

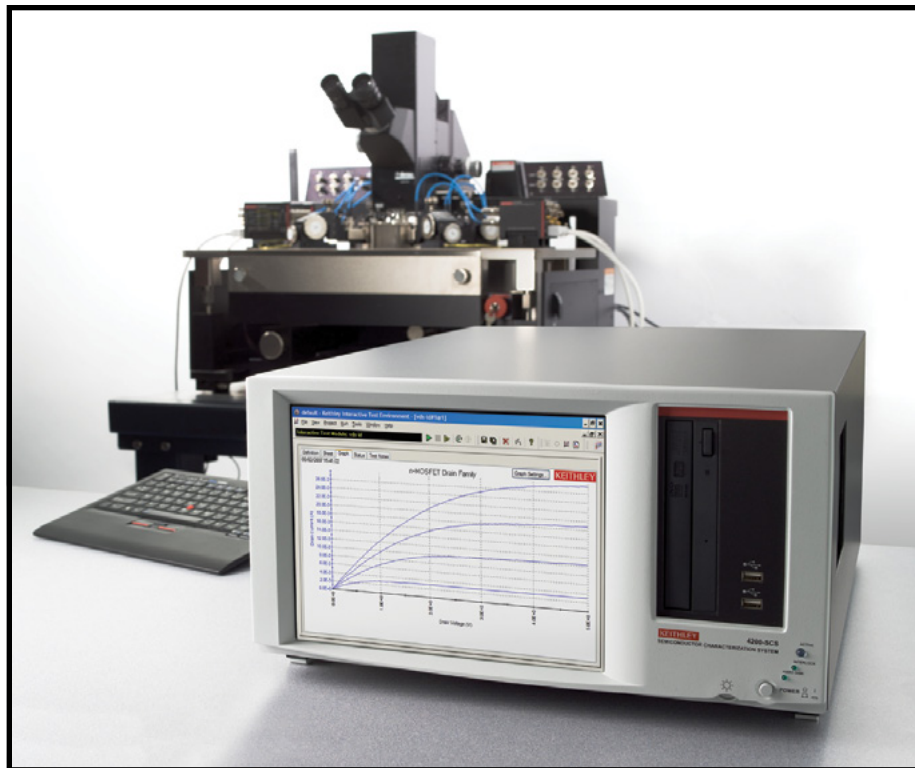
4225-PMU 4225-RPM 4220-PGU

- Provides voltage outputs with programmable timing from 60ns to DC in 10ns steps
- Measure I and V simultaneously, at acquisition rates of up to 200 megasamples/second (MS/s)
- Choose from two voltage source ranges ($\pm 10V$ or $\pm 40V$) and four current measurement ranges (800mA, 200mA, 10mA, 100 μ A)
- Each module provides two channels of integrated simultaneous I-V sourcing and measurement; plug in up to four modules in a single chassis for eight synchronized channels
- Model 4220-PGU Pulse Generator Unit offers a voltage-sourcing-only alternative to the 4225-PMU
- Optional Model 4225-RPM Remote Amplifier/Switch expands current ranges (10mA, 1mA, 100 μ A, 10 μ A, 1 μ A, 100nA), switches sourcing/measurement between the Model 4225-PMU, Model 4210-CVU, Model 4200-SMU, and 4210-SMU

APPLICATIONS

- Ultra-fast general-purpose I-V measurements
- Pulsed I-V and transient I-V measurements
- Flash, PCRAM, and other non-volatile memory tests
- Isothermal testing of medium-sized power devices
- Materials testing for scaled CMOS, such as high- κ dielectrics
- NBTI/PBTI reliability tests

Ultra-Fast I-V Module for the Model 4200-SCS



The Model 4225-PMU Ultra Fast I-V Module is the latest addition to the growing range of instrumentation options for the Model 4200-SCS Semiconductor Characterization System. It integrates ultra-fast voltage waveform generation and signal observation capabilities into the Model 4200-SCS's already powerful test environment to deliver unprecedented I-V testing performance, expanding the system's materials, device, and process characterization potential dramatically. Just as important, it makes ultra-fast I-V sourcing and measurement as easy as making DC measurements with a traditional high-resolution Source-Measure Unit (SMU).

Three types of measurements are necessary to characterize a device, material, or process thoroughly. The first two are precision DC I-V measurements (usually made with the Model 4200-SCS's SMUs) and AC impedance measurements (which can be made with the Model 4210-CVU C-V Instrument). The Model 4225-PMU represents the last segment of this characterization triangle—ultra-fast I-V or transient I-V measurements. Now, all three measurement types can be integrated in a single, flexible, cost-effective test system.

