Tektronix®

4200A-SCS Parameter Analyzer

DATASHEET

See your innovations come to life. The 4200A-SCS is a customizable and fully-integrated parameter analyzer that provides synchronized insight into current-voltage (I-V), capacitance-voltage (C-V), and ultra-fast pulsed I-V characterization. The highest performance parameter analyzer, the 4200A-SCS accelerates semiconductor, materials, and process development.

The 4200A-SCS Clarius™ GUI-based Software provides clear, uncompromised measurement and analysis capability. Furnished with embedded measurement expertise and hundreds of ready-to-use application tests, Clarius Software enables you to dig deeper into your research with speed and confidence.

The 4200A-SCS Parameter Analyzer is completely customizable and fully upgradable, so you can add the instruments you need now – or later. With the 4200A-SCS Parameter Analyzer, making connections to your bold discoveries has never been easier.

Key Performance Specifications

I-V Source Measure Units (SMUs)

- ±210 V/100 mA or ±210 V/1 A modules
- 100 fA measure resolution
- 10 aA measure resolution with optional preamp
- 10 mHz – 10 Hz very low frequency capacitance measurements
- 100 µF load capacitance
- 4-quadrant operation
- 2 or 4-wire connections

C-V Multi-frequency Capacitance Units (CVUs)

- AC impedance measurements (C-V, C-f, C-t)
- 1 kHz – 10 MHz frequency range
- ±30 V (60 V differential) built-in DC bias, expandable to ±210 V (420 V differential)
- Simple switching between I-V and C-V measurements with the optional CVIV Multi-Switch

Pulsed I-V Ultra-fast Pulse Measure Unit (PMU)

- Two independent or synchronized channels of high-speed pulsed I-V source and measure
- 200 MS/s, 5 ns sampling rate
- ±40 V (80 V_{p-p}), ±800 mA
- Transient waveform capture mode
- Arbitrary waveform generator for multi-level pulse waveform with 10 ns programmable resolution

High Voltage Pulse Generator Unit (PGU)

- Two channels of high-speed pulsed V source
- ±40 V (80 V_{p-p}), ±800 mA
- Arbitrary waveform generator Segment ARB® mode for multi-level pulse waveform with 10 ns programmable resolution

I-V/C-V Multi-Switch Module (CVIV)

- Easily switch between I-V and C-V measurements without re-cabling or lifting prober needles
- Move the C-V measurement to any terminal without re-cabling or lifting prober needles
- ±210 V DC bias capable

Remote Preamplifier/Switch Module (RPM)

- Automatically switches between I-V, C-V, and ultra-fast pulsed I-V measurements
- Extends current sensitivity of the 4225-PMU to tens of picoamps
- Reduces cable capacitance effects

KEITHLEY
A Tektronix Company

The Ultimate Parameter Analyzer for Materials, Semiconductor Devices and Process Development

Perform I-V, C-V and pulsed I-V characterization with speed, clarity and confidence with the powerful Clarius software.

4200A-SCS Instruments and Modules

Model	Description	Key Measurements	Range	Measure Resolution
4200-SMU	Medium Power Source-Measure Unit	DC I-V Very Low Frequency C-V QSCV	±105 mA, ±210 V	0.2 µV, 100 fA
4201-SMU	Medium Power SMU with increased low I stability			
4210-SMU	High Power Source-Measure Unit		±1.05 A, ±210 V	
4211-SMU	High Power SMU with increased low I stability			
4200-PA	Remote Preamplifier Module		Extends current ranges for all SMUs	0.2 µV, 10 aA
4210-CVU	Capacitance-Voltage Unit	AC Impedance C-V, C-f, C-t	1 kHz – 10 MHz ±30 V built-in DC bias (60 V differential) ±210 V DC bias with SMUs 100 mV AC drive	1 aF, 1 nS, 0.001 degree
4215-CVU	High Resolution Capacitance-Voltage Unit	AC Impedance C-V, C-f, C-t	1 kHz – 10 MHz ±30 V built in DC bias (60 V differential) ±210 V DC bias with SMUs 1 V AC drive	1 kHz 1 aF, 1 nS, 0.001 degree
4200A-CVIV	I-V/C-V Multi-Switch Module	DC I-V and C-V with Automatic Switching	–	–
4225-PMU	Ultra-Fast Pulse Measure Unit	Pulsed I-V SegmentARB® Multi-level Pulsing Transient Waveform Capture	±40 V (80 V_{p-p}), ±800 mA 200 MS/s simultaneous I and V measure 2048 unique segments 20 ns PW source only 60 ns PW source/measure	75 nA
4225-RPM	Remote Preamplifier/Switch Module	Enables automatic switching between SMU, CVU and PMU	Extends current range of 4225-PMU unit	200 pA
4220-PGU	High Voltage Pulse Generator Unit	Pulsed Voltage Source SegmentARB® Multi-level Pulsing	±40 V (80 V_{p-p}) 2048 unique segments	–
Ground Unit	Built-in, Low Noise Ground Unit	–	Triaxial connection: 2.6 A Binding post: 9.5 A	–

Example List of Extracted or Measured Parameters

CMOS transistor	Id-Vg, Id-Vd, Ig-Vg, Vth, Vtlin, Sub-Vt, Rds-on, breakdown, capacitance, QSCV, Low-frequency CV, self-heating reduction and more
BJT	Ic-Vc, Vcsat, Gummel plot, capacitance, βF, αF
Non-volatile Memory	Vth, endurance test, capacitance
Nanoscale	Resistance, Id-Vg, Id-Vd, Ic-Vc
Discrete components	Id-Vg, Id-Vd, Ic-Vc, V_{fdiode}, V_{rdiode}, capacitance
Materials	Van der Pauw, 4-point collinear resistivity, Hall Effect
Photovoltaics	$I_{forward}$, $I_{reverse}$, HiR, LoR
Power device	Pulsed Id-Vg, pulsed Id-Vd, breakdown
Reliability	NBTI/PBTI, charge pumping, hot carrier injection, V-Ramp, J-Ramp, TDDB

1. Clarius Software

Take your research to new levels of understanding with the new Clarius Software user interface. The 4200A-SCS includes the Clarius+ software package, which allows performing nearly any type of I-V, C-V, and pulsed I-V characterization test. The Clarius Software user interface provides touch-and-swipe or point-and-click control for advanced test definition, parameter analysis, graphing, and automation capabilities for modern semiconductor, materials, and process characterization.

Key Features

- Ready-to-use, modifiable application tests, projects and devices that reduce test development time
- Industry's first instrument with built-in measurement videos from world-wide Application engineers, in four languages, to reduce learning curve
- Pin to pad contact check ensures reliable measurements
- Select data from multiple tests and combine parameters into project-level analysis
- Data display, analysis and arithmetic functions

Reduce Characterization Complexity with Expert Videos

Engage quickly with your application and reduce your learning curve by watching built-in videos from Keithley worldwide application engineers. Hours of expert measurement expertise help will guide you when unexpected results occur or questions arise on how to set up your test. All videos are provided in English, and many are translated into other languages including Chinese, Japanese, and Korean. These short expert videos enable quick insight to your bold discoveries.

Select from Ready-to-Use Application Tests

With over 450 furnished application tests in the Clarius library, select or modify the pre-defined application tests to accelerate your characterization or easily create custom tests from the beginning. With three easy steps, Clarius Software guides even the new user through parameter analysis like an expert.

Real-time Results and Parameters

Accelerate your time to insight with automated data display, arithmetic functions, analysis and real-time parameter extraction. Never worry about losing your data because all test history is stored.

Verify Pulse Measurements without an Oscilloscope

Pulse timing preview mode provides an easy-to-read view of your pulse timing parameters that confirms your pulsed I-V test will execute as needed. Use the transient I-V or waveform capture mode to make time-based current or voltage measurements without the need of an external oscilloscope.

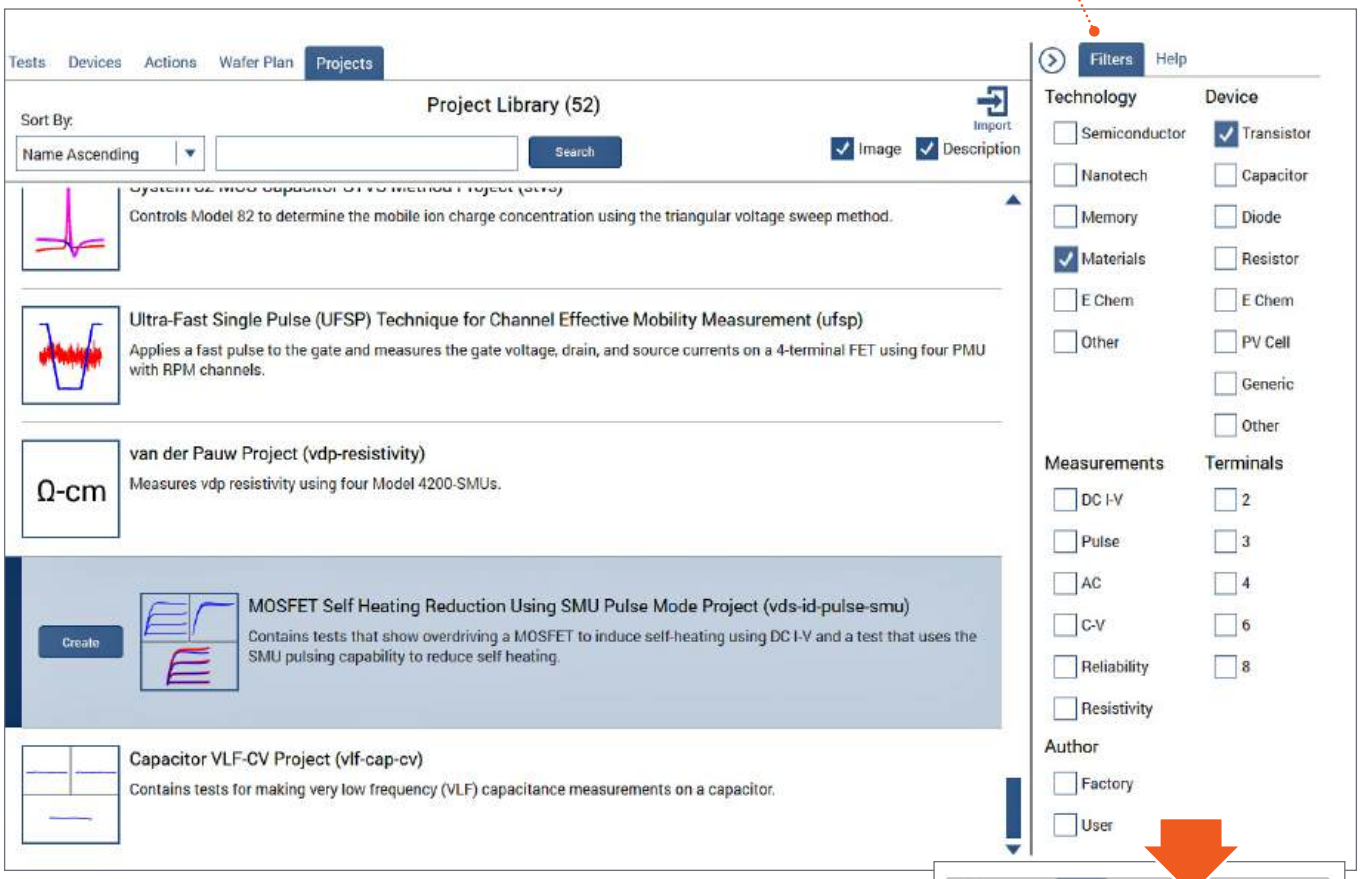
Typical Applications

- Bio FETs and Sensors
- MOSFET, BJT Transistors
- Materials Characterization
- Non-volatile Memory Devices
- Resistivity & Hall Effect Measurements
- Interface Trap Density
- 1/f Noise Testing
- NBTI/PBTI
- III-V Devices
- Failure Analysis
- Nanoscale Devices
- Diodes and pn Junctions
- Solar Cells
- Sensors
- MEMS Devices
- Electrochemistry
- LED and OLED

Step 1 - Build your Test Plan

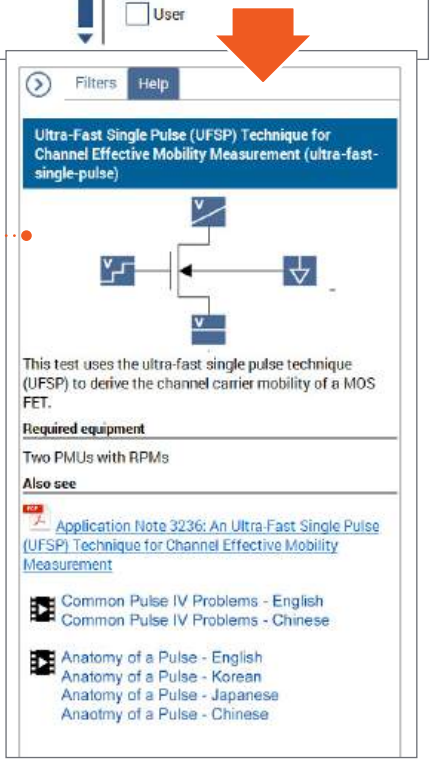
Search, filter, and select from more than 450 pre-defined application tests, projects, and devices from the Clarius library.

Filter test, device, or project libraries for quick selection



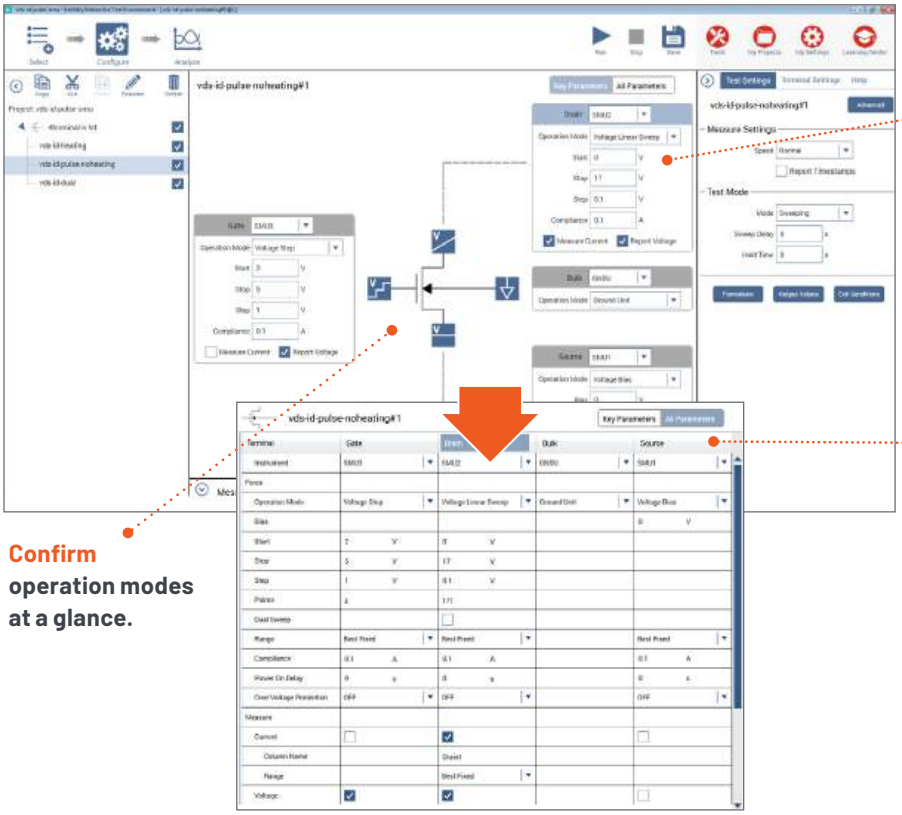
Learn about each test with more detailed information including:

- Comprehensive test descriptions
- Schematic view of test
- Required equipment
- Short videos and application notes



Step 2 – Configure Your Tests

Quickly modify the test parameters using the Key Parameters View or All Parameters View.



