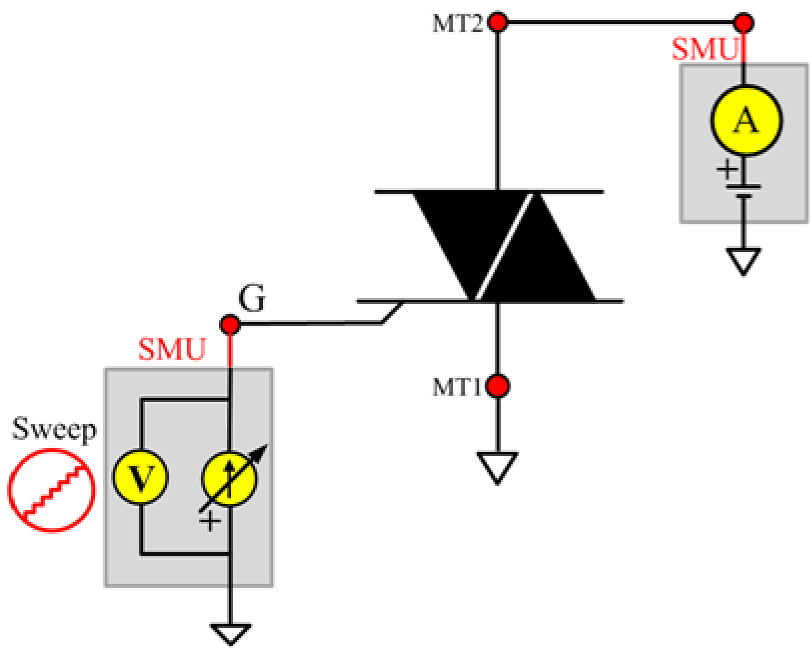
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the gate trigger current. Measures the minimum current required between the gate and cathode (MT1) to turn on the device.

Pin connections: Use the Model 2651A to apply the specified voltage and measure the current between terminals MT2 (or A2) to MT1 (or A1). Use the Model 2600B SMU to sweep current and measure voltage between gate and cathode MT1. If required, connect a resistance load RL at specified value in series with the TRIAC device to achieve a defined on-state current IT.

Figure 230: TRIAC IGT pin connections



IHneg

Module name: IHneg

Module type: ITM

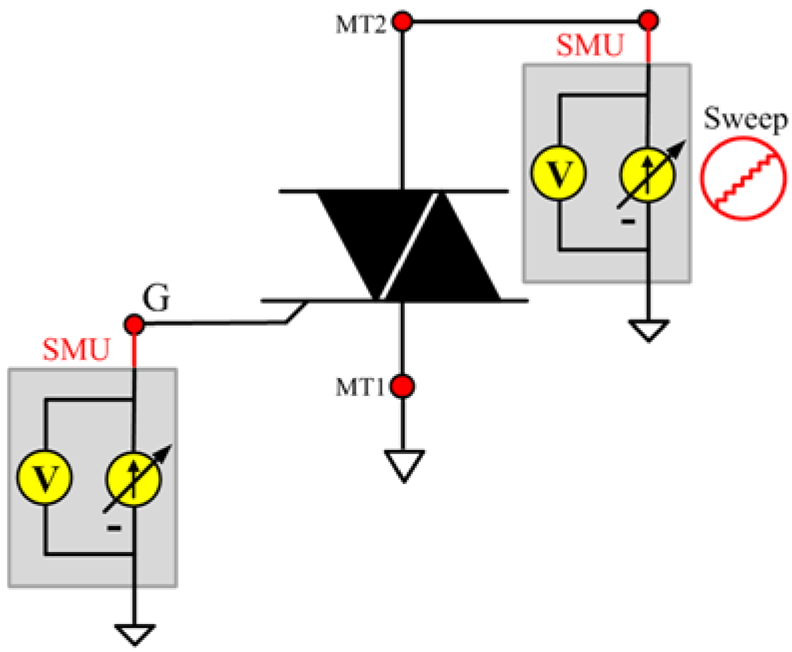
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the holding current. Measures the minimum current across the main terminals to keep the device in the on-state.

Pin connections: Use the Model 2651A SMU to apply current between terminals MT2 (or A2) to MT1 (or A1). Use the Model 2600B SMU to apply the specified current between Gate and cathode MT1.

Figure 231: TRIAC IHneg pin connections



IHpos

Module name: IHpos

Module type: ITM

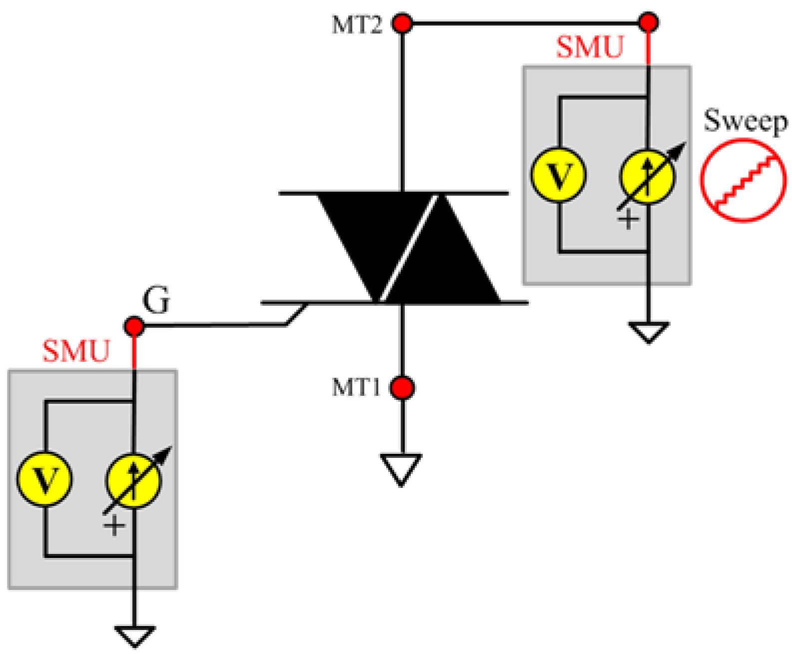
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the holding current. Measures the minimum current across the main terminals to keep the device in the on-state.

Pin connections: Use the Model 2651A SMU to apply current between terminals MT2 (or A2) to MT1 (or A1). Use the Model 2600B SMU to apply the specified current between Gate and cathode MT1.

Figure 232: TRIAC IHpos pin connections



ILneg

Module name: ILneg

Module type: ITM

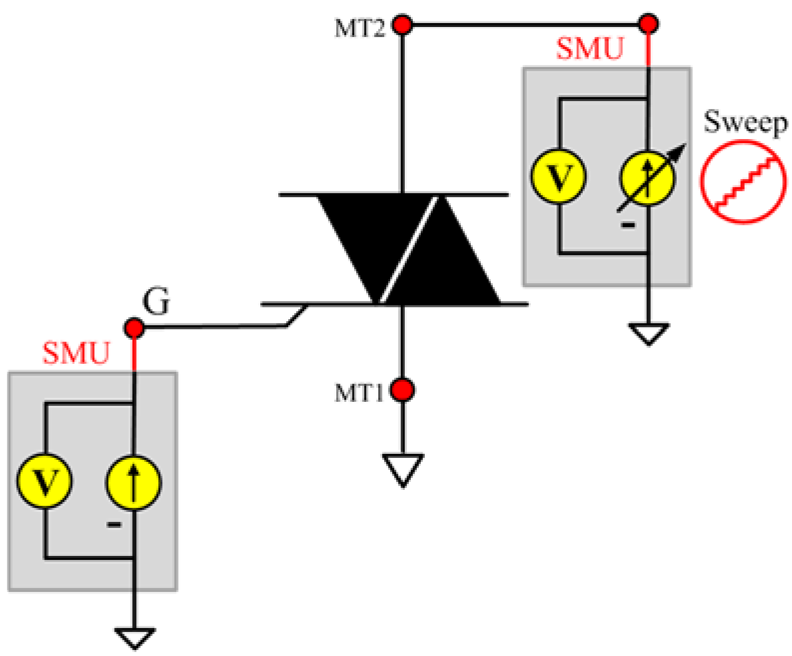
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the latching current. Measures the minimum current across the main terminals to keep the device in the on-state. This occurs immediately after switching from off-state to on-state and the triggering gate signal has been removed.

Pin connections: Use the Model 2651A SMU to apply current between terminals MT2 (or A2) to MT1 (or A1). Use the Model 2600B SMU to apply the specified current between Gate and cathode MT1.

Figure 233: TRIAC ILneg pin connections



ILpos

Module name: ILpos

Module type: ITM

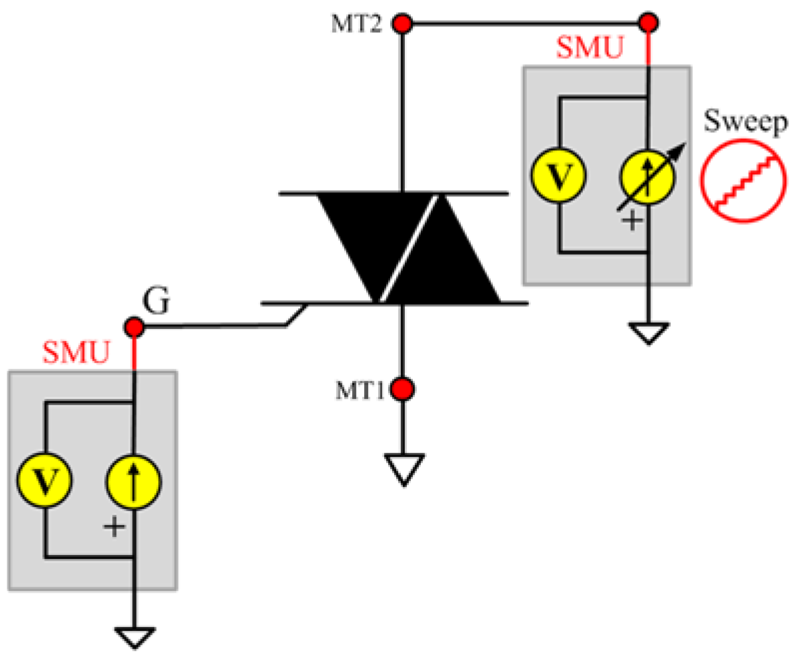
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the latching current. Measures the minimum current across the main terminals to keep the device in the on-state. This occurs immediately after switching from off-state to on-state and the triggering gate signal has been removed.

Pin connections: Use the Model 2651A SMU to apply current between terminals MT2 (or A2) to MT1 (or A1). Use the Model 2600B SMU to apply the specified current between Gate and cathode MT1.

Figure 234: TRIAC ILpos pin connections



IRRM

Module name: IRRM

Module type: ITM

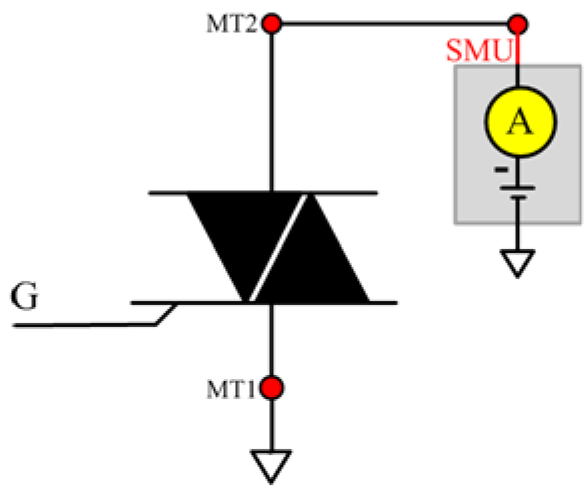
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal TRIAC

Function: Measures the peak repetitive reverse blocking current. Measures the maximum instantaneous value of the reverse off-state current that results from the application of repetitive peak off-state voltage.

Pin connections: Use the Model 2657A SMU to apply voltage and measure current between terminals MT2 (or A2) to MT1 (or A1). Connect gate to GND or use a SMU to supply a zero-voltage bias.

Figure 235: TRIAC IRRM pin connections



VGT

Module name: VGT

Module type: ITM

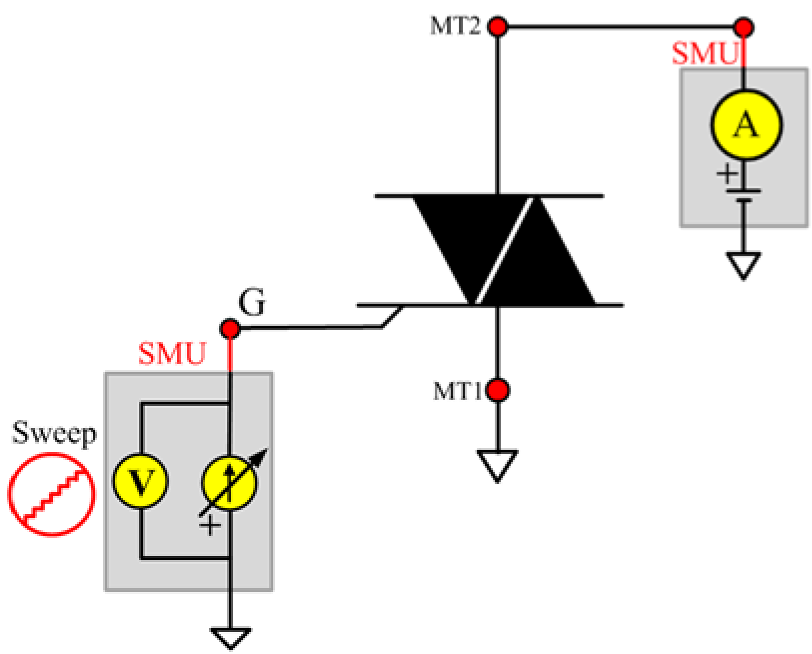
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the gate trigger voltage. Measures the minimum voltage required between the gate and cathode to reach the gate trigger current and then to trigger the device.

Pin connections: Use the Model 2651A SMU to apply the specified voltage and measure current between terminals MT2 (or A2) to MT1 (or A1). Use the Model 2600B SMU to sweep the current and measure voltage between gate and cathode MT1. Two SMUs are used. One SMU applies a specified voltage and measures current between terminals A2 (or MT2) to A1 (or MT1). If required, connect a resistance load (RL) at a specified value in series with the TRIAC device to achieve a defined on-state current IT.

Figure 236: TRIAC VGT pin connections



VTneg

Module name: VTneg

Module type: ITM

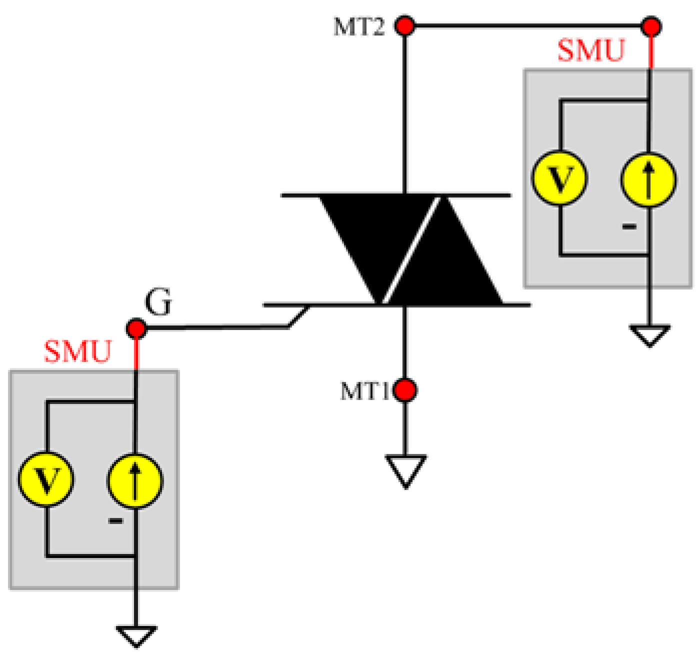
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the peak on-state voltage. Measures the maximum voltage drop across the main terminals at stated conditions when the devices are in the on-state. Typically measured at a short pulse width and low duty cycle to prevent heating of the junction.

Pin connections: One or two SMUs are used. One SMU applies a specified current and measures voltage between terminals A2 (or MT2) to A1 (or MT1). The other SMU may be required to apply a gate current to turn the device on. The gate current >= IGT must be applied until the load current is >= IL.

Figure 237: TRIAC VTneg pin connections



VTpos

Module name: VTpos

Module type: ITM

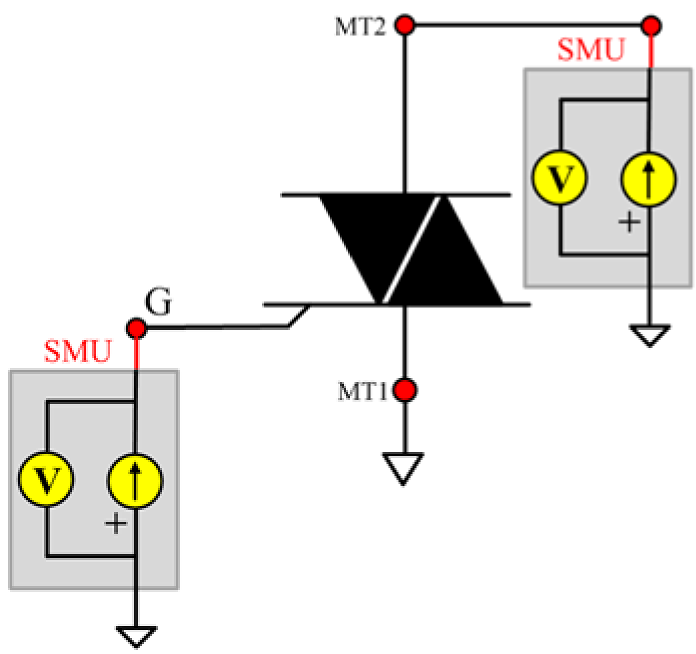
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal TRIAC

Function: Measures the peak on-state voltage. Measures the maximum voltage drop across the main terminals at stated conditions when the devices are in the on-state. Typically measured at a short pulse width and low duty cycle to prevent heating of the junction.

Pin connections: One or two SMUs are used. One SMU applies a specified current and measures voltage between terminals A2 (or MT2) to A1(or MT1). The other SMU may be required to apply a gate current to turn the device on. The gate current >= IGT must be applied until the load current is >= IL.

Figure 238: TRIAC VTpos pin connections



IGBT library

The IGBT parametric test module templates are used to test parameters of an IGBT device, including leakage, breakdown, gain, on-state and characteristic curves.

BVCES

Module name: BVCES

Module type: ITM

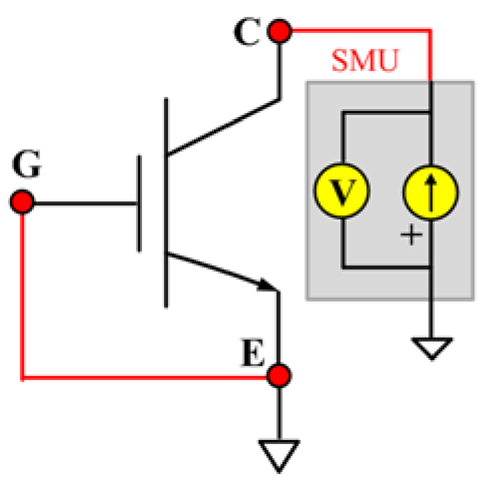
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal IGBT

Function: Measures the breakdown voltage from the collector to emitter. The voltage is measured by applying a breakdown current to the collector and the gate-emitter is shorted.

Pin connections: Use a Model 2657A to apply current and make a voltage measurement at the Collector. Connect the gate and emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 239: IGBT BVCES pin connections



ICES

Module name: ICES

Test type: ITM

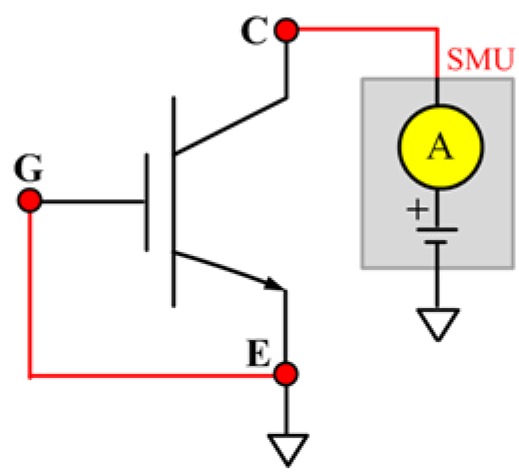
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal IGBT

Function: Measures the collector-emitter cut-off current with the gate shorted to the emitter.

Pin connections: Use a Model 2657A to apply voltage and make a current measurement from the collector to the emitter. Short the gate to the emitter or use a SMU to supply a zero-voltage bias.

Figure 240: IGBT ICES pin connections



IcON

Module name: IcON

Test type: ITM

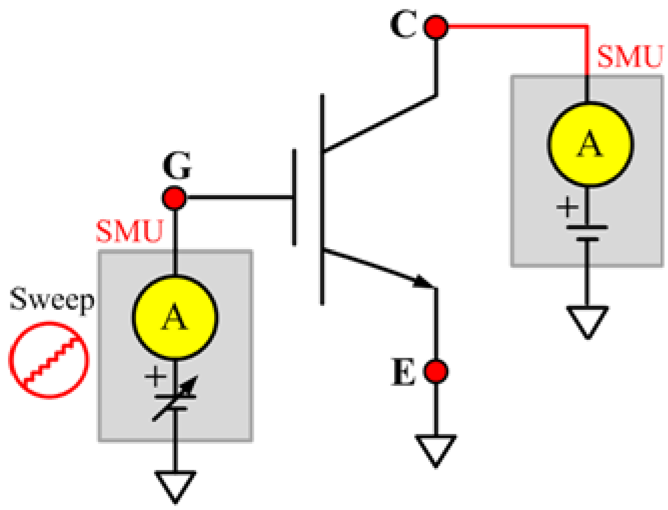
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal IGBT

Function: Measures the on-state collector current. Measures current on the collector by applying voltage to the collector-emitter with a specific gate voltage to turn on the device at a certain collector current value that is given in the data sheet.

Pin connections: Use the Model 2651A to force voltage and make a current measurement at the collector. Use the low-power Model 2600B to source sweep voltage at the gate. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 241: IGBT IcON pin connections



IcVce_StepVge

Module name: IcVce_StepVge

Test type: ITM

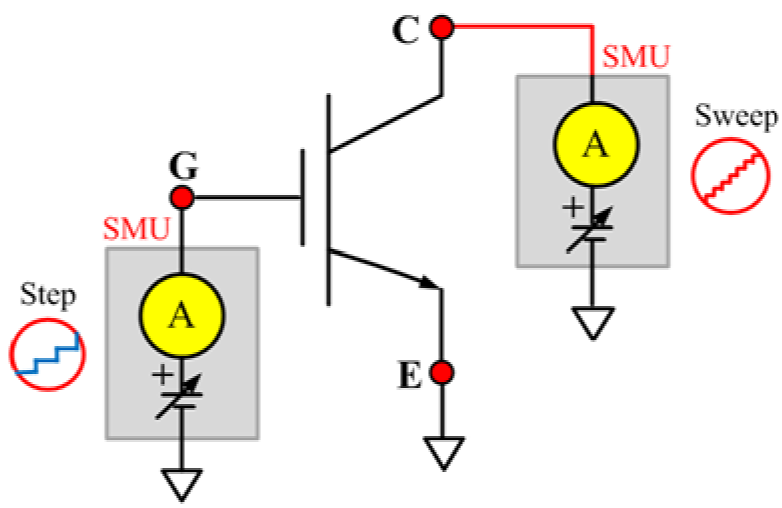
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal IGBT

Function: Measures the standard family of IcVce curves. Each time the voltage steps on the gate-emitter, a voltage sweep and a set of current measurements occur on the collector.

Pin connections: Use the Model 2651A to apply a voltage sweep and make a current measurement at the collector. Use the low-power Model 2600B to source a specific voltage at the gate. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 242: IGBT IcVce_StepVge pin connections



IcVge

Module name: IcVge

Module type: ITM

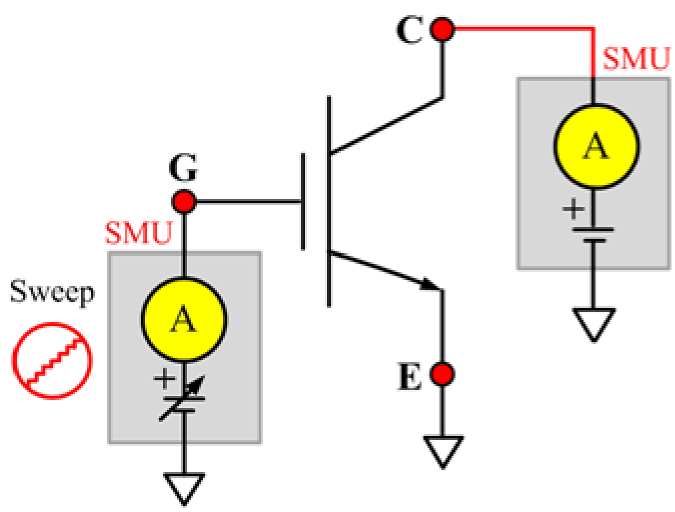
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal IGBT

Function: Measures the transfer characteristics of the IGBT with a specific voltage bias from the collector to emitter.

Pin connections: Use the Model 2651A to apply voltage and make current measurements at the collector. Use the low-power Model 2600B to sweep voltage at the gate. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 243: IGBT IcVge pin connections



IGESF

Module name: IGESF

Test type: ITM

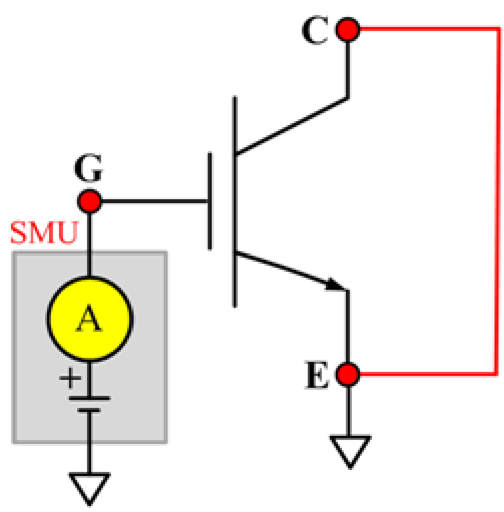
Instrument: Keithley Instruments Series 2600B

DUT: Three-terminal IGBT

Function: Measures the gate body forward leakage current. Measures current on the gate at a maximum permissible positive voltage from the gate to emitter.

Pin connections: Use a SMU to force voltage and make a current measurement from the gate to the emitter. Connect the collector and emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 244: IGBT IGESF pin connections



IGESR

Module name: IGESR

Module type: ITM

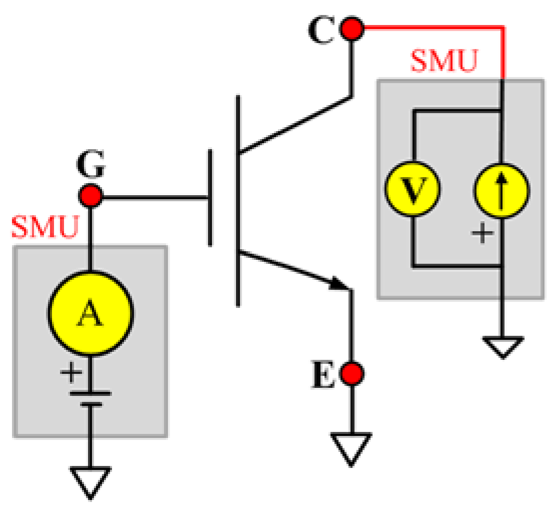
Instrument: Keithley Instruments Series 2600B

DUT: Three-terminal IGBT

Function: Measures the gate body reversed leakage current. Measures current on the gate at a maximum permissible negative voltage from the gate to emitter.

Pin connections: Use a SMU to force voltage and make a current measurement from the gate to the emitter. Connect the collector to GND or use a SMU to supply a zero-voltage bias.

Figure 245: IGBT IGESR pin connections



VceSAT

Module name: VceSAT

Module type: ITM

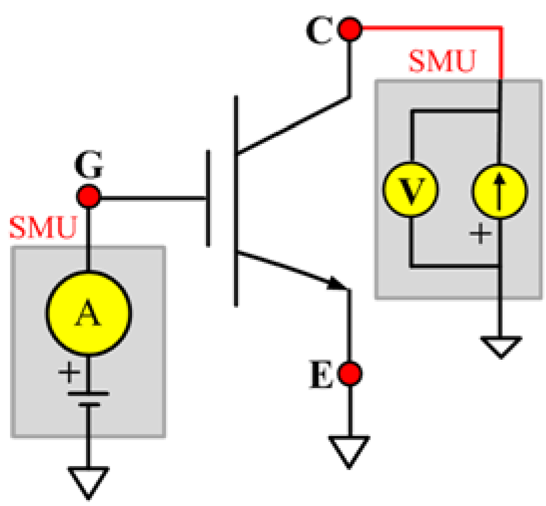
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal IGBT

Function: Measures the collector-emitter saturation voltage. The voltage is measured with a specific gate-emitter voltage and collector current that is given in the data sheet.