Each plug-in 4225-PMU module provides two channels of integrated sourcing and measurement but occupies only a single slot in the Model 4200-SCS's nine-slot chassis. Unlike competitive solutions, each channel of the 4225-PMU combines high speed voltage outputs (with pulse widths ranging from 60 nanoseconds to DC) with simultaneous current and voltage



Each Model 4200-SCS chassis can accommodate up to four Model 4225-PMU modules to provide up to eight ultra-fast source and measure channels.

4225-PMU 4225-RPM 4220-PGU

Ordering Information

4225-PMU Ultra-Fast I-V Module
4225-RPM Remote Amplifier/Switch
4220-PGU Pulse Generator Unit
 (voltage-source only)

Accessories Supplied

For the 4225-PMU or 4220-PGU:
SMA to SMA 50 Ω cables, 2m (4 ea.)
SMA to SSMC Y-Cable
Assembly, 6 in (2 ea.)

For the 4225-RPM:
SMA to SMA 50 Ω cable,
20 cm (1 ea.)
Triax to BNC Adapter (1 ea.)
BNC to SMA Adapter (1 ea.)
RPM Cable, 2.1 m (1 ea.)

ACCESSORIES AVAILABLE

4200-BTI-A	Hardware and software ultra-fast package for complete NBTI/PBTI reliability testing (see 4200-BTI-A Data Sheet for details).
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.
4210-MMPC-C	Multi Measurement Performance Cables for Cascade. One kit required per manipulator.
4210-MMPC-S	Multi Measurement Performance Cables for Suss. One kit required per manipulator.
4225-RPM	Remote Amplifier/Switch. Up to two of these units can be used with a single 4225-PMU module.
ACS V4.2	Automated Characterization Suite software

Ultra-Fast I-V Module for the Model 4200-SCS

measurements. With this combination of ultra high-speed voltage source and voltage and current measurement capabilities, existing Model 4200-SCS systems can be easily upgraded into a flexible measurement tool for a wide range of ultra-fast I-V test applications. Each chassis can accommodate up to four 4225-PMU modules, for a maximum of eight ultra-fast source and measure channels, leaving five other chassis slots free for installing other types of instrumentation. These hardware and software capabilities are also available for new Model 4200-SCS systems as factory-installed options.

Test library support

A variety of standard ultra-fast I-V tests are included in the latest version of KTEI, including support for characterizing isothermal pulse I-V and transient effects of trapped charges on a MOSFET, as well as charge pumping, resistor, diode, capacitor, flash memory, and solar cell testing. Programming examples that illustrate the use of the built-in waveform and Segment ARB[®] functions and the optional Model 4225-RPM Remote Amplifier/Switch are included.



The 4225-PMU Ultra-Fast I-V Module plugs directly into a Model 4200-SCS instrument slot and can be equipped with up to two optional Model 4225-RPM Remote Amplifier/Switches. The 4225-RPM Remote Amplifier/Switch extends the Model 4225-PMU low current measurement capabilities and allows switching between the Model 4225-PMU and other modules in the chassis.



For applications that don't require the Model 4225-PMU's integrated measurement capabilities, the Model 4220-PGU offers a voltage-source-only alternative.

Hardware options expand source-measure flexibility

The optional Model 4225-RPM Remote Amplifier/Switch expands on the Model 4225-PMU's capabilities by providing four additional low current ranges, offering current sensitivity down to tens of picoamps. The Model 4225-RPM also reduces cable capacitance effects and supports switching automatically between the Model 4225-PMU, the Model 4210-CVU, and other SMU modules installed in the chassis, allowing the operator to choose the most appropriate instrument for a particular measurement task without re-cabling. The Model 4220-PGU Pulse Generator Unit offers a voltage-sourcing-only alternative to the Model 4225-PMU.

Support for both general-purpose and reliability testing applications

The Model 4225-PMU's wide programmable voltage and current measurement ranges, pulse widths, and rise times make it well-suited for a variety of test applications that demand both ultra-fast voltage outputs and measurement—from nanometer CMOS to flash memory. It provides high speed voltage pulsing with simultaneous current and voltage measurement, at acquisition rates of up to 200 megasamples/second (MS/s) with 14-bit analog-to-digital converters (A/Ds), using two A/Ds per channel (four A/Ds per card). System operators can choose from two voltage source ranges ($\pm 10V$ or $\pm 40V$ into $1M\Omega$) and four current measurement ranges (800mA, 200mA, 10mA, $100\mu A$).