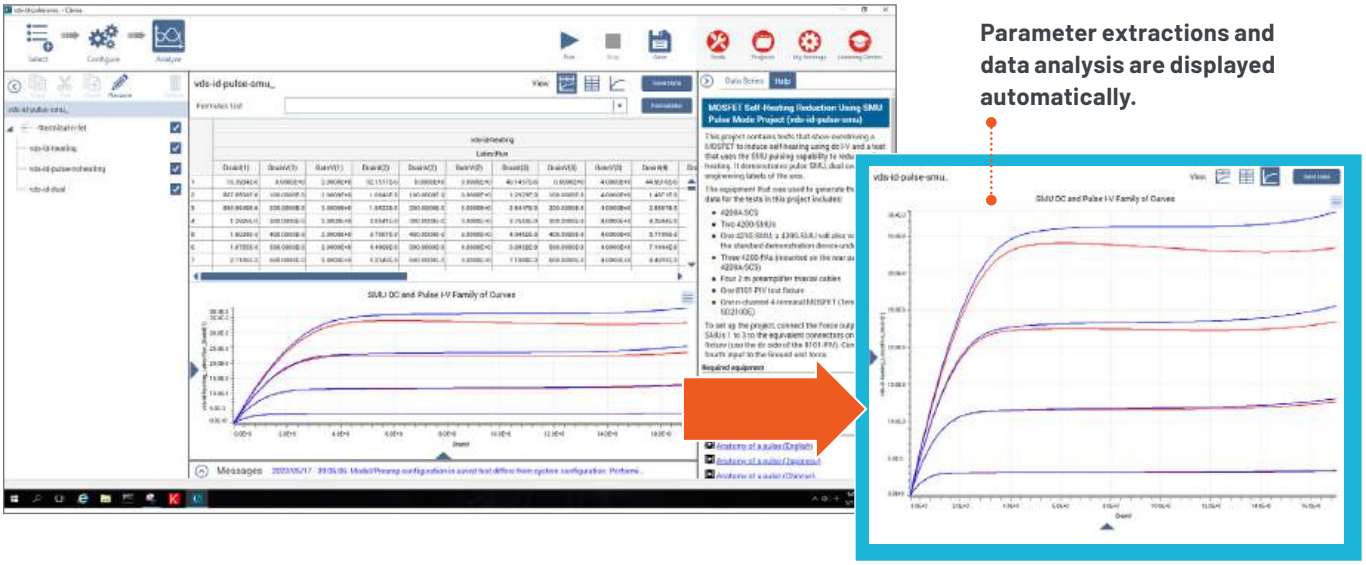
Key Parameters View provides a visual perspective on each test and device and helps to reduce the learning curve.

All Parameters View is ideal for entering test parameters.

Confirm operation modes at a glance.

Step 3 – Analyze Results

View results either graphically or numerically, filter your test data, and tag data for easy identification.

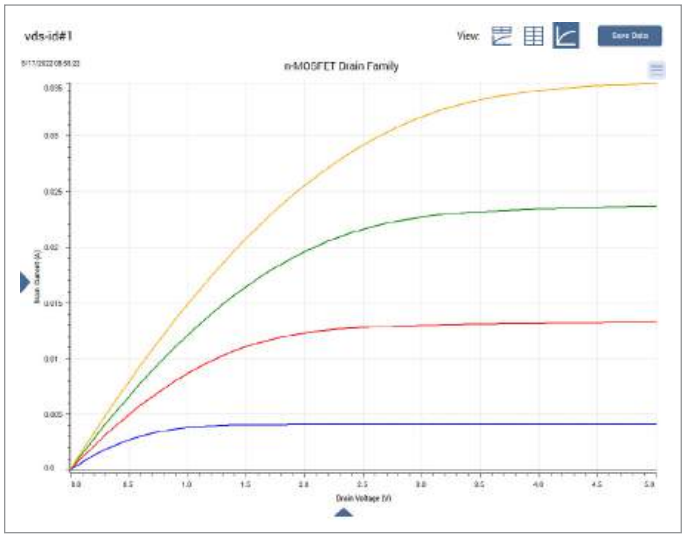


Parameter extractions and data analysis are displayed automatically.

2. Source Measure Units (SMU)

Precision DC current vs. voltage (I-V) measurements are the cornerstone of device and materials characterization. World-class source measure unit (SMU) instruments are at the core of the 4200A-SCS Parameter Analyzer. A source measure unit can source either voltage or current and can simultaneously measure both voltage and current with high resolution and accuracy. The SMU integrates the voltage source, current source, ammeter and voltmeter in one instrument card for tight synchronization of I-V measurements.

A source measure unit has four-quadrant capability, which means it can not only source but also sinks current, as when taking current from a device under test (DUT), such as a charged capacitor or solar cell.



I-V sweep measurement.

The 4200A-SCS Parameter Analyzer can be configured with up to nine SMUs. Four SMU models are available: two medium power SMUs that have a range up to 210 V and 105 mA and two high power SMUs that have a range up to 210 V and 1.05 A. The 4201-SMU and 4211-SMU can source into a fixture with a load capacitance of up to 10 µF and 100 µF respectively depending on the current range.

All 4200A-SCS SMUs have shielded triaxial connections with active guarding for low current and high impedance measurements and 4-wire (Kelvin) force and sense connections.

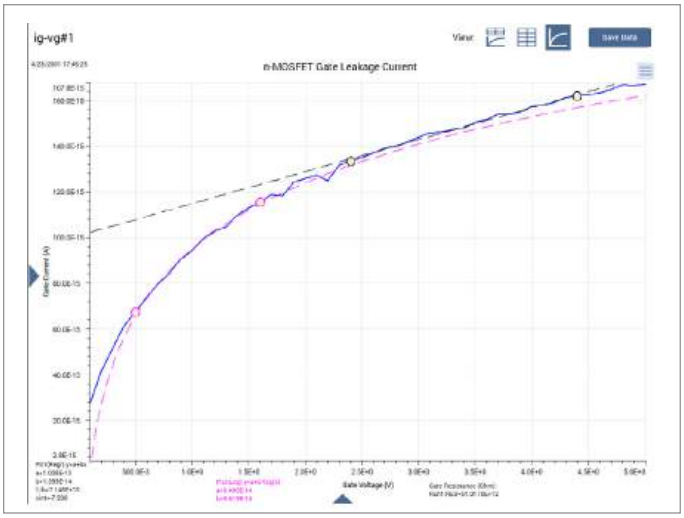
Field Installable SMUs

Need to replace or add SMUs to your existing 4200A-SCS mainframe? Now available, a first-in-class field installable SMU and SMU/PA. Eliminate the time-consuming requirement of returning your parameter analyzer to a service center just to add or replace SMUs. These distinct SMUs can be installed at your facility and will maintain their specifications over the standard one year calibration cycle.

Extend Measurement Resolution to 10 aA

Many critical applications demand the ability to measure very low currents – such as determining the gate leakage current of FETs, testing sensitive nano-scale devices, and measuring leakage current of insulators and capacitors.

When the SMUs are configured with the optional 4200-PA Remote Preamp, they are capable of exceptionally low current measurements. The 4200-PA provides 10 aA resolution by adding additional current ranges to either SMU model. To the user, the SMU simply appears to have additional measurement resolution available.

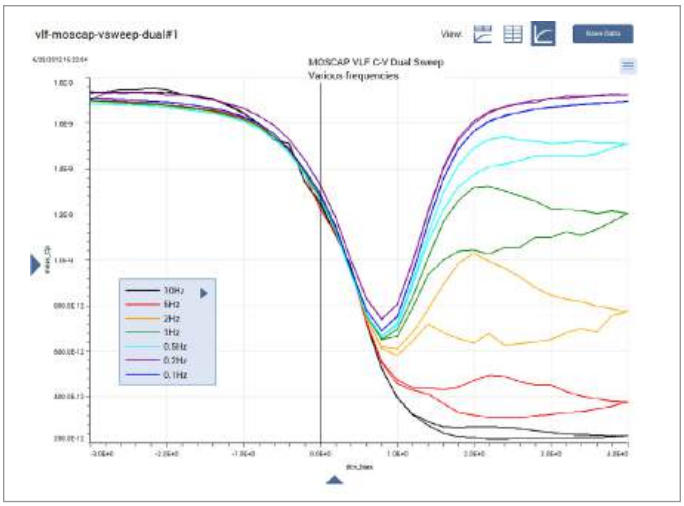


Sub-fA measurements with optional 4200-PA preamplifier module.

The preamplifier is shipped installed on the back of the 4200A-SCS mainframe. This installation allows for standard cabling to a prober, test fixture or switch matrix. The preamplifier can be removed from the back panel and placed in a remote location (such as in a light-tight enclosure or on a prober platen) to eliminate measurement problems due to long cables.

Very-low Frequency C-V Technique with SMUs

The 4200A-SCS offers the unique ability to perform very-low frequency capacitance-voltage measurements without an LCR meter or capacitance module. Low frequency C-V measurements are used to characterize the slow trapping and de-trapping phenomenon in some materials.



Very low frequency C-V measurements with SMUs and preamps.

The 4200A-SCS uses a new narrow-band technique that takes advantage of the low current measurement capability of the integrated SMU instruments to perform C-V measurements at specified low frequencies in the range of 10 mHz to 10 Hz. This approach uses the 4200A-SCS's SMUs with preamplifiers; no additional hardware or software is required.

Local Switching Options

To accommodate switching between I-V and other measurement types, the 4200A-SCS offers several options for switching easily between measurement types:

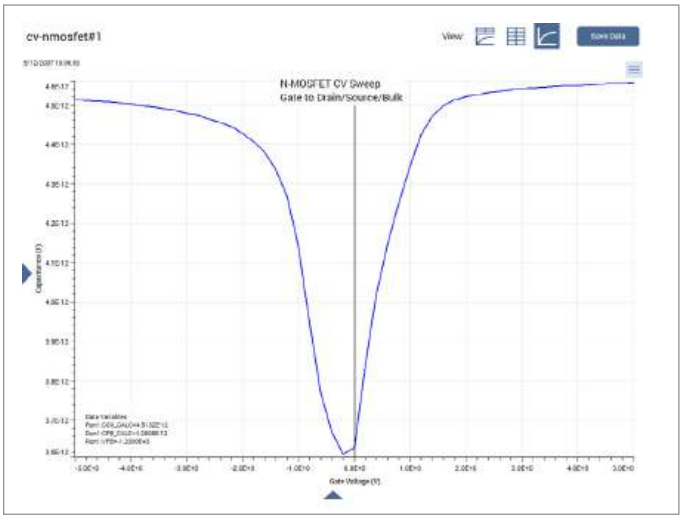
- 4200A-CVIV Multi-Switch Module – up to four channels that effortlessly switch between I-V and C-V measurements. In addition, the C-V measurements can be moved around the device under test without lifting the prober needles or changing the test setup.
- 4225-RPM Remote Preamplifier/Switch Module acts as a multiplexer switch that automatically switches between precision DC SMUs, C-V, and the ultra-fast pulsed I-V instruments. In addition, the RPM extends the low current measurement capability of the 4225-PMU Ultra-fast Pulsed I-V Instrument Module.

3. Capacitance-Voltage Unit (CVU)

Capacitance-voltage (C-V) measurements are often used to characterize a MOSFET's gate oxide thickness, oxide defect density, doping profiles, etc. In this measurement, as the gate voltage varies, the capacitance of the gate to the drain and source changes. Capacitance measurements are typically made using an AC technique. The multi-frequency C-V instrument modules measure AC impedance by applying a DC bias voltage and sourcing an AC voltage across the device under test (DUT) and then measuring the resultant AC current and phase angle.

AC Measurements from 1 kHz – 10 MHz

Both the 4215-CVU and 4210-CVU instrument modules perform multi-frequency capacitance measurements from femtofarads (f F) to microfarads (µF) at test frequencies from 1 kHz to 10 MHz and while providing a DC bias voltage of up to ±30 V or 60 V differential. The difference between the two CVUs are the number of test frequencies and the AC drive voltage. The 4215-CVU has 10,000 discreet frequencies with 1 kHz resolution and the 4210-CVU has 37 discreet frequencies. The AC drive voltage range of the 4215-CVU is 10 mV to 1 V rms and the range of the 4210-CVU is 10 mV to 100 mV rms.



Capacitance-Voltage sweeps.

With up to 4096 measurement points, the CVU instrument can be used to measure capacitance vs. voltage (C-V), capacitance vs. frequency (C-f) and capacitance vs. time (C-t) to extract many important parameters such as:

- Doping profiles
- T_{OX}
- Carrier lifetime tests
- Junction, pin-to-pin, and interconnect capacitance measurements

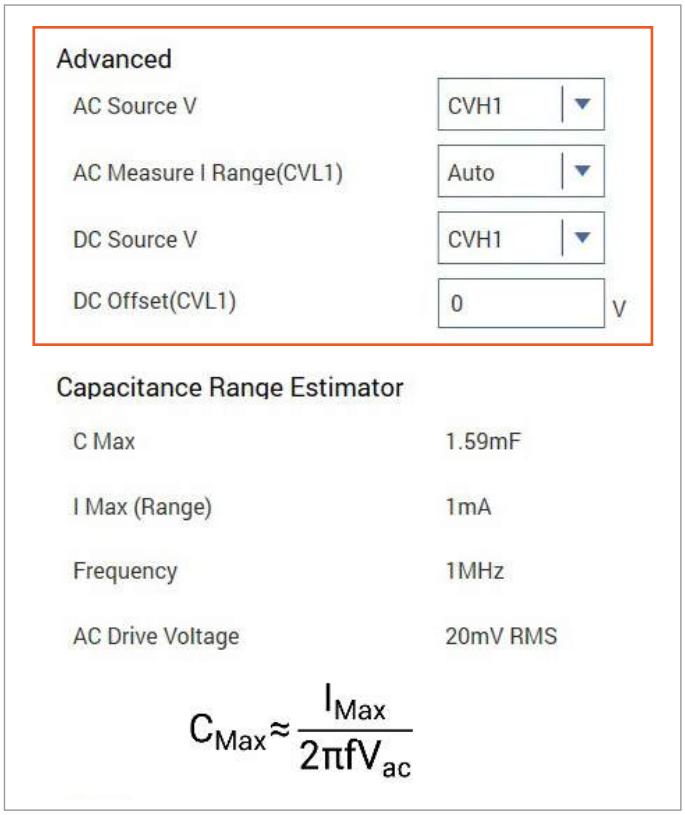
The 4200-CVU-PWR option is available to support:

- High power C-V measurements up to 400 V (200 V per device terminal) for testing high power devices, such as MEMS devices, LDMOS devices, and displays.
- DC currents up to 300 mA for measuring capacitance when a transistor is turned on.

Ensure Validity of your Results

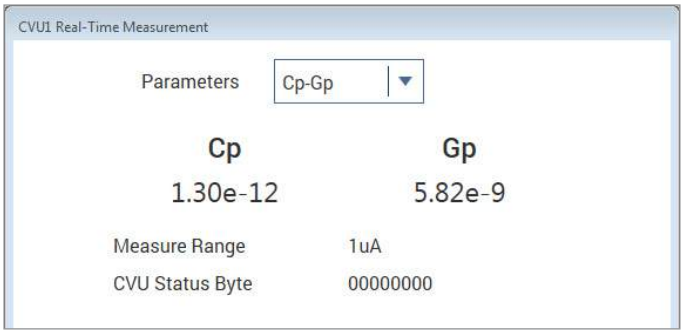
Unlike other C-V modules on the market, the 4210-CVU and 4215-CVU are designed with unique, patented circuitry to support features and diagnostic tools that ensure the validity of your results.

- **Switch the AC ammeter in software.** This simple feature ensures that you are measuring the AC signal on the least noisy terminal, which will provide a more useful measurement. Without having to manually change cables, lift the prober needles, or change the test setup, you have easily eliminated potential mistakes.



Change AC and DC sources to least noisy terminal with a simple click of the mouse.

- **Move the DC bias to the terminal of choice.** With just a click in the Clarius Software, you can change the terminal to which the DC bias is applied to ensure proper control of the electric field.
- **Real-time C-V meter.** The real-time C-V meter displays quick and accurate capacitance measurements with no need to run a pre-programmed test. This is especially useful to ensure you have an open and short circuit before you perform a measurement compensation. Additionally, you can use the real-time C-V meter for troubleshooting your test setup and device under test.