Pin connections: Use the Model 2651A to apply current and make voltage measurement from the collector to the emitter. Use the Model 2600B to apply a voltage bias to the gate.

Figure 246: IGBT VceSAT pin connections



VF

Module name: VF

Module type: ITM

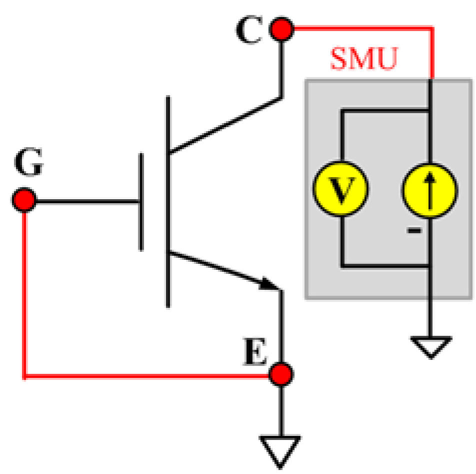
Instrument: Keithley Instruments Series 2600B

DUT: Three-terminal IGBT

Function: Measures the forward voltage of the emitter-collector diode with the gate shorted to the emitter.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the emitter. Connect the gate to GND or use a SMU to supply a zero-voltage bias.

Figure 247: IGBT VF pin connections



VgeON

Module name: VgeON

Module type: ITM

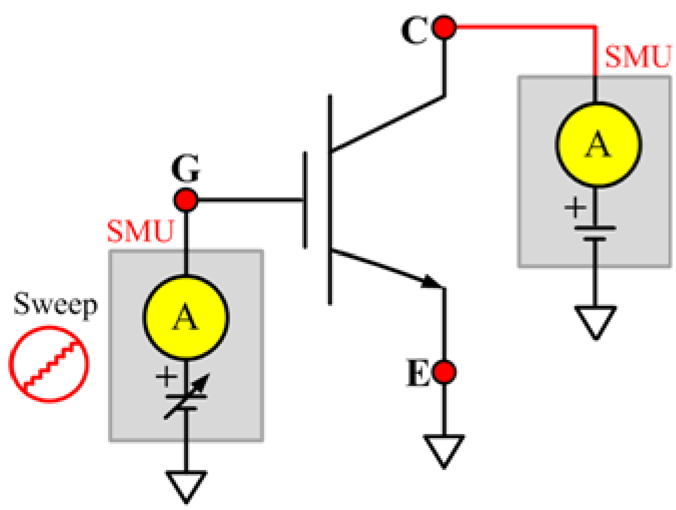
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal IGBT

Function: Measures the gate to emitter on-state voltage. Measures current on the collector by applying a voltage sweep to the gate-emitter, applying a specific collector-emitter voltage to turn on the device at a certain collector current value that is given in the data sheet, while measuring the collector current.

Pin connections: Use a Model 2651A to apply a voltage and make a current measurement at the collector. Use the low-power Model 2600B to sweep voltage at the gate. Connect the emitter to GND or use a SMU to supply a zero-voltage bias. Two SMUs are used. The Model 2651A SMU applies voltage and takes current measurements at the collector. The other SMU sweeps voltage at the gate.

Figure 248: IGBT VgeON pin connections



VGETH

Module name: VGETH

Module type: ITM

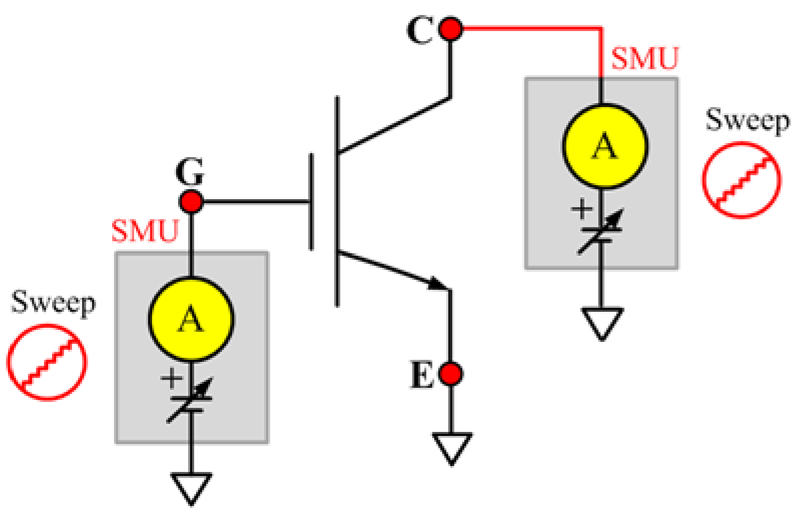
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal IGBT

Function: Measures the threshold voltage from the gate to emitter, which is required to turn on the device at a certain collector current value that is given in the data sheet.

Pin connections: Use the Model 2651A to apply voltage and make a current measurement at the collector. Use the low-power Model 2600B to sweep voltage at the gate. Connect the emitter to GND or use a SMU to supply a zero-voltage bias.

Figure 249: IGBT VGETH pin connections



IcVce_StepVge_MIX

Module name: IcVce_StepVge_MIX

Module type: PTM

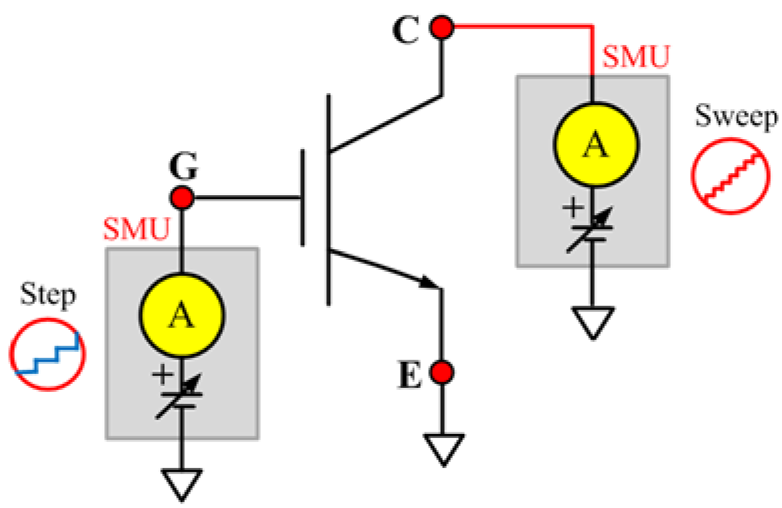
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal IGBT

Function: Measures the standard family of IcVce curves. Each time the voltage steps on the gate-emitter, a voltage sweep and a set of current measurements occur on the collector.

Pin connections: Use the Model 2651A to apply a voltage sweep and make a current measurement at the collector. Use the other SMU to source a specific voltage at the gate.

Figure 250: IGBT IcVce_StepVge_MIX pin connections



IcVge_MIX

Module name: IcVge_MIX

Module type: PTM

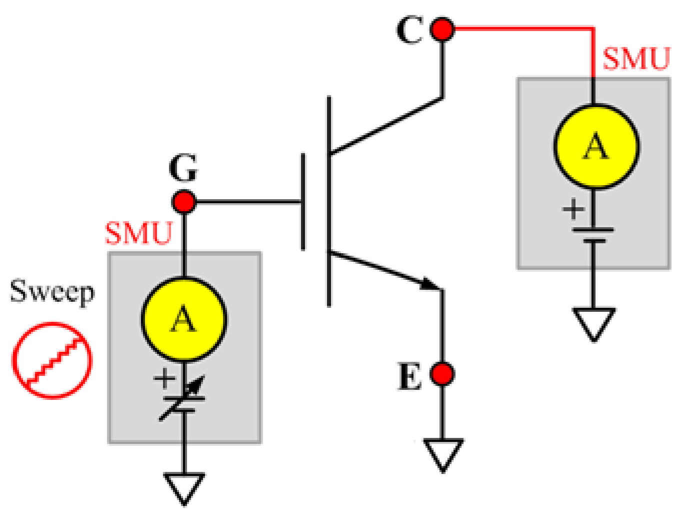
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal IGBT

Function: Measures the transfer characteristics of the IGBT with a specific voltage bias from the collector to the emitter.

Pin connections: The Model 2651A SMU applies voltage and makes current measurements at the collector. Use the other SMU to sweep voltage at the gate.

Figure 251: IGBT IcVge_MIX pin connections



VceSAT_MIX

Module name: VceSAT

Module type: PTM

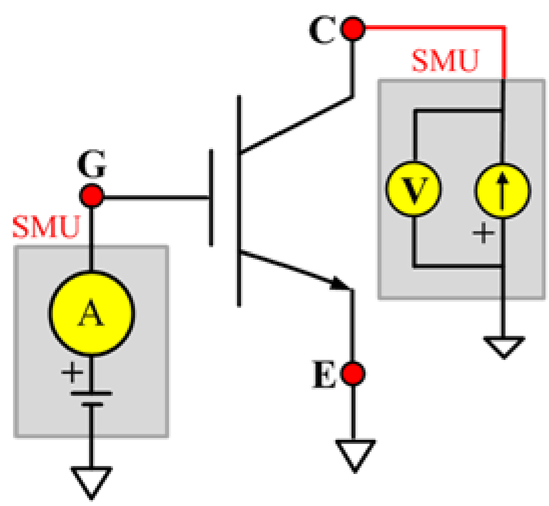
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal IGBT

Function: Measures the collector-emitter saturation voltage. The voltage is measured with a specific gate-emitter voltage and collector current that is given in the data sheet.

Pin connections: Use a SMU to force current and make a voltage measurement from the collector to the emitter. Use the other SMU to apply a voltage bias to the gate.

Figure 252: IGBT VceSAT_MIX pin connections



Cce

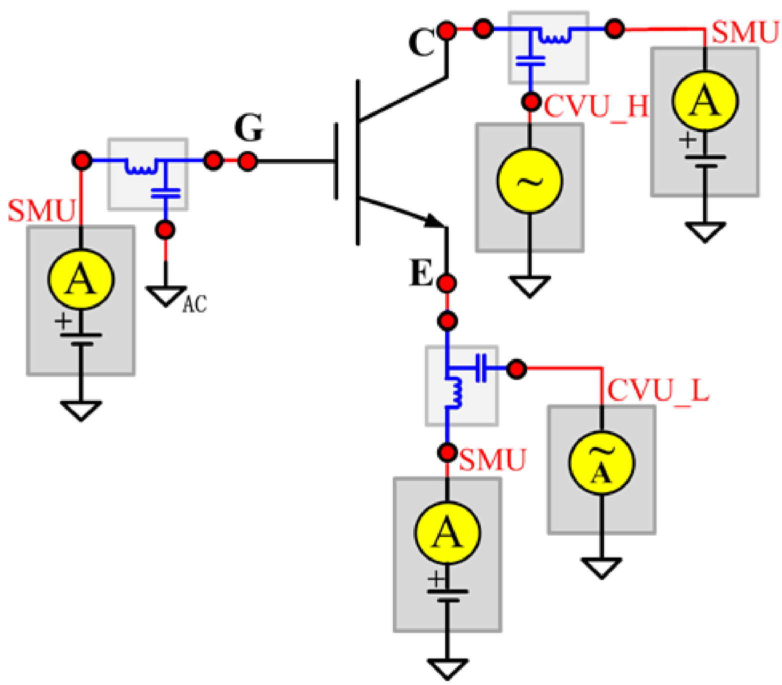
Module name: Cce

DUT: Three-terminal IGBT

Function: Measures the capacitance between the collector and emitter terminals with the gate terminal connected to the ac guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the guard terminal of a three-terminal bridge through one remote bias tee to the base. Use the Series 2600B to supply zero voltage bias.

Figure 253: Three-terminal IGBT Cce pin connections



Cgc

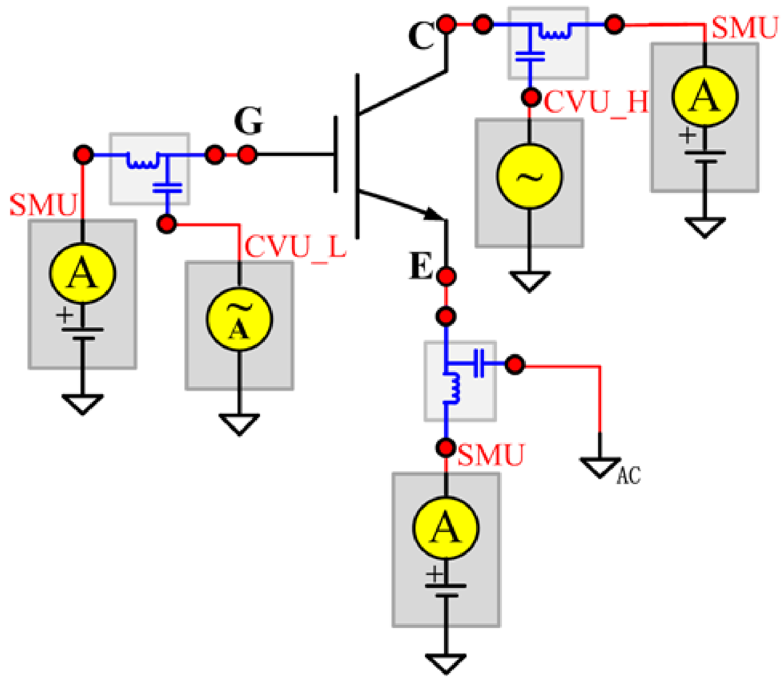
Module name: Cgc

DUT: Three-terminal IGBT

Function: Measures the capacitance between the collector and gate terminals with the emitter terminal connected to the AC guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect one Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias.

Figure 254: Three-terminal IGBT Cgc pin connections



Cge

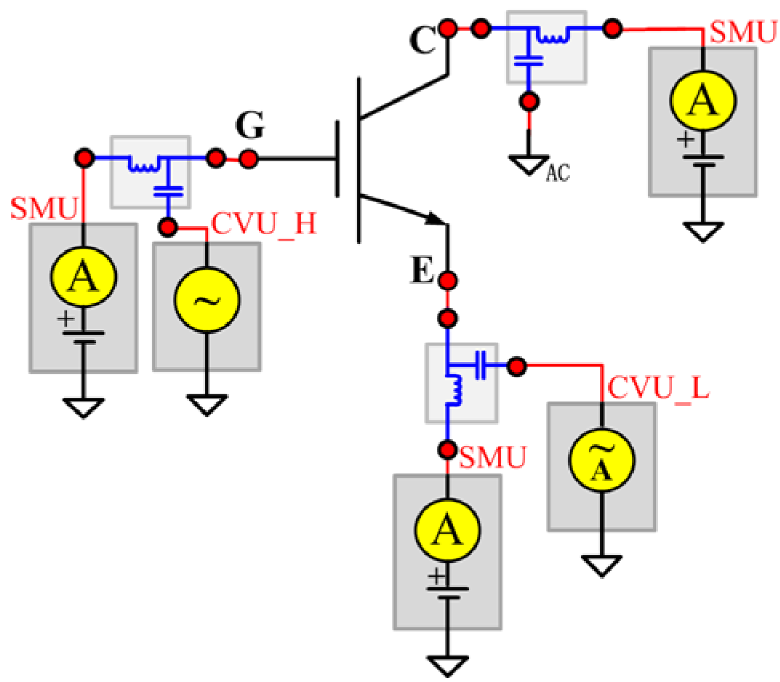
Module name: Cge

DUT: Three-terminal IGBT

Function: Measures the capacitance between the gate and emitter terminals with the collector terminal connected to the ac guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect one Series 2600B the ac guard of a three-terminal bridge through one remote bias tee to the collector. Use the Series 2600B to supply zero voltage bias.

Figure 255: Three-terminal IGBT Cge pin connections



Cies

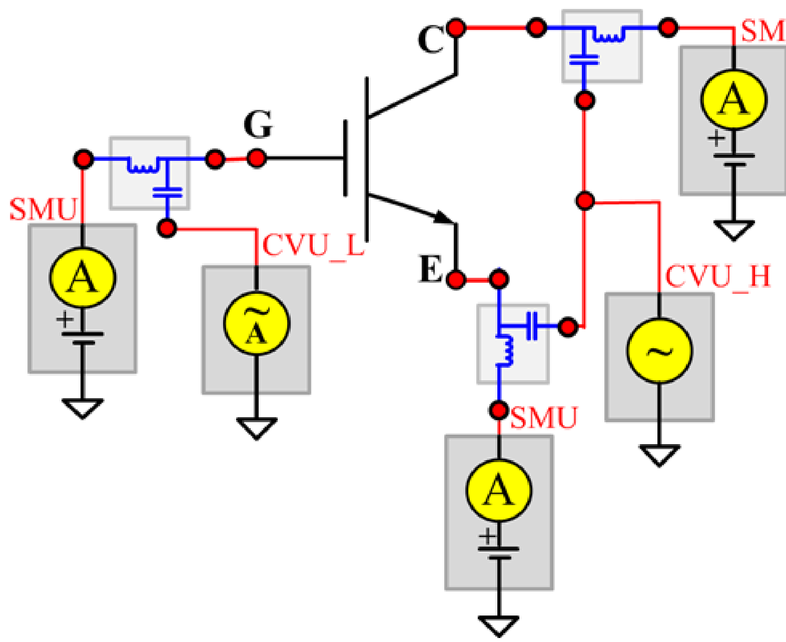
Module name: Cies

DUT: Three-terminal IGBT

Function: Measures the capacitance between the gate and emitter terminals with the collector terminal ac short-circuited to the emitter terminal.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. AC short-circuit the collector terminal to the emitter terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias.

Figure 256: Three-terminal IGBT Cies pin connections



Coes

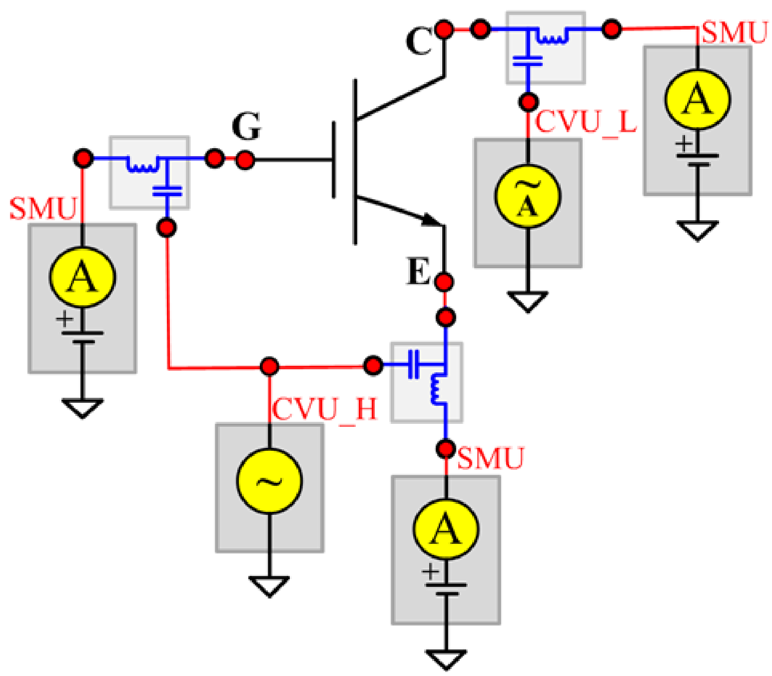
Module name: Coes

DUT: Three-terminal IGBT

Function: Measures the capacitance between the collector and emitter terminals with the gate terminal ac short-circuited to the emitter terminal.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. AC short-circuit the gate terminal to the emitter terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage.

Figure 257: Three-terminal IGBT Coes pin connections



Cres

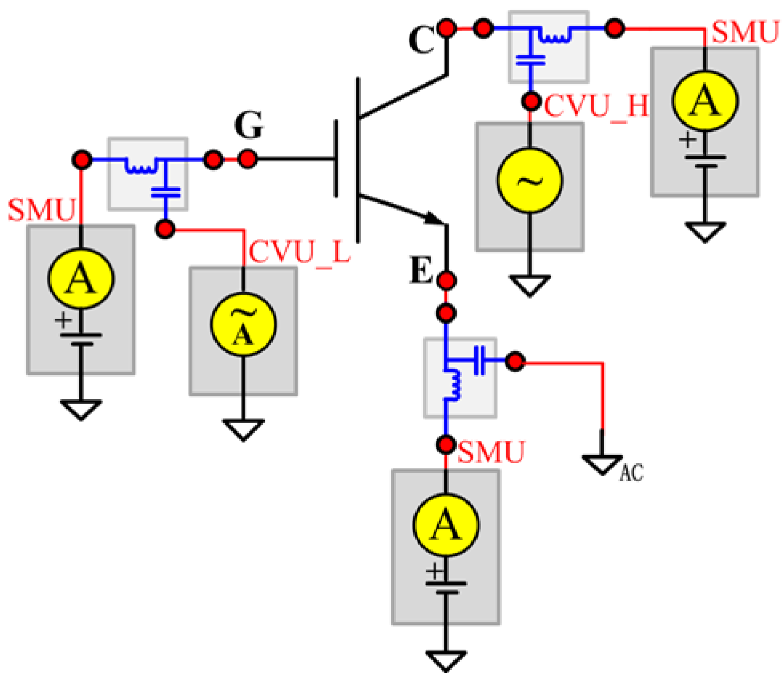
Module name: Cres

DUT: Three-terminal IGBT

Function: Measures the capacitance between the gate and collector terminals with the emitter terminal connected to the ac guard of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the collector. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the emitter. Use the Series 2600B to supply zero voltage bias.

Figure 258: Three-terminal IGBT Cres pin connections



nPowerMOSFET test module template

The nPowerMOSFET parametric test module template is used to test some parameters of a n-type power MOSFET, including leakage, breakdown, gain, on-state and characteristic curves.

BVDSS

Module name: BVDSS

Module type: ITM

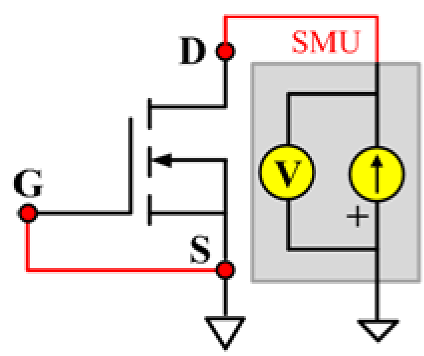
Instrument: Keithley Instruments Model 2657A

DUT: Three-terminal nPowerMOSFET

Function: Measures the breakdown voltage from the drain to the source. Measures voltage on the drain-source by applying a breakdown current to the drain and gate that is shorted to the source.

Pin connections: Use the Model 2657A instrument to apply current and make a voltage measurement at the drain. Connect the gate and source to GND or use a SMU to supply a zero-voltage bias.

Figure 259: nPowerMOSFET_BVDSS pin connections



GFS

Module name: GFS

Module type: ITM

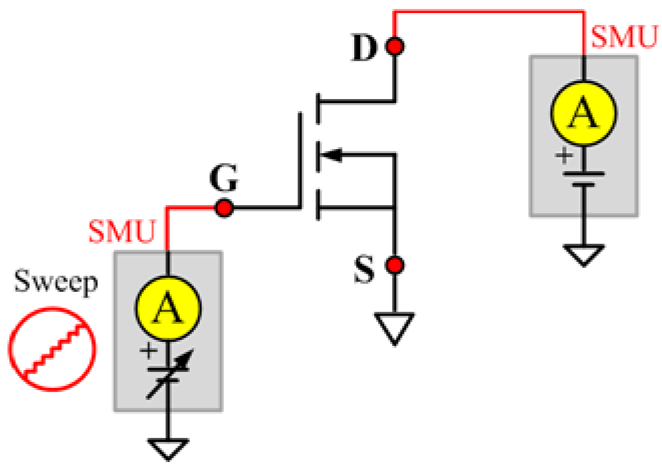
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the forward transconductance. Measures the current on the drain by applying a voltage sweep from the gate to the source and calculates the ratio of change in the Id for a change in the Vgs: GFS = delta (Id)/delta(Vgs).

Pin connections: Use the Model 2651A to apply voltage and make a current measurement at the drain. Use the low power Model 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 260: nPowerMOSFET GFS pin connections



IdON

Module name: IdON

Module type: ITM

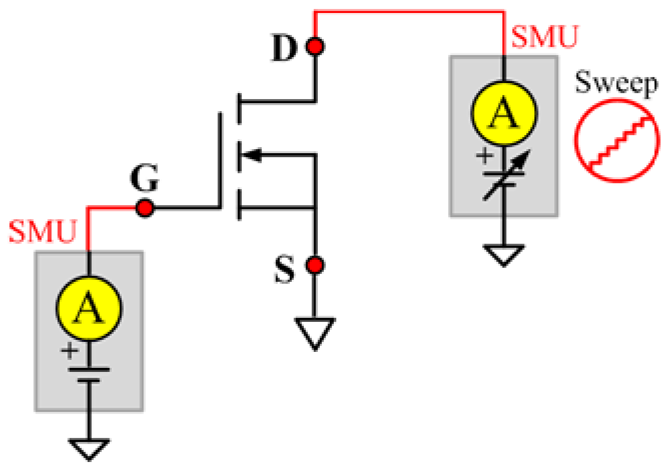
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the on-state drain current. Measures the current on the drain by applying a voltage sweep to the drain-source with a specific gate voltage to turn on the device at a specific Id current value that is given in the datasheet.

Pin connections: Use the Model 2651A to apply a voltage sweep and make a current measurement at the drain. Use the low power Model 2600A to source a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 261: nPowerMOSFET IdON pin connections



IDSS

Module name: IDSS

Module type: ITM

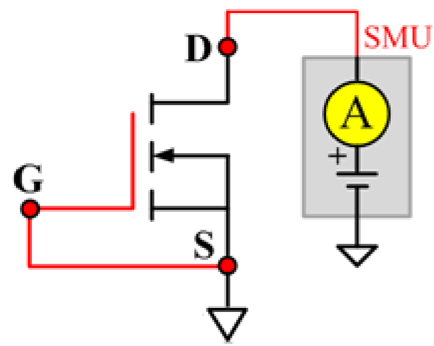
Instrument: Keithley Instruments Model 2657A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the leakage current from the drain to the Source when the device is off. Measures the current on the drain by applying a maximum permissible voltage between the drain and source, while the gate is shorted to the source.

Pin connections: Use the Model 2657A to apply voltage and make a current measurement at the drain. Connect the gate and source to GND or use a SMU to supply a zero-voltage bias.

Figure 262: nPowerMOSFET IDSS pin connections



IdVd_StepVg

Module name: IdVd_StepVg

Module type: ITM

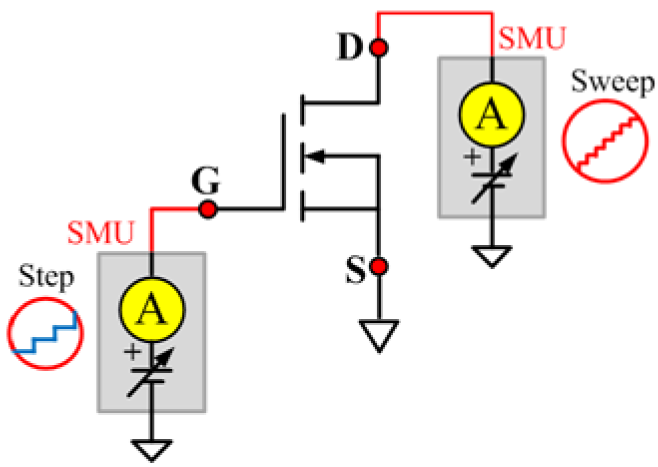
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the drain current at the specified gate voltage and sweeps the drain in pulse mode. Generates the standard family of IdVd curves.

Pin connections: Use the Model 2651A to apply a voltage sweep and make a current measurement at the drain. Use the low power Model 2600A to source a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 263: nPowerMOSFET IdVd_StepVg pin connections



IdVg_StepVd

Module name: IdVg_StepVd

Module type: ITM

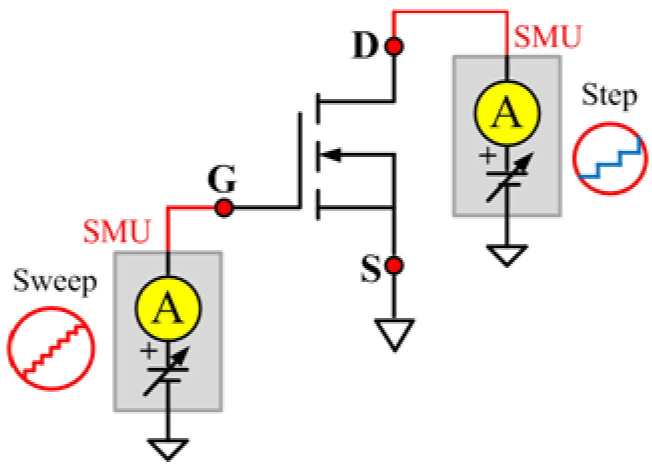
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the transfer characteristic of the device. Each time the voltage steps on the drain-source, a voltage sweep is performed on the gate-source and set of current measurements occurs on the drain.