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4225-PMU 4225-RPM 4220-PGU

Ultra-Fast I-V Module for the Model 4200-SCS

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

- **General-purpose ultra-fast I-V measurements.** Pulsed I-V testing can be performed on a variety of devices for many different purposes, including preventing device self-heating by using narrow pulses and/or low duty cycle pulses rather than DC signals.
- **CMOS device characterization.** The Model 4225-PMU/4225-RPM's high speed voltage sourcing and current measurement sensitivity make this combination well suited for CMOS device characterization, including high- κ devices and advanced CMOS technologies like Silicon-on-Insulator (SOI).
- **Non-volatile memory device testing.** The Model 4200-SCS's KTEI software includes toolkits for testing both flash and phase change memory (PCM) devices. The Model 4225-PMU is the ideal instrument for testing single memory cells or a small array of cells, such as when isolated cells need to be tested in research and development or for process verification.
- **Characterizing compound semiconductor devices and materials.** Pulsed I-V testing is often necessary to characterize devices made from III-V materials, such as GaN, GaAs, and other compound semiconductor materials. The Model 4225-PMU allows setting a pulse offset voltage so that measurements can be made from a non-zero value (Q-point), which can be used to investigate the amplifier gain or linearity of a device.
- **NBTI/PBTI reliability tests.** In addition to the standard reliability test sequences included in KTEI, users can incorporate test sequences available in Keithley's optional Automated Characterization Suite (ACS) V4.2 for reliability testing. The Model 4200-BTI-A Ultra-Fast BTI Package combines all the hardware and software needed for a broad range of ultra-fast BTI test applications, as well as general characterization and lab automation tasks.

Segment ARB® waveform generation

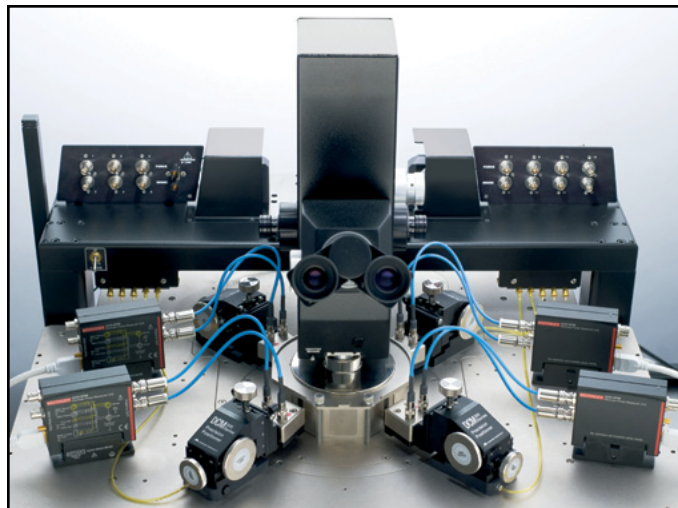
The Model 4225-PMU can generate four types of sweeps: Linear Sweep, Pulsed, Arbitrary Waveform, and Segment ARB (patent pending). The Segment ARB mode simplifies creating, storing, and generating waveforms made up of up to 2048 user-defined line segments. Each segment can have a different duration, allowing exceptional waveform generation flexibility.

High performance cabling

The Model 4225-PMU/4225-RPM combination is compatible with most semi-automatic probe stations. An optional multi-measurement performance cable kit (4210-MMPC-x) connects the Model 4200-SCS to a probe manipulator, simplifying switching between DC I-V, C-V, and ultra-fast I-V testing configurations. This kit eliminates the need for re-cabling, as well as maximizing signal fidelity by eliminating the measurement errors that often result from cabling errors. Versions engineered for Cascade Microtech and SUSS MicroTec probes are available. There's also a general-purpose kit (4200-PMU-PROBER-KIT) for connecting the 4225-PMU to other triaxial and coaxial probe stations.

Ongoing system enhancements ensure ongoing ROI

Keithley's Model 4200-SCS replaces a variety of electrical test tools with a single, tightly integrated characterization solution that's ideal for a wide variety of applications. To assure customers of the ongoing viability of their systems, Keithley has continually enhanced the system's hardware and software. This ongoing commitment ensures a cost-effective system upgrade path to address new testing needs as they arise. That means Model 4200-SCS users will never have to buy a new parametric analyzer because the old one is obsolete. The Model 4200-SCS is engineered to adapt readily to the industry's changing test needs—making our customers' capital investments stretch further and improving ROI.



Each Model 4220-SCS chassis can accommodate up to four Model 4225-PMU modules to provide up to eight ultra-fast source and measure channels. Pictured are four 4225-RPM modules connected to a 4-pin probe.