Real-time capacitance measurements.

- **Confidence Check.** This diagnostic tool allows users to check the integrity of open and short connections and the connections to the DUT. When performing an open or short test, an impedance and noise measurement is made on the high and low sides of the test circuit. This is especially useful to confirm that contact has been made with the pads on a wafer or that the switch matrix is connected properly. If the Confidence check diagnostic test fails, additional troubleshooting guidance is given.

Local Switching Options

Because it can be difficult to switch between C-V and other measurement types, the 4200A-SCS offers several options to switch easily between measurement types:

- **4200A-CVIV Multi-Switch Module** – Up to four channels that effortlessly switch between I-V and C-V measurements. In addition, the C-V measurements can be moved around the DUT without lifting the prober needles or changing the test setup.
- **4225-RPM Remote Preamplifier/Switch Module** This acts as a multiplexer switch that automatically switches between precision DC SMUs, C-V, and the ultra-fast pulsed I-V instruments. In addition, the RPM extends the low current measurement capability of the 4225-PMU Ultra-fast Pulsed I-V Instrument Module.

4. Ultra-fast Pulse Measure Unit (PMU)

Ultra-fast I-V sourcing and measuring have become increasingly important capabilities for many technologies, including compound semiconductors, medium power devices, non-volatile memory, MEMS devices and more.

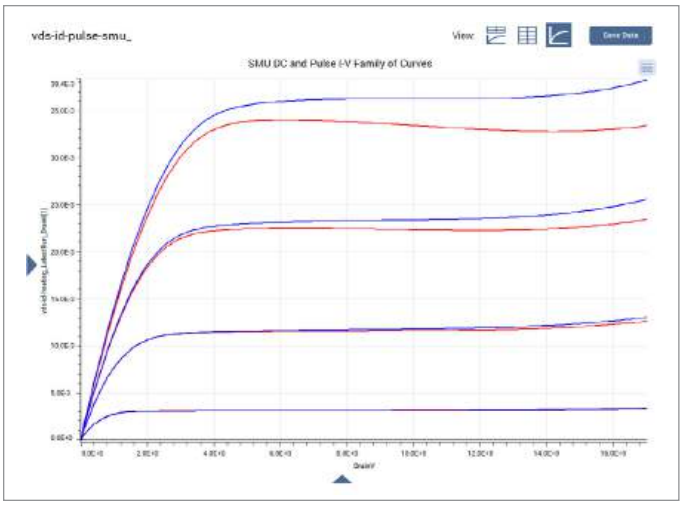
The 4225-PMU instrument card integrates ultra-fast voltage waveform generation and signal observation capabilities into the already-powerful 4200A-SCS test environment to deliver unprecedented I-V testing performance, expanding the system's materials, device, and process characterization dramatically. It replaces traditional pulse/measure hardware configurations, which typically included an external pulse generator, a multi-channel oscilloscope, specially designed interconnect hardware, and integrated software.

Each module has two independent channels. Each channel can measure both voltage and current simultaneously with parallel 14-bit A/D converters with deep memory, allowing up to one million samples at 5 ns per sample (200 MS/s).

Three Operating Modes for Complete Characterization

The 4225-PMU can be used to perform three types of ultra-fast I-V tests: pulsed I-V, transient I-V, and pulsed sourcing.

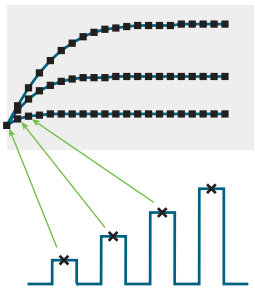
Pulsed I-V refers to any test with a pulsed source and a corresponding high speed, timed-based measurement that provides DC-like results. Using pulsed I-V signals to characterize devices rather than DC signals makes it possible to study or reduce the effects of self-heating (Joule heating) or to minimize current drift or degradation in measurements due to trapped charge.



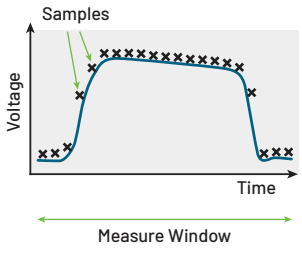
Minimize self-heating effects with ultra-fast pulsed I-V.

Transient I-V or waveform capture is a time-based current and/or voltage measurement that is typically the capture of a pulsed waveform. A transient test is typically a single pulse waveform that is used to study time-varying parameters, such as the drain current degradation versus time due to charge trapping or self-heating. Transient I-V measurements can be made to test a dynamic test circuit or can be used as a diagnostic tool for choosing the appropriate pulse settings in the pulsed I-V mode.

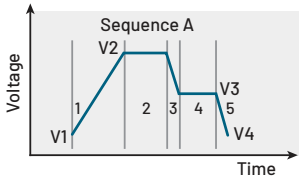
Pulsed Sourcing involves outputting user-defined two-level or multi-level pulses using the built-in Segment ARB® function or outputting an arbitrarily defined waveform. When the instrument's Segment ARB mode is used for multi-level pulsing, individual voltage segments can be as short as 20 ns and waveforms can have up to 2048 unique segments per channel, which provides the flexibility necessary to build waveforms for characterizing flash devices and other non-volatile memory technologies.



Pulsed I-V
Pulse/Measure with DC-like results
Train, Sweep, Step modes
General device characterization



Transient I-V
Time-based I and V measurements
Waveform capture
Dynamic device testing



Sequence A Definition			
Segment	Start V	Stop V	Duration
1	V1	V2	T1
2	V2	V2	T2
3	V2	V3	T3
4	V3	V3	T4
5	V3	V4	T5

Pulsed Sourcing
Multi-level pulsing
Arbitrary waveform generator
AC stress testing with measure

4225-PMU Operating Modes.

5. Switching Solutions

Tie it all together with your choice of high speed, high integrity switching solutions from Keithley.

4200A-CVIV Multi-Switch

One of the most difficult problems associated with integrating various measurements into device characterization is that the cabling required for each measurement type is fundamentally different.

Matching cabling to the measurement type enhances measurement integrity. However, changing cables for each measurement type is so time-consuming that many users simply tolerate the sub-optimal results. Moreover, whenever cables are rearranged, users run the risk of reconnecting them improperly, thereby causing errors and demanding extra troubleshooting time. Worse still, these errors may go unnoticed for a long time.

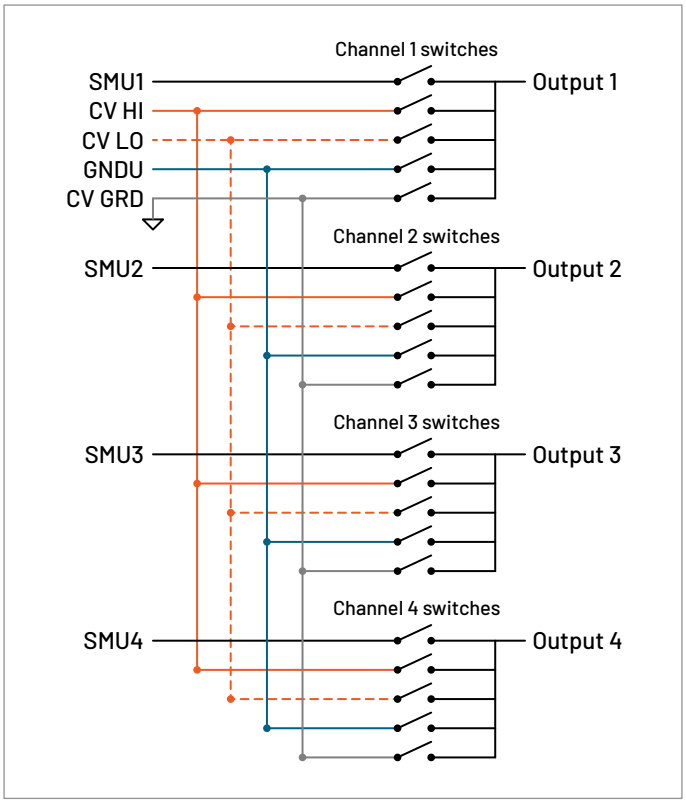
One alternative is to use a remote switch capable of handling I-V and C-V signals, such as the Keithley 4200A-CVIV Multi-Switch.

4200A-CVIV Multi-Switch.

The new 4200A-CVIV Multi-Switch automatically switches between I-V and C-V measurements. In addition, C-V measurements can be moved to any output channel without re-cabling. This four-channel switch allows the user to maintain the same impedance during the I-V and C-V tests by keeping the probe needles on the wafer test site. Additionally, the test setup and cables don't need to be changed to enhance the measurement.

The built-in display provides exceptional, clear test information where you need it, near the device under test.

- View real-time test status
- Personalize output naming convention via Clarius software
- Rubber bumpers allow 2-way orientation on probe station
- Ability to rotate text allows user to orient the module as needed
- Turn off display to reduce light near DUT



4200A-CVIV Multi-Switch connection schematic.

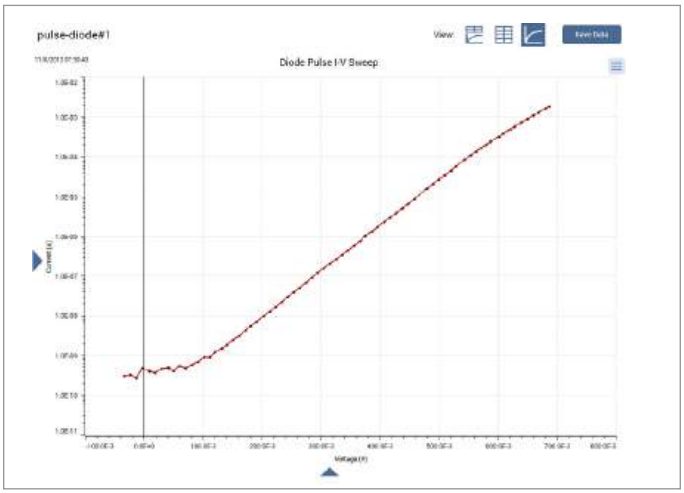
4225-RPM Remote Preamplifier/Switch Module

For some devices, multiple types of electrical measurements are required, such as pulsed I-V, DC I-V, and C-V tests. This usually requires an external switch matrix capable of switching the various types of signals to the device under test. However, the optional 4225-RPM Remote Preamplifier/Switch Module allows for switching automatically between DC I-V, C-V, and pulsed I-V measurements, greatly simplifying the connections to the device.

4225-RPM Remote Preamplifier/Switch Module.

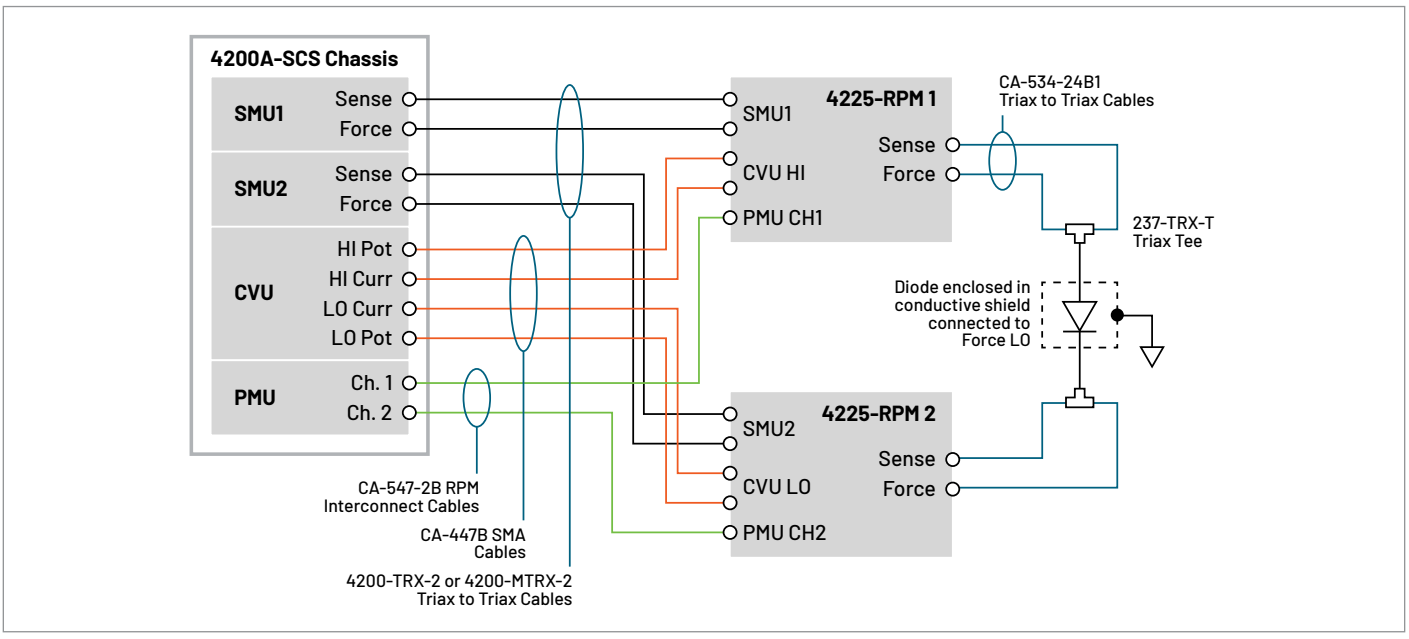
Users can perform all the electrical measurements on the device without having to disconnect and reconnect cabling for each test, which ultimately saves valuable test time and reduces frustration.

The 4225-RPM also serves as a preamp to extend the lower current ranges on the PMU. This is especially important for devices, such as diodes, that have I-V characteristics that extend over several decades of current. The pulsed I-V measurements of the diode through the 4225-RPM Remote Preamplifier/Switch are shown below. Its unique auto-range feature enables automatic range selection while the pulsed I-V sweep is in progress, so the user isn't forced to select a fixed range, which can reduce measurement resolution.



4225-RPM provides lower current ranges for pulse applications.

The optional Multi-measurement Prober Cable Kits (4210-MMPC) connect the 4200A-SCS Parameter Analyzer to a prober manipulator. In addition to eliminating the need for re-cabling, these kits help maximize signal fidelity by eliminating the measurement errors that often result from cabling errors.



Connection diagram when using 4225-RPM Remote Preamplifer/Switch Module.

Switch Matrices

A number of switch matrix configurations are available for the 4200A-SCS.

The six-slot 707B and single-slot 708B Semiconductor Switch Matrix mainframes slash the time from command to connection, offering significantly faster test sequences and overall system throughput than earlier mainframe designs.

708B and 707B Switch Matrix mainframes.

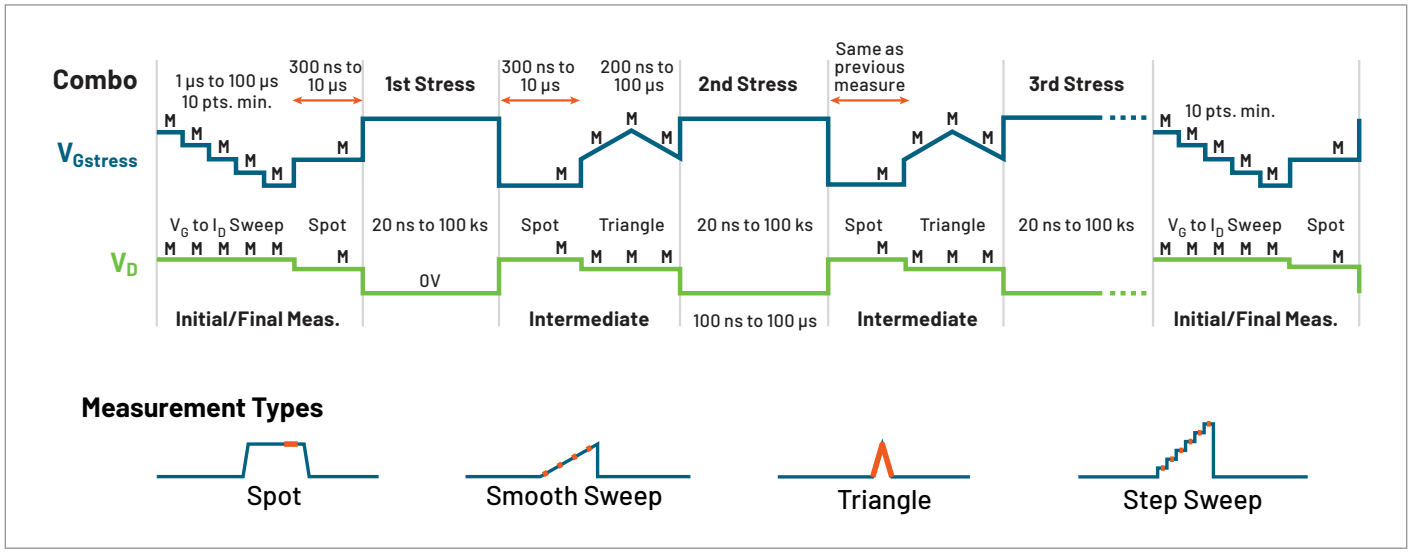
They are specifically designed for the requirements of both semiconductor lab and production test environments, delivering ultra-low current switching performance using standard triaxial connectors and cables.