Pin connections: Use the Model 2651A to apply a voltage step and make a current measurement at the drain. Use the low power Model 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 264: nPowerMOSFET IdVg_StepVd pin connections



IGSSF

Module name: IGSSF

Module type: ITM

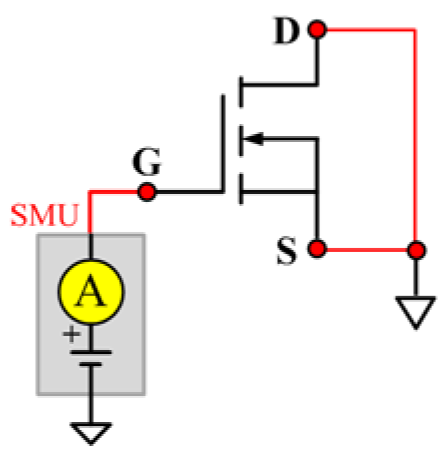
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the gate forward leakage current. Measures the current on the gate at the maximum permissible positive voltage from the gate to the source.

Pin connections: Use a SMU to force voltage and make a current measurement at the gate. Connect the drain and source to GND or use a SMU to supply a zero-voltage bias.

Figure 265: nPowerMOSFET IGSSF pin connections



IGSSR

Module name: IGSSR

Module type: ITM

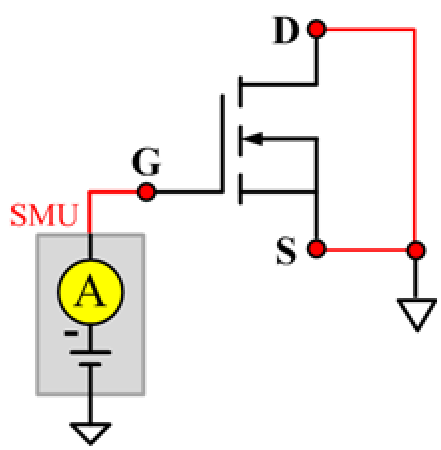
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the gate body reversed leakage current. Measures current on the gate at the maximum permissible negative voltage from gate to source.

Pin connections: Use a SMU to force voltage and make a current measurement from the gate. Connect the drain and source to GND or use a SMU to supply a zero-voltage bias.

Figure 266: nPowerMOSFET IGSSR pin connections



RdsON

Module name: RdsON

Module type: ITM

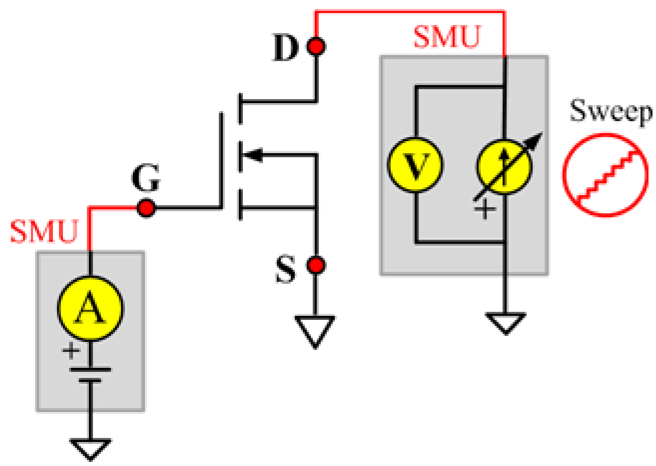
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the drain to source on-state resistance. Measures resistance by applying a current sweep to the drain with a specific gate voltage that is calculated by dividing the measured drain voltage by the Sourced current: Rds = Vds/Id.

Pin connections: Use the Model 2651A to apply a current sweep and make a voltage measurement at the drain. Use the low-power Model 2600B to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 267: nPowerMOSFET RdsON pin connections



VdsON

Module name: VdsON

Module type: ITM

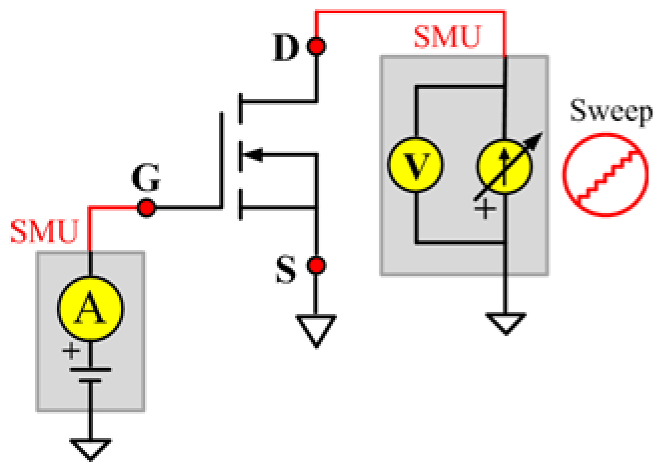
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the drain to source on-state voltage. Measures voltage on the drain-source by applying a current sweep to the drain with a specific gate voltage to turn on the device at a certain resistance value.

Pin connections: Use the Model 2651A SMU to apply a current sweep and make a voltage measurement at the drain. Use the low-power Model 2600B to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 268: nPowerMOSFET VdsON pin connections



VgsON

Module name: VgsON

Module type: ITM

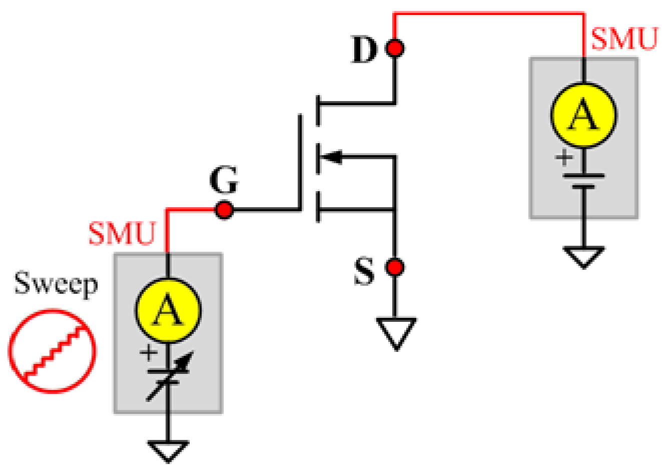
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the Gate to Source on-state voltage. Measures current on the Drain by applying a voltage sweep to the Gate-Source with a specific Drain to Source voltage to turn on the device to a certain Id current value.

Pin connections: Use the Model 2651A to apply voltage and make a current measurement at the drain. Use the low-power Model 2600B to sweep voltage at the gate. Connect source to GND or use a SMU to supply a zero-voltage bias.

Figure 269: nPowerMOSFET VgsON pin connections



VGSTH

Module name: VGSTH

Module type: ITM

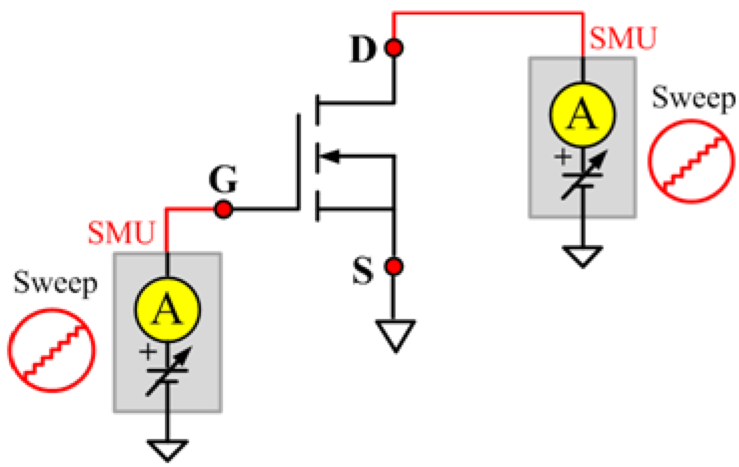
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the threshold voltage from the gate to source that is required to turn on the device at a specific Id current value that is given in the data sheet.

Pin connections: Use the Model 2651A SMU to force voltage and make a current measurement at the drain. Use the low-power Model 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 270: nPowerMOSFET VGSTH pin connections



VSD

Module name: VSD

Module type: ITM

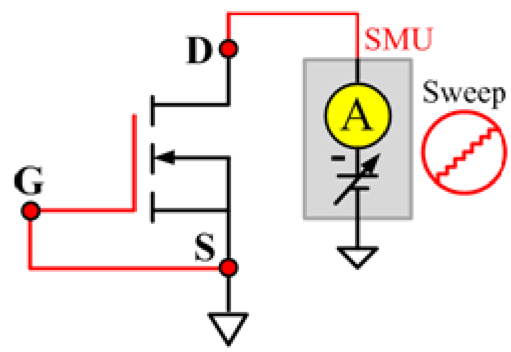
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal nPowerMOSFET

Function: Measures the forward voltage drop of the parasitic diode between the drain and source. Measures current on the drain by applying a voltage sweep from the source to drain with the gate shorted to the source.

Pin connections: Use the Model 2651A SMU to force voltage and make a current measurement at the Drain. Connect the gate and source to GND or use a SMU to supply a zero-voltage bias.

Figure 271: nPowerMOSFET VSD pin connections



IdON_MIX

Module name: IdON_MIX

Module type: PTM

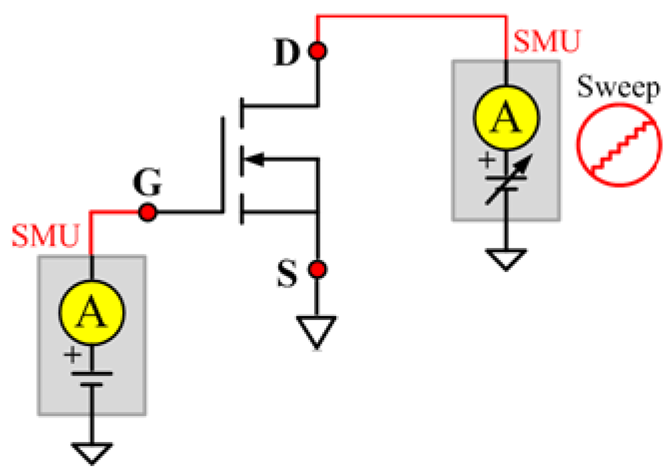
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal nPowerMOSFET

Function: Measures the on-state drain current. Measures current on the drain by applying a voltage sweep to the drain-source with a specific gate voltage to turn on the device at a certain Id current value that is given in the data sheet.

Pin connections: Use the Model 2651A SMU to apply a voltage sweep and make a current measurement at the drain. Use another SMU to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 272: nPowerMOSFET IdON_MIX pin connections



IdVd_StepVg_MIX

Module name: IdVd_StepVg_MIX

Module type: PTM

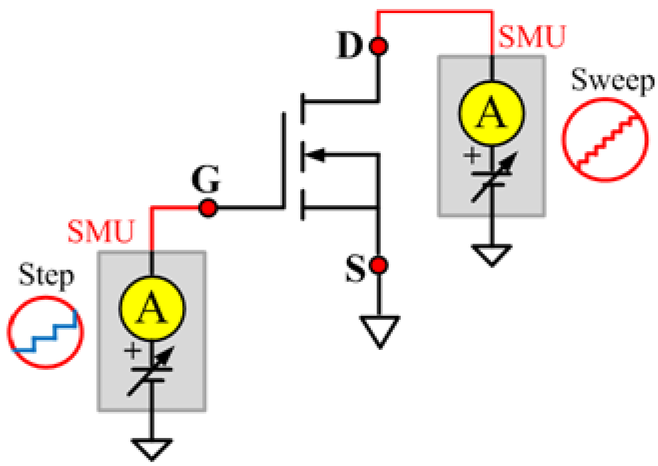
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal nPowerMOSFET

Function: Measures the standard family of IdVd curves. Each time the voltage steps on the gate-source, a voltage sweep and a set of current measurements occur on the drain.

Pin connections: Use the Model 2651A SMU to apply a voltage sweep and make a current measurement at the drain. Use a SMU to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 273: nPowerMOSFET IdVd_StepVg_MIX pin connections



RdsON_MIX

Module name: RdsON_MIX

Module type: PTM

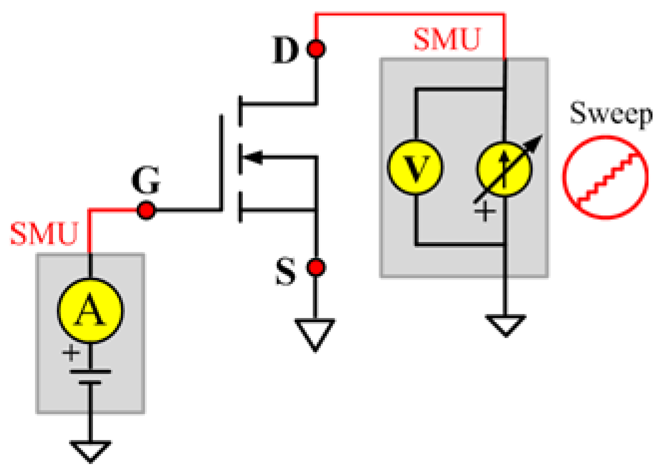
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal nPowerMOSFET

Function: Measures the drain to source on-state resistance. Measures resistance by applying a current sweep to the drain with a specific gate voltage that is calculated by dividing the measured drain voltage by the Sourced current: Rds = Vds/Id.

Pin connections: Use the Model 2651A SMU to apply a current sweep and make a voltage measurement at the drain. Use a SMU to force specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 274: nPowerMOSFET RdsON_MIX pin connections



VgsON_MIX

Module name: VgsON_MIX

Module type: PTM

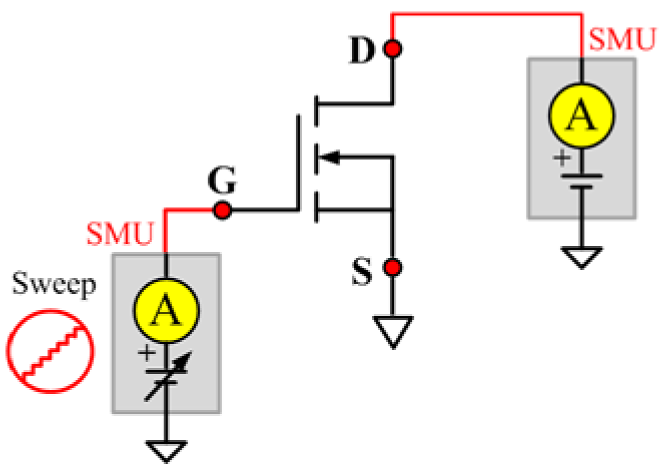
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A SMU

DUT: Three-terminal nPowerMOSFET

Function: Measures the gate to source on-state voltage. Measures current on the drain by applying a voltage sweep to the gate-source with a specific drain to source voltage to turn on the device at a certain Id current value.

Pin connections: Use the Model 2651A SMU to apply voltage and make a current measurement at the drain. Use the low-power 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 275: nPowerMOSFET VgsON_MIX pin connections



Cds

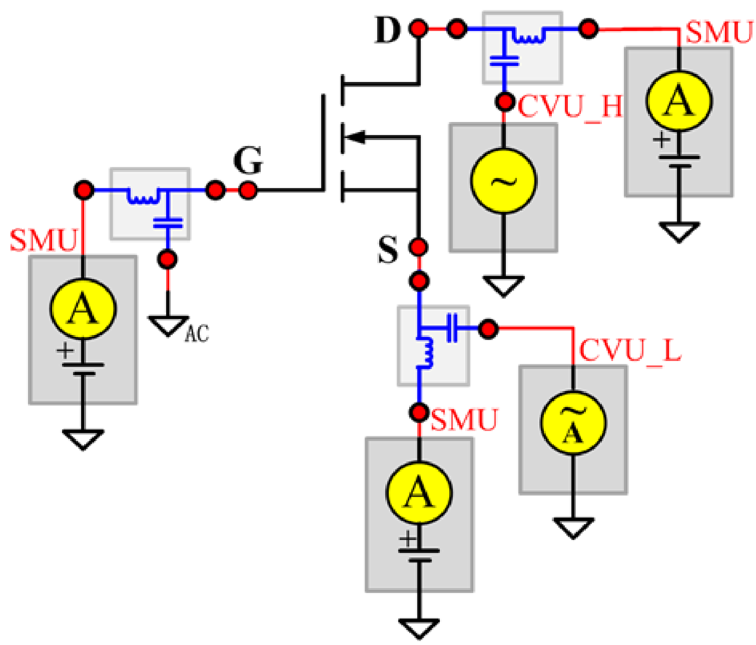
Module name: Cds

DUT: Three-terminal nPowerMOSFET

Function: Measures the capacitance between the Drain and Source terminals with the Gate terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect the guard terminal of a three-terminal bridge through one remote bias tee to the gate.

Figure 276: Three-terminal nPowerMOSFET Cds pin connections



Cgd

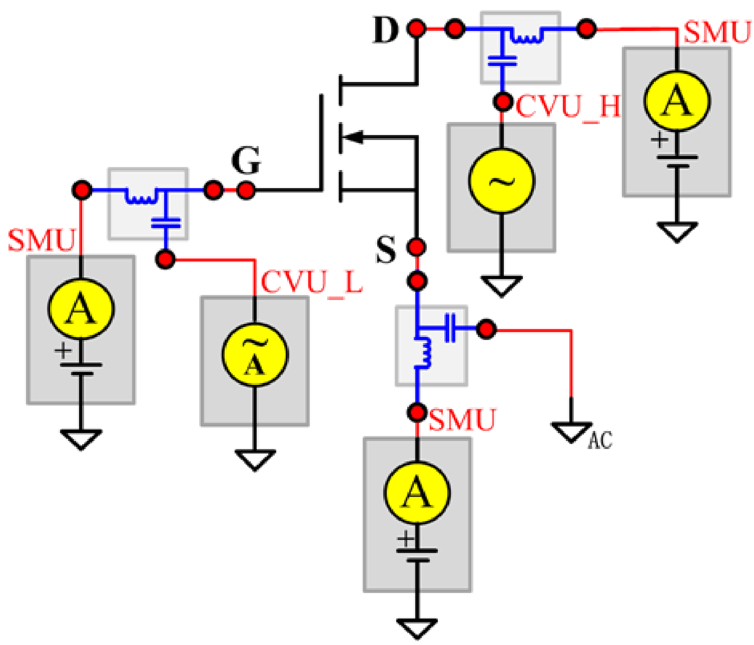
Module name: Cgd

DUT: Three-terminal nPowerMOSFET

Function: Measures the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the AC guard of a three-terminal bridge through one remote bias tee to the source.

Figure 277: Three-terminal nPowerMOSFET Cgd pin connections



Cgs

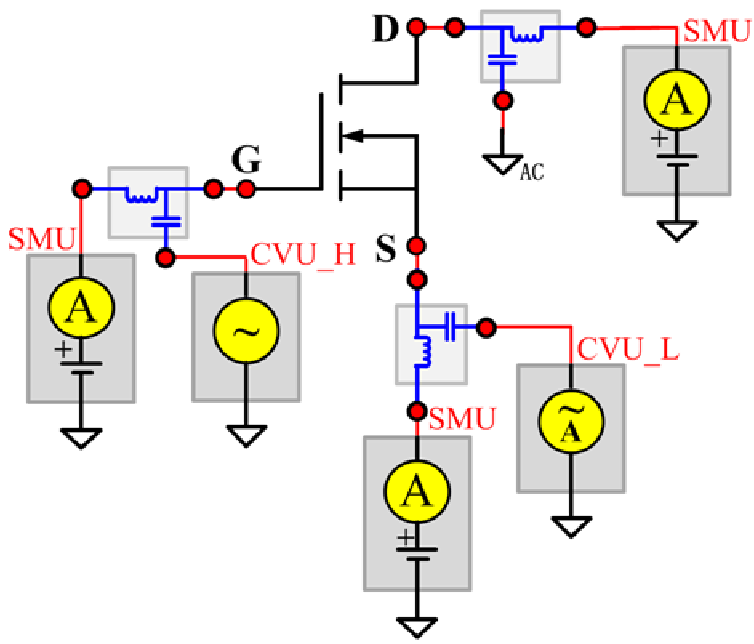
Module name: Cgs

DUT: Three-terminal nPowerMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the drain. Use the Series 2600B to supply zero voltage bias.

Figure 278: Three-terminal nPowerMOSFET Cgs pin connections



Ciss

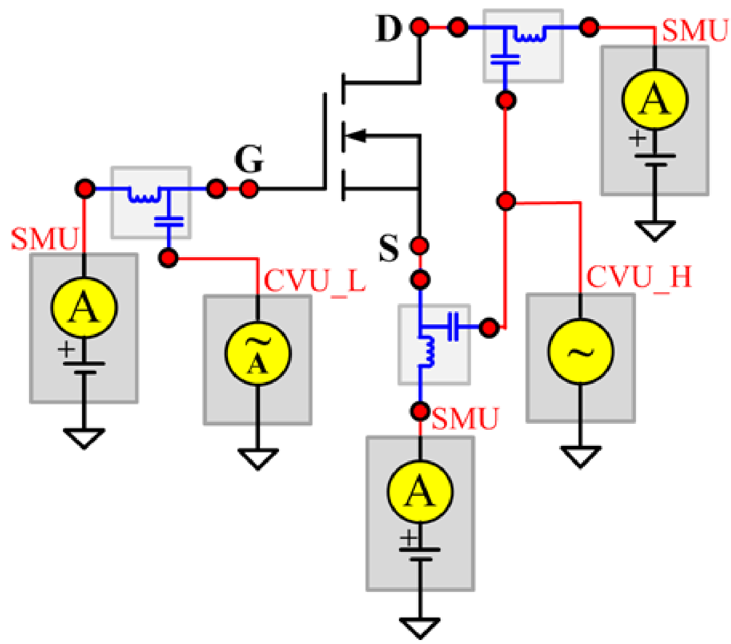
Module name: Ciss

DUT: Three-terminal nPowerMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal ac short-circuited to the Source terminal.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. AC short circuit the drain to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias.

Figure 279: Three-terminal nPowerMOSFET Ciss pin connections



Coss

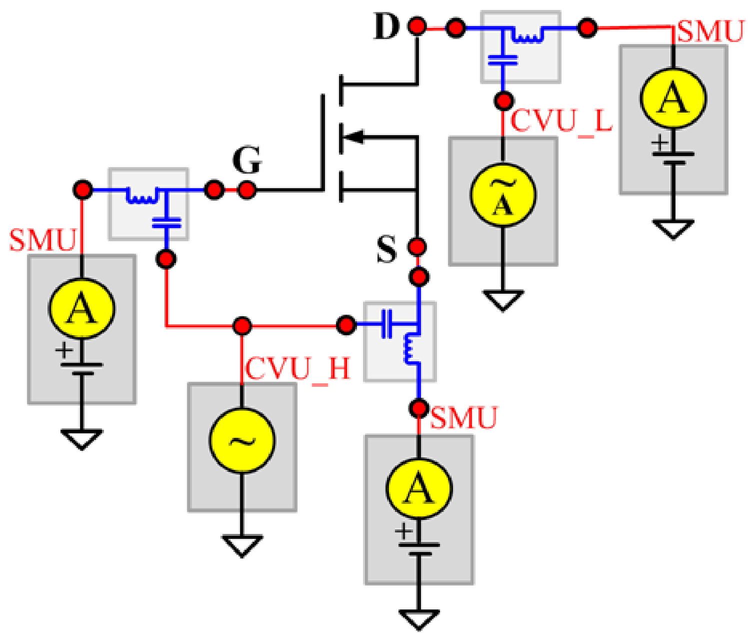
Module name: Coss

DUT: Three-terminal nPowerMOSFET

Function: Measures the capacitance between the drain and source terminals with the gate terminal ac short-circuited to the source terminal.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. AC short circuit the gate to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage.

Figure 280: Three-terminal nPowerMOSFET Coss pin connections



Crss

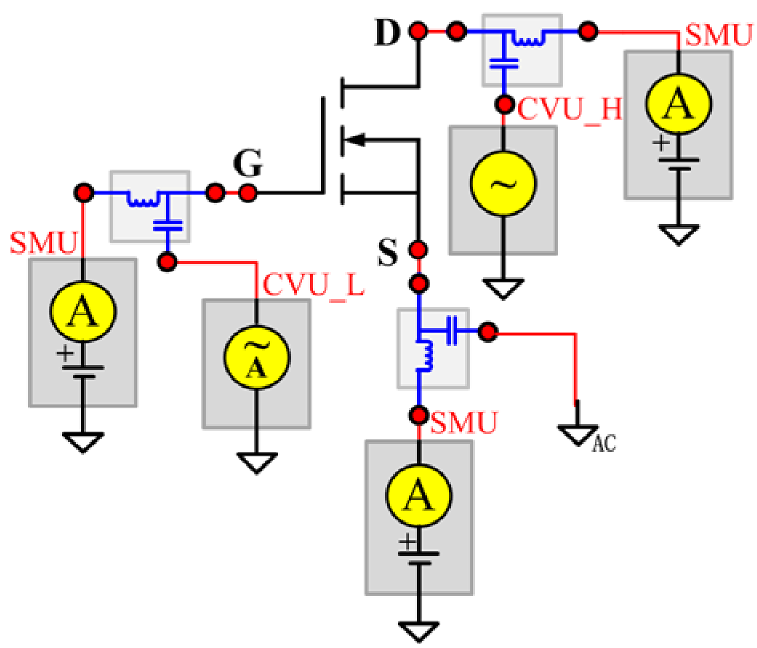
Module Name: Crss

DUT: Three-terminal nPowerMOSFET

Function: Measures the common-source short-circuit input capacitance by testing the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge.

Pin Connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the AC guard of a three-terminal bridge through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias.

Figure 281: Three-terminal nPowerMOSFET Crss pin connections



pPowerMOSFET test module template

The pPowerMOSFET parametric test module template is used to test parameters of a p-type power MOSFET, including leakage, breakdown, gain, on-state and characteristic curves.

BVDSS

Module name: BVDSS

Module type: ITM

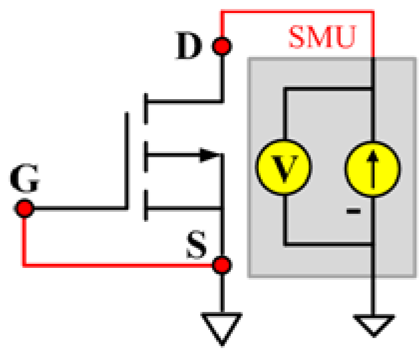
Instrument: Keithley Instruments Model 2657A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the breakdown voltage from the drain to source. Measures voltage on the drain-source by applying a breakdown current to the drain and the gate is shorted to the source.

Pin connections: Use the Model 2657A instrument to apply current and make a voltage measurement at the drain. Connect the gate and source to GND or use a SMU to supply a zero-voltage bias.

Figure 282: pPowerMOSFET BVDSS pin connections



GFS

Module name: GFS

Module type: ITM

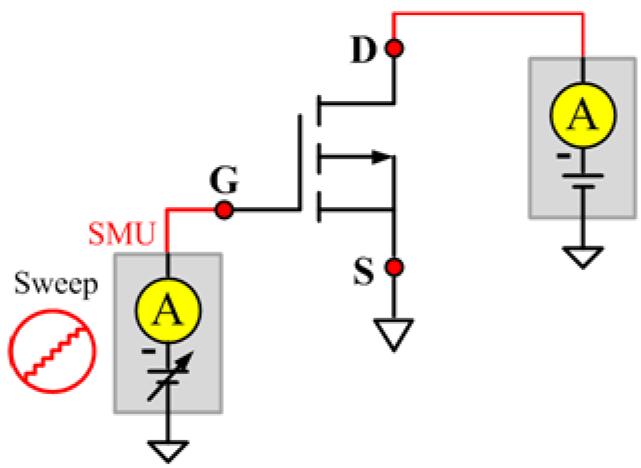
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the forward transconductance. Measures the current on the drain by applying a voltage sweep from the gate to source and calculates the ratio of change in Id for a change in the Vgs: GFS=delta(Id)/delta(Vgs).

Pin connections: Use the Model 2651A to apply voltage and make current measurements at the drain. Use the low-power Model 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 283: pPowerMOSFET GFS pin connections



IdON

Module name: IdON

Module type: ITM

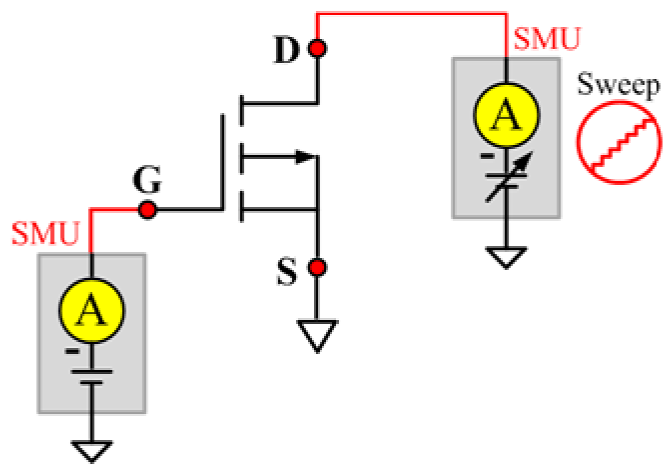
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the on-state drain current. Measures current on the drain by applying a voltage sweep to the drain-source with a specific gate voltage to turn on the device at a certain Id current value that is given in the datasheet.