6. NBTI/PBTI Package

Modeling negative/positive bias temperature instability (NBTI/PBTI) is a challenge when developing deeply scaled silicon CMOS transistor designs. Over time, NBTI effects cause a transistor's threshold voltage (V_T) to shift and its sub-threshold drain current to increase significantly, severely limiting transistor lifetime and circuit performance. These effects must be accurately modeled during device development and monitored during process integration and production. During BTI characterization, the transistor is alternately stressed and characterized. However, the BTI mechanism is susceptible to relaxation effects, which means that the instant the stress is removed, the transistor starts to recover and the degradation fades. Characterizing the degradation prior to relaxation demands the use of ultra-fast I-V techniques.

The 4200A-SCS offers the industry's most advanced NBTI/PBTI test platform for making sophisticated measurements on leading edge silicon CMOS technology. BTI testing requires a 4225-PMU Ultra Fast I-V Module, two 4225-RPM Remote Preamplifier/Switches, and Keithley's Automated Characterization Suite (ACS) software. The ACS software includes a built in Ultra-Fast BTI Test Project Module.

The Ultra-Fast BTI test software module supports spot, step sweep, smooth sweep, and sample measurement types. Each type's timing is defined by the test sample rate and the individual measurement settings. The software module also provides control over the voltage conditions between each element in the test sequence, for maximum flexibility and ease of use, even when defining complex test sequences.



Ultra-fast BTI package supports spot, smooth sweep, triangle, and step sweep measurement types.

Specifications

All specifications are guaranteed unless noted otherwise. All specifications apply to all models unless noted otherwise.

1. Source Measure Units

	4200-SMU and 4201-SMU Medium Power	4210-SMU and 4211-SMU High Power	Optional 4200-PA Remote Preamplifier
Current, maximum	105 mA	1.05 A	Extends low current measure range of all SMUs
Voltage, maximum	210 V	210 V	
Power	2.1 W	21 W	

General Information

	Four-quadrant source/sink operation
	A/D converter on every SMU
	Full remote sense capability
	Linear, log, list, and segment measurement sweeps
	4200A-SCS mainframe can accept up to nine medium or high power SMU instruments
Output Connectors	Three mini-triaxial (f) on each SMU for Force, Sense and Sense Lo One custom, 15-pin, D-Sub (f) for connection to 4200-PA
Optional Accessory	4200-PA remote preamplifier module
Equivalent Instruments	Field installable SMUs (4200-SMU-R, 4201-SMU-R, 4210-SMU-R, and 4211-SMU-R) have equivalent specifications to their non-field installable counterparts

SMU Current Specifications [4]

		Current Range [1]	Max. Voltage	Measure		Source	
				Resolution [3]	Accuracy ±(% rdg + amps)	Resolution [3]	Accuracy ±(% rdg + amps)
4210-SMU High Power SMU and 4211-SMU High Power SMU [2]		1 A	21 V	1 µA	0.100% + 200 µA	50 µA	0.100% + 350 µA
		100 mA	210 V	100 nA	0.045% + 3 µA	5 µA	0.050% + 15 µA
	4200-SMU Medium Power SMU and 4201-SMU Medium Power SMU [2]	100 mA	21 V	100 nA	0.045% + 3 µA	5 µA	0.050% + 15 µA
		10 mA	210 V	10 nA	0.037% + 300 nA	500 nA	0.042% + 1.5 µA
		1 mA	210 V	1 nA	0.035% + 30 nA	50 nA	0.040% + 150 nA
		100 µA	210 V	100 pA	0.033% + 3 nA	5 nA	0.038% + 15 nA
		10 µA	210 V	10 pA	0.050% + 600 pA	500 pA	0.060% + 1.5 nA
		1 µA	210 V	1 pA	0.050% + 100 pA	50 pA	0.060% + 200 pA
		100 nA	210 V	100 fA	0.050% + 30 pA	5 pA	0.060% + 30 pA
42XX-SMU with optional 4200-PA Preamp		10 nA	210 V	10 fA	0.050% + 1 pA	500 fA	0.060% + 3 pA
		1 nA	210 V	1 fA	0.050% + 100 fA	50 fA	0.060% + 300 fA
		100 pA	210 V	300 aA	0.100% + 30 fA	15 fA	0.100% + 80 fA
		10 pA	210 V	100 aA	0.500% + 15 fA	5 fA	0.500% + 50 fA
		1 pA	210 V	10 aA	1.000% + 10 fA	1.5 fA	1.000% + 40 fA
Voltage Compliance: Bipolar limits set with a single value between full scale and 10% of selected voltage range.							

Notes

1. All ranges extend to 105% of full scale.
2. Specifications apply on these ranges with or without a 4200-PA.
3. Display resolution is limited by fundamental noise limits. Measured resolution is 6½ digits on each range. Source resolution is 4½ digits on each range.
4. The measurement and source accuracy are specified at the termination of the supplied cables.
   - 23°C ±5°C, within 1 year of calibration, RH between 5% and 60%, after 30 minutes of warmup.
   - Speed set to NORMAL.
   - Guarded Kelvin connection.
   - ±1°C and 24 hours from ACAL.

SMU Voltage Specifications[3]

Voltage Range[1]	Max. Current		Measure		Source	
	4200-SMU and 4201-SMU	4210-SMU and 4211-SMU	Resolution[2]	Accuracy ±(% rdg + volts)	Resolution[2]	Accuracy ±(% rdg + volts)
200 V	10.5 mA	105 mA	200 µV	0.015% + 3 mV	5 mV	0.02% + 15 mV
20 V	105 mA	1.05 A	20 µV	0.01% + 1 mV	500 µV	0.02% + 1.5 mV
2 V	105 mA	1.05 A	2 µV	0.012% + 150 µV	50 µV	0.02% + 300 µV
200 mV	105 mA	1.05 A	0.2 µV	0.012% + 100 µV	5 µV	0.02% + 150 µV
Current Compliance: Bipolar limits set with a single value between full scale and 10% of selected current range.						

Notes

1. All ranges extend to 105% of full scale.
2. Specifications apply on these ranges with or without a 4200-PA.
3. The measurement and source accuracy are specified at the termination of the supplied cables.
   - 23°C ±5°C, within 1 year of calibration, RH between 5% and 60%, after 30 minutes of warmup.
   - Speed set to NORMAL.
   - Guarded Kelvin connection.

SMU Maximum Capacitance Specifications

	Current Range	Maximum Load Capacitance between Force HI and Force LO terminals	Maximum Guard Capacitance between Force HI and Guard terminals	Maximum Shield Capacitance between Guard and Force LO terminals
4211-SMU	1 A	100 µF	5 nF	10 nF
4201-SMU or 4211-SMU	100 mA	100 µF		
4201-SMU or 4211-SMU	100 nA to 10 mA	10 µF		
4201-SMU or 4211-SMU with 4200-PA preamplifier	1 nA to 10 nA	10 µF		
	1 pA to 100 pA	1 µF		
4200-SMU, 4210-SMU	All current ranges	10 nF	1500 pF	3300 pF

Voltage Monitor Mode

High impedance voltmeter mode set at 0 Amps.

Accuracy & Resolution

Voltage Range	Measure Resolution	Measure Accuracy ±(%rdg + volts)
200 V	200 µV	0.015% + 3 mV
20 V	20 µV	0.01% + 1 mV
2 V	2 µV	0.012% + 110 µV
200 mV	0.2 µV	0.012% + 80 µV

Input Impedance	$>10^{13}\,\Omega$
Input Leakage Current	<30 pA
Measurement Noise	0.02% of measure range (rms).
Differential Voltage Monitor	Use two SMUs in VMU mode or use the low sense terminal provided with each SMU.

SMU Supplemental Information

Supplemental information is not warranted but provides useful information about the 4200-SMU, 4201-SMU, 4210-SMU, and 4211-SMU instruments.

Compliance Accuracy
Voltage compliance equals the voltage source specifications
Current compliance equals the current source specifications

Overshoot
<0.1% typical

Voltage
Full scale step, resistive load, and 10 mA range

Current
1 mA step, R_L = 10 kΩ, 20 V range

Range Change Transient

Voltage Ranging
<200 mV

Current Ranging
<200 mV

Temperature and Humidity Effect on Accuracy
Accuracy specifications are multiplied by one of the following factors, depending upon the ambient temperature and humidity.

Temperature	% Relative Humidity	
	5–60	60–80
10°–18°C	×3	×3
18°–28°C	×1	×3
28°–40°C	×3	×5

Remote Sense
<10 Ω in series with FORCE terminal not to exceed a 5 V difference between FORCE and SENSE terminals

±30 V maximum between COMMON and SENSE LO.

Maximum Guard Offset Voltage
3 mV from FORCE

Guard Output Impedance
100 kΩ

4200-SMU and 4210-SMU Shunt Resistance (Force to Common)
$>10^{12}$ Ω (100 nA–1 µA ranges)

4200-PA Shunt Resistance (Force to Common)
$>10^{16}$ Ω (1 pA and 10 pA ranges), $>10^{13}$ Ω (100 pA–100 nA ranges)

Noise Characteristics (typical)

- **Voltage Source (rms)** 0.01% of output range
- **Current Source (rms)** 0.1% of output range
- **Voltage Measure (p-p)** 0.02% of measurement range
- **Current Measure (p-p)** 0.2% of measurement range

Maximum Slew Rate
0.2 V/µs

DC Floating Voltage
Common can be floated ±32 V from chassis ground

2. SMU Preamplifier Module

The low current measurement capabilities of any SMU can be extended by adding an optional 4200-PA preamplifier. The preamplifier provides 10 aA resolution by effectively adding five current ranges to either SMU model. The preamp module is fully integrated with the system; to the user, the SMU simply appears to have additional measurement resolution available.

4200-PA General information

Installation	
Local	The preamplifier is shipped installed on the back panel of the 4200A-SCS for local operation.
Remote	Users can remove the preamplifier from the back panel and place it in a remote location (such as in a light-tight enclosure or on the prober platen) to eliminate measurement problems due to long cables.
Input Connectors	One custom, 15 pin, D-Sub (m)
Output Connectors	Two triaxial (f)
Dimensions	0.79 in. wide × 4.4 in. deep × 2.2 in. tall (2 cm wide × 11.3 cm deep × 5.6 cm tall)
Weight	4.8 oz. (136 g)

SMU Current Specifications with 4200-PA Preamplifier [4]

		Current Range [1]	Max. Voltage	Measure		Source	
				Resolution [3]	Accuracy ±(% rdg + amps)	Resolution [3]	Accuracy ±(% rdg + amps)
4210-SMU High Power SMU and 4211-SMU High Power SMU [2]		1 A	21 V	1 µA	0.100% + 200 µA	50 µA	0.100% + 350 µA
		100 mA	210 V	100 nA	0.045% + 3 µA	5 µA	0.050% + 15 µA
	4200-SMU Medium Power SMU and 4201-SMU Medium Power SMU [2]	100 mA	21 V	100 nA	0.045% + 3 µA	5 µA	0.050% + 15 µA
		10 mA	210 V	10 nA	0.037% + 300 nA	500 nA	0.042% + 1.5 µA
		1 mA	210 V	1 nA	0.035% + 30 nA	50 nA	0.040% + 150 nA
		100 µA	210 V	100 pA	0.033% + 3 nA	5 nA	0.038% + 15 nA
		10 µA	210 V	10 pA	0.050% + 600 pA	500 pA	0.060% + 1.5 nA
		1 µA	210 V	1 pA	0.050% + 100 pA	50 pA	0.060% + 200 pA
		100 nA	210 V	100 fA	0.050% + 30 pA	5 pA	0.060% + 30 pA
42XX-SMU with optional 4200-PA Preamp		10 nA	210 V	10 fA	0.050% + 1 pA	500 fA	0.060% + 3 pA
		1 nA	210 V	1 fA	0.050% + 100 fA	50 fA	0.060% + 300 fA
		100 pA	210 V	300 aA	0.100% + 30 fA	15 fA	0.100% + 80 fA
		10 pA	210 V	100 aA	0.500% + 15 fA	5 fA	0.500% + 50 fA
		1 pA	210 V	10 aA	1.000% + 10 fA	1.5 fA	1.000% + 40 fA
Voltage Compliance: Bipolar limits set with a single value between full scale and 10% of selected voltage range.							

Notes

1. All ranges extend to 105% of full scale.
2. Specifications apply on these ranges with or without a 4200-PA.
3. Display resolution is limited by fundamental noise limits. Measured resolution is 6½ digits on each range. Source resolution is 4½ digits on each range.
4. The measurement and source accuracy are specified at the termination of the supplied cables.
   - 23°C ±5°C, within 1 year of calibration, RH between 5% and 60%, after 30 minutes of warmup.
   - Speed set to NORMAL.
   - Guarded Kelvin connection.

3. Multi-Frequency Capacitance-Voltage Units

	4210-CVU	4215-CVU
General Information		
Measurement configuration	Four-terminal pair, High POT, High CUR, Low POT, Low CUR	Four-terminal pair, High POT, High CUR, Low POT, Low CUR
Output connectors	Four SMA (f)	Four SMA (f)
Supplied cable	100 Ω, SMA (m) to SMA (m), 1.5 m, 4 each	100 Ω, SMA (m) to SMA (m), 1.5 m, 4 each
Optional cables	100 Ω, SMA (m) to SMA (m), 3 m	100 Ω, SMA (m) to SMA (m), 3 m
Measurement Functions		
Measurement parameters	C_P-G, C_P-D, C_S-R_S, C_S-D, R-jX, Z-theta , Y-theta	C_P-G, C_P-D, C_S-R_S, C_S-D, R-jX, Z-theta , Y-theta
Ranging	Auto and fixed	Auto and fixed
Integration time	Fast, Normal, Quiet, and Custom	Fast, Normal, Quiet, and Custom
Test Signal		
Frequency range	1 kHz to 10 MHz	1 kHz to 10 MHz
Minimum resolution	1 kHz, 10 kHz, 100 kHz, 1 MHz depending on frequency range	1 kHz for entire range
Source frequency accuracy	±0.1%	±0.1%
Signal output level range	10 mV rms to 100 mV rms	10 mV to 1 V rms
Resolution	1 mV rms	1 mV rms
Accuracy	±(10.0% + 1 mV rms) unloaded (at rear panel)	±(10.0% + 1 mV rms) unloaded (at rear panel)
Output impedance	100 Ω, typical	100 Ω, typical
DC Bias Function		
DC voltage bias range	±30 V (60 V differential)	±30 V (60 V differential)
DC voltage bias resolution	1.0 mV	1.0 mV
DC voltage bias accuracy	±(0.5% + 5.0 mV) unloaded	±(0.5% + 5.0 mV) unloaded
Maximum DC current	10 mA	10 mA
Sweep Characteristics		
Available sweep parameters	DC bias voltage, frequency, AC voltage	DC bias voltage, frequency, AC voltage
Sweep type	Linear, custom	Linear, log, custom
Sweep direction	Up sweep, down sweep	Up sweep, down sweep
Number of measurement points	4096	4096

Measurement Accuracy [4,5]

Example of C/G Measurement Accuracy

Frequency	Measured Capacitance	C Accuracy [1]	G Accuracy [1, 2, 6]
10 MHz [3]	1 pF	±0.92%	4210-CVU: ±600 nS 4215-CVU: ±1.7 µS
	10 pF	±0.32%	±3.9 µS
	100 pF	±0.29%	±17 µS
	1 nF	±0.35%	±176 µS
1 MHz	1 pF	±1.17%	±64 nS
	10 pF	±0.19%	±65 nS
	100 pF	±0.10%	±610 nS
	1 nF	±0.09%	±4 µS
100 kHz	10 pF	±0.31%	±28 nS
	100 pF	±0.18%	±59 nS
	1 nF	±0.10%	±450 nS
	10 nF	±0.10%	±3 µS
10 kHz	100 pF	±0.31%	±15 nS
	1 nF	±0.15%	±66 nS
	10 nF	±0.08%	±450 nS
	100 nF	±0.10%	±3 µS
1 kHz	1 nF	±0.82%	±40 nS
	10 nF	±0.40%	±120 nS
	100 nF	±0.10%	±500 nS
	1 µF	±0.15%	±10 µS

Notes

1. The capacitance and conductance measurement accuracy is specified under the following conditions: DX < 0.1.
2. Conductance accuracy is specified as the maximum conductance measured on the referenced capacitor.
3. Specifications at 10 MHz are typical, non-warranted, apply at 23 °C, and are provided solely as useful information.
4. Integration time: 1 s or 10 s below 10 kHz. Test signal level: 30 mV rms. At the rear panel of the 4210-CVU or 4215-CVU.
   All specifications apply at 23 °C ±5°C, within one year of calibration, RH between 5% and 60%, after 30 minutes of warmup.
5. Above specifications also apply for the 4215-CVU at 300 mV.
6. G Accuracy is a typical, non-warranted specification provided for reference.