Pin connections: Use the Model 2651A to apply a voltage sweep and make a current measurement at the drain. Use the low power Model 2600A to source a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 284: pPowerMOSFET IdON pin connections



IDSS

Module name: IDSS

Module type: ITM

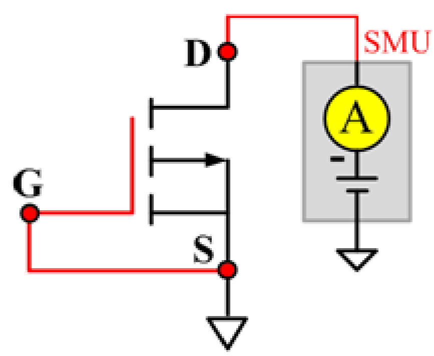
Instrument: Keithley Instruments Model 2657A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the leakage current from the drain to the Source when the device is off. Measures the current on the drain by applying a maximum permissible voltage between the drain and source, while the gate is shorted to the source.

Pin connections: Use the Model 2657A to apply voltage and make a current measurement at the drain. Connect the gate and source to GND or use a SMU to supply a zero-voltage bias.

Figure 285: pPowerMOSFET IDSS pin connections



IdVd_StepVg

Module name: IdVd_StepVg

Module type: ITM

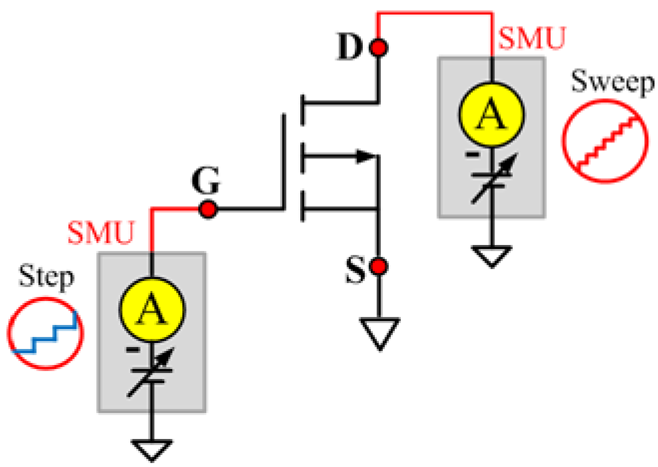
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the drain current at the specified gate voltage and sweeps the drain in pulse mode. Generates the standard family of IdVd curves.

Pin connections: Use the Model 2651A to apply a voltage sweep and make a current measurement at the drain. Use the low power Model 2600A to source a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 286: pPowerMOSFET IdVd_StepVg pin connections



IdVg_StepVd

Module name: IdVg_StepVd

Module type: ITM

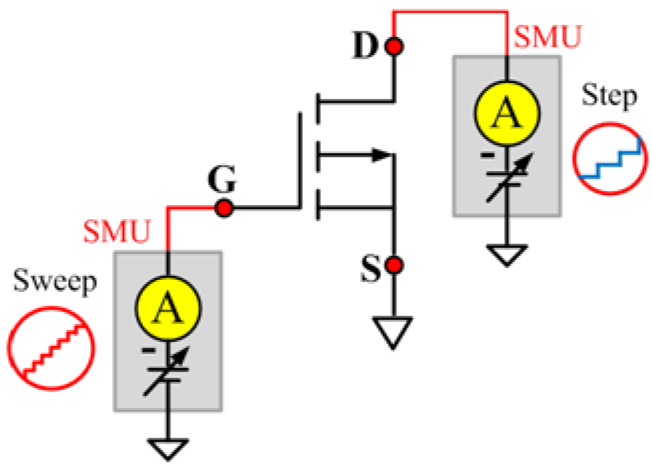
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the transfer characteristic of the device. Each time the voltage steps on the drain-source, a voltage sweep is performed on the gate-source and set of current measurements occurs on the drain.

Pin connections: Use the Model 2651A to apply a voltage step and make a current measurement at the drain. Use the low power Model 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 287: pPowerMOSFET IdVg_StepVd pin connections



IGSSF

Module name: IGSSF

Module type: ITM

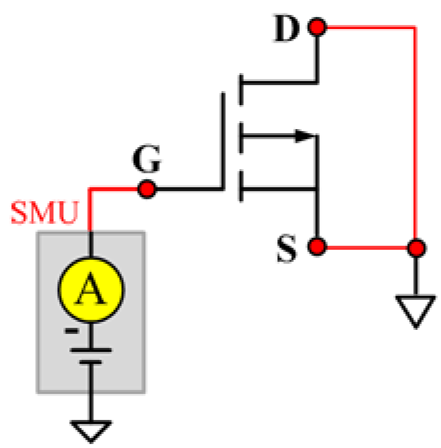
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the gate body forward leakage current. Measures current on the gate at the maximum permissible negative voltage from the gate to source.

Pin connections: One or two SMUs are used. One SMU applies voltage and takes current measurements at the gate. The drain and source are connected to ground or have no voltage bias from the other SMU. Use a SMU to force voltage and make a current measurement at the gate. Connect the drain and source to GND or use a SMU to supply a zero-voltage bias.

Figure 288: pPowerMOSFET IGSSF pin connections



IGSSR

Module name: IGSSR

Module type: ITM

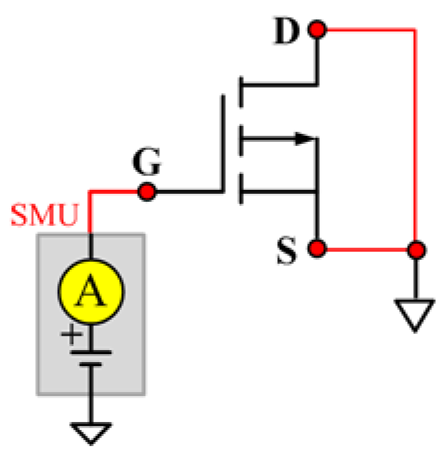
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the gate body reversed leakage current. Measures current on the gate at the maximum permissible positive voltage from the gate to source.

Pin connections: Use a SMU to force voltage and make a current measurement from the gate. Connect the drain and source to GND or use a SMU to supply a zero-voltage bias.

Figure 289: pPowerMOSFET IGSSR pin connections



RdsON

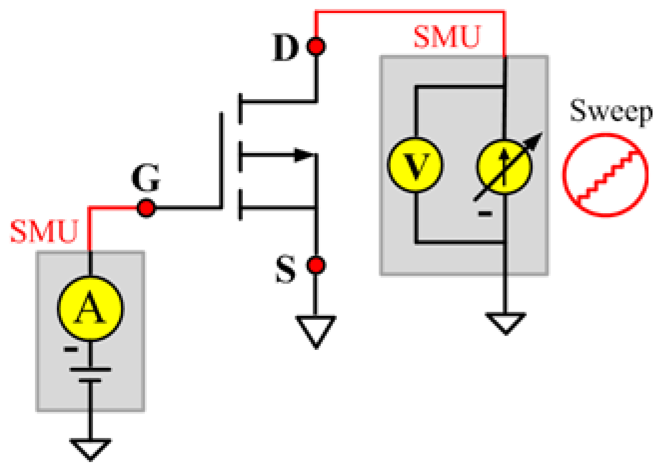
Module name: RdsON

DUT: Four-terminal pPowerMOSFET

Function: Measures the drain to source on-state resistance. Measures resistance by applying a current sweep to the drain with a specific gate voltage that is calculated by dividing the measured drain voltage by the Sourced current: Rds = Vds/Id.

Pin connections: Use the Model 2651A to apply a current sweep and make a voltage measurement at the drain. Use the low-power Model 2600B to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 290: pPowerMOSFET RdsOn pin connections



VdsON

Module name: VdsON

Module type: ITM

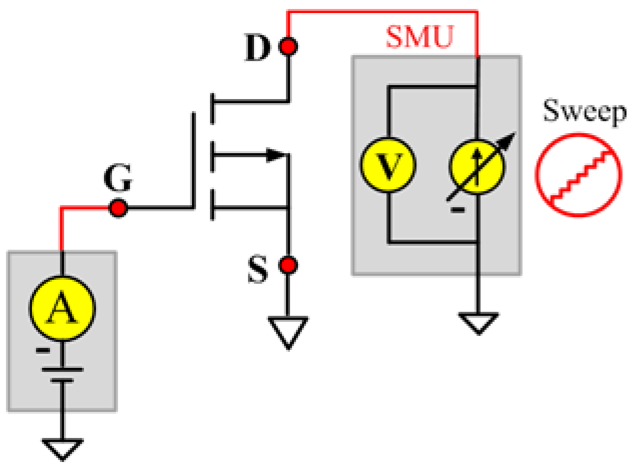
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the drain to source on-state voltage. Measures voltage on the drain-source by applying a current sweep to the drain with a specific gate voltage to turn on the device at a certain resistance value.

Pin connections: Use the Model 2651A SMU to apply a current sweep and make a voltage measurement at the drain. Use the low-power Model 2600B to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 291: pPowerMOSFET VdsON pin connections



VgsON

Module name: VgsON

Module type: ITM

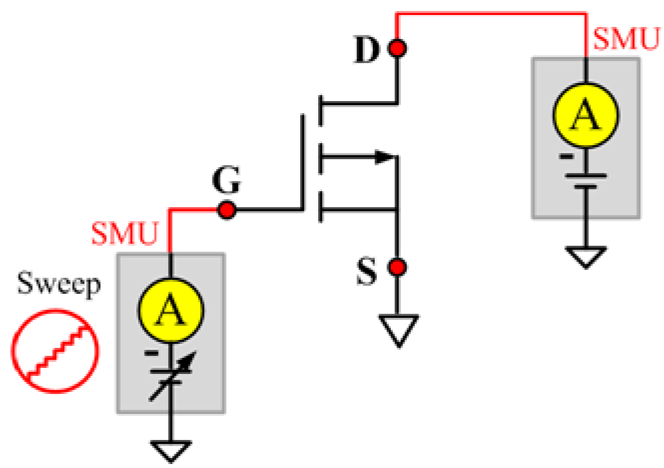
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the Gate to Source on-state voltage. Measures current on the Drain by applying a voltage sweep to the Gate-Source with a specific Drain to Source voltage to turn on the device to a certain Id current value.

Pin connections: Use the Model 2651A to apply voltage and make a current measurement at the drain. Use the low-power Model 2600B to sweep voltage at the gate. Connect source to GND or use a SMU to supply a zero-voltage bias.

Figure 292: pPowerMOSFET VgsON pin connections



VGSTH

Module name: VGSTH

Module type: ITM

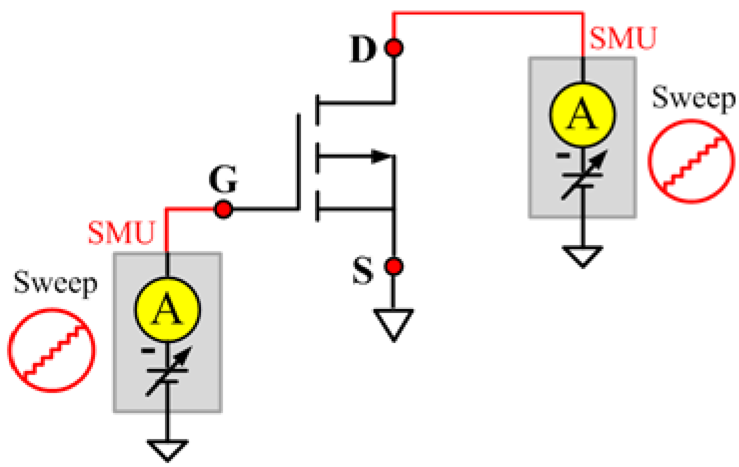
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the threshold voltage from the gate to source that is required to turn on the device at a specific Id current value that is given in the data sheet.

Pin connections: Use the Model 2651A SMU to force voltage and make a current measurement at the drain. Use the low-power Model 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 293: pPowerMOSFET VGSTH pin connections



VSD

Module name: VSD

Module type: ITM

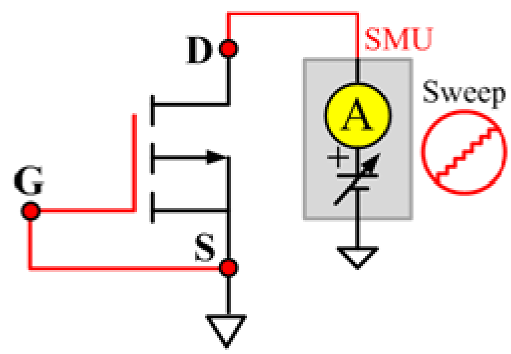
Instrument: Keithley Instruments Model 2651A, Series 2600B

DUT: Three-terminal pPowerMOSFET

Function: Measures the forward voltage drop of the parasitic diode between the drain and source. Measures current on the drain by applying a voltage sweep from the source to drain with the gate shorted to the source.

Pin connections: Use the Model 2651A SMU to force voltage and make a current measurement at the Drain. Connect the gate and source to GND or use a SMU to supply a zero-voltage bias.

Figure 294: pPowerMOSFET VSD pin connections



IdVd_StepVg_MIX

Module name: IdVd_StepVg_MIX

Module type: PTM

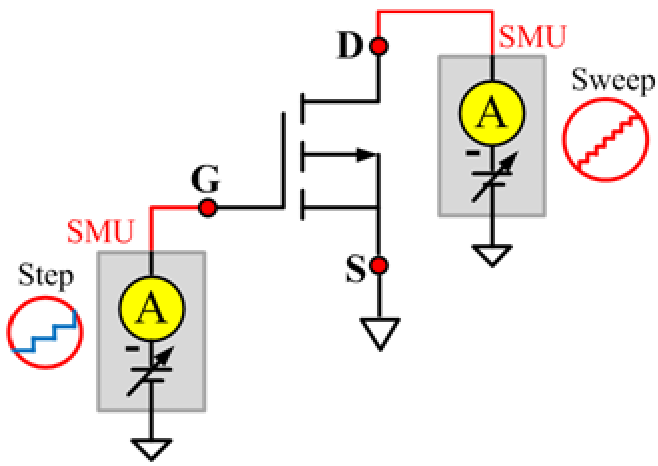
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal pPowerMOSFET

Function: Measures the drain current at the specified gate voltage and sweeps the drain in pulse mode. Generates the standard family of IdVd curves.

Pin connections: Use the Model 2651A SMU to apply a voltage sweep and make a current measurement at the drain. Use a SMU to force a specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 295: pPowerMOSFET IdVd_StepVg_MIX pin connections



RdsON_MIX

Module name: RdsOn_MIX

Module type: PTM

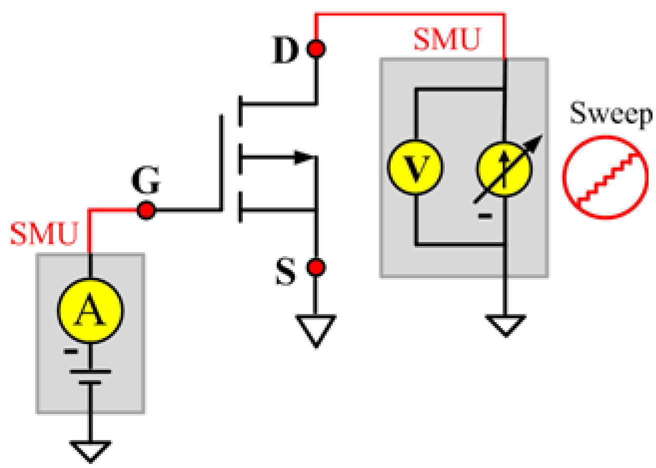
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A-SMU

DUT: Three-terminal pPowerMOSFET

Function: Measures the drain to source on-state resistance. Measures resistance by applying a current sweep to the drain with a specific gate voltage that is calculated by dividing the measured drain voltage by the Sourced current: Rds = Vds/Id.

Pin connections: Use the Model 2651A SMU to apply a current sweep and make a voltage measurement at the drain. Use a SMU to force specific voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 296: pPowerMOSFET RdsON_MIX pin connections



VgsON_MIX

Module name: VgsON_MIX

Module type: PTM

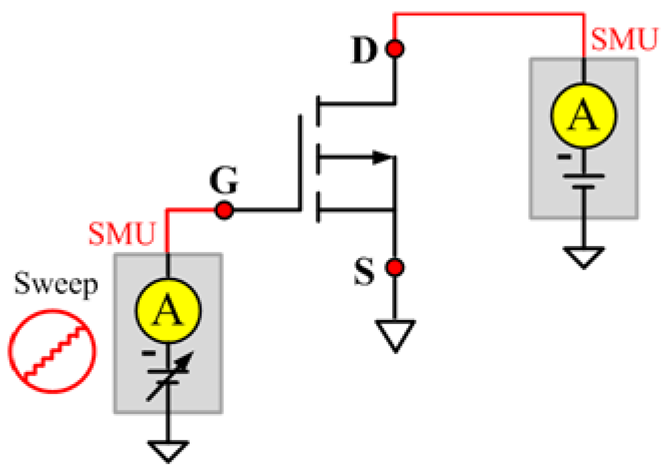
Instrument: Keithley Instruments Model 2651A, Series 2600B, Series 2400, Model 4200A SMU

DUT: Three-terminal pPowerMOSFET

Function: Measures the gate to source on-state voltage. Measures current on the drain by applying a voltage sweep to the gate-source with a specific drain to source voltage to turn on the device at a certain Id current value.

Pin connections: Use the Model 2651A SMU to apply voltage and make a current measurement at the drain. Use the low-power 2600B to sweep voltage at the gate. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 297: pPowerMOSFET VgsON_MIX pin connections



Cds

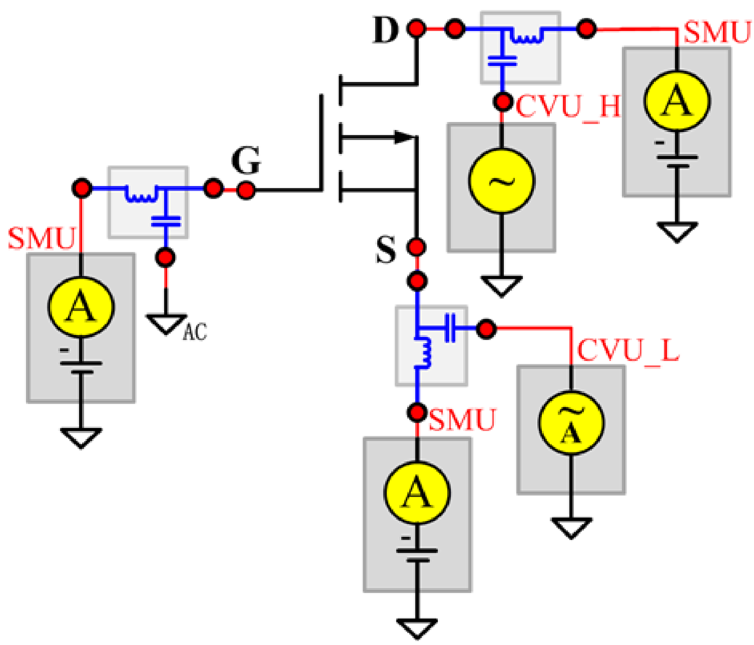
Module Name: Cds

DUT: Three-terminal pPowerMOSFET

Function: Measures the capacitance between the Drain and Source terminals with the Gate terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect the guard terminal of a three-terminal bridge through one remote bias tee to the gate.

Figure 298: Three-terminal nPowerMOSFET Cds pin connections



Cgd

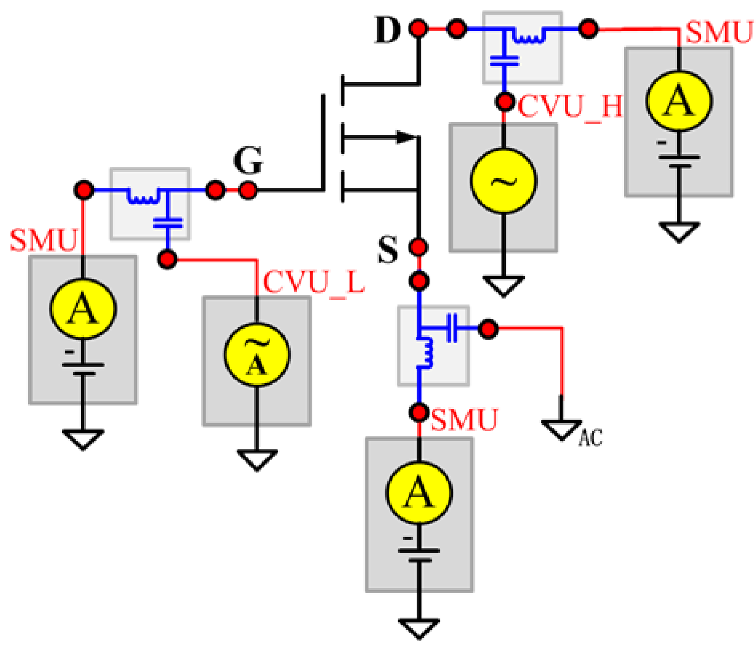
Module Name: Cgd

DUT: Three-terminal pPowerMOSFET

Function: Measures the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge.

Pin Connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the AC guard of a three-terminal bridge through one remote bias tee to the source.

Figure 299: Three-terminal pPowerMOSFET Cgd pin connections



Cgs

Description:

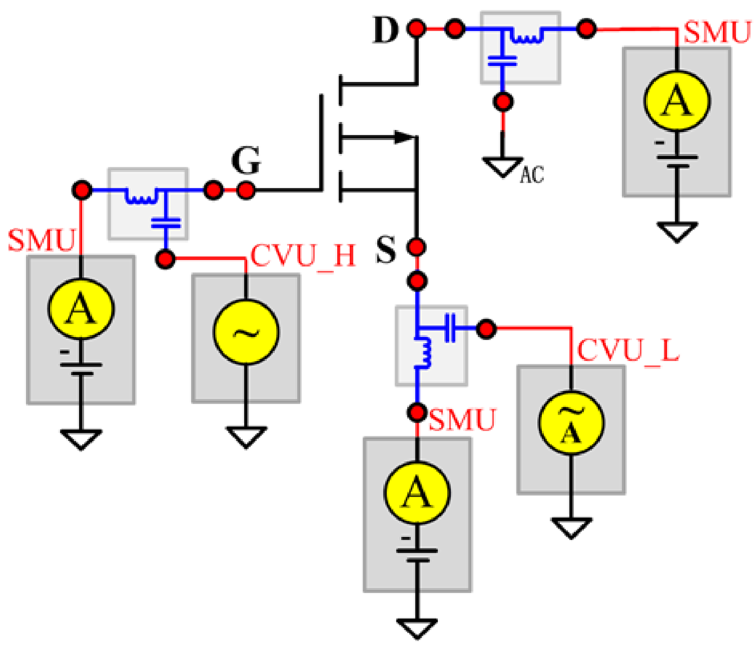
Module name: Cgs

DUT: Three-terminal pPowerMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal connected to the guard terminal of a three-terminal bridge.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the drain. Use the Series 2600B to supply zero voltage bias.

Figure 300: Three-terminal pPowerMOSFET Cgs pin connections



Ciss

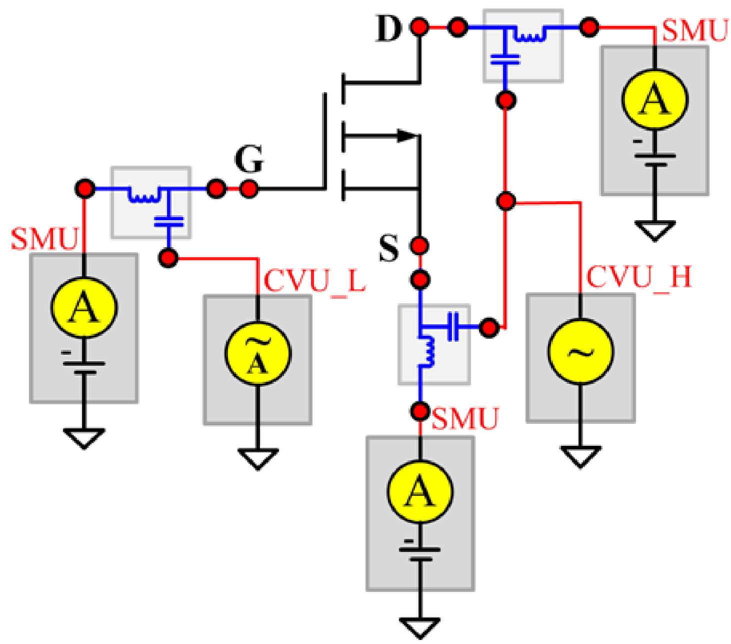
Module name: Ciss

DUT: Three-terminal pPowerMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal ac short-circuited to the Source terminal.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. AC short circuit the drain to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias.

Figure 301: Three-terminal pPowerMOSFET Ciss pin connections



Coss

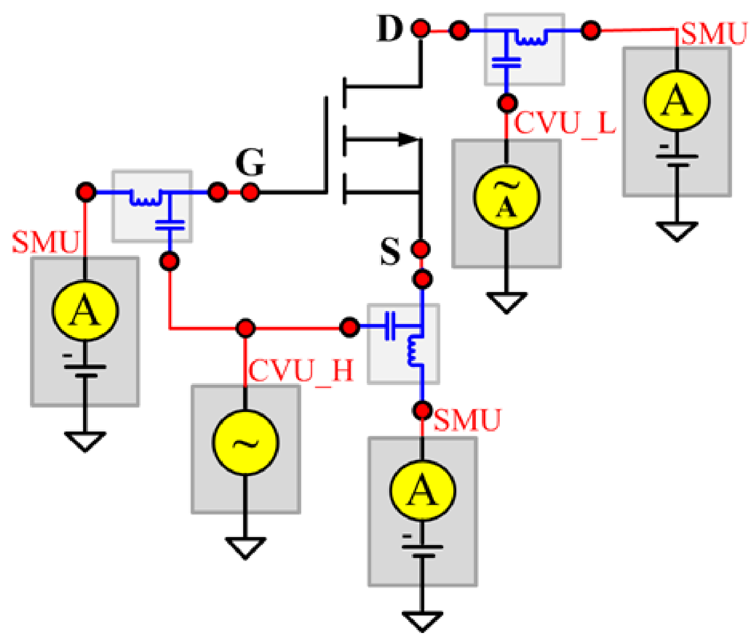
Module name: Coss

DUT: Three-terminal pPowerMOSFET

Function: Measures the capacitance between the drain and source terminals with the gate terminal ac short-circuited to the source terminal.

Pin Connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. AC short circuit the gate to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage.

Figure 302: Three terminal pPowerMOSFET Coss pin connections



Crss

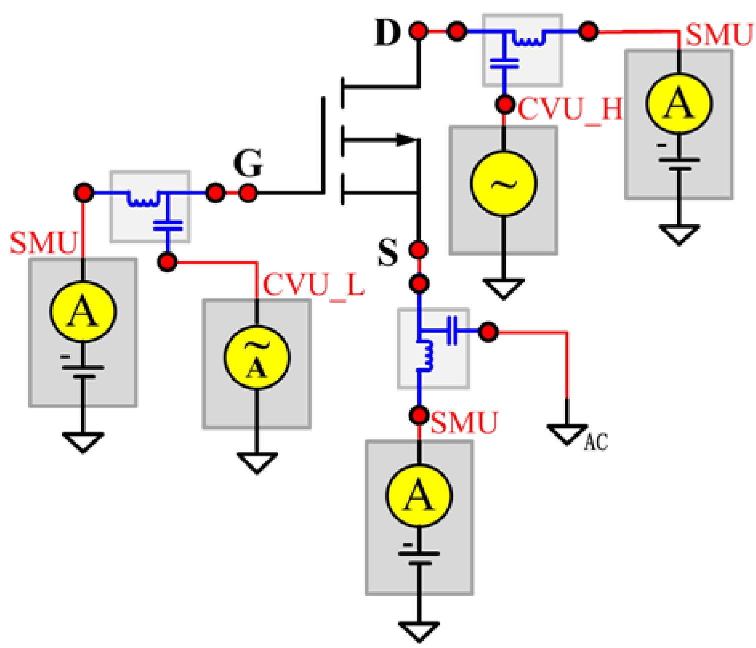
Module Name: Crss

DUT: Three-terminal pPowerMOSFET

Function: Measures the common-source short-circuit input capacitance by testing the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge.

Pin Connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias.

Figure 303: Three-terminal pPowerMOSFET Crss pin connections



nMOSFET test module template

The nMOSFET parameter test module template is used to test some parameters of an n-type MOSFET, including leakage, breakdown, gain, on-state and characteristic curves.