CVU Supplemental Cable Specification [3,4]

The following specifications are examples of typical accuracy when taking measurements though cables. They are standalone specifications and therefore are provided separately from the specifications above which represent the guaranteed accuracy at the rear terminals of the CVU. These specifications are typical, non-warranted, apply at 23°C, and are provided solely as useful information.

4210-CVU and 4215-CVU Typical C Accuracy[1] with 1.5m Cables (supplemental)

Measured Capacitance	1kHz	10kHz	100kHz	1MHz	10MHz
1 pF	N/A	±8.38%	±1.95%	±0.43%	N/A
10 pF	N/A	±0.94%	±0.21%	±0.18%	N/A
100 pF	N/A	±0.29%	±0.20%	±0.15%	±1%
1 nF	±0.72%	±0.17%	±0.12%	±0.16%	±2%
10 nF	±0.28%	±0.12%	±0.13%	±0.55%	N/A
100 nF	±0.12%	±0.13%	±0.22%	±1.14%	N/A
1 µF	±0.17%	±0.21%	N/A	N/A	N/A

4210-CVU and 4215-CVU Typical C Accuracy[1] with 3m Cables (supplemental)

Measured Capacitance	1kHz	10kHz	100kHz	1MHz	10MHz
1 pF	N/A	±8.5 %	±2.05%	±0.57%	N/A
10 pF	N/A	±0.96%	±0.23%	±0.21%	N/A
100 pF	N/A	±0.29%	±0.20%	±0.17%	N/A
1 nF	±0.72%	±0.17%	±0.12%	±0.18%	N/A
10 nF	±0.28%	±0.12%	±0.13%	±0.65%	N/A
100 nF	±0.12%	±0.13%	±0.22%	±1.16%	N/A
1 µF	±0.17%	±0.21%	N/A	N/A	N/A

Notes

1. The capacitance and conductance measurement accuracy is specified under the following conditions: DX < 0.1.
2. These specs are typical, non-warranted, apply at 23°C, and are provided solely as useful information.
3. Integration time: 1 s or 10 s below 10 kHz. Test signal level: 30 mV rms.
4. Above specifications also apply for the 4215-CVU at 300 mV.

4. CV-IV Multi-Switch Module

The C-V/I-V Multi-Switch automatically switches between I-V and C-V measurements. In addition, C-V measurements can be moved to any output channel without recabling. Each channel is user configurable for low current measurement capabilities using the 4200-PA preamplifier or standard current resolution with a SMU Pass Thru 4200A-CVIV-SPT.

4200A-CVIV General Information

Input connectors	**4200-PA Preamplifier:** Custom, 15-pin, D-Sub (m) **4200A-CVIV-SPT SMU Pass-thru Module:** Two triaxial (f) per module **CVU:** Four SMA (f) **CVIV Ground Unit:** Mini-triaxial
Output connectors	Eight triaxial (f)
Dimensions	19.8 cm wide × 14.2 cm high × 11.1 cm deep (7.8 in. wide × 5.6 in. tall × 4.4 in. deep)
Weight	1.5 kg (3.3 lb)
Power	From 4200A-SCS mainframe via USB cable
Output channels	Configurable up to 4 channels
Voltage, max.	210 V
Current, max.	1 A

SMU Path	**With 4200-PA**	**With 4200A-CVIV-SPT**
Offset current	<100 fA	<1 pA
Offset voltage	<100 µV	<100 µV
Shunt resistance	>1e15 Ω	>1e14 Ω
DC output resistance (2-wire)	1.5 Ω	1.5 Ω
DC output resistance (4-wire)	<100 mΩ	<100 mΩ

CVU Path	
AC output impedance	100 Ω, typical (center pin to outer shield)
Accuracy, typical	Refer to chart below

CVU DC Bias Function, using CVU Instrument

DC biasing of AC signals is provided by the 4210-CVU or 4215-CVU instrument models. See next section for biasing with SMUs.

Range	±30V at 10 mA max. (60 V differential)
Resolution	1 mV
Additional errors (for CVU bias)	<50 µV
DC output resistance (4 wire)	<100 mΩ

Typical Accuracy of 4210-CVU and 4215-CVU through the 4200A-CVIV Multi-Switch, 2-wire mode with 4200-TRX-0.75 cables unless otherwise noted [1,3]

Measured Capacitance	1 kHz	10 kHz	100 kHz	1 MHz
1 pF	Not Specified	±9.0%	±2.2%	±0.7%
10 pF	Not Specified	±1.0%	±0.5%	±0.5%
100 pF	Not Specified	±0.5%	±0.5%	±0.5%
1 nF	±0.8%	±0.5%	±0.5%	±0.5% [2]
10 nF	±0.5%	±0.5%	±0.5%	±0.75% [2]
100 nF	±0.5%	±0.5%	±0.5%	±1.25% [2]
1 µF	±0.5%	±0.5%	Not Specified	Not Specified

Notes

1. Valid when CVU compensation is applied from a <1 month old compensation acquisition.
2. Specified in 4-wire mode; 4-wire always recommended for low impedance devices
3. The specifications above are typical, non-warranted, apply at 25°C, and are provided solely as useful information.

CVU DC Bias Function, using SMU Instrument in bias tee

DC biasing of AC signals is provided by the 42XX-SMU instrumen**t modules.**

Range

BiasT CV LO I Mode: ±210 V (420 V differential) and 1 mA maximum.
BiasT CV Mode: ±210 V (420 V differential) and 1 A maximum.

Typical Accuracy of 4210-CVU and 4215-CVU through the 4200A-CVIV Multi-Switch, 2-terminal bias tee

Measured Capacitance	1 kHz	10 kHz	100 kHz	1 MHz
1 pF	Not Specified	Not Specified	±2.4%	±0.7%
10 pF	Not Specified	±2.9%	±0.5%	±0.5%
100 pF	Not Specified	±0.5%	±0.5%	±0.5%
1 nF	±1.9%	±0.5%	±0.5%	±0.5%
10 nF	±0.7%	±0.5%	±0.5%	±0.75%
100 nF	±0.7%	±0.5%	±0.5%	±2.3%
1 µF	±3.5%	±2.0%	Not Specified	Not Specified

Notes

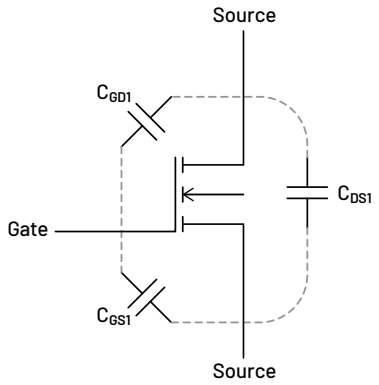
- These specs are typical, non-warranted, apply at 23 °C, and are provided solely as useful information.
- Measurements verified using 4210-CVU and 4215-CVU in 2 wire and Bias Tee Low I modes.
- Specification is valid up to 1 mA. Accuracy of measurements taken while sourcing above 1 mA is not specified.
- Measurement speed: Quiet, Test signal level: 30 mV rms, AC Measure I Range: Auto.
- Valid when CVU CVIV compensation is applied from a <1 month old compensation acquisition.

Typical Accuracy of 4210-CVU and 4215-CVU through the 4200A-CVIV Multi-Switch, 3-terminal bias tee

Measured Capacitance	1 kHz	10 kHz	100 kHz	1 MHz
Cgd = 100 pF	Not Specified	±5.0%	±5.0%	Not Specified
Cds = 1 nF	±10.0%	±2.0%	±2.0%	±30.0%
Cgs = 10 nF	±3.0%	±2.0%	±2.0%	±3.0%
Measured Capacitance	1 kHz	10 kHz	100 kHz	1 MHz
Cgd = 100 pF	Not Specified	±2.0%	±2.0%	±5.0%
Cds = 420 pF	±20.0%	±2.0%	±2.0%	±5.0%
Cgs = 1 nF	±6.0%	±2.0%	±2.0%	±3.0%

Notes

- These specs are typical, non-warranted, apply at 23 °C, and are provided solely as useful information.
- Measurements verified using 4210-CVU and 4215-CVU and the following CVIV configuration:
  - Ch1: BiasT: SMU LO I CV HI
  - Ch2: BiasT: SMU LO I CV LO
  - Ch3: Ground Unit
  - Ch4: Open
  - 2-Wire Mode
- Measurement speed: Quiet, Test signal level: 30 mV rms, AC Measure I Range: Auto
- Valid when CVU CVIV compensation is applied from a <1 month old compensation acquisition.



5. Ultra-fast Pulse Measure Unit

The two-channel 4225-PMU provides the combination of ultra-fast voltage waveform generation with fast simultaneous voltage and current measurements.

4225-PMU General Information

Output connectors	Four SMA (f) and two HDMI
Supplied cables	SMA (m) to SMA (m), 2 m, 4 each (CA-404B)
	SMA to SSMC Y-cable, 15 cm (6 in.), 2 each (4200-PRB-C)
Optional accessory	4225-RPM single-channel, remote preamplifier/switch module

PMU Current Measurement

Timing parameters, typical[1] with or without the 4225-RPM Remote Preamplifier/Switch Module

	10 V Range		40 V Range
Current measure ranges	10 mA	200 mA	800 mA
Recommended minimum pulse width[2]	160 ns	70 ns	770 ns
Recommended minimum measure window[2]	20 ns	20 ns	100 ns
Recommended minimum transition time[3]	20 ns	20 ns	100 ns
Noise[4]	15 µA	50 µA	200 µA
Settling time[5]	100 ns	30 ns	500 ns

Notes

1. All typical values measured with an open circuit.
2. Using default measure window of 75% to 90% of pulse top. Recommended minimum pulse width = (Settling Time) / 75%.
3. Recommended rise/fall time to minimize overshoot.
4. RMS noise measured over the Recommended Minimum Measure Window for the given voltage or current range, typical.
5. Time necessary for the signal to settle to the DC accuracy level. (Example: 10 mA settling time on the PMU 10 V range is defined when the signal is within 1.25% of the final value. This calculation: Accuracy = 0.25% + 100 µA = 0.25% + (100 µA/10 mA) = 0.25% + 1% = 1.25%).
6. 10 mA noise specification is different if RPM is used. See table below

Timing parameters, typical[1] with the 4225-RPM Remote Preamplifier/Switch Module

	10V Range						40 V Range	
Current measure ranges	100 nA	1 µA	10 µA	100 µA	1 mA	10 mA[6]	100 µA	10 mA
Recommended minimum pulse width[2]	134 µs	20.4 µs	8.36 µs	1.04 µs	370 ns	160 ns	6.4 µs	770 ns
Recommended minimum measure window[2]	10 µs	1.64 µs	1 µs	130 ns	40 ns	20 ns	1 µs	100 ns
Recommended minimum transition time[3]	1 µs	360 ns	360 ns	40 ns	30 ns	20 ns	1 µs	100 ns
Noise[4]	200 pA	2 nA	5 nA	50 nA	300 nA	1.5 µA	75 nA	5 µA
Settling time[5]	100 µs	15 µs	6 µs	750 ns	250 ns	100 ns	4 µs	500 ns

Notes

1. All typical values measured with an open circuit.
2. Using default measure window of 75% to 90% of pulse top. Recommended minimum pulse width = (Settling Time) / 75%.
3. Recommended rise/fall time to minimize overshoot.
4. RMS noise measured over the Recommended Minimum Measure Window for the given voltage or current range, typical.
5. Time necessary for the signal to settle to the DC accuracy level. (Example: 10 mA settling time on the PMU 10 V range is defined when the signal is within 1.25% of the final value. This calculation: Accuracy = 0.25% + 100 µA = 0.25% + (100 µA/10 mA) = 0.25% + 1% = 1.25%).
6. 10 mA noise specification is different without RPM. See table above.

PMU Voltage Sourcing and Current Measurement Accuracy

		Voltage Range	Current Range	Current Measurement Accuracy	Voltage Sourcing Accuracy
4225-PMU		40 V	800 mA	±(0.25% + 3 mA)	±(0.25% + 40 mV)
			10 mA	±(0.5% + 100 µA)	
			100 µA	±(0.25% + 1 µA)	
		10 V	200 mA	±(0.25% + 250 µA)	±(0.25% + 10mV)
			10 mA[1]	±(0.25% + 100 µA)[1]	
4225-PMU with 4225-RPM		10 V	10 mA	±(0.5% + 10 µA)	±(0.25% + 10 mV)
			1 mA	±(0.5%+1 µA	
			100 µA	±(0.5% + 100 nA)	
			10 µA	±(0.5% + 30 nA)	
			1 µA	±(0.5% + 1 nA)	
			100 nA	±(0.5% + 1 nA)	

Notes

1. Accuracy for 10mA range is ±(0.25% + 100uA) if no 4225-RPM attached and is ±(0.5% + 10uA) with 4225-RPM attached.

PMU Voltage Measurement

Timing parameters, typical[1]

	4225-PMU		4225-RPM
Voltage measure ranges	10 V	40 V	10 V
Recommended minimum pulse width[2]	70 ns	150 ns	160 ns
Recommended minimum measure window[2]	20 ns	20 ns	20 ns
Recommended minimum transition time[3]	20 ns	100 ns	20 ns
Noise[4]	2 mV	8 mV	1 mV
Settling time[5]	30 ns	30 ns	100 ns

Notes

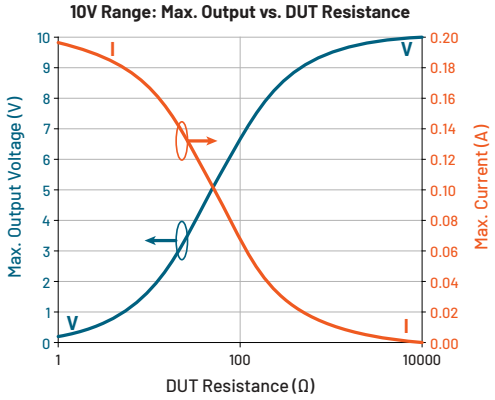
1. All typical values measured with an open circuit.
2. Using default measure window of 75% to 90% of pulse top. Recommended minimum pulse width = (Settling Time) / 75%.
3. Recommended rise/fall time to minimize overshoot.
4. RMS noise measured over the Recommended Minimum Measure Window for the given voltage or current range, typical.
5. Time necessary for the signal to settle to the DC accuracy level. (Example: 10 mA settling time on the PMU 10 V range is defined when the signal is within 1.25% of the final value. This calculation: Accuracy = 0.25% + 100 µA = 0.25% + (100 µA/10 mA) = 0.25% + 1% = 1.25%).