The WLR script library provides certain wafer-level reliability tests on devices with Series 2600B instruments, with an XRC user interface. Note that the HCI module is a test script file based on the Series 2600B LPT library and is available in this library.

BVDSS

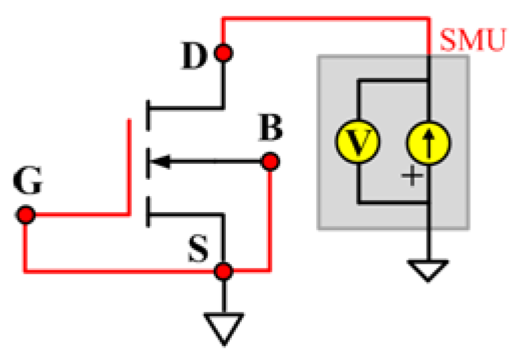
Module name: BVDSS

DUT: Four-terminal nMOSFET

Function: Measures the drain-source breakdown voltage of the nMOSFET with the gate-source shorted.

Pin connections: Use a SMU to apply a breakdown current on the drain. Short gate, source, and Bulk (connect them all to GND or use a SMU to supply a zero-voltage bias).

Figure 304: Four-terminal nMOSFET BVDSS pin connections



BVDSV

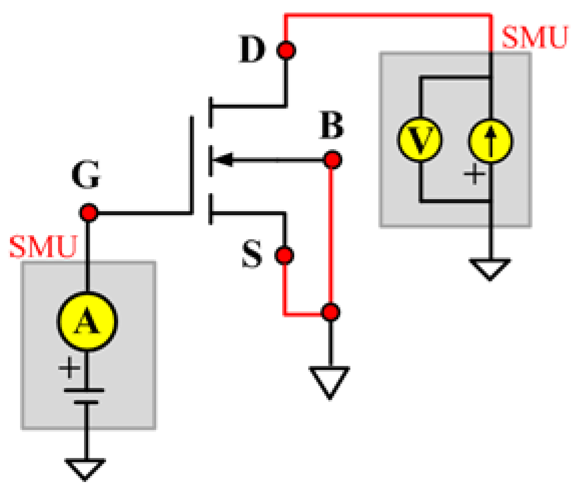
Module name: BVDSV

DUT: Four-terminal nMOSFET

Function: Measures the drain-source breakdown voltage of the nMOSFET with the gate biased.

Pin connections: Connect the source and bulk to GND or use a SMU to supply a zero-voltage bias. Use a SMU to bias the gate. Use a SMU to apply a breakdown current on the drain.

Figure 305: Four-terminal nMOSFET BVDSV pin connections



BVGSO

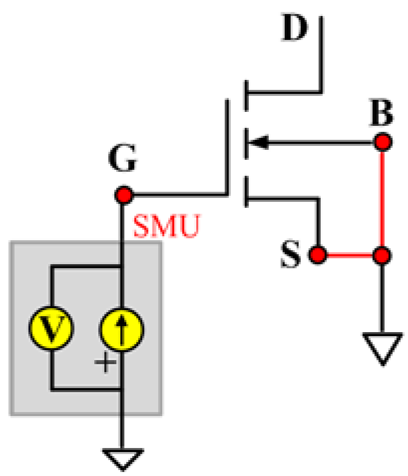
Module name: BVGSO

DUT: Four-terminal nMOSFET

Function: Measures the gate-source breakdown voltage of the nMOSFET with the drain opened.

Pin connections: Use a SMU to apply a breakdown current on the gate. Open the circuit to the drain or use a SMU to supply a zero-current bias. Short bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 306: Four-terminal nMOSFET BVGSO pin connections



BVGDS

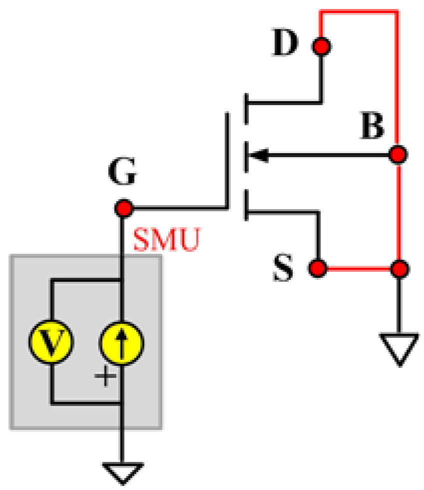
Module name: BVGDS

DUT: Four-terminal nMOSFET

Function: Measures the gate-drain breakdown voltage of the nMOSFET with the source-drain shorted.

Pin connections: Connect the source, bulk, and drain to GND or use a SMU to supply a zero-voltage bias. Use a SMU to apply a breakdown current on the gate.

Figure 307: Four-terminal nMOSFET BVGDS pin connections



BVGDO

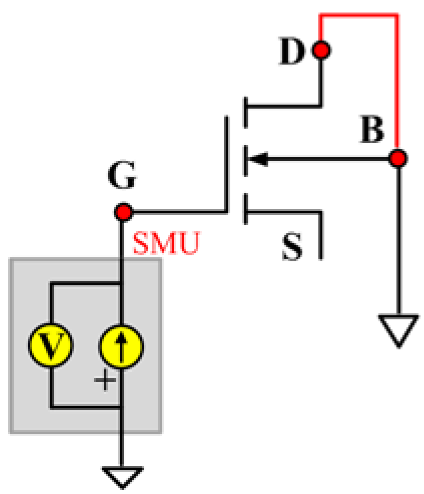
Module name: BVGDO

DUT: Four-terminal nMOSFET

Function: Measures the gate-drain breakdown voltage of the nMOSFET with the source opened.

Pin connections: Use a SMU to apply a breakdown current on the gate. Open the circuit to the source or use a SMU to supply a zero-current bias. Short bulk and drain to GND or use a SMU to supply a zero-voltage bias.

Figure 308: Four-terminal nMOSFET BVGDO pin connections



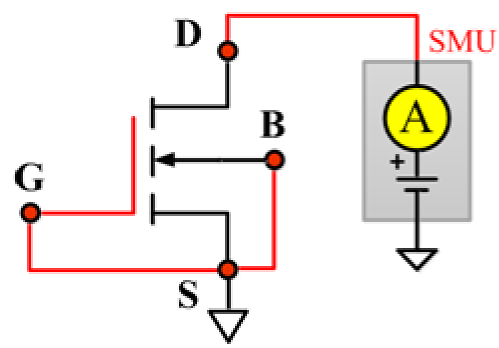
IDL

Module name: IDL

Function: Measures the drain leakage current with the gate-source shorted.

Pin connections: Short the gate and source. Apply a voltage to the drain, and connect the bulk, gate, and source to ground.

Figure 309: Four-terminal nMOSFET IDL pin connections



IDS_ISD

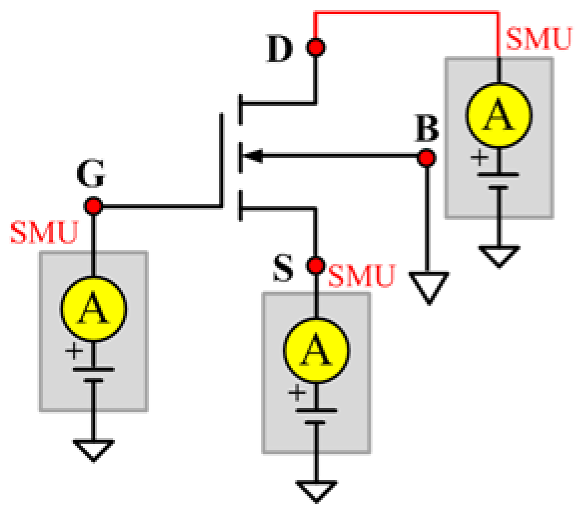
Module name: IDS_ISD

DUT: Four-terminal nMOSFET

Function: Measures the drain-source and source-drain current with the gate biased.

Pin connections: Use a SMU to force voltage to the gate. Use a SMU to force voltage to the drain. Connect source and bulk to GND or use a SMU to supply a zero-voltage bias.

Figure 310: Four-terminal nMOSFET IDS_ISD pin connections



IdVd_BiasVg

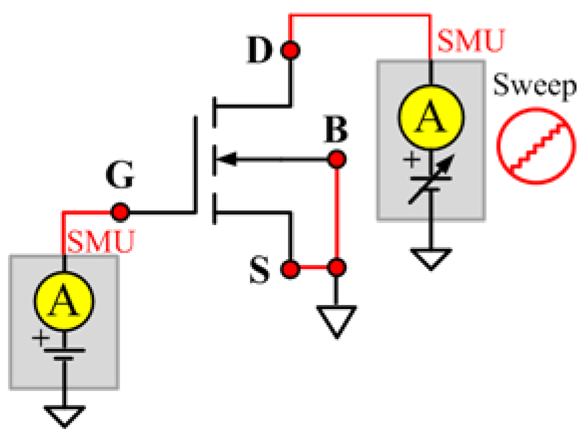
Module name: IdVd_BiasVg

DUT: Four-terminal nMOSFET

Function: Measures the drain current during a specified drain voltage sweep, and the drain current and the drain voltage curve.

Pin connections: Use a SMU to bias voltage to the gate. Use a SMU to apply a sweep voltage to the drain. Short bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 311: Four-terminal nMOSFET IdVd_BiasVg pin connections



IdVd_StepVg

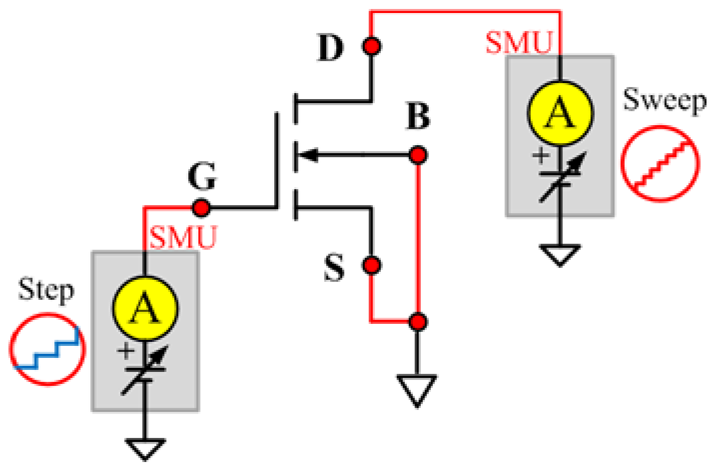
Module name: IdVd_StepVg

DUT: Four-terminal nMOSFET

Function: Measures the drain current during a specified drain voltage sweep, and the series of drain current tests and the drain voltage curve.

Pin connections: Use a SMU to sweep the drain. Use a SMU to step the gate. Short bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 312: Four-terminal nMOSFET IdVd_StepVg pin connections



IdVg_BiasVd

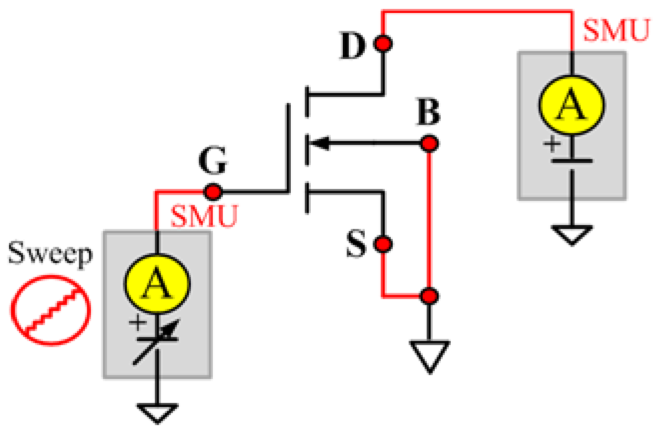
Module name: IdVg_BiasVd

DUT: Four-terminal nMOSFET

Function: Measures the drain current during a specified gate voltage sweep, and the drain current and the gate voltage curve.

Pin connections: Use a SMU to bias voltage to the drain. Use a SMU to apply a sweep voltage to the gate. Short the bulk and source or use a SMU to supply a zero-voltage bias.

Figure 313: Four-terminal nMOSFET IdVg_BiasVd pin connections



IdVg_StepVd

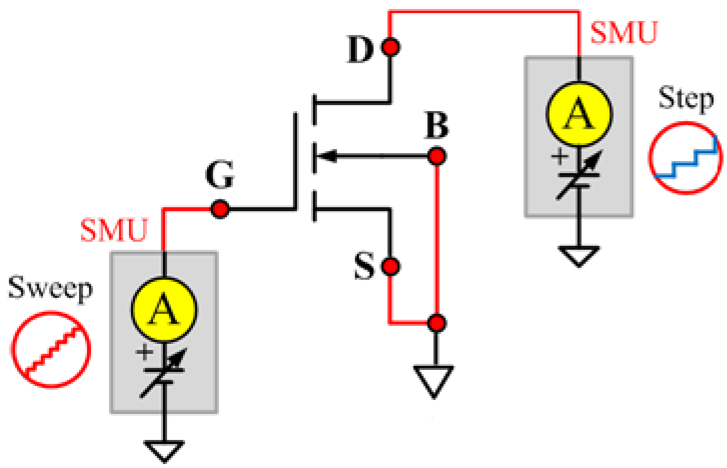
Module Name: IdVg_StepVd

DUT: Four-terminal nMOSFET

Function: Measures the drain current during a specified gate voltage sweep with the drain step, and a series of drain currents and a gate voltage curve.

Pin connections: Use a SMU to step the drain. Use a SMU to sweep the gate. Short bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 314: Four-terminal nMOSFET IdVg_StepVd pin connections



IdVg_StepVsub

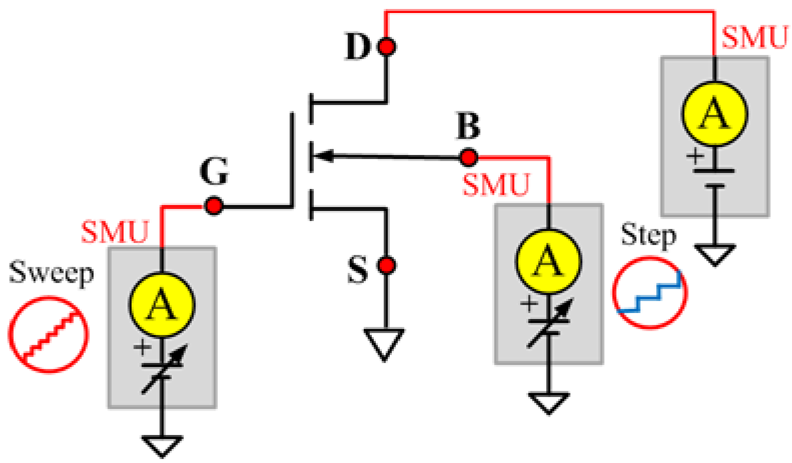
Module name: IdVg_StepVsub

DUT: Four-terminal nMOSFET

Function: Measures the drain current during a specified gate voltage sweep with a bulk step, and a series of drain currents and a gate voltage curve.

Pin connections: Use a SMU to step the bulk. Use a SMU to sweep the gate. Use a SMU to bias the drain. Connect the source to GND or use a SMU to supply a zero-voltage bias.

Figure 315: Four-terminal nMOSFET IdVg_StepVsub pin connections



IGL

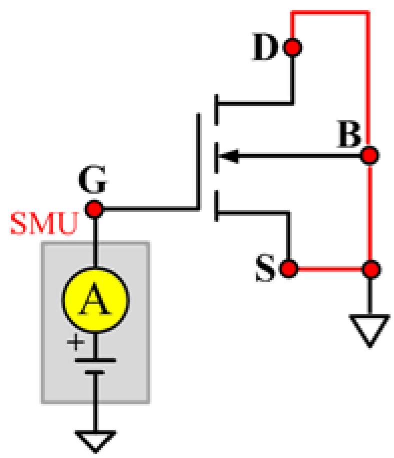
Module name: IGL

DUT: Four-terminal nMOSFET

Function: Measures the gate leakage current when the source and drain are shorted.

Pin connections: Use a SMU to force voltage to the gate. Connect the source, drain, and bulk to GND or use a SMU to supply a zero-voltage bias.

Figure 316: Four-terminal nMOSFET IGL pin connections



IgVg

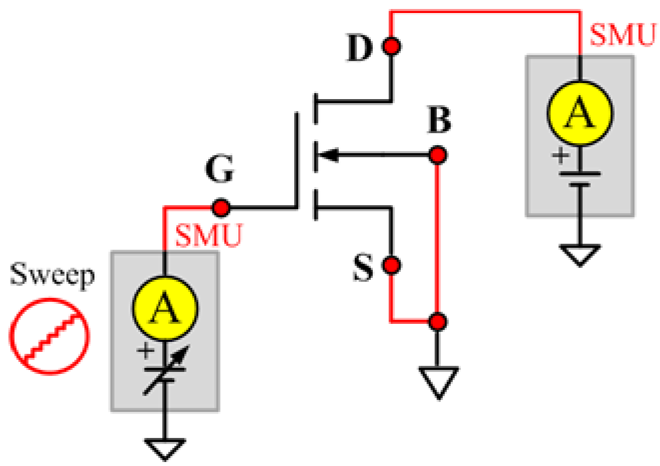
Module name: IgVg

DUT: Four-terminal nMOSFET

Function: Measures the gate current during a specified gate voltage sweep when the drain is biased, and the gate current and gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. Short the bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 317: Four-terminal nMOSFET IgVg pin connections



ISL

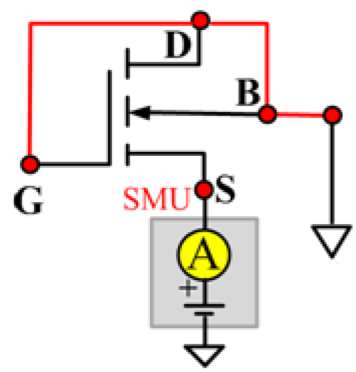
Module name: ISL

DUT: Four-terminal nMOSFET

Function: Measures the source leakage current when the gate-drain is shorted.

Pin connections: Use a SMU to force voltage to the source. Short bulk, gate, and drain to GND or use a SMU to supply a zero-voltage bias.

Figure 318: Four-terminal nMOSFET ISL pin connections



Vtci

Module name: Vtci

DUT: Four-terminal nMOSFET

Function: Measures the constant current threshold voltage of the nMOSFET device, and the drain current and the gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. Input source and bulk voltage when needed. Usually, they are connected to GND for NMOS and connected to the nominal power supply voltage (VDD) for PMOS.

Procedure: The constant current threshold voltage:

`Vth_ci=VGS (@ID=1 uA.W/L)`	NMOS
`Vth_ci=VGS (@ID=-0.025 uA.W/L)`	PMOS

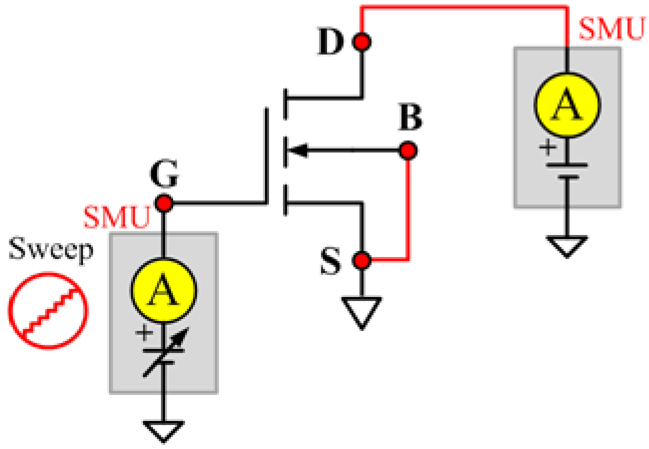
Where `W` and `L` are the gate width and gate length as printed on the wafer. Set a target drain current `Id_tar (Id_tar=1uA.W/L, or -0.025uA.W/L)`, which is the sign to be near threshold, then search the gate voltage to make the drain current equal to `Id_tar`.

NOTE

The `Four_term_nMOSFET_Vth_ci` measurement procedure must determine `Vth_ci` to within a 1 mV resolution. If the VGS step size is larger than 1 mV, then a linear interpolation method may be used to achieve the 1 mV resolution.

Typical DC bias voltages for `Vth_ci` measurements are `VDS = VDS_lin`, `VBS = VBB` for linear region measurement, or `VDS = VDS_sat`, (`VBS = VBB` for saturation region measurement). Typically, for PMOS, `VDS_lin = -0.1 V(@VDD =5 V)`; for `NMOS, VDS_lin=0.1 V(@VDD = 5 V).`

Figure 319: Four-terminal nMOSFET Vtci pin connections



Vtext

Module name: Vtext

DUT: Four-terminal nMOSFET

Function: Measures the drain current during a gate voltage sweep, extracts the trans-conductance (Gm) and measure the maximum trans-conductance (Gmmax), measures the extracted threshold voltage (Vth_ex), measures the drain current and the gate voltage curve, and measures the Gm drain current or the Gm gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. Input source and bulk voltage when needed. Usually, they are connected to GND for NMOS and connected to the nominal power supply voltage (VDD) for PMOS.

Procedure: The threshold voltage is extrapolated from the measurement of the maximum slope (`Gmmax`) of the ID-VGS curve:

```
Vth_ex = VGS (@Gmmax)-ID(@Gmmax)/Gmmax
```

Where:

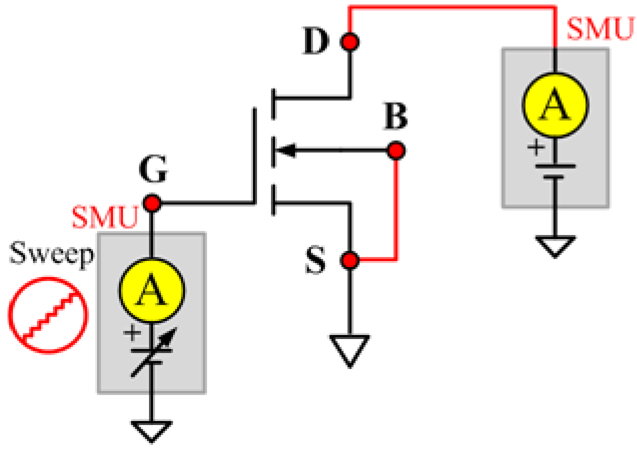
- `VGS @Gmmax)` is the gate voltage at the point of the maximum slope of the ID-VGS curve
- `ID(@Gmmax)` is the drain current at the point of the maximum slope of the ID-VGS curve
- `Gmmax` is the maximum slope of the ID-VGS curve

NOTE

DC bias voltages for `Vth_ex` measurements are `VDS = VDS_lin`, `VBS = VBB` for linear measurement.

`VDS = VDS_sat`, `VBS = VBB` for saturation. Typically, for PMOS, `VDS_lin = -0.1 V(@VDD = 5 V)`; for NMOS, `VDS_lin = 0.1 V(@VDD = 5 V).`

Figure 320: Four-terminal nMOSFET Vtext pin connections



Vtext_llsq

Module name: Vtext_llsq

Module type: Standard STM

Instrument: Keithley Instruments Series 2600B SMU

DUT: Four-terminal nMOSFET

Function: Measures the drain current at the gate voltage sweep, extracts the trans-conductance (Gm) and extract the maximum trans-conductance (Gmmax), measures the extracted threshold voltage (Vth_ex), measure the drain current and the gate voltage curve, and measures the Gm drain current or the Gm gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. If needed, input the source and bulk voltage. Usually, they are connected to GND for NMOS and connected to the nominal power supply voltage (VDD) for PMOS.

Procedure: The threshold voltage is extrapolated from the measurement of the maximum slope (`Gmmax`) of the IDVGS curve.

```
Vth_ex = VGS (@Gmmax)-ID(@Gmmax)/Gmmax
```

Where:

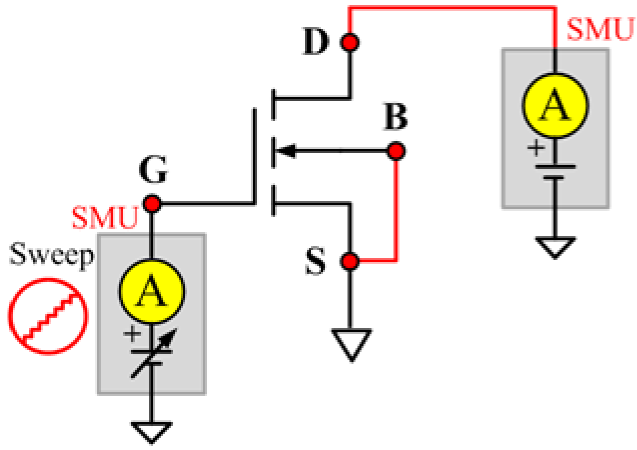
- `VGS(@Gmmax)` is the gate voltage at the point of the maximum slope of the IDVGS curve
- `ID(@Gmmax)` is the drain current at the point of the maximum slope of the IDVGS curve
- `Gmmax` is the maximum slope of the IDVGS curve

NOTE

DC bias voltages for `Vth_ex` measurements are `VDS = VDS_lin`, `VBS = VBB` for linear measurement.

VDS = VDS_sat, VBS = VBB for saturation. Typically, for PMOS, VDS_lin = -0.1 V(@VDD = 5 V); for NMOS,VDS_lin = 0.1 V(@VDD = 5 V).

Figure 321: Four-terminal nMOSFET Vtext_llsq pin connections



Cds

Description:

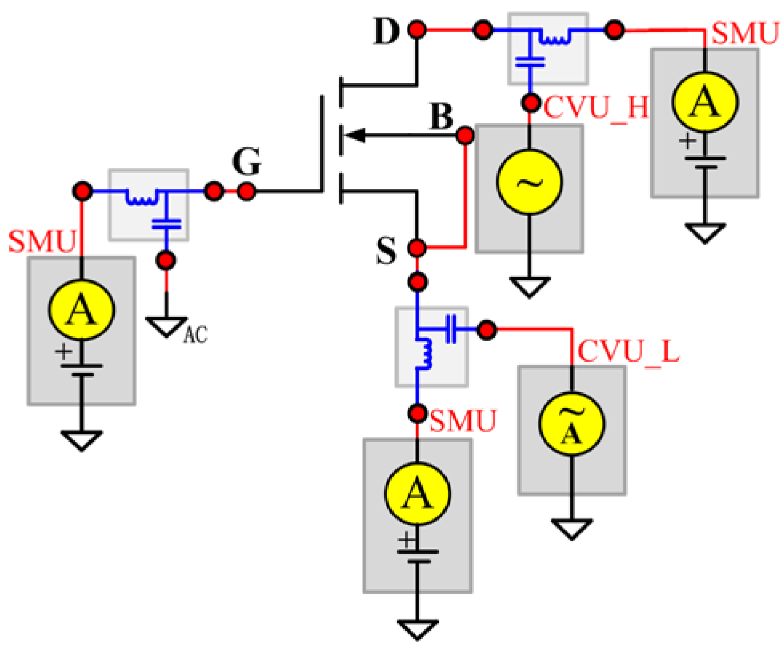
Module Name: Cds

DUT: Four-terminal nMOSFET

Function: Measures the capacitance between the Drain and Source terminals with the Gate terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Short bulk to source. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect the guard terminal of a three-terminal bridge through one remote bias tee to the gate.

Figure 322: Four-terminal nMOSFET Cds pin connections



Cgd

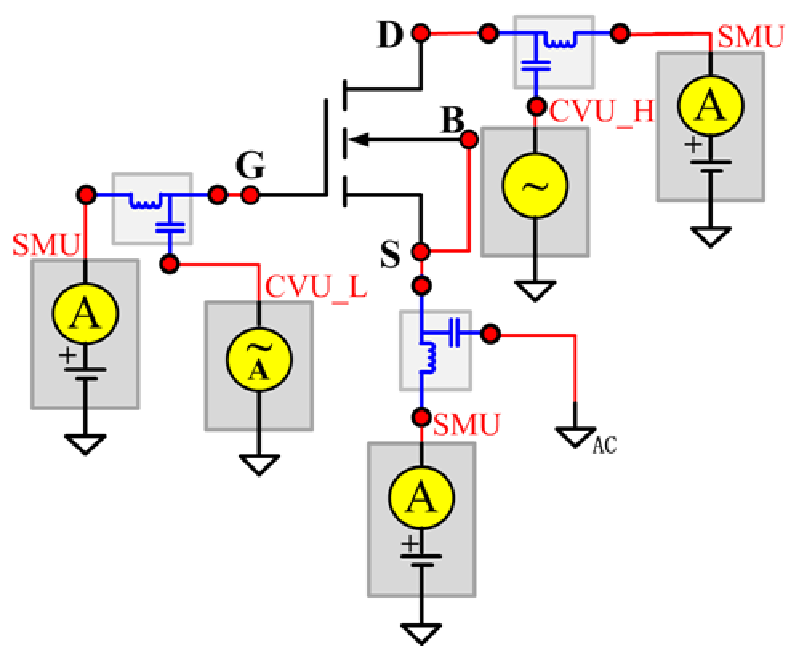
Module name: Cgd

DUT: Four-terminal nMOSFET

Function: Measures the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the source.