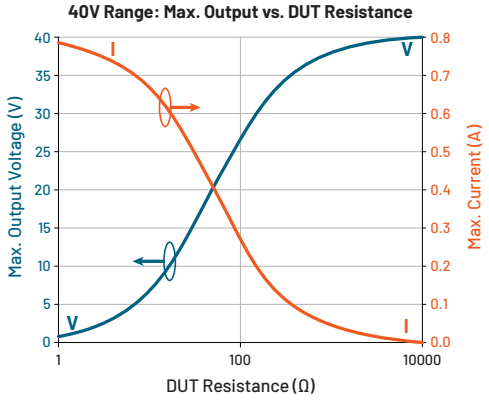
Voltage and Current, Maximum [1]

Resistance [2]	10V Range		40V Range	
	Maximum V [2]	Maximum I [2]	Maximum V [2]	Maximum I [2]
1 Ω	0.196 V	196 mA	0.784 V	784 mA
5 Ω	0.909 V	182 mA	3.64 V	727 mA
10 Ω	1.67 V	167 mA	6.67 V	667 mA
25 Ω	3.33 V	133 mA	13.3 V	533 mA
50 Ω	5.00 V	100 mA	20.0 V	400 mA
100 Ω	6.67 V	66.7 mA	26.7 V	267 mA
250 Ω	8.33 V	33.3 mA	33.3 V	133 mA
1 kΩ	9.52 V	9.5 mA	38.1 V	38.1 mA
10 kΩ	9.95 V	995 µA	39.8 V	3.98 mA

Notes

6. To calculate the approximate maximum current and voltage for any resistance
   I_{MAX} = V range/(50 Ω + Resistance)
   $V_{MAX} = I_{MAX} \cdot$ Resistance
   where Resistance is the total resistance connected to the PMU or PGU channel and V range is either 10 or 40.
   Example: 10 V range using R = 10 Ω (for DUT + interconnect)
   $V_{MAX} = I_{MAX} \cdot R = 0.167 \cdot 10 = 1.67$ V
7. Typical maximum at pulse output connector. Resistance is the total resistance connected to the pulse output connector, including device and interconnect.





PMU Pulse/Level [1,2]

		10 V Range	40 V Range
V_{OUT}	50 Ω into 1 MΩ	–10 V to +10 V	–40 V to +40 V
	50 Ω into 50 Ω	–5 V to +5 V	–20 V to +20 V
Accuracy		±(0.5% + 10 mV)	±(0.2% + 20 mV)
Resolution	50 Ω into 50 Ω	<250 µV	<750 µV
	50 Ω into 1 MΩ	<0.05 mV	<1.5 mV
Overshoot/pre-shoot/ringing [3]	50 Ω into 50 Ω	±(3% + 20 mV)	±(3% + 80 mV)
	50 Ω into 50 Ω, typical best case	±(2% + 20 mV)	±(0.8% + 40 mV)
Baseline noise		±(0.3% + 1 mV) RMS typical	±(0.1% + 5 mV) RMS typical
Source impedance		50 Ω nominal	50 Ω nominal
Current into 50Ω load (at full scale)		±100 mA typical	±400 mA typical
Short circuit current		±200 mA	±800 mA
Output limit		Programmable limit to protect the device under test	

Notes

1. Unless stated otherwise, all specifications assume a 50 Ω termination.
2. Level specifications are valid after 50 ns typical settling time (after slewing) for the 10 V source range and after 500 ns typical settling time (after slewing) for the 40 V source range into a 50 Ω load.
3. With transition time of 20 ns (0%–100%) for the 10 V source range and 100 ns (0% to 100%) for the 40 V source range.

PMU Pulse Timing

	10 V Range Source Only	10 V Range with Measure	40 V Range Source Only	40 V Range with Measure
Frequency range	1 Hz to 50 MHz	1 Hz to 8.3 MHz	1 Hz to 10 MHz	1 Hz to 3.5 MHz
Timing resolution	10 ns	10 ns	10 ns	10 ns
RMS jitter (period, width), typical	0.01% + 200 ps	0.01% + 200 ps	0.01% + 200 ps	0.01% + 200 ps
Period range	20 ns to 1 s	120 ns to 1 s	100 ns to 1s	280 ns to 1s
Accuracy	±1%	±1%	±1%	±1%
Pulse width range	10 ns to (Period–10 ns)	60 ns to (Period–10 ns)	50 ns to (Period–10 ns)	140 ns to (Period–10 ns)
Accuracy	±(1% + 200 ps)	±(1% + 200 ps)	±(1% + 5 ns)	±(1% + 5 ns)
Programmable transition time (0%–100%)	10 ns to 33 ms	20 ns to 33 ms	30 ns to 33 ms[1]	100 ns to 33 ms
Transition slew rate accuracy	±1% (transitions > 100 ns)	±1% (transitions > 100 ns)	±1% (transitions > 1 µs)	±1% (transitions > 100 ns)
Solid state relay open/close time	25 µs	25 µs	25 µs	25 µs

Notes

1. 40 V range minimum programmable transition time (source only) is 30 ns for voltage <10 V and 100 ns for voltages >10 V.

Voltage Source, Best Performance

When the 4225-PMU is used as a voltage source only (no measurements of voltage or current), the timing performance is improved. The following is provided to offer a clearer idea of best performance when used as a voltage source, as achievable under optimal conditions. This should not be interpreted as a guarantee.

	10V Range	40V Range
Rise time	<10 ns	50 ns to 10 V, 100 ns to 40 V
Pulse width	10 ns (FWHM)	50 ns (FWHM)
Period	20 ns	100 ns
Overshoot/preshoot/ringing	±(2% + 20 mV)	±(0.5% + 40 V)

Trigger

Trigger output impedance	50 Ω
Trigger output level	TTL
Trigger in impedance	10 kΩ
Trigger in level	TTL
Trigger in transition timing, maximum	<100 ns
Trigger in to pulse output delay	400 ns
Trigger synchronization/jitter[1]	<2 ns

Segment ARB® and Timing

Segment ARB capabilities are available with the 4225-PMU and 4220-PGU, with or without the 4225-RPM Remote Preamplifier/Switch Module.

Max. Number of Segments[2]	2048
Max. Number of Sequences[2]	512
Max. Number of Sequence Loops when using library commands	10^{12}
Max. Number of Sequence Loops when using PMU example library	10^{9}
Time per Segment	20 ns to 40 s
Segment Timing Resolution	10 ns
Control Parameters for Each Segment	Start V Stop V Duration Measurement window (PMU or PMU+RPM only) Measurement type (PMU or PMU+RPM only)
RMS Jitter (Segment)	0.01% + 200 ps typical

Notes

1. For multiple 4225-PMU or 4220-PGU cards in a single 4200A-SCS chassis
2. Per channel

6. Pulse Generator Unit

The two-channel, voltage-only pulse generator is an economical alternative to the 4225-PMU Ultra-fast Pulse Measure Unit if pulse measurement is not needed.

4220-PGU General Information

Output connectors	Four SMA (f)
Supplied cables	SMA (m) to SMA (m), 2 m, 4 each (CA-404B)
	SMA (m) to SSMC 4-cable, 15 cm (6 in.), 2 each (4200-PRB-C)

Pulse/Level [1, 2]

		10V Range	40V Range
V_{OUT}	50 Ω into 1 MΩ	–10 V to +10 V	–40 V to +40 V
	50 Ω into 50 Ω	–5 V to +5 V	–20 V to +20 V
Accuracy	–	±(0.5% + 10 mV)	±(0.2% + 20 mV)
Resolution	50 Ω into 50 Ω	<250 µV	<750 µV
	50 Ω into 1 MΩ	<0.5 mV	<1.5 mV
Overshoot/pre-shoot/ringing [3]	50 Ω into 50 Ω	±(3% + 20 mV)	±(3% + 80 mV)
	50 Ω into 50 Ω, typical best case	±(2% + 20 mV)	±(0.8% + 40 mV)
Baseline noise	–	±(0.3% + 1 mV) RMS typical	±(0.1% + 5 mV) RMS typical
Source impedance	–	50 Ω nominal	50 Ω nominal
Current into 50 Ω load (at full scale)	–	±100 mA typical	±400 mA typical
Short circuit current	–	±200 mA	±800 mA
Output limit	–	Programmable limit to protect the device under test	

Notes

1. Unless stated otherwise, all specifications assume a 50 Ω termination.
2. Level specifications are valid after 50 ns typical settling time (after slewing) for the 10 V source range and after 500 ns typical settling time (after slewing) for the 40 V source range into a 50 Ω load.
3. With transition time of 20 ns (0%–100%) for the 10 V source range and 100 ns (0%–100%) for the 40 V source range.

Pulse Timing

	10 V Range Source Only	40 V Range Source Only
Frequency range	1 Hz to 50 MHz	1 Hz to 10 MHz
Timing resolution	10 ns	10 ns
RMS jitter (period, width), typical	0.01% + 200 ps	0.01% + 200 ps
Period range	20 ns to 1 s	100 ns to 1s
Accuracy	±1%	±1%
Pulse width range	10 ns to (Period–10 ns)	50 ns to (Period–10 ns)
Accuracy	±(1% + 200 ps)	±(1% + 5 ns)
Programmable transition time (0%–100%)	10 ns to 33 ms	30 ns to 33 ms [1]
Transition slew rate accuracy	±1% (transitions > 100 ns)	±1% (transitions > 1 µs)
Solid state relay open/close time	25 µs	25 µs

Notes

1. 40 V range minimum programmable transition time (source only) is 30 ns for voltage <10 V and 100 ns for voltages >10 V.

Voltage Source, Best Performance

When the 4225-PMU is used as a voltage source only (no measurements of voltage or current), the timing performance is improved. The following is provided to offer a clearer idea of best performance when used as a voltage source, as achievable under optimal conditions. This should not be interpreted as a guarantee.

	10 V Range	40 V Range
Rise Time	<10 ns	50 ns to 10 V, 100 ns to 40 V
Pulse Width	10 ns (FWHM)	50 ns (FWHM)
Period	20 ns	100 ns
Overshoot/Preshoot/Ringing	±(2% + 20 mV)	±(0.5% + 40 mV)

Trigger

Trigger output impedance	50 Ω
Trigger output level	TTL
Trigger in impedance	10 kΩ
Trigger in level	TTL
Trigger in transition timing, maximum	<100 ns
Trigger in to pulse output delay	400 ns
Trigger synchronization/jitter[1]	<2 ns

Segment ARB® and Timing

Segment ARB capabilities are available with the 4225-PMU and 4220-PGU, with or without the 4225-RPM Remote Preamplifier/Switch Module.

Max. Number of Segments	2048 per PMU channel
Max. Number of Sequences	512 per PMU channel
Max. Number of Sequence Loops when using library commands	10^{12}
Max. Number of Sequence Loops when using PMU example library	10^{9}
Time per Segment	20 ns to 40 s
Segment Timing Resolution	10 ns
Control Parameters for Each Segment	Start V Stop V Duration Measurement window (PMU or PMU+RPM only) Measurement type (PMU or PMU+RPM only)
RMS Jitter (Segment)	0.01% + 200 ps typical

Notes

1. For multiple 4225-PMU or 4220-PGU cards in a single 4200A-SCS chassis

7. Remote Preamplifier/Switch Module

The 4225-RPM enables automatic switching between I-V, C-V and Pulsed I-V measurements, allowing you to choose the appropriate measurement without recabling your test setup. Additionally, the RPM expands the range of the 4225-PMU Pulse Measure Module.

4225-RPM General Information

Inputs	Three inputs. SMU Force, SMU Sense, CVU Pot, CVU Cur, RPM Control
Outputs	One channel
Input connector	Triaxial (f), two SMA (f), two HDMI
Output connector	Triaxial (f), two
Dimensions	1.34 in. wide × 4.9 in. deep × 3.0 in. tall (3.4 cm wide × 12.5 cm deep × 7.6 cm tall)
Dimensions with base	1.34 in. wide × 4.9 in. deep × 3.8 in. tall (3.4 cm wide × 12.5 cm deep × 9.6 cm tall)
Weight	8.6 oz. (245 g) (with base: 13.4 oz. (381 g))
Included Accessories	Magnetic base

RPM Current Measurement

Timing parameters, typical[1] with the 4225-PMU and 4225-RPM Remote Preamplifier/Switch Module

	10V Range					
Current measure ranges	100 nA	1 µA	10 µA	100 µA	1 mA	10 mA
Recommended minimum pulse width[2]	134 µs	20.4 µs	8.36 µs	1.04 µs	370 ns	160 ns
Recommended minimum measure window[2]	10 µs	1.64 µs	1 µs	130 ns	40 ns	20 ns
Recommended minimum transition time[3]	1 µs	360 ns	360 ns	40 ns	30 ns	20 ns
Noise[4]	200 pA	2 nA	5 nA	50 nA	300 nA	1.5 µA
Settling time[5]	100 µs	15 µs	6 µs	750 ns	250 ns	100 ns

Notes

1. All typical values measured with an open circuit.
2. Using default measure window of 75% to 90% of pulse top. Recommended minimum pulse width = (Settling Time) / 75%.
3. Recommended rise/fall time to minimize overshoot.
4. RMS noise measured over the Recommended Minimum Measure Window for the given voltage or current range, typical.
5. Time necessary for the signal to settle to the DC accuracy level. (Example: 10 mA settling time on the PMU 10 V range is defined when the signal is within 1.25% of the final value. This calculation: Accuracy = 0.25% + 100 µA = 0.25% + (100 µA/10 mA) = 0.25% + 1% = 1.25%).

Current Measurement Accuracy

4225-PMU and RPM Combined

	10 V Range					
Current measure ranges	100 nA	1 µA	10 µA	100 µA	1 mA	10 mA
Accuracy (DC)	±(0.5% + 1 nA)	±(0.5% + 1 nA)	±(0.5% + 30 nA)	±(0.5% + 100 nA)	±(0.5% + 1 µA)	±(0.5% +10 µA)

Pulse/Level [1]

Pulse/Level[1]	4225-PMU with 4225-RPM
V_{OUT}	–10 V to +10 V
Accuracy[2] into open load	±(0.5% ± 10 mV)
Resolution	<0.05 mV
Baseline noise	±(0.39% ± 1 mV) RMS typical
Overshoot/Pre-shoot/Ringing[3]	±2% of amplitude ±20 mV

Notes

1. Performance at the triax output connection of the 4225-RPM when using a 2 m RPM interconnect cable between the 4225-PMU and 4225-RPM Remote Preamplifier/Switch Module.
2. 100 mV to 10 V.
3. Typical, with transition time of 100 ns (0% to 100%).

RPM Voltage Measurement with the 4225-PMU

Timing parameters, typical[1]

	4225-RPM
Voltage measure range	10 V
Recommended minimum pulse width[2]	160 ns
Recommended minimum measure window[2]	20 ns
Recommended minimum transition time[3]	20 ns
Noise[4]	1 mV
Settling time[5]	100 ns

Notes

1. All typical values measured with an open circuit.
2. Using default measure window of 75% to 90% of pulse top. Recommended minimum pulse width = (Settling Time) / 75%.
3. Recommended rise/fall time to minimize overshoot.
4. RMS noise measured over the Recommended Minimum Measure Window for the given voltage or current range, typical.
5. Time necessary for the signal to settle to the DC accuracy level. (Example: 10 mA settling time on the PMU 10 V range is defined when the signal is within 1.25% of the final value. This calculation: Accuracy = 0.25% + 100 µA = 0.25% + (100 µA/10 mA) = 0.25% + 1% = 1.25%).

8. Switch Matrix Configurations

Ultra-Low Current/Local Sense Configuration (4200-UL-LS-24)

The Ultra Low Current/Local Sense switch configuration is built using two Keithley 7174A Low Current Matrix Cards with the 707B Switch Matrix. These switch cards are designed for semiconductor research, development, and production applications requiring high quality, high performance switching of I-V and C-V signals. This configuration provides eight instrument inputs and 24 output pins at only 10 fA typical offset current. Additional cards can be added to provide up to 72 output pins.