Figure 323: Four-terminal nMOSFET Cgd pin connections



Cgs

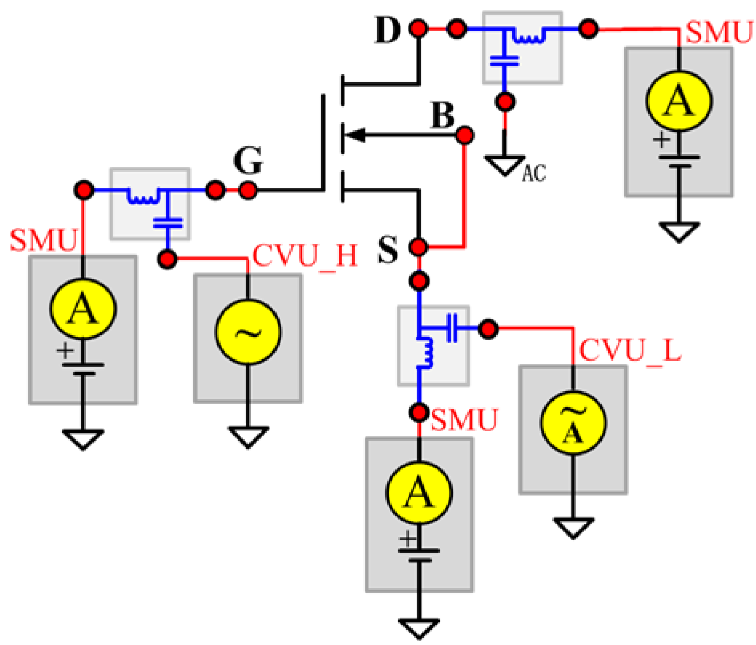
Module name: Cgs

DUT: Four-terminal nMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the drain.

Figure 324: Four-terminal nMOSFET Cgs pin connections



Ciss

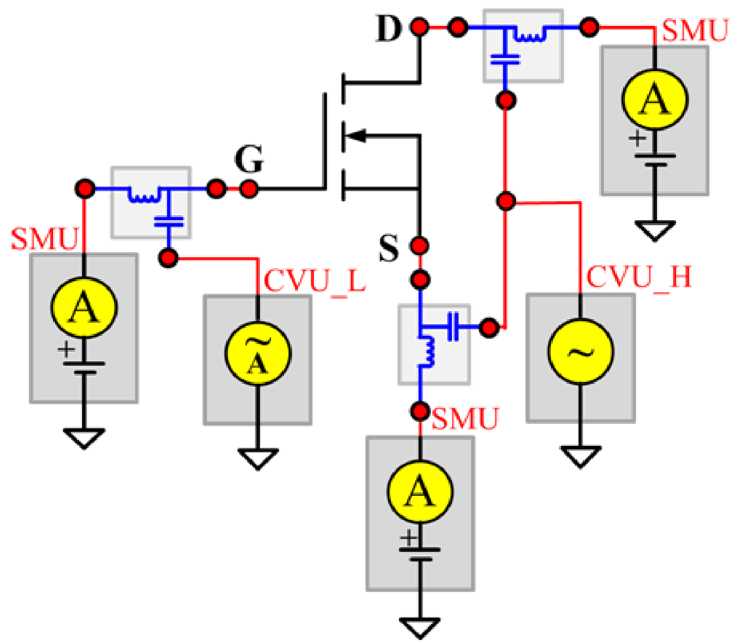
Module name: Ciss

DUT: Four-terminal nMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal ac short-circuited to the Source terminal. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. AC short circuit the drain to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias.

Figure 325: Three-terminal nPowerMOSFET Ciss pin connections



Coss

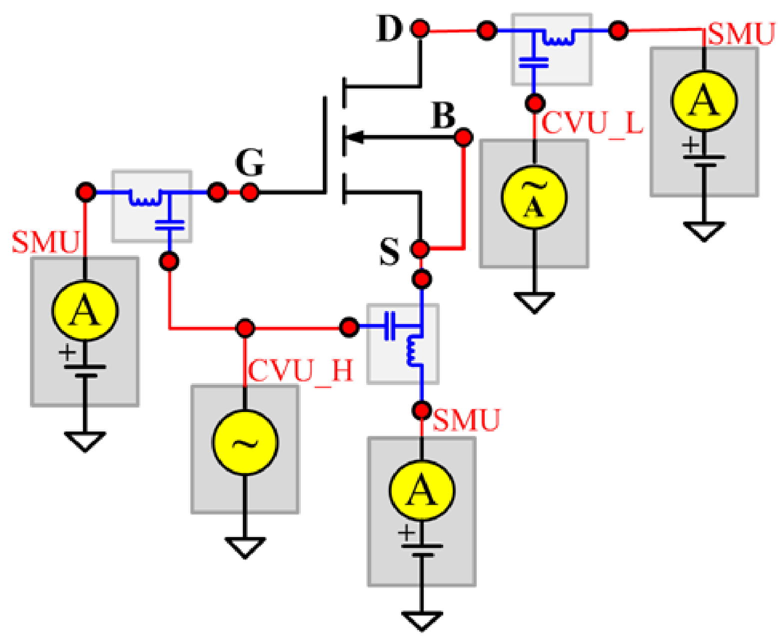
Module name: Coss

DUT: Four-terminal nMOSFET

Function: Measures the capacitance between the drain and source terminals with the gate terminal ac short-circuited to the source terminal. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. AC short circuit the gate to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage.

Figure 326: Four-terminal nMOSFET Coss pin connections



Crss

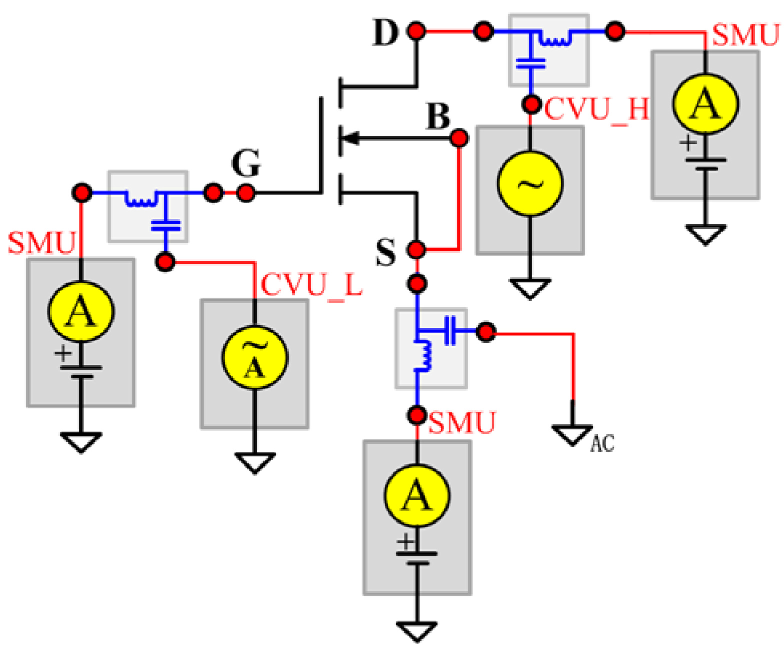
Module name: Crss

DUT: Four-terminal nMOSFET

Function: Measures the common-source short-circuit input capacitance by testing the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin Connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias.

Figure 327: Four-terminal nMOSFET Crss pin connections



pMOSFET test module template

The pMOSFET parametric test module template is used to test parameters of a p-type MOSFET, including leakage, breakdown, gain, on-state and characteristic curves.

BVDSS

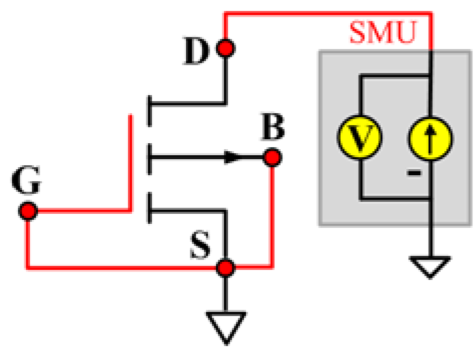
Module name: BVDSS

DUT: Four-terminal pMOSFET

Function: Measures the drain-source breakdown voltage of the pMOSFET with the gate-source shorted.

Pin connections: Use a SMU to apply a breakdown current on the drain. Short the bulk, gate, and source to GND or use a SMU to supply a zero-voltage bias.

Figure 328: Four-terminal pMOSFET BVDSS pin connections



BVDSV

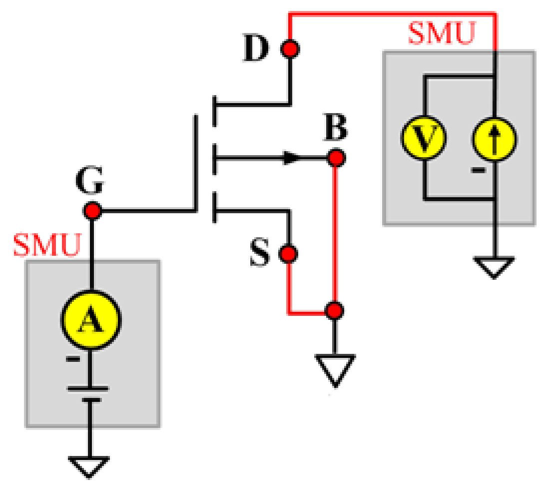
Module name: BVDSV

DUT: Four-terminal pMOSFET

Function: Measures the drain-source breakdown voltage of the pMOSFET with the gate biased.

Pin connections: Use a SMU to bias the gate. Use a SMU to apply a breakdown current on the drain. Connect the source and bulk to GND or use a SMU to supply a zero-voltage bias.

Figure 329: Four-terminal pMOSFET BVDSV pin connections



BVGSO

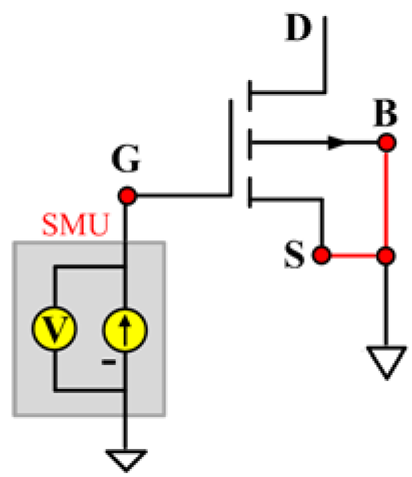
Module name: BVGSO

DUT: Four-terminal pMOSFET

Function: Measures the gate-source breakdown voltage of the pMOSFET with the drain opened.

Pin connections: Use a SMU to apply a breakdown current on the gate. Open the circuit to the drain or use a SMU to supply a zero-current bias. Connect the bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 330: Four-terminal pMOSFET BVGSO pin connections



BVGDS

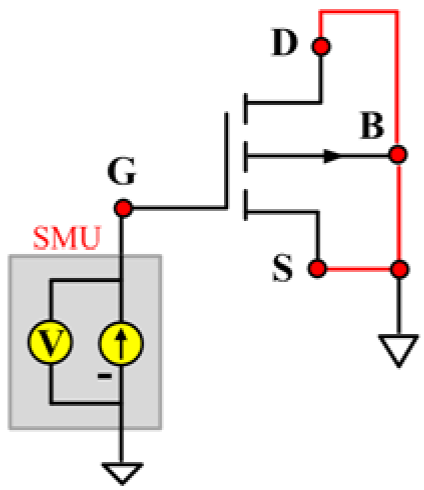
Module name: BVGDS

DUT: Four-terminal pMOSFET

Function: Measures the gate-drain breakdown voltage of the pMOSFET with the source-drain shorted.

Pin connections: Use a SMU to apply a breakdown current on the gate. Connect the source, drain, and bulk to ground or use a SMU to supply a zero-voltage bias.

Figure 331: Four-terminal pMOSFET BVGDS pin connections



BVGDO

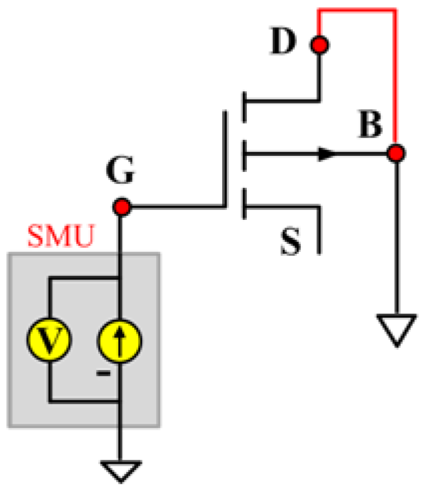
Module name: BVGDO

DUT: Four-terminal pMOSFET

Function: Measures the gate-drain breakdown voltage of the pMOSFET with the source opened.

Pin connections: Use a SMU to apply a breakdown current on the gate. Open the circuit to the source or use a SMU to supply a zero-current bias. Connect the bulk and drain to GND or use a SMU to supply a zero-voltage bias.

Figure 332: Four-terminal pMOSFET BVGDO pin connections



IDL

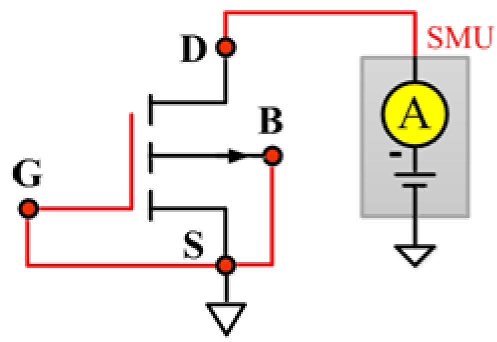
Module name: IDL

DUT: Four-terminal pMOSFET

Function: Measures the drain leakage current with the gate-source shorted.

Pin connections: Use a SMU to force voltage to the drain. Connect the gate, source, and bulk to GND or use a SMU to supply a zero-voltage bias.

Figure 333: Four-terminal pMOSFET IDL pin connections



IDS

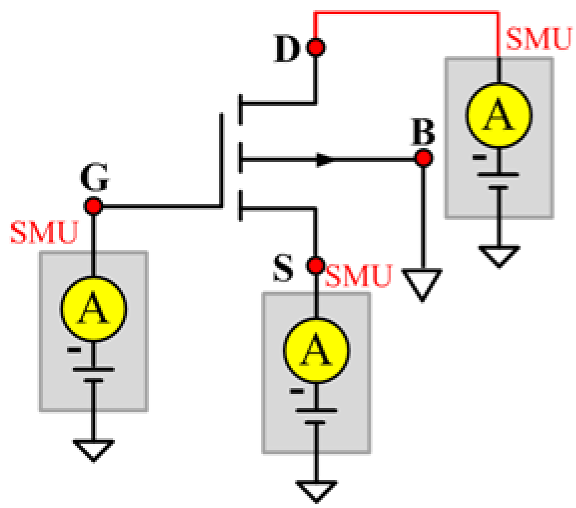
Module name: IDS

DUT: Four-terminal pMOSFET

Function: Measures the drain-source and source-drain current with the gate biased.

Pin connections: Use a SMU to force voltage to the gate. Use a SMU to force voltage to the drain. Connect source and bulk to GND or use a SMU to supply a zero-voltage bias.

Figure 334: Four-terminal pMOSFET IDS pin connections



IdVd_BiasVg

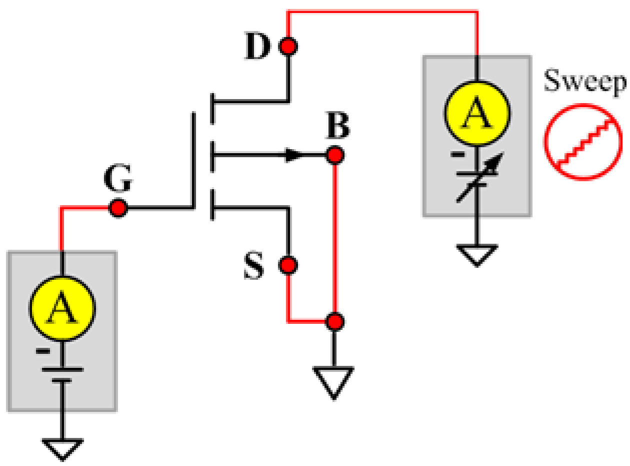
Module name: IdVd_BiasVg

DUT: Four-terminal pMOSFET

Function: Measures the drain current during a specified drain voltage sweep, and the drain current and drain voltage curve.

Pin connections: Use a SMU to bias the gate. Use a SMU to sweep the drain. Connect bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 335: Four-terminal pMOSFET IdVd_BiasVg pin connections



IdVd_StepVg

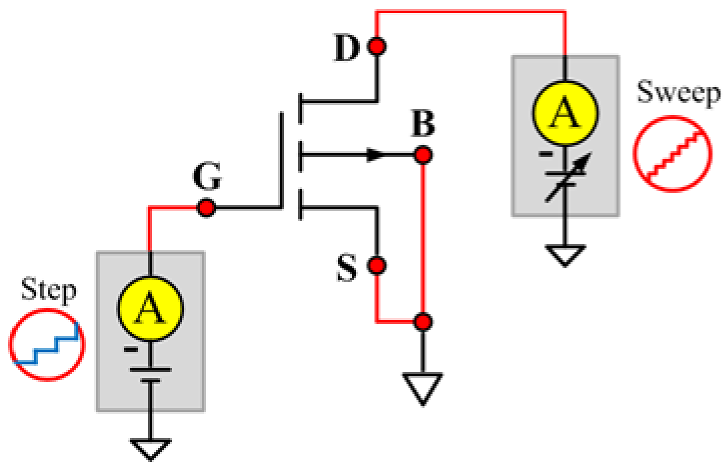
Module name: IdVd_StepVg

DUT: Four-terminal pMOSFET

Function: Measures the drain current during a specified drain voltage sweep, and a series of drain currents and the drain voltage curve.

Pin connections: Use a SMU to sweep the drain. Use a SMU to step the gate. Connect the bulk and source to ground or use a SMU to supply a zero-voltage bias.

Figure 336: Four-terminal pMOSFET IdVd_StepVg pin connections



IdVg_BiasVd

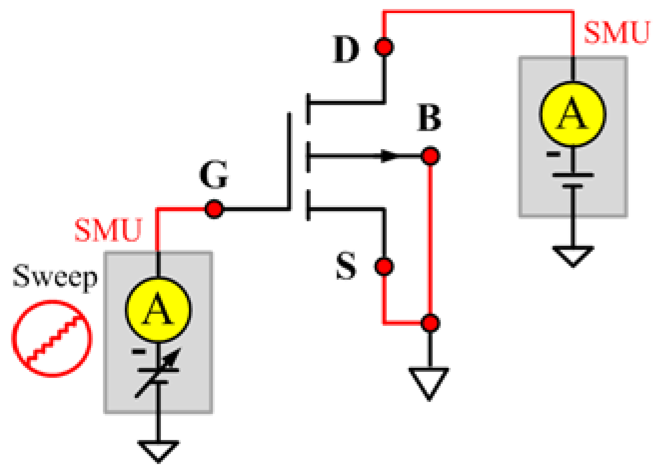
Module name: IdVg_BiasVd

DUT: Four-terminal pMOSFET

Function: Measures the drain current during a specified gate voltage sweep, and the drain current value and the gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the sweep the gate. Connect the bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 337: Four-terminal pMOSFET IdVg_BiasVd pin connections



IdVg_StepVd

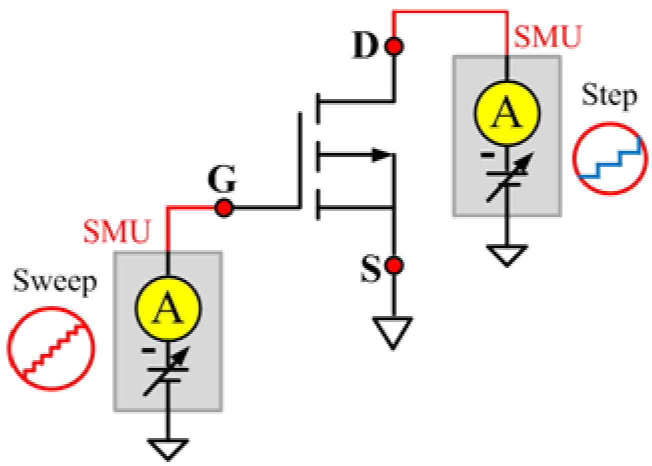
Module name: IdVg_StepVd

DUT: Four-terminal pMOSFET

Function: Measures the drain current at a specified gate voltage sweep with a drain step, and the series of drain currents and gate voltage curve.

Pin connections: Use a SMU to step the drain. Use a SMU to sweep the gate. Connect the bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 338: Four-terminal pMOSFET IdVg_StepVd pin connections



IGL

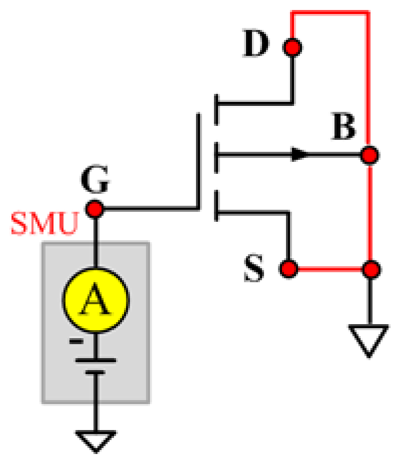
Module name: IGL

DUT: Four-terminal pMOSFET

Function: Measures the gate leakage current when the source and drain are shorted.

Pin connections: Use a SMU to force voltage to the gate. Connect the source, drain, and bulk to GND or use a SMU to supply a zero-voltage bias.

Figure 339: Four-terminal pMOSFET IGL pin connections



IgVg

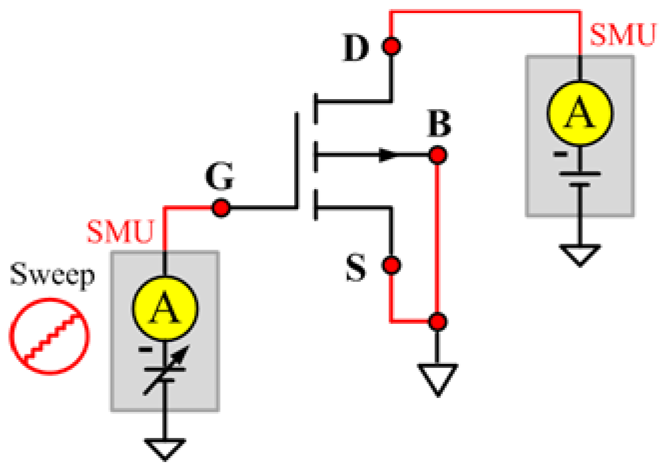
Module name: IgVg

DUT: Four-terminal pMOSFET

Function: Measures the gate current at a specified gate voltage sweep when the drain is biased, and the gate current and gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. Connect the bulk and source to GND or use a SMU to supply a zero-voltage bias.

Figure 340: Four-terminal pMOSFET IgVg pin connections



ISL

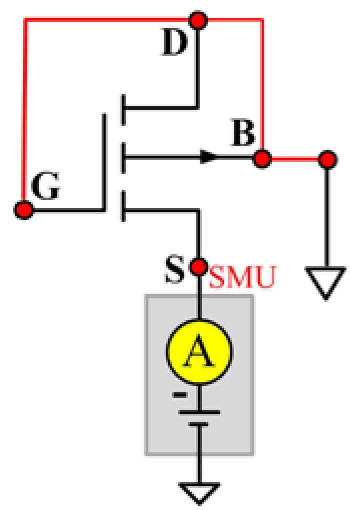
Module name: ISL

DUT: Four-terminal pMOSFET

Function: Measures the source leakage current when the gate-drain is shorted.

Pin connections: Use a SMU to force voltage to the source. Connect the bulk, gate, and drain to GND or use a SMU to supply a zero-voltage bias.

Figure 341: Four-terminal pMOSFET ISL pin connections



IsubVg

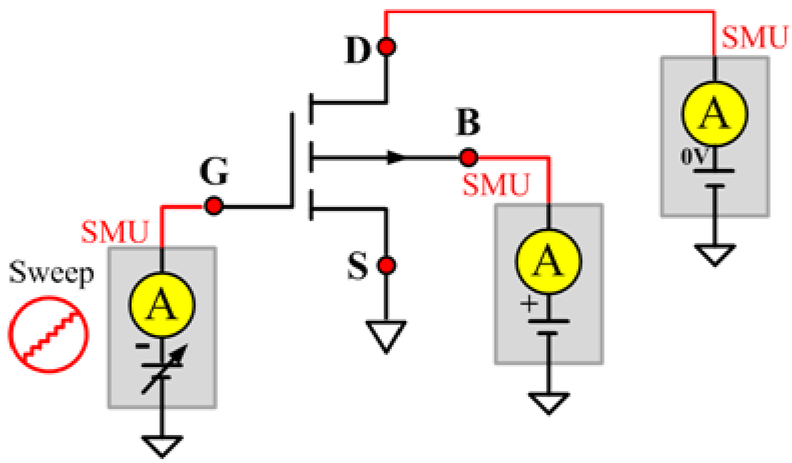
Module name: IsubVg

DUT: Four-terminal pMOSFET

Function: Measures the bulk current at a specified gate voltage sweep, the bulk current and the gate voltage curve, and the maximum bulk current and the corresponding gate voltage.

Pin connections: Use a SMU to sweep the gate. Use a SMU to bias the drain and bulk. Connect the source to ground or use a SMU to supply a zero-voltage bias.

Figure 342: Four-terminal pMOSFET IsubVg pin connections



Vtci

Module name: Vtci

DUT: Four-terminal pMOSFET

Function: Measures the constant current threshold voltage of the pMOSFET device, and the drain current and the gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. If needed, input voltage to source and bulk. Usually, they are connected to GND for NMOS and connected to the nominal power supply voltage (VDD) for PMOS.

Procedure: The constant current threshold voltage.

`Vth_ci = VGS (@ID = 1uA.W/L)`	NMOS
`Vth_ci = VGS (@ID = -0.025uA.W/L)`	PMOS

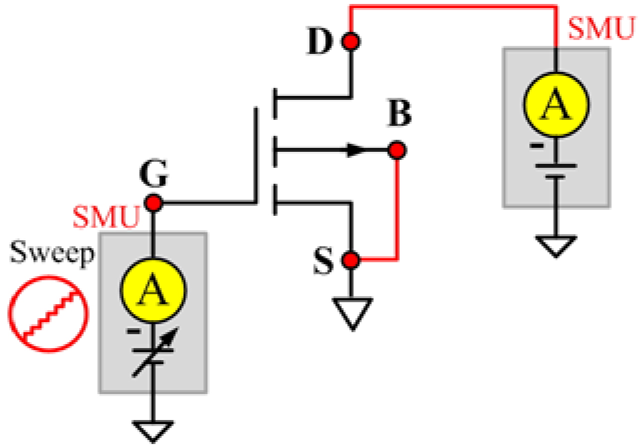
Where `W` and `L` are the gate width and gate length as printed on the wafer. Set a target drain current Id_tar (Id_tar=1 uA.W/L or −0.025 uA.W/L), which is the sign to be near threshold, then search the gate voltage to make the drain current equal to Id_tar.

NOTE

The `Four_term_pMOSFET_Vth_ci` measurement procedure must determine `Vth_ci` to within 1 mV resolution. If the VGS step size is larger than 1 mV, a linear interpolation method may be used to achieve the 1 mV resolution.

Typical DC bias voltages for `Vth_ci` measurements are VDS = VDS_lin, VBS = VBB for linear region measurement, or VDS = VDS_sat (VBS = VBB for saturation region measurement). Typically, for PMOS, `VDS_lin = -0.1 V(@VDD = 5 V)`; for NMOS, `VDS_lin = 0.1 V(@VDD = 5 V).`

Figure 343: Four-terminal pMOSFET Vtci pin connections



Vtext

Module name: Vtext

DUT: Four-terminal pMOSFET

Function: Measures the drain current at the gate voltage sweep, extracts the trans-conductance (Gm) and measure the maximum trans-conductance (Gmmax), measures the extracted threshold voltage (Vth_ex), measures the drain current and the gate voltage curve, and measures the Gm and the drain current or the Gm and the gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. If needed, input the source and bulk. Usually, they are connected to GND for NMOS and connected to the nominal power supply voltage (VDD) for PMOS.

Procedure: The threshold voltage is extrapolated from the measurement of the maximum slope (Gmmax) of the IDVGS curve:

```
Vth_ex = VGS (@Gmmax)-ID(@Gmmax)/Gmmax
```

Where:

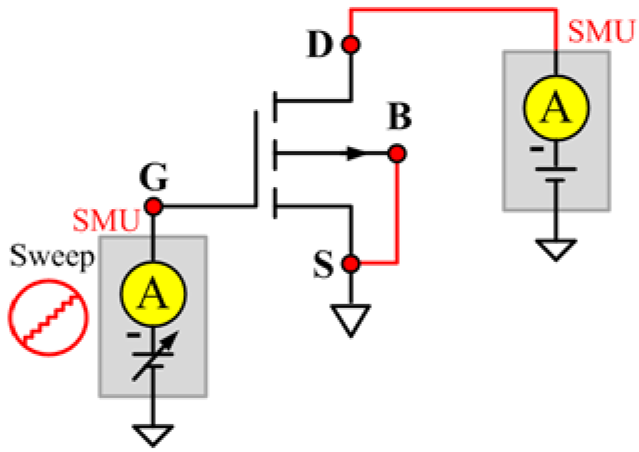
- VGS (@Gmmax) is the gate voltage at the point of the maximum slope of the IDVGS curve
- ID(@Gmmax) is the drain current at the point of the maximum slope of the IDVGS curve
- Gmmax is the maximum slope of the IDVGS curve

NOTE

DC bias voltages for the Vth_ex measurements are VDS = VDS_lin, VBS = VBB for linear measurement.