General Information

Connector Type	3-lug triax
Maximum Signal Level	200 V, 2 A
Offset Current	100 fA max, 10 fA typical
Maximum Leakage	0.01 pA/V
3 dB Bandwidth	30 MHz typical

Package Contents

	(1) 707B Switch Mainframe
	(2) 7174A Switch Cards
	(24) 4200-TRX-3 Cables
	(1) 7007-1 IEEE-488 Cable
	(2) 7078-TRX-BNC Adapter

Low Current/Local Sense Configuration (4200-LC-LS-24)

The Low Current/Local Sense switch configuration is built using the Keithley 7072 Semiconductor Matrix Card, which is designed for semiconductor applications requiring good quality I-V and C-V signals. The configuration provides eight instrument inputs with 24 output pins with less than 1 pA output current. Additional cards can be added to provide up to 72 output pins.

General Information

Connector Type	3-lug triax
Maximum Signal Level	200 V, 1 A
Offset Current	<1 pA (Rows A to B)
Maximum Leakage	0.1 pA/V
3 dB Bandwidth	5 MHz typical (Rows G to H)

Package Contents

	(1) 707B Switch Mainframe
	(2) 7072 Switch Cards
	(24) 4200-TRX-3 Cables
	(1) 7007-1 IEEE-488 Cable
	(2) 7078-TRX-BNC Adapter

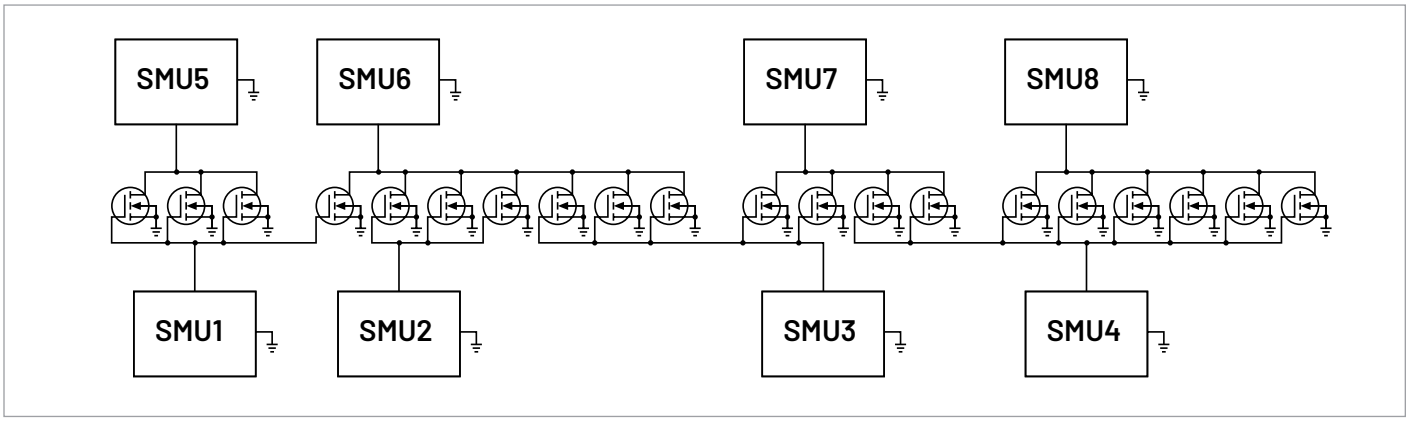
9. NBTI/PBTI Capability

The BTI capability on the 4200A-SCS combines advanced DC I-V and ultra-fast I-V measurement capabilities of Keithley with ACS test executive softwaree to provide the most advanced NBTI/PBTI test platform available in the semiconductor test industry. This solution provides all of the instruments, interconnects, and software needed to make the most sophisticated NBTI and PBTI measurements on leading-edge silicon CMOS technology.

4200A-SCS with ACS Standard

Offers the best high-speed, low-current measurement sensitivity available in a single-box integrated solution.

	Ensures that source/measure instrumentation will not be the limiting factor when making low-level measurements.
	The ACS software supports building complex test sequences, including up to 20 measurement sequences and full prober integration. It also:
	• Easily integrates DC I-V and ultra-fast I-V measurements into a pre- and post-stress measurement sequence.
	• Characterizes degradation and recovery behaviors using either AC or DC stress.
	• Incorporates single pulse charge trapping (SPCT) measurements into longer stress-measure sequences.
	• 4225-PMU and 4225-RPMs include all necessary cabling.
	• ACS software includes the ultra-fast BTI test project module.
Ultra-fast NBTI/PBTI Capability Requires:	
	(1) 4225-PMU Ultra-Fast I-V Module
	(2) 4225-RPM Remote Preamplifier/Switch Modules
	ACS-STANDARDFL Automated Characterization Suite (ACS) Software



Example of using eight SMUs to stress 20 devices in parallel for HCI and NBTI. A separate ground unit (GNDU) is used for common terminals.

10. Clarius+ Software

Clarius+ software provides a variety of tools for operating and maintaining the 4200A-SCS parameter analyzer.

Furnished Software Modules

Clarius	The graphical user interface for testing and characterizing your devices, materials and processes. Clarius software provides a unified measurement interface that guides you through complex characterization tests, enabling you to focus on your research or development projects.
Keithley User Library Tool (KULT)	Assists test engineers to create custom test routines as well as use existing Keithley and third-party C-language subroutine libraries. Users can edit and compile subroutines, then integrate libraries of subroutines with Clarius, allowing the 4200A-SCS to control an entire test rack from a single user interface.
Keithley External Control Interface (KXCI)	Controls the 4200A-SCS from an external computer via GPIB bus or Ethernet.
Keithley Configuration Utility (KCon)	Allows test engineers to define the configuration of GPIB instruments, switch matrices, and analytical probers connected to the 4200A-SCS. It also provides diagnostic functions.
KPulse	A graphical user interface that is a non-programming alternative to configure and control the installed 4225-PMU or 4220-PGU pulse generator modules. It is used for quick tests requiring minimal interaction with other 4200A-SCS test resources.

Clarius User Interface Software

	Clarius is the resident user interface software running on the 4200A-SCS. Clarius runs on the embedded Windows 10 operating system. It provides test plan selection and development, advanced test configurations, parameter analysis and graphing, and automation capabilities required for modern semiconductor device, materials and process characterization.
Data Analysis	Two methods of parameter extraction are available. The Formulator executes data transformations for performing automated line fits and parameter extraction. A spreadsheet offers standard spreadsheet analysis tools. Many of the sample libraries include parameter extraction examples.

Formulator

The Formulator supports mathematical functions, conversion functions, search functions, common industry constants and line fit/parameter extraction functions. The Formulator supports the following functions:

Mathematical Functions	Addition (+), subtraction (-), division (/), multiplication (*), exponent (^), absolute value (ABS), value at an index position (AT), average (AVG), moving average (MAVG), conditional computation (COND), derivative (DELTA), differential coefficient (DIFF), exponential (EXP), square root (SQRT), natural logarithm (LN), logarithm (LOG), integral (INTEG), standard deviation (STDEV), moving summation (SUMMV), arc cosine (ACOS), arc sine (ASIN), arc tangent (ATAN), cosine (COS), sine (SIN), tangent (TAN)
Conversion Functions	Radians to degrees (DEG), degrees to radians (RAD)
Line Fits and Parameter Extraction Functions	
	Exponential line fit (EXPFIT), coefficient a (EXPFITA), coefficient b (EXPFITB), linear fit (LINFIT), linear slope (LINFITSLP), x intercept (LINFITXINT), y intercept (LINFITYINT), logarithmic line fit (LOGFIT), coefficient a (LOGFITA), coefficient b (LOGFITB), linear regression line fit (REGFIT), slope (REGFITSLP), x intercept (REGFITXINT), y intercept (REGFITYINT), tangent line fit (TANFIT), slope (TANFITSLP), x intercept (TANFITXINT), y intercept (TANFITYINT), polynomial line fit including POLYFIT2, POLY2COEFF, and POLYNFIT, maximum value (MAX), minimum value (MIN), midpoint (MEDIAN)
Search Functions	Find down (FINDD), find up (FINDU), find using linear interpolation (FINDLIN), maximum position (MAXPOS), minimum position (MINPOS), first position (FIRSTPOS), last position (LASTPOS), sub array (SUBARRAY), return a specified number of points (INDEX)
FFT Analysis Functions	FFT real components (FFT_R), FFT imaginary components (FFT_I), inverse FFT real components (IFFT_R), Inverse FFT imaginary components (IFFT_I), get FFT frequencies (FFT_FREQ), get positive FFT frequencies (FFT_FREQ_P), digital smoothing (Smooth)

Formulator Constants	The Formulator supports user-supplied constants for use in parameter extractions. These constants are factory installed: PI = 3.14159 rad (π) K = 1.38065 × 10^{-23} J/K (Boltzmann's constant) Q = 1.60218 × 10^{-19} C (Charge of electron) M_0 = 9.10938 × 10^{-31} kg (Electron mass) E_V = 1.60218 × 10^{-19} J (Electron Voltage) U_0 = 1.25664 × 10^{-6} N/A^2 (Permeability) E_0 = 8.85419 × 10^{-12} F/m (Permittivity of a Vacuum) H = 6.62607 × 10^{-34} m^2 * kg/s (Planck's constant) C = 2.99792 × 10^{+8} m/s (Speed of light) KT/Q = 0.02568 V (Thermal Voltage)

Automation

Test Sequencing	Clarius provides point-and-click test sequencing on a device, a group of devices (subsite, module, or test element group), or a user-programmable number of probe sites on a wafer.
Prober Control	Keithley provides integrated prober control for supported analytical probers when test sequencing is executed on a user-programmable number of probe sites on a wafer. Contact the factory for a list of supported analytical probers. A manual prober mode prompts the operator to perform prober operations during the test sequence.
Supported Probers	**Manual Prober** Use the manual prober driver to test without utilizing automatic prober functionality. Manual prober replaces all computer control of the prober with that of the operator. At each prober command, a dialog box appears, instructing the operator what operation is required.
	Fake Prober The Fake prober is useful when prober actions are not desired, such as when debugging, without having to remove prober commands from a sequence.
	Supported Semi-automatic (Analytical) Probers FormFactor (formerly Cascade Microtech) Summit™ 12K Series - Verified with Nucleus UI, compatible with Velox Karl Suss Model PA-200 - Verified with Wafermap for ProberBench NT, NI-GPIB Driver for ProberBench NT, PBRS232 Interface for ProberBench NT, Navigator for ProberBench NT, Remote Communicator for ProberBench NT MicroManipulator 8860 Prober - Verified with pcBridge, pcLaunch, pcIndie, pcWfr, pcNav, pcRouter MPI TS2000 and TS3000 Probers - Verified with MPI Sentio Software Suite version 2.9 Signatone CM500 driver also works with other Signatone probers with interlock controller such as the WL250 and S460SE Wentworth Laboratories Pegasus™ FA Series SemiProbe Probe System for Life (PS4L) semiautomatic and fully automatic probers and Pilot software Other probers supported but not listed
	Supported Cryogenic Temperature Controllers LakeShore Model 336 Cryogenic Temperature Controller

Keithley User Library Tool (KULT)

The Keithley User Library Tool supports creating and integrating C-language subroutine libraries with the test environment. User library modules are accessed in Clarius through User Test Modules. Factory supplied libraries provide up and running capability for supported instruments. Users can edit and compile subroutines, then integrate libraries of subroutines with Clarius, allowing the 4200A-SCS to control an entire test rack from a single user interface.

System Configuration and Diagnostics (KCon)

The Keithley Configuration Utility (KCon) simplifies programming and maintaining a fully integrated test station. KCon provides a single interface for configuring external instruments, switch matrices, and analytical probers, and for executing system diagnostics.

External Instrument Configuration

KCon allows lab managers to integrate external instruments with the 4200A-SCS and a supported switch matrix. After the user configures the GPIB addresses for supported instruments, Keithley-supplied libraries will function and test modules can be transferred between 4200A-SCS systems without any user modification. In addition to the standard supported instruments, the General Purpose Instrument allows users to develop subroutines and control switches for a generic two-terminal or four-terminal instrument. For the widest possible system extensibility, users can develop their own test libraries for general purpose instruments.

Outside of KCon, users can configure GPIB or USB control of simple instruments, switches, lamps, etc. with included user libraries.

Switch Matrix Configuration

Users define the connection of 4200A-SCS instruments and external instruments to device under test (DUT) pins through a supported switch matrix configuration. (See Switch Matrix Support and Configurations.) Once connections are defined, users need only enter the instrument terminal name and pin number to establish connections. The 4200A-SCS applications and standard user libraries manage the routing of test signals between instrument terminals and DUT pins. The user doesn't need to remember and program row and column closures. Test modules can transfer between 4200A-SCS systems without re-entering connection information.

4200A-SCS Instrument Diagnostics

Users can confirm system integrity of SMUs, C-V measurement unit, pulse generator, oscilloscopes, and remote preamplifiers by running a system self-test. For more complex problems, the system's configuration analysis tool can generate reports that assist the Technical Support staff of Keithley in diagnosing problems.

Keithley External Control Interface (KXCI)

With KXCI, you can use an external computer to control the SMUs and CVU modules in the 4200A-SCS directly. KXCI also provides you with indirect control of the Ultra-fast I-V Pulse Measure Unit, using UTMs via either the built-in GPIB or Ethernet. For the SMUs, the KXCI command set includes an HP 4145 compatibility mode, allowing many programs already developed for the HP4145 to use the 4200A-SCS instead.

11. Supplied Accessories

4200A-SCS	**Parameter Analyzer Mainframe**
	(1) 236-326A Interlock Cable, 3 m (10 ft)
	(2) 4200-TRX-2 Ultra Low Noise Triax Cables, 2 m (6.6 ft)
4200-SMU	**Medium Power Source-Measure Unit for 4200A-SCS, 100 mA to 100 fA, 200 V to 0.2 µV, 2 Watts**
If configured with a preamp:	All cables are provided with the 4200-PA. See 4200-PA below.
If configured without a preamp:	(2) 4200-MTRX-2 Mini Ultra Low Noise Triax Cables, 2 m (6.6 ft)
	Not recommended for new designs.
4201-SMU	**Medium Power Source-Measure Unit for 4200A-SCS and high-capacitance setups, 100 mA to 100 fA, 200 V to 0.2 µV, 2 Watts, 10 µF load capacitance**
If configured with a preamp:	All cables are provided with the 4200-PA. See 4200-PA below
If configured without a preamp:	(2) 4200-MTRX-2 Mini Ultra Low Noise Triax Cables, 2 m (6.6 ft)
4210-SMU	**High Power Source-Measure Unit for 4200A-SCS, 1 A to 100 fA, 200 V to 0.2 µV, 20 Watts**
If configured with a preamp:	All cables are provided with the 4200-PA. See 4200-PA below.
If configured without a preamp:	(2) 4200-MTRX-2 Mini Ultra Low Noise Triax Cables, 2 m (6.6 ft)
	Not recommended for new designs.
4211-SMU	**High Power Source-Measure Unit for 4200A-SCS and high-capacitance setups, 1 A to 100 fA, 200 V to 0.2 µV, 20 Watts, 100 µF load capacitance**
If configured with a preamp:	All cables are provided with the 4200-PA. See 4200-PA below
If configured without a preamp:	(2) 4200-MTRX-2 Mini Ultra Low Noise Triax Cables, 2 m (6.6 ft)
4200-PA	**Remote Preamp Option for 4201, 4211, 4200, and 4210 SMUs, extends SMU to 0.01 fA resolution**
	(1) 4200-RPC remote preamp cable, 3 m (9.8 ft)
	(2) 4200-TRX-2 Ultra Low Noise Triax Cables, 2 m (6.6 ft)
4215-CVU	**High Resolution Capacitance Voltage (C-V) Module**
	(4) CA-447B SMA Cables, male to male, 100 Ω, 1.5 m (5 ft)
	(4) CS-1247 Female SMA to Male BNC Adapters
	(2) CS-701 BNC Tee Adapters
4225-PMU	**Ultra-Fast Pulse Measure Unit**
	(4) CA-404B SMA-to-SMA 50 Ω cables, 2 m (6.6 ft)
	(2) 4200-PRB-C SMA-to-SSMC Y-Cable Assembly, 15 cm (6 in.)
4225-RPM	**Remote Preamplifier/Switch Module**
	(1) CA-452A SMA-to-SMA 50 Ω Cable, 20 cm (7.9 in)
	(1) 7078-TRX-BNC Triax-to-BNC Adapter
	(1) CS-1247 BNC-to-SMA Adapter
	(1) CA-547-2B RPM Cable, 2.1 m (6.9 ft)

4220-PGU	**High Voltage Pulse Generator**
	(4) CA-404B SMA-to-SMA 50 Ω cables, 2 m (6.6 ft)
	(2) 4200-PRB-C SMA-to-SSMC Y-Cable Assembly, 15 cm (6 in.)
4200A-CVIV	**I-V, C-V Multi-switch Module**
	(2) 4200A-CVIV-SPT SMU Pass-Thru Modules
	(2) 214543500 Slot Blockers
	(1) 174691500 USB Cable
	(1) 4200-MTRX-2 Mini Ultra Low Noise Triax Cable, 2 m (6.6 ft)
	NOTE: For each SMU connected through the 4200A-CVIV, one 4200A-CVIV-SPT or one 4200-PA is required.