VDS = VDS_sat, VBS = VBB for saturation. Typically, for PMOS, VDS_lin = −0.1 V(@VDD = 5 V); for NMOS, VDS_lin = 0.1 V(@VDD = 5 V).

Figure 344: Four-term pMOSFET Vtext pin connections



Vtext_llsq

Module name: Vtext_llsq

DUT: Four-terminal pMOSFET

Function: Measures the drain current at the gate voltage sweep, extracts the trans-conductance (Gm) and measure the maximum trans-conductance (Gmmax), measures the extracted threshold voltage (Vth_ex), measures the drain current and the gate voltage curve, and measures the Gm and the drain current or the Gm and the gate voltage curve.

Pin connections: Use a SMU to bias the drain. Use a SMU to sweep the gate. If needed, input the source and bulk voltages. Usually, they are connected to GND for NMOS and connected to the nominal power supply voltage (VDD) for PMOS.

Procedure: The threshold voltage is extrapolated from the measurement of the maximum slope (Gmmax) of the IDVGS curve:

```
Vth_ex = VGS (@Gmmax)-ID(@Gmmax)/Gmmax
```

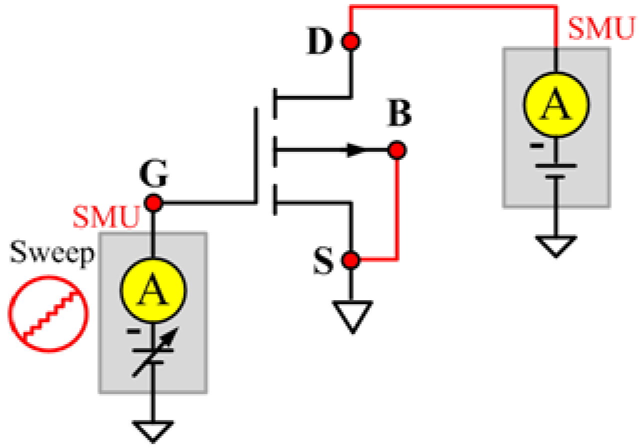
Where:

- VGS(@Gmmax) is the gate voltage at the point of the maximum slope of the IDVGS curve
- ID(@Gmmax) is the drain current at the point of the maximum slope of the IDVGS curve
- Gmmax is the maximum slope of the IDVGS curve

NOTE

DC bias voltages for the Vth_ex measurements are VDS = VDS_lin, VBS = VBB for linear measurement. VDS = VDS_sat, VBS = VBB for saturation. Typically, for PMOS, VDS_lin = −0.1 V(@VDD = 5 V); for NMOS, VDS_lin = 0.1 V(@VDD = 5 V).

Figure 345: Four-terminal pMOSFET Vtext_Ilsq pin connections



Cds

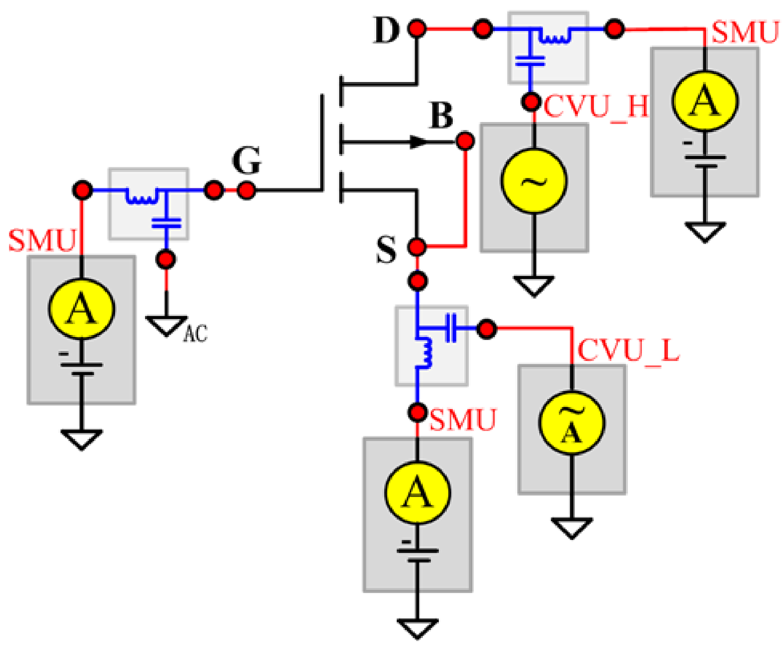
Module name: Cds

DUT: Four-terminal pMOSFET

Function: Measures the capacitance between the Drain and Source terminals with the Gate terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Short bulk to source. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect the guard terminal of a three-terminal bridge through one remote bias tee to the gate.

Figure 346: Four-terminal pMOSFET Cds pin connections



Cgd

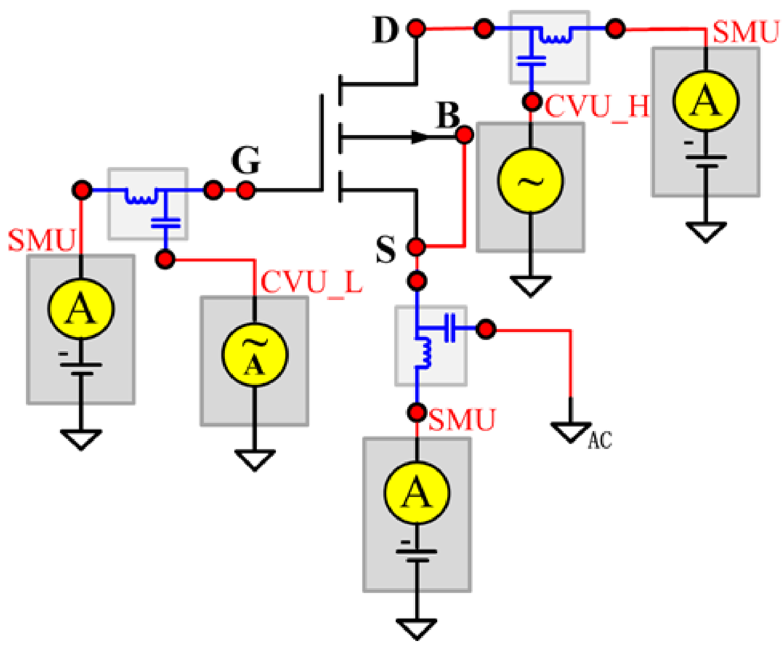
Module name: Cgd

DUT: Four-terminal pMOSFET

Function: Measures the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the source.

Figure 347: Four-terminal pMOSFET Cgd pin connections



Cgs

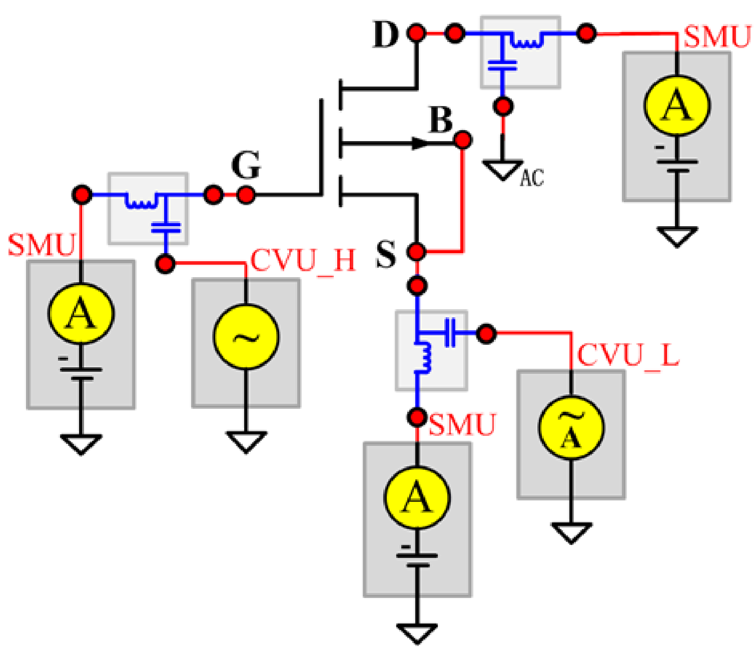
Module name: Cgs

DUT: Four-terminal pMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the drain.

Figure 348: Four-terminal pMOSFET Cgs pin connections



Ciss

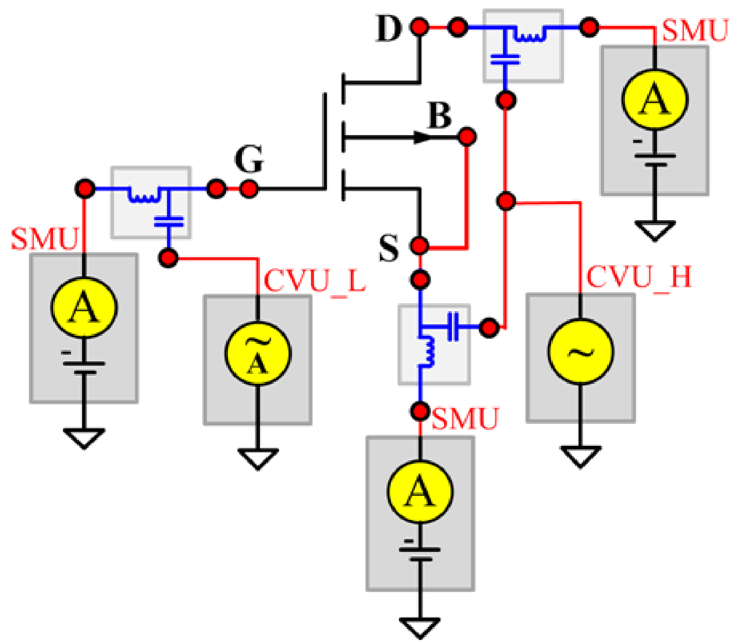
Module name: Ciss

DUT: Four-terminal pMOSFET

Function: Measures the capacitance between the Gate and Source terminals with the Drain terminal ac short-circuited to the Source terminal. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. AC short circuit the drain to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias.

Figure 349: Four-terminal pMOSFET Ciss pin connections



Coss

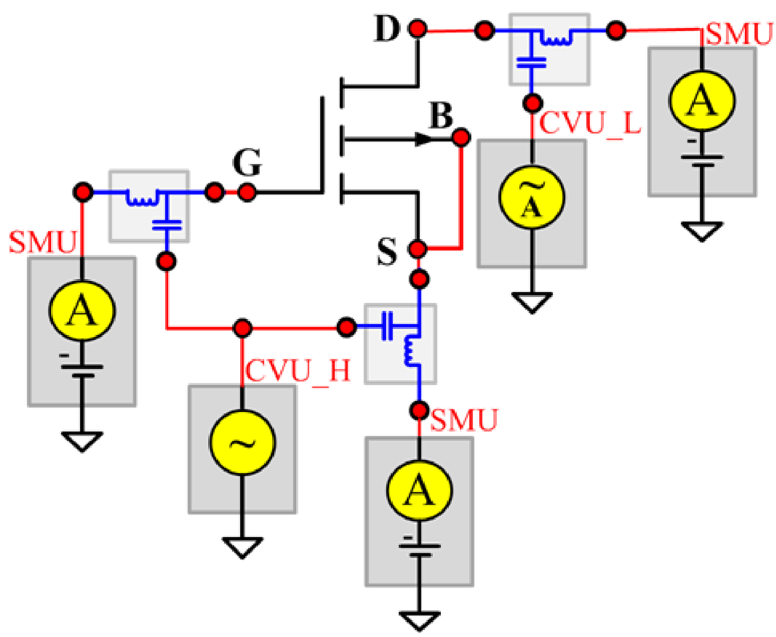
Module name: Coss

DUT: Four-terminal pMOSFET

Function: Measures the capacitance between the drain and source terminals with the gate terminal ac short-circuited to the source terminal. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. AC short circuit the gate to the source terminal. Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage.

Figure 350: Four-terminal pMOSFET Coss pin connections



Crss

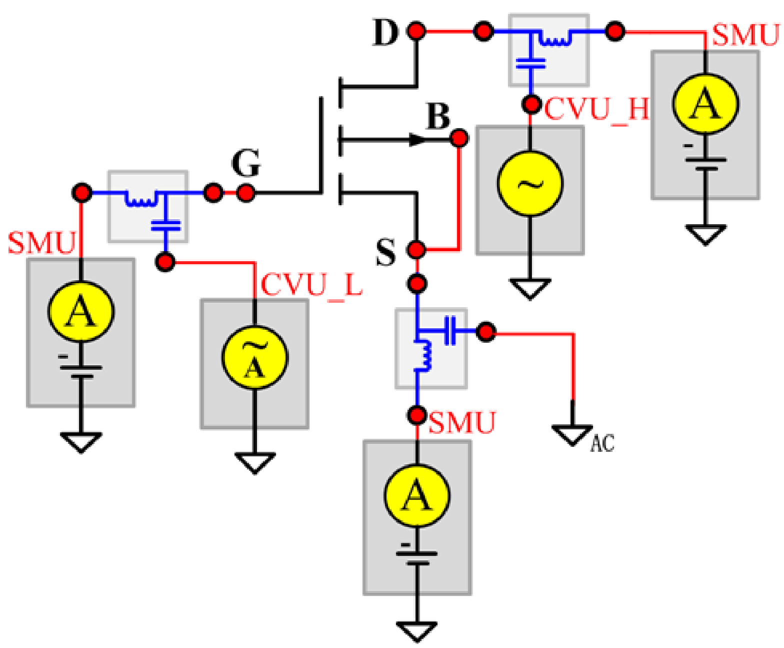
Module name: Crss

DUT: Four-terminal pMOSFET

Function: Measures the common-source short-circuit input capacitance by testing the capacitance between the Drain and Gate terminals with the Source terminal connected to the guard terminal of a three-terminal bridge. Short bulk to source.

Pin connections: Connect a Series 2600B and the CVH1 (HPOT and HCUR) terminals of the Model 4200A-CVU through one remote bias tee to the drain. Use the Series 2600B to sweep voltage. Connect a Series 2600B and the CVL1 (LPOT and LCUR) terminals of the Model 4200A-CVU through one remote bias tee to the gate. Use the Series 2600B to supply zero voltage bias. Connect a Series 2600B and the ac guard of a three-terminal bridge through one remote bias tee to the source. Use the Series 2600B to supply zero voltage bias.

Figure 351: Four-terminal pMOSFET Crss pin connections



Section 6

Power MOSFET (SiC) reliability application

In this section:

Vds and Vgs breakdown test plans 6-1

Vds and Vgs breakdown test plans

The Vds breakdown test plans use ramped voltage stress (`Vds_Vramp`) or constant voltage stress HTRB (high temperature reverse bias) to characterize the drain-source breakdown properties of a device (usually a power device).

For Vgs breakdown testing, a constant DC voltage is applied at the gate-source of the device under test (DUT) as the stress voltage, for example, a high temperature gate bias (HTGB) test.

The test module templates are in the following folder:
`C:\ACS\TestModuleTemplate\device\PowerMOSFET_SiC_Reliability_App`.

To import the test module template:

1. Right-click any device (add a new device if needed) in the configuration navigator.
2. Select **Import.**

You can import the module templates based on the device connection that you have. For example, the following folders are available based on the device connection:

- `SingleDevice_RT`
- `MultiDevice_SourceOnly_RT`
- `MultiDevice_GateSource_RT`
- `MultiDevice_SourceOnly_ComDrain_RT`
- `MultiDevice_GateSource_ComDrain_RT`

Import a test plan

To import a test plan:

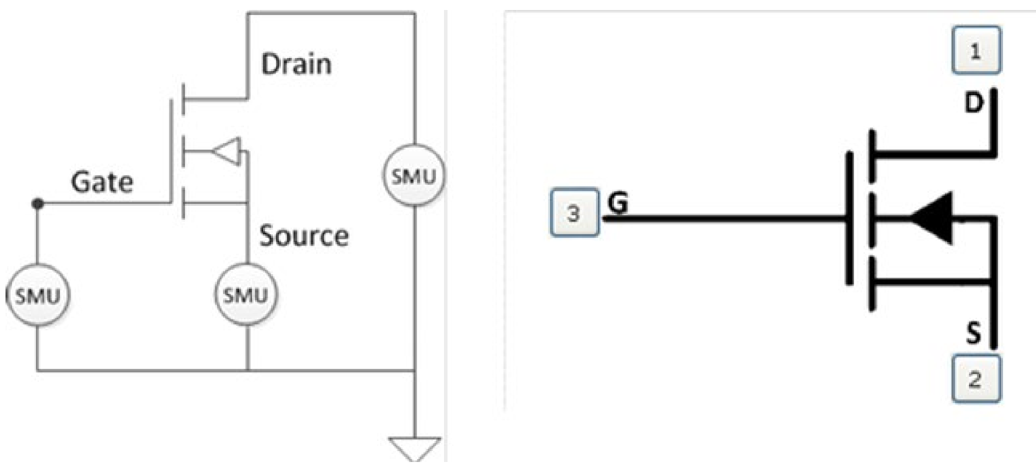
1. Right-click any device in the configuration navigator.
2. Select **Import**.
3. Select the appropriate `.xml` file in the folder `C:\ACS\TestModuleTemplate\device\PowerMOSFET_SiC_Reliability_App`.

   Once you have selected the test module template, a new device is added to the configuration navigator and is ready to use for testing.

   Depending on the number of instruments and devices, you can implement different connection schemes to set up the preferred stress configuration.

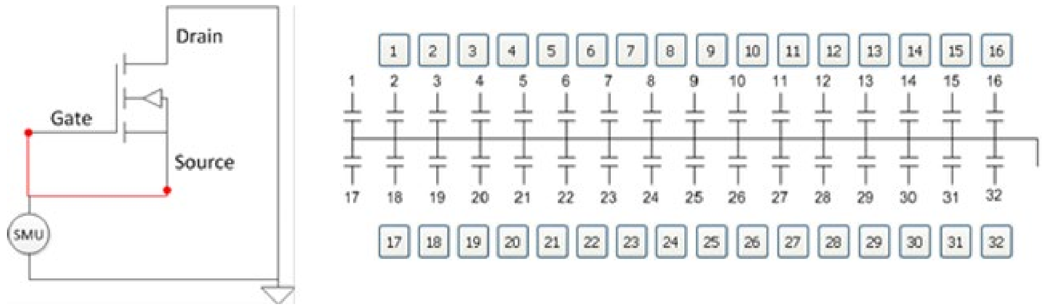
- **Single device:** During a Vds breakdown test, one SMU is connected to the drain and measures the Vds stress. Another SMU (optional) is connected to the gate to keep the device off. The source can be connected to a SMU or ground (GND).
- For a Vgs breakdown test, the SMU connected to the gate is used for Vgs stress and measure.

Figure 352: Single device pin connection



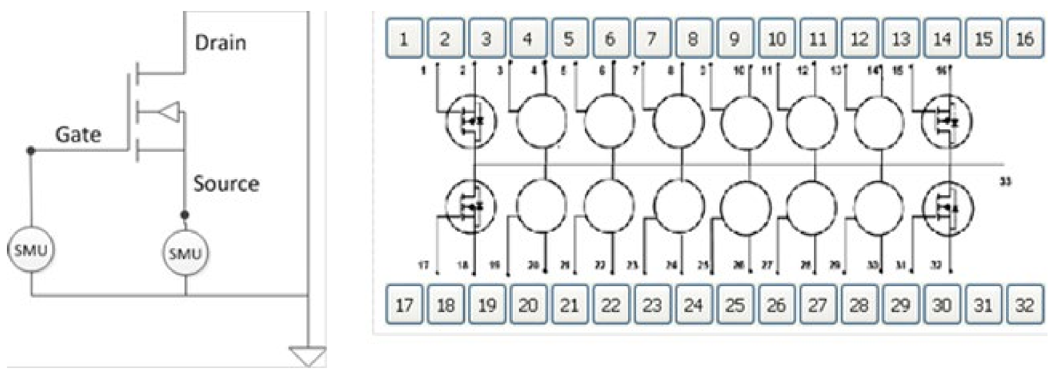
- **Multidevice (source only):** This uses one SMU and one device. The gate and source are shorted together and connected to one SMU for the Vds stress and measure test. The drain is connected to the low terminal.

Figure 353: Multidevice (source only) pin connection



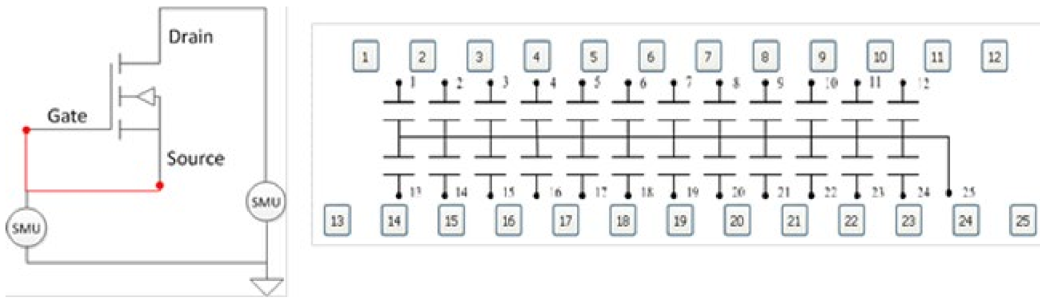
- **Multidevice (gate-source):** This uses two SMUs and one device. During a Vds breakdown test, the gate and source are connected to the SMU individually. The drain is connected to the low terminal. During a Vgs breakdown test, one SMU is connected to the source for a zero-voltage bias.

Figure 354: Multidevice (gate-source) pin connection



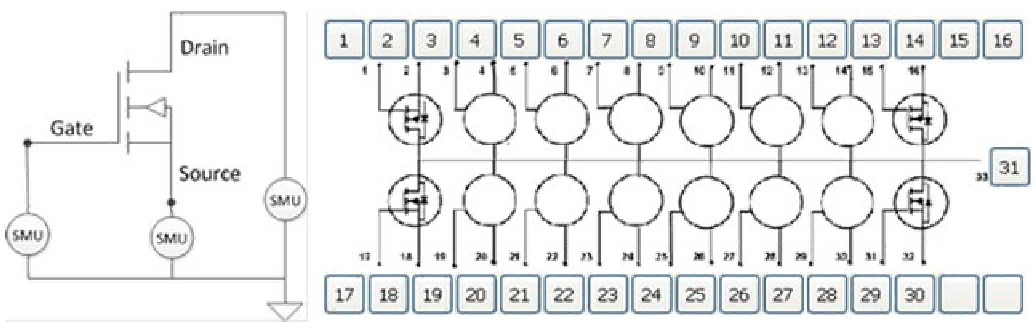
- **Multidevice (source only with a common drain):** This uses one SMU with the gate and source shorted together. The drain (all devices have a common drain) is connected to another SMU to extend the range of the Vds stress.

Figure 355: Multidevice (source only common drain) pin connection



- **Multidevice (gate-source with a common drain):** During a Vds breakdown test, one SMU with the gate and source connected individually. The drain (all devices have a common drain) is connected to another SMU to extend the range of the Vds stress.
- During a Vgs breakdown test, one SMU is connected to the gate for Vgs stress and measure. SMUs are used at the drain and the source end to supply a zero-voltage bias.

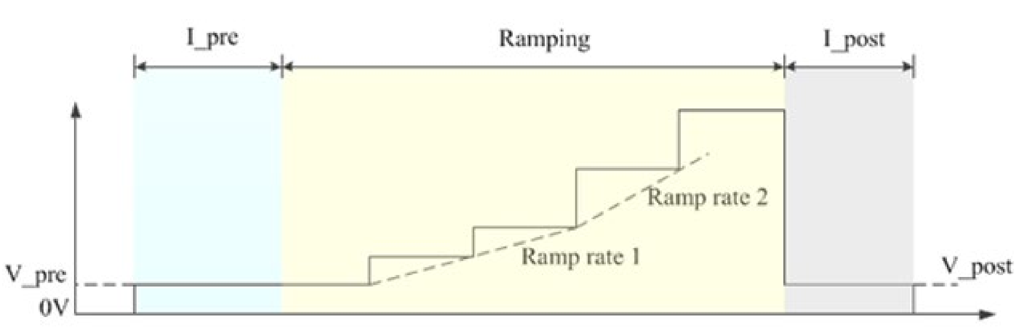
Figure 356: Multidevice (gate-source common drain) pin connection



Vds_Vramp test

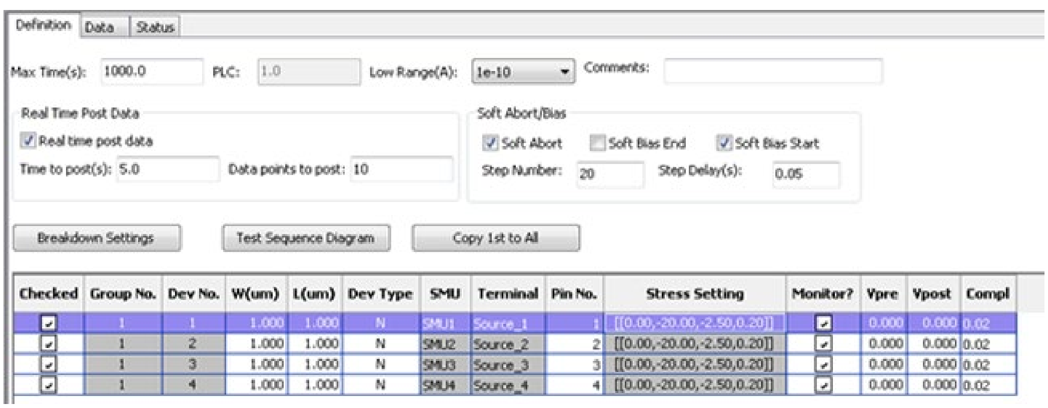
The Vds_Vramp test uses a ramped voltage stress on the source-drain for breakdown characterization. The following figure indicates how the stress voltage flows during the test.

Figure 357: Vds_Vramp voltage stress



The following figure shows the Vds_Vramp test settings user interface.

Figure 358: Vds_Vramp test settings



Max Time(s): Maximum time for the voltage ramp. When the maximum time is reached, the ramp test will end and the device is considered to have passed the test.

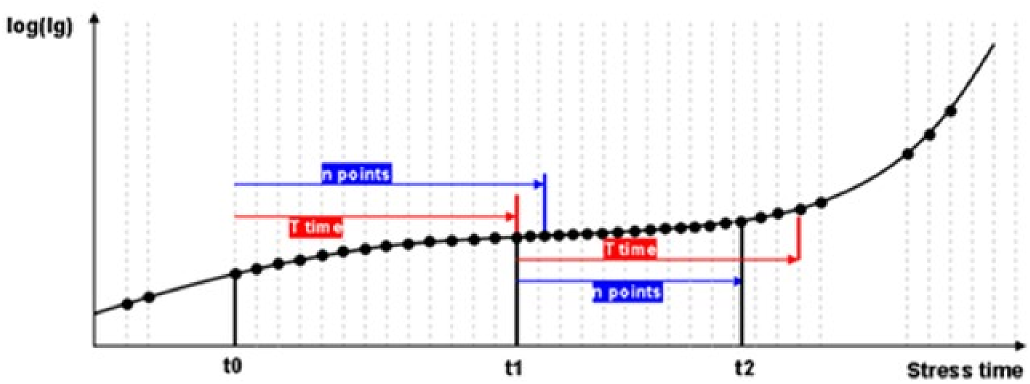
PLC: Number of power line cycles (this parameter is constant and cannot be changed).

Low Range (A): Lowest current measure range that is used during autoranging.

Real time post data:

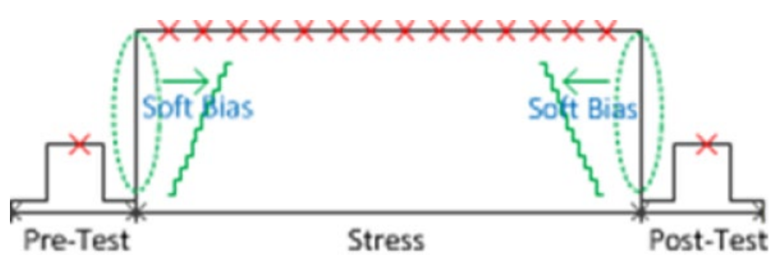
- When cleared, the test module posts all the data after the entire ramp test is done.
- When selected, the Time to post(s) and Data points to post options are enabled. The test data post and are sent from the instruments to ACS after every Time to post time interval or after the specified number of points, based on the Data points to post setting. These settings are critical when the VRamp module is used in a large-scale ramp test. If multiple instruments are used in one group (for example, up to eight Model 2636B instruments) with an extended ramp test, this option is safe for data logging and transferring.

Figure 359: Real-time post-data diagram



Soft Abort/Bias: Enables a sweep process to substitute the start or end of the stress, or the abort situation. This function prevents sharp changes in the stress voltage on the device. The soft abort function is used to monitor the Pin 3 digital I/O for the abort command input. If the pin electrical level is set to low, it will be treated as an abort command and will invoke the soft abort function which will abort the whole test.

Figure 360: Soft bias for stress start and end



Breakdown Condition Settings: Select the Breakdown Settings button for the breakdown criteria settings.

Init I(A): Initial current for the Vramp that is used during the pre-ramp and post-ramp testing (see the following figure).

Max I(A): Maximum current that is used during the stress ramp phase.

Critical I(A): Critical current that is used during the stress ramp phase. If the current exceeds this value, more breakdown judgments (Slope x (Pre) and I x (Pre)) will be performed.

Max Q(Q): Maximum charge quantity used during the stress ramp phase.

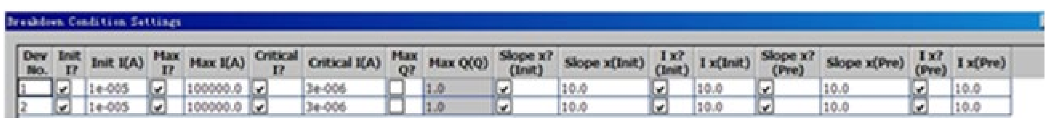
Slope x(Init): Checks the difference between the current and voltage to determine if the time exceeds the initial slope.

I x(Init): Checks to determine if the current exceeds the initial current reading.

Slope x(Pre): Checks to determine if the current and voltage slope exceeds the previous slope reading.

I x(Pre): Checks to determine if the current exceeds the previous current reading.

Figure 361: Breakdown settings for Vds_Vramp



Device and SMU settings: The device and SMU settings determine the force and measure functions for SMUs related to the device terminals (see the following figure).

W(um), L(um): Determine the MOSFET device dimensions.

Dev Type: "N" for NMOS and "P" for PMOS.

Stress Setting: Double-click the cell to open the Ramp Segments Setting dialog.

> **Number of Ramp Segments:** One through five can be specified.
>
> **Start (V):** Start voltage of the ramp segment.
>
> **Stop (V):** Stop voltage of the ramp segment.
>
> **Ramp Rate (V/s):** Voltage ramp rate of the ramp segments. Each segment has its own ramp rate.
>
> **Stress Intv (s):** Stress interval which is the time between two ramp steps. All stress intervals are the same for all segments.
>
> **Ramp Step (V):** Calculated based on the ramp rate and stress interval.

Monitor: Monitors the current during each ramp step (this is always selected).

Vpre: Applied voltage for the pre-ramp test.

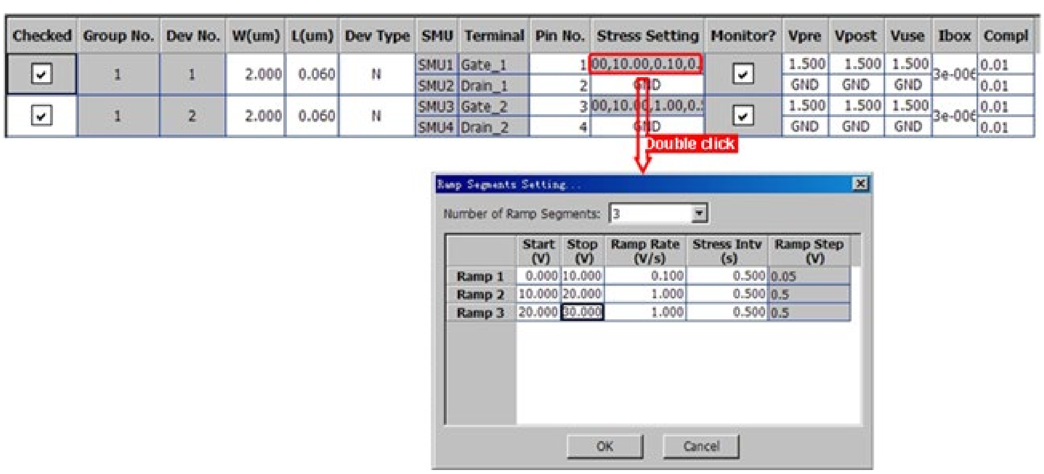
Vpost: Applied voltage for the post-ramp test.

Vuse: Voltage applied when the Monitor at Vuse is selected.

Ibox: Enabled when the Output Vbox at Ibox is selected. Logs the Vbox step voltage when the current exceeds the value for the first time.

Compl: Current compliance (limit) value.

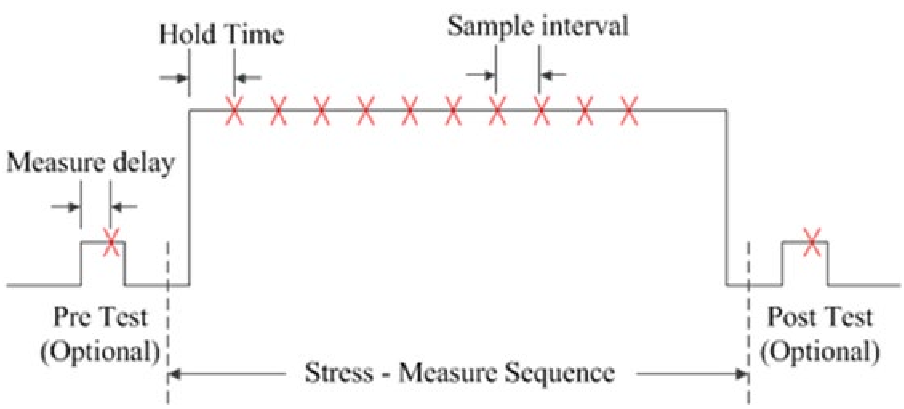
Figure 362: Device and SMU settings for VRamp



HTRB test

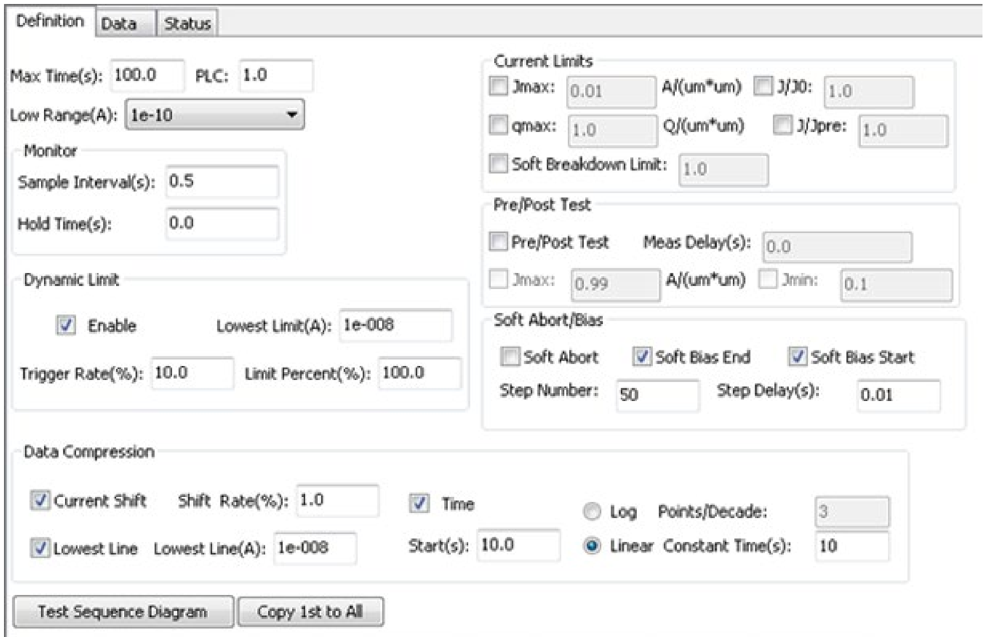
The high temperature reverse bias (HTRB) test uses a constant voltage stress on the source-drain for breakdown characterization. Refer to JEDEC for specific JESD47 standards, available at jedec.org. See the following figure for an example of the stress voltage flow.

Figure 363: Vds_Constant stress voltage test sequence



HTRB test settings

Figure 364: HTRB test settings



Checked	Dev No.	W(um)	L(um)	SMU	Terminal	Pin No.	Compliance	Stress V	Monitor?
☑	1	1.00	1.00	SMU2	Source_1	2	0.02	-195	☑
				SMU1	Gate_1	1	0.02	-200	☑
☑	2	1.00	1.00	SMU4	Source_2	4	0.02	-195	☑
				SMU3	Gate_2	3	0.02	-200	☑

Max Time(s): Ending measure phase time.

PLC: Number of power line cycles (0.001 to 25).

Low Range(A): Lowest current measure range that is used during autoranging.

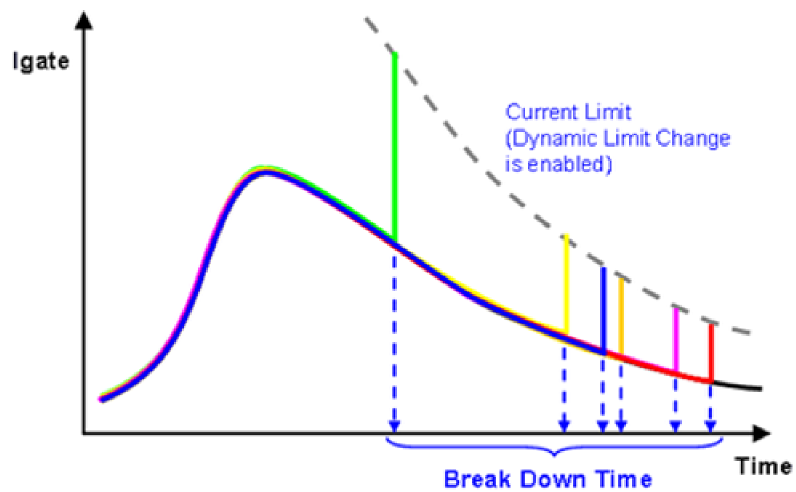
Monitor: Time settings, which are defined as current measurements during the stress phase.

- **Sample Interval(s):** Time interval between two monitor points.
- **Hold Time(s):** Amount of time the stress voltage is applied before the monitor measurement is made (during the stress phase).

Dynamic limit setting

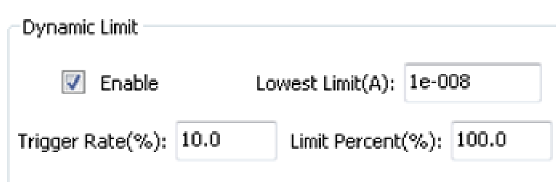
The Dynamic Limits Change allows the limit values to vary. The following figure is an example of a Dynamic Limits Change with a varying limit.

Figure 365: Dynamic limit change



The Series 2600B can set the current limits when applying the voltage. The output current will be clamped to the set limit to prevent damage to the device under test (DUT). The Dynamic Limit setting enables the dynamic limit change feature. When enabled, the limit value will vary according to the settings. The limit value can be set as a multiple of the measured current. If the current changes smoothly, the limit will not be reached. However, if the current changes suddenly, which indicates a breakdown, the output will be clamped to the limit value and protect the DUT from severe damage (see the following figure).

Figure 366: Dynamic limit settings



Lowest Limit(A): Dynamic Limit will not be applied if the current is lower than this value.

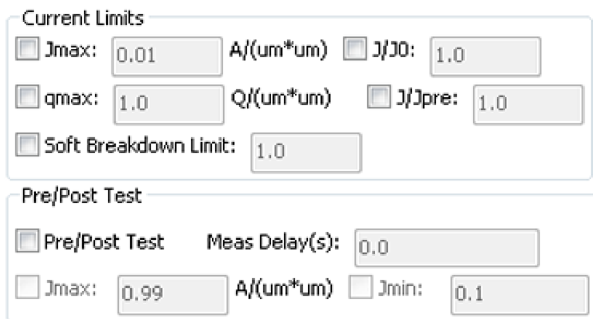
Trigger Rate(%): Trigger Rate percent as compared to the previous value; the limit value changes if the current changes.

Limit Percent(%): Limit value is set as the (100%+Limit Percent) multiplier of the measured current.

Breakdown settings

When the measured current exceeds the setting limits, the DUT is treated as reaching breakdown (see the following figure).

Figure 367: Breakdown settings



Current Limits: Breakdown settings used during current monitoring. If these fields are selected, they are used to evaluate the DUT.

- **Jmax:** Maximum current density. The current density is calculated by I/(W×L). The W and L are width and length, which is set in the configuration navigator device (for a single sub-device) or SMU settings (multiple sub-devices). If the monitor current density exceeds this value, the device has failed.
- **J/J0:** Current density change ratio compared to the first value. If the monitor current density change ratio exceeds this value, the device has failed.
- **qmax:** Maximum accumulated charge density. The accumulated charge density is calculated by the accumulated charge divided by the area. If it exceeds this value, the device has failed.

J/Jpre: Current density change ratio compared to the previous value. If the current density change ratio exceeds this value, the device has failed.

- **Soft Breakdown Limit:** Soft breakdown judgment is made by calculating the current noise using the last five measured current values, and then checking if the current noise setting soft breakdown limit times are larger than the baseline noise. The calculation of the current noise and noise baseline is referred to a JEDEC standards, which is described in the JESD92 procedure. This procedure is used for characterizing time-dependent dielectric breakdown of ultra-thin gate dielectrics. For more specific information, refer to the JEDEC standards at jedec.org.

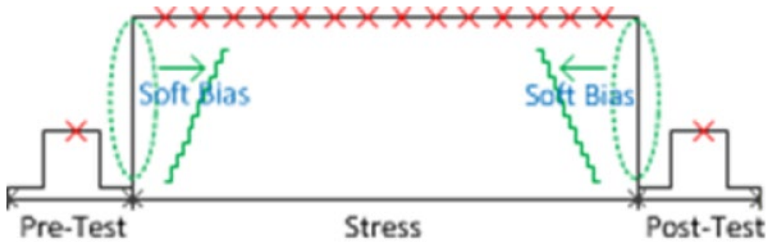
Pre/Post-Test: Breakdown of settings for the pre-test and post-test.

- **Jmax:**
  - Maximum current density. If the pre-test current or post-test current densities exceed this value, the device has failed.
  - Minimum current density. If the pre-test current or post-test current densities are lower than this value, the device has failed.

Soft bias start and soft bias end

Soft bias start and soft bias end enables a sweep process to substitute the start or end of the stress, or the abort situation. This function prevents a sharp change to the device stress voltage. The soft abort function is used to monitor Pin3 of the digital I/O for the abort command input. When the pin electrical level is set to low, it is treated as an abort command, invokes the soft abort function, and aborts the whole test (see the following figure).

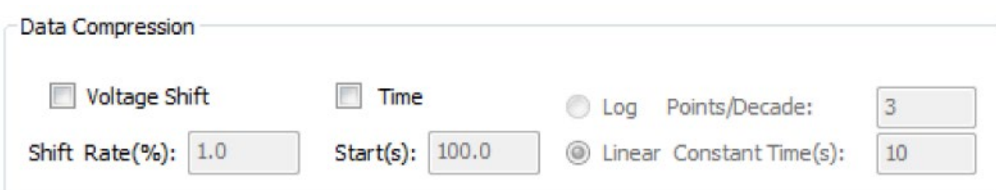
Figure 368: Soft bias stress start and end



Data compression settings

ACS will log the compressed data according to the following settings (see the next figure). This function can reduce the total amount of data without losing the parameter change tracking information.

Figure 369: Data compression settings



Current Shift: if the current shifts the "Shift Rate" percentage and this parameter is selected, it will be logged.

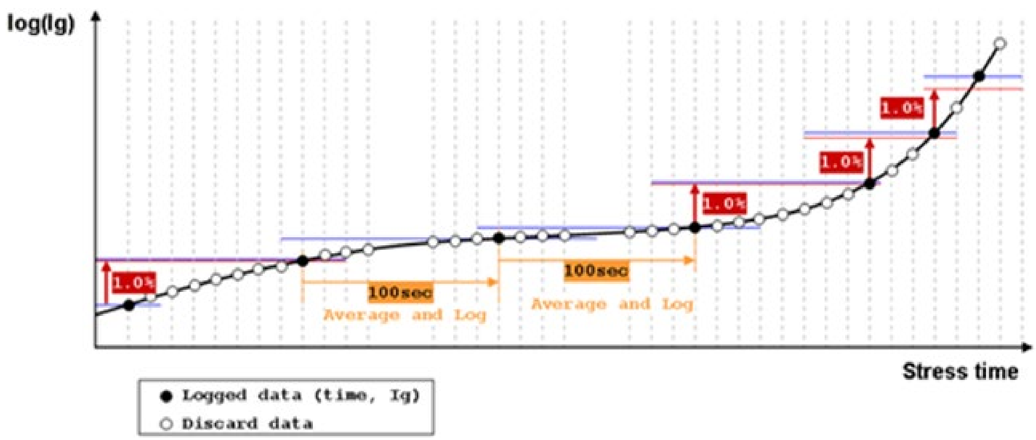
- **Shift Rate (%):** If the current measured data change ratio exceeds the Shift Rate percentage, compared to the previous logged data (data will be logged).
- **Lowest Line(A):** If the absolute value of the measured data is lower than this value, the current Shift is not affected. When the current is near the noise level, this function prevents the measured data from being logged.

Time: Logged data is time-compressed. Only Linear or Log can be selected.

- **Linear:** Constant Time is logged. The data is the mean value of the time.
- **Log:** Points/Decade is logged. The data is the measured value at each time point.

Start(s): Before the time of stress, the Data Compression is not affected. The data before this time is logged.

Figure 370: Data compression diagram



Device and SMU settings

The device and SMU settings are all set at the device level. For example, all the devices and SMUs that are assigned at the device level of the configuration navigator, such as the Group No., Dev No., SMU, and Terminal, are shown in the following figure.

W(um), L(um): MOSFET device dimensions. These parameters are used to calculate the current density and charge density.

Comp V: Voltage compliance (limit) value.

Comp I: Current compliance (limit) value.

Stress I: Sets the stress current value.

Stress V: Sets the stress voltage value.

Monitor: Current monitor measurements on the terminal.

Pre/Post Vuse: Sets the pre-test and post-test bias voltage values.

Figure 371: Device and SMU settings

Checked	Dev No.	W(um)	L(um)	SMU	Terminal	Pin No.	Compliance	Stress	Monitor?
☑	1	5.00	0.50	SMU2	Drain	1	0.01	0	☑
				SMU3	Source	2	0.01	0	☑
				SMU1	Gate	3	0.01	0	☑

HTGB test

The high temperature gate bias (HTGB) test is used to stress the gate by applying a constant voltage for breakdown characterization. The test sequence has a flow like the HTRB test. For the test sequence and test settings, you can refer to the HTRB test settings (on page 6-10) and duplicate the settings that are displayed in the GUI.

With the dynamic limit settings, you can set the current limits to prevent damage to the device under test (DUTs). Refer to the Dynamic limit setting (on page 6-11) in the HTRB test (on page 6-9) topic for specific information.

Using the breakdown settings, when the measured current exceeds the setting limits, the DUT will be treated as a breakdown. Refer to the Breakdown settings (on page 6-12) in the HTRB test (on page 6-9) topic for information and descriptions of each parameter.

The soft abort/bias function allows the forced voltage or current to reach the programmed value by ramping gradually at the start or the end of the stress, or when aborting the test, instead of changing suddenly. This helps to prevent inrush currents and unexpected device breakdowns. Refer to the Soft bias start and soft bias end (on page 6-14) for details.

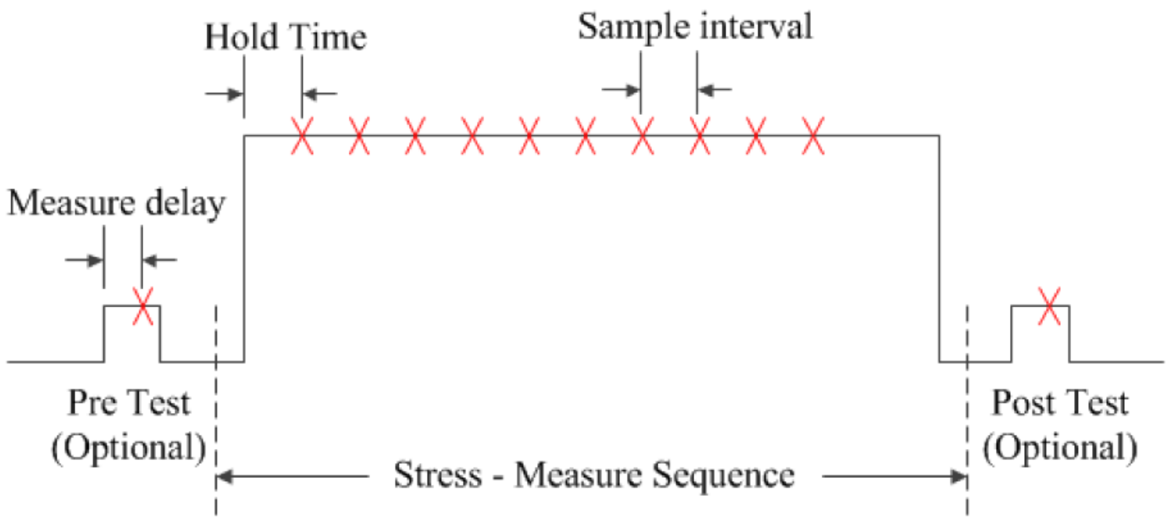
In the data compression settings, the reliability tests can run for a long time and have the potential to accumulate large data sets. This feature allows you to log only the important data rather than collecting all the data produced. Refer to the Data compression settings (on page 6-21) of the HTRB test topic for details.

The device and SMU settings determine the force and measure functions for the SMU connected to the device terminals. Refer to the Device and SMU settings (on page 6-16) of the HTRB test topic for details.

Vds_ccs test

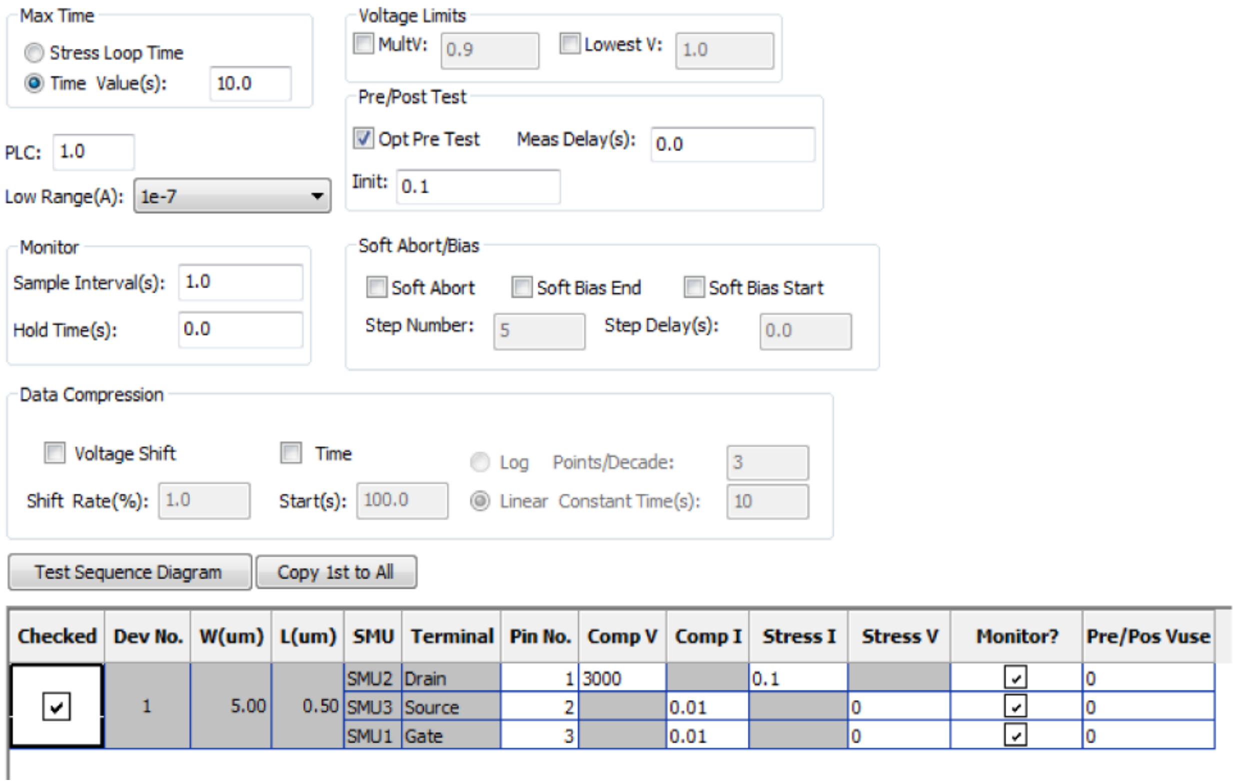
The vds_ccs test uses a constant current stress on the source-drain for breakdown characterization. See the following figure for an example of the stress current flow.

Figure 372: Vds_ccs stress current test sequence



Vds_ccs test settings

Figure 373: vds_ccs test settings



PLC: Number of power line cycles, 0.001 to 25.

Max Time (s): Ending measure phase time or stress loop value.

Low Range (A): Lowest current measure range to be used during autoranging.

Monitor: Time settings (defined as current measurements during the stress phase).

- **Sample Interval(s):** Time interval between two monitor points.
- **Hold Time(s):** Amount of time the stress voltage will be applied before the monitor measurement is made (during the stress phase).

Voltage Limits: Breakdown settings used during voltage monitoring. If these fields are selected, they are used to evaluate the DUT.

- **MultV:** Determines if the voltage is lower than the multV times compared to the previous multV. The value is 0 to 1.0.
- **Lowest V:** Determines if the voltage is lower than this value.

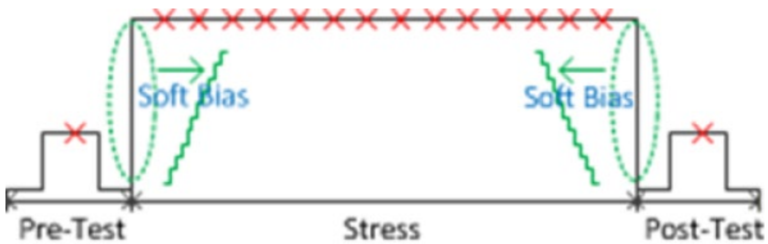
Pre/Post Test: Breakdown of settings for the pre-test and post-test.

- **Opt Pre-Test:** If selected, the test will run the optional pre-test at the beginning of the flow.
- **Meas Delay:** Delay time before measurement.
- **Iinit:** During the optional pre-test, used to determine if the measured current (Iuse) exceeds the Iinit. During the pre-test and post-test, the force Iinit is used to determine if the measured voltage values (Vpre and Vpost) are lower than Vuse.

Soft bias start and soft bias end

Soft bias start and soft bias end enables a sweep process to substitute the start or end of the stress, or the abort situation. This function prevents a sharp change to the device stress voltage. The soft abort function is used to monitor Pin3 of the digital I/O for the abort command input. When the pin electrical level is set to low, it is treated as an abort command, invokes the soft abort function, and aborts the whole test (see the following figure).

Figure 374: Soft bias stress start and end



Data compression settings

ACS will log the compressed data according to the following settings (see the next figure). This function can reduce the total amount of data without losing the parameter change tracking information.

Figure 375: Data compression settings

Voltage Shift: If the voltage shifts the "Shift Rate" percentage and this parameter is selected, it is logged.

- **Shift Rate (%):** The current measured data change ratio exceeds the Shift Rate percentage compared to the previous logged data (data is logged).

Time: Logged data is time-compressed. Only Linear or Log can be selected.

- **Linear:** Constant Time is logged. The data is the mean value of the time.
- **Log:** Points/Decade is logged. The data is the measured value at each time point.

Start(s): Before the time of stress, the Data Compression is not affected. The data before this time is logged.

Device and SMU settings

The device and SMU settings are all set at the device level. For example, all the devices and SMUs that are assigned at the device level of the configuration navigator, such as the Group No., Dev No., SMU, and Terminal, are shown in the following figure.

W(um), L(um): MOSFET device dimensions. These parameters are used to calculate the current density and charge density.

Comp V: Voltage compliance (limit) value.

Comp I: Current compliance (limit) value.

Stress I: Sets the stress current value.

Stress V: Sets the stress voltage value.

Monitor: Current monitor measurements on the terminal.

Pre/Post Vuse: Sets the pre-test and post-test bias voltage values.

Figure 376: Device and SMU settings

Checked	Dev No.	W(um)	L(um)	SMU	Terminal	Pin No.	Compliance	Stress	Monitor?
☑	1	5.00	0.50	SMU2	Drain	1	0.01	0	☑
				SMU3	Source	2	0.01	0	☑
				SMU1	Gate	3	0.01	0	☑

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