Switching Systems and Cards

707B	**6-slot Switching Matrix Mainframe**
	CA-180-4A CAT 5 Ethernet Crossover Cable, 1 m (3.3 ft)
	CA-179-2A CAT 5 Ethernet Cable 3 m (10 ft)
	CO-7 Line Cord
	Rear Fixed Rack Mount Hardware
708B	**Single-slot Switching Matrix Mainframe**
	CA-180-4A CAT 5 Ethernet Crossover Cable, 1 m (3.3 ft)
	CA-179-2A CAT 5 Ethernet Cable 3 m (10 ft)
	CO-7 Line Cord
7072	8×12, Semiconductor Matrix Card
7174A	8×12, High Speed, Low Leakage Current, Matrix Card

12. Optional Accessories

Connectors and Adapters

CS-565	Female BNC to Female BNC Adapter
CS-701	BNC Tee Adapter (female, male, female)
CS-719	3-lug Triax Jack Receptacle
CS-1247	SMA Female to BNC Male Adapter
CS-1249	SMA Female to SMB Plug Adapter
CS-1251	BNC Female to SMB Plug Adapter
CS-1252	SMA Male to BNC Female Adapter
CS-1281	SMA Female to SMA Female Adapter
CS-1390	Male LEMO Triax to Female SMA Adapter
CS-1391	SMA Tee Adapter (female, male, female)
CS-1479	SMA Male to BNC Male Adapter
237-BAN-3A	Triax Cable Center Conductor terminated in a safety banana plug
237-BNC-TRX	Male BNC to 3-lug Female Triax Adapter
237-TRX-BAR	3-lug Triax Barrel Adapter (female to female)
237-TRX-T	3-slot Male to Dual 3-lug Female Triax Tee Adapter
7078-TRX-BNC	3-slot Male Triax to BNC Adapter
7078-TRX-GND	3-slot Male Triax to Female BNC Connector (guards removed)

Test Fixtures

8101-PIV	Pulse I-V Demo Fixture

Cabinet Mounting Accessories

4200A-RM	Fixed Cabinet Mount Kit for 4200A-SCS

Cables and Cable Sets

NOTE: All 4200A-SCS systems and instrument options are supplied with required cables, 3 m (9.8 ft.) length.

CA-19-2	BNC to BNC Cable, 1.5 m
CA-404B	SMA to SMA Coaxial Cable, 2 m
CA-405B	SMA to SMA Coaxial Cable, 15 cm
CA-406B	SMA to SMA Coaxial Cable, 33 cm
CA-446A	SMA to SMA Coaxial Cable, 3 m
CA-447B	SMA to SMA Coaxial Cable, 1.5 m
CA-451A	SMA to SMA Coaxial Cable, 10.8 cm
CA-452A	SMA to SMA Coaxial Cable, 20.4 cm
236-326A	Interlock Cable, 3 m (10 ft) Note: Replacement interlock cables must be ordered through Keithley Service Department.
237-ALG-2	Low Noise Triax Input Cable terminated with 3 alligator clips, 2 m
4210-MMPC-C	Multi-Measurement (I-V, C-V, Pulse) Prober Cable Kit for Cascade Microtech 12000 prober series
4210-MMPC-S	Multi-Measurement (I-V, C-V, Pulse) Prober Cable Kit for SUSS MicroTec PA200/300 prober series

4210-MMPC-L	Multi-Measurement (I-V, C-V, Pulse) Prober Cable Kit for Lucas Signatone probers
4210-MMPC-W	Multi-Measurement (I-V, C-V, Pulse) Prober Cable Kit for Wentworth Laboratories probers
4200-MTRX-*	Ultra Low Noise SMU Triax Cable: 1 m, 2 m, and 3 m options
4200-RPC-2	Remote Preamp Cable, 2 m
4200-TRX-*	Ultra Low Noise Preamp Triax Cable: 0.3 m, 2 m, 3 m options
4200-TRX-0.75	Ultra Low Noise Triax Cable for connecting the CVIV output to device fixtures
CA-300-1A	Double-Shielded Premium GPIB Cable, 1 m
CA-300-2A	Double-Shielded Premium GPIB Cable, 2 m
CA-426D	4200-PRB-C SMA-to-SSMC Y-Cable Assembly, 15 cm (6 in.)

Adapter, Cable, and Stabilizer Kits

4200-CVU-PWR	CVU Power Package for ±200 V C-V
4200-CVU-PROBER-KIT	Accessory Kit for connection to popular analytical probers
4200-PMU-PROBER-KIT	General Purpose Cable/Connector Kit. For connecting the 4225-PMU to most triax and coax probe stations. One kit required per 4225-PMU module.

Software

ACS-BASICFL	Component Characterization Software
ACS-STANDARDFL	Advanced Component Characterization Software

Other Accessories

EM-50A	Modified Power Splitter
TL-31	SMA Torque Wrench
4200A-CASE	Transport Case for 4200A-SCS

13. General Specifications

Mainframe Display	15.6 in. LCD, capacitive touchscreen 1920 × 1080 full HD 10 point touch
External Display	External VGA, HDMI, or Display Port: The system is designed to work with an external monitor of resolution 1920 × 1080
Temperature Range	**Operating:** +10° to +40°C **Storage:** –15° to +60°C
Humidity Range	**Operating:** 5% to 80% RH, non-condensing **Storage:** 5% to 90% RH, non-condensing
Altitude	**Operating:** 0 to 2000 m **Storage:** 0 to 4600 m
Power Requirements	100 V to 240 V, 50 to 60 Hz
Maximum VA	1000 VA
Regulatory Compliance	**Safety:** European Low Voltage Directive. NRTL listed by Intertek for the US and Canada. **EMC:** European EMC Directive
Dimensions	43.6 cm wide × 22.3 cm high × 56.5 cm deep (17 5/32 in × 8 3/4 in × 22 1/4 in)
Weight (approx.)	29.7 kg (65.5 lb) for typical configuration of four SMUs
I/O Ports	USB, SVGA, Display Port, RS-232, GPIB, Ethernet, mouse, keyboard, audio
Ground Unit	Voltage error when using the ground unit is included in the 4200-SMU, 4210-SMU, and 4200-PA specifications. No additional errors are introduced when using the ground unit.
Output Terminal Connection	Dual triaxial, 5-way binding post
Maximum Current	2.6 A using dual triaxial connection; 9.5 A using 5-way binding posts
Load Capacitance	No limit
Cable Resistance	FORCE ≤1 Ω, SENSE ≤10 Ω
LCD Display Pixel Guideline	LCD displays are made up of a matrix of pixels, with each pixel consisting of red, green, and blue sub-pixels. These pixels and sub-pixels can become fixed in an unchanging state resulting in permanently black, white, or colored spots on the display. These are typically categorized as Bright or Black pixel (or dot) defects. **Bright dot defect:** A dot that is always lit, either as a white or colored dot, visible on a black check pattern. **Black dot defect:** A dot that appears as either black or purple (magenta) on red, green, and/or blue check patterns. The LCD display used in the 4200A-SCS is permitted to have a maximum of 6 (six) bright dot defects upon receipt of a new instrument. A maximum of three bright dot defect pairs (adjacent defective dots) are permitted. Three adjacent bright dots are not permitted under the pixel guideline. The LCD display is permitted to have a maximum of 5 (five) black dot defects. Two adjacent black dot defects are to be counted as a single black dot defect. A maximum of three black dot defect pairs (adjacent defective dots) are permitted. Three adjacent black dot defects are not permitted under the pixel guideline.

14. Ordering Information

Mainframes

4200A-SCS	Parameter Analyzer with 15.6" LCD display
4200A-SCS-ND	Parameter Analyzer without LCD display

Instruments/Modules

4200-PA	Remote SMU Preamplifier Module
4200-SMU	Medium Power Source Measure Unit
4200-SMU-R	Field Installable, Medium Power Source Measure Unit
4200-SMU/PA-R	Field Installable, Medium Power Source Measure Unit with Preamplifier
4201-SMU	Medium power Source Measure Unit for high-capacitance setups
4201-SMU-R	Field installable medium power Source Measure Unit for high-capacitance setups
4201-SMU/PA-R	Field Installable, medium Power Source Measure Unit for high-capacitance setups with Preamplifier
4210-SMU	High Power Source Measure Unit
4210-SMU-R	Field Installable, High Power Source Measure Unit
4210-SMU/PA-R	Field Installable, High Power Source Measure Unit with Preamplifier
4211-SMU	High power Source Measure Unit for high-capacitance setups
4211-SMU-R	Field installable high power Source Measure Unit for high-capacitance setups
4211-SMU/PA-R	Field Installable, high power Source Measure Unit for high-capacitance setups with Preamplifier
4215-CVU	High Resolution Multi-frequency C-V Unit
4225-PMU	Ultra-fast Pulsed I-V Unit
4220-PGU	Pulse Generator Unit
4225-RPM	Remote Preamplifier/Switch Module
4200A-CVIV	CVIV Multi-Switch Module
4200-CVU-PWR	C-V Power Package

Use these part numbers to order additional modules for an existing system or to order additional modules with a 4200A-MF-UP. For configuring a new system, see next section.

Mainframe Options

4200A	Do not install backup software
4200A-SCS-5-EW	5 Year KeithleyCare extended warranty
4200A-SCS-EW	1 Year KeithleyCare extended warranty
C/NEW DATA ISO	Include ISO-17025 calibration data
C/4200A-SCS-3Y-STD	KeithleyCare 3 year standard calibration plan
C/4200A-SCS-3Y-17025	KeithleyCare 3 year ISO 17025 calibration plan
C/4200A-SCS-5Y-STD	KeithleyCare 5 year standard calibration plan
C/4200A-SCS-5Y-17025	KeithleyCare 5 year ISO 17025 calibration plan

15. Configuration Instructions

New 4200A-SCS systems are configured with options for each available module slot. Each option ends with the module option number that it is selected under. For instance, if a 4200-SMU is selected for module option 3, it will be 4200SMU3. Excess slots with no installed modules need to have the "NONEx" option selected, where "x" represents the module option number.

The following table shows which instrument modules are available in each module option:

Module	Description	Module Options
4200SMUx	4200-SMU medium power SMU	1-9
4200SMU-PAx	4200-SMU with 4200-PA preamplifer	1-9
4201SMUx	4201-SMU medium power SMU for capacitive setups	1-9
4201SMU-PAx	4201-SMU with 4200-PA preamplifer	1-9
4210SMUx	4210-SMU high power SMU	1-9
4210SMU-PAx	4210-SMU with 4200-PA preamplifier	1-9
4211SMUx	4211-SMU high power SMU for capacitive setups	1-9
4211SMU-PAx	4211-SMU with 4200-PA preamplifier	1-9
4215CVUx	4215-CVU capacitance voltage unit	5*
4225PMUx	4225-PMU pulse measure unit	6-9
4225PMU-RPMx	4225-PMU with two 4225-RPM preamplifiers	6-9
4220PGUx	4220-PGU pulse generator unit	6-9
NONEx	No instrument in this module slot	1-9

*The 4215-CVU can only be selected in module option 5.

An example 4200A-SCS with three SMUs, two PA modules, a CVU, and a PMU with RPMs should be ordered like so:

1 4200A-SCS
4200SMU-PA1
4210SMU-PA2
4210SMU3
4200NONE4
4215CVU5
4225PMU-RPM6
4200NONE7
4200NONE8
4200NONE9

16. Upgrading the 4200A-SCS Parameter Analyzer

Besides adding instrument modules to your parameter analyzer, there are other upgrade options available to keep your parameter analyzer up-to-date with the latest technologies and applications tests.

4200A-MF-UP	This upgrade service will convert any 4200-SCS mainframe to the 4200A-SCS widescreen mainframe with Clarius+ software. Any instrument modules in the 4200-SCS will be moved to the 4200A-SCS mainframe, and the system will receive a factory calibration and a one year warranty on the mainframe and all modules.
4200A-IFC	Required installation and factory calibration service when any instrument module is added to the 4200A-SCS mainframe. Only one 4200A-IFC is required per instrument module upgrade order. Not required when ordering the 4200A-MF-UP.
4200-SMU-MOD/4210-SMU-MOD	Modernize an older SMU in order to add new SMUs to the same system. Should not be ordered with 4200A-MF-UP.

17. Warranty Information

Warranty Summary

This section summarizes the warranties of the 4200A-SCS. Any portion of the product that is not manufactured by Keithley is not covered by this warranty and Keithley will have no duty to enforce any other manufacturer's warranties.

Hardware Warranty

Keithley Instruments warrants the Keithley manufactured portion of the hardware for a period of one year from defects in materials or workmanship; provided that such defect has not been caused by use of the Keithley hardware which is not in accordance with the hardware instructions. The warranty does not apply upon any modification of Keithley hardware made by the customer or operation of the hardware outside the environmental specifications.

Software Warranty

Keithley warrants for the Keithley produced portion of the software or firmware will conform in all material respects with the published specifications for a period of ninety (90) days; provided the software is used on the product for which it is intended in accordance with the software instructions. Keithley does not warrant that operation of the software will be uninterrupted or error-free, or that the software will be adequate for the customer's intended application. The warranty does not apply upon any modification of the software made by the customer.

18. Embedded Computer Policy

CAUTION: If you install software that is not part of the standard application software for the 4200A-SCS, the non-standard software may be removed if the instrument is sent in for service. Back up the applications and any data related to them before sending the instrument in for service.

CAUTION: Do not reinstall or upgrade the Microsoft® Windows® operating system (OS) on any 4200A-SCS. This action should only be performed at an authorized Keithley Instruments service facility. Violation of this precaution will void the 4200A-SCS warranty and may render the 4200A-SCS unusable. Any attempt to reinstall or upgrade the operating system (other than a Windows service pack update) will require a return-to-factory repair and will be treated as an out-of-warranty service, including time and material charges.

Although you must not attempt to reinstall or upgrade the operating system, you can restore the hard drive image (complete with the operating system) using the built-in software backup tool included with the 4200A-SCS.

Contact Information:

Australia 1 800 709 465
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3530-8901
Canada 1 800 833 9200
Central East Europe / Baltics +41 52 675 3777
Central Europe / Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400 820 5835
India 000 800 650 1835
Indonesia 007 803 601 5249
Italy 00800 2255 4835
Japan 81 (3) 6714 3086
Luxembourg +41 52 675 3777
Malaysia 1 800 22 55835
Mexico, Central/South America and Caribbean 52 (55) 88 69 35 25
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
New Zealand 0800 800 238
Norway 800 16098
People's Republic of China 400 820 5835
Philippines 1 800 1601 0077
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea +82 2 565 1455
Russia / CIS +7 (495) 6647564
Singapore 800 6011 473
South Africa +41 52 675 3777
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2656 6688
Thailand 1 800 011 931
United Kingdom / Ireland* 00800 2255 4835
USA 1 800 833 9200
Vietnam 12060128

* European toll-free number. If not accessible, call: +41 52 675 3777

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