4225-PMU 4225-RPM 4220-PGU

Ultra-Fast I-V Module for the Model 4200-SCS

Typical Performance Window

The 4225-PMU represents a new generation of ultra-fast I-V measurement capability. Because measurement speed is integrally linked to settling time, accuracy, resolution, and noise, the following chart was created to illustrate the typical measurement performance that can be achieved. This chart is neither the maximum (best) performance nor a guaranteed specification; it is simply intended to offer users an indication of the performance achievable with this new module. The timing parameters below are the suggested minimums for the measurement type. These suggested values do not include settling time for the interconnect or the device-under-test.

TYPICAL MINIMUM TIMING PARAMETERS FOR CURRENT MEASUREMENT¹

4225-PMU ULTRA-FAST I-V MODULE
(with or without optional 4225-RPM Remote Amplifier/Switch)

	10V Range		40V Range		
Current Measure Ranges	10 mA	200 mA	100 μ A	10 mA	800 mA
Recommended Minimum Pulse Width ²	160 ns	70 ns	6.4 μ s	770 ns	770 ns
Recommended Minimum Measure Window ²	20 ns	20 ns	1 μ s	100 ns	100 ns
Recommended Minimum Transition Time ³	20 ns	20 ns	1 μ s	100 ns	100 ns
Noise ⁴	15 μ A	50 μ A	75 nA	5 μ A	200 μ A
Settling Time ⁵	100 ns	30 ns	4 μ s	500 ns	500 ns

TYPICAL MINIMUM TIMING PARAMETERS FOR CURRENT MEASUREMENT¹

4225-RPM REMOTE AMPLIFIER/SWITCH (RPM optional to 4225-PMU)

	10V Range					
Current Measure Ranges	100 nA	1 μ A	10 μ A	100 μ A	1 mA	10 mA
Recommended Minimum Pulse Width ²	134 μ s	20.4 μ s	8.36 μ s	1.04 μ s	370 ns	160 ns
Recommended Minimum Measure Window ²	10 μ s	1.64 μ s	1 μ s	130 ns	40 ns	20 ns
Recommended Minimum Transition Time ³	1 μ s	360 ns	360 ns	40 ns	30 ns	20 ns
Noise ⁴	200 pA	2 nA	5 nA	50 nA	300 nA	1.5 μ A
Settling Time ⁵	100 μ s	15 μ s	6 μ s	750 ns	250 ns	100 ns

TYPICAL MINIMUM TIMING PARAMETERS FOR VOLTAGE MEASUREMENT¹

4225-PMU and 4225-RPM

	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 FOR THE TYPICAL PERFORMANCE WINDOW SECTION:

- All typical values measured with an open circuit.
- Using default measure window of 75% to 90% of pulse top.
Recommended minimum pulse width = (Settling Time) / 0.75.
- Recommended rise/fall time to minimize overshoot.
- RMS noise measured over the Recommended Minimum Measure Window for the given voltage or current range, typical.
- Time necessary for the signal to settle to the DC accuracy level. (Example: 10mA settling time on the PMU 10V range is defined when the signal is within 1.25% of the final value. This calculation: Accuracy = 0.25% + 100 μ A = 0.25% + (100 μ A/10mA) = 0.25% + 1% = 1.25%.)

TYPICAL MAXIMUM VOLTAGE AND CURRENT¹

4225-PMU and 4220-PGU

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 k Ω	9.52 V	9.5 mA	38.1 V	38.1 mA
10 k Ω	9.95 V	995 μ A	39.8 V	3.98 mA

- To calculate the approximate maximum current and voltage for any resistance:

$$I_{\text{MAX}} = V \text{ range} / (50\Omega + \text{Resistance})$$

$$V_{\text{MAX}} = I_{\text{MAX}} \cdot \text{Resistance}$$

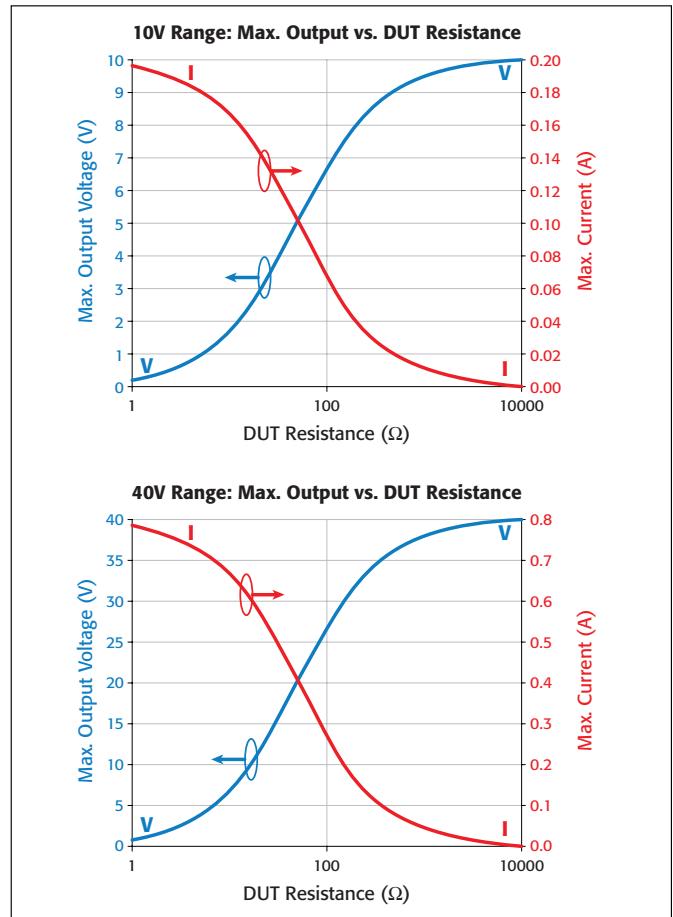
where Resistance is the total resistance connected to the PMU or PGU channel and V range is either 10 or 40.

Example: 10V range using R = 10 Ω (for DUT + interconnect)

$$I_{\text{MAX}} = V \text{ range} / (50 + R) = 10 / (50 + 10) = 10 / 60 = 0.167\text{A}$$

$$V_{\text{MAX}} = I_{\text{MAX}} \cdot R = 0.167 \cdot 10 = 1.67\text{V}$$

- Typical maximum at pulse output connector. Resistance is the total resistance connected to the pulse output connector, including device and interconnect.



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4225-PMU 4225-RPM 4220-PGU

Ultra-Fast I-V Module for the Model 4200-SCS

4225-PMU and 4220-PGU Specifications ¹

PULSE/LEVEL ²

		10V Range	40V Range
V _{OUT}	50 Ω into 1 MΩ	–10 V to +10 V	–40 V to +40 V
V _{OUT}	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 50Ω Load (at full scale)		±100 mA typical	±400 mA typical
Short Circuit Current		±200 mA	±800 mA
Output Connectors		SMA	SMA
Output Limit		Programmable limit to protect the device under test	

TIMING

	10 V Range Source Only	10 V Range with Meas.	40 V Range Source Only	40 V Range with Meas.
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 1 s	280 ns to 1 s
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 1 s	30 ns to 33 ms ⁴	100 ns to 1 s
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

CURRENT MEASUREMENT (4225-PMU Only)

	10 V Range			40 V Range	
Current Measure Ranges	10 mA	200 mA	100 μA	10 mA	800 mA
Accuracy (DC)	±(0.25% + 100 μA)	±(0.25% + 250 μA)	±(0.25% + 1 μA)	±(0.5% + 100 μA)	±(0.25% + 3 mA)

4225-RPM CURRENT MEASUREMENT

	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)

4225-PMU and 4225-RPM VOLTAGE MEASUREMENT

	±10V PMU	±40V PMU	±10V RPM
Accuracy (DC)	±(0.25% + 10 mV)	±(0.25% + 40 mV)	±(0.25% + 10 mV)

NOTES

1. Unless stated otherwise, all specifications assume a 50Ω termination.
2. Level specifications are valid after 50ns typical settling time (after slewing) for the 10V source range and after 500ns typical settling time (after slewing) for the 40V source range into a 50Ω load.
3. With transition time of 20ns (0%–100%) for the 10V source range and 100ns (0%–100%) for the 40V source range.
4. 40V Range minimum programmable transition time (source only) is 30ns for voltage <10V and 100ns for voltages >10V.
5. For multiple 4225-PMU or 4220-PGU cards in a single 4200-SCS chassis.
6. Per channel.

All specifications apply at 23° ±5°C, within one year of calibration, RH between 5% and 60%, after 30 minutes of warmup.

TRIGGER

TRIGGER OUTPUT IMPEDANCE: 50Ω.

TRIGGER OUTPUT LEVEL: TTL.

TRIGGER IN IMPEDANCE: 10kΩ.

TRIGGER IN LEVEL: TTL.

TRIGGER IN TRANSITION TIMING, MAXIMUM: <100ns.

TRIGGER IN TO PULSE OUTPUT DELAY: 400ns.

TRIGGER SYNCHRONIZATION/JITTER ⁵: <2ns.

SEGMENT ARB [®] AND TIMING

4220-PGU, 4225-PMU w/ or w/o 4225-RPM

MAX. NUMBER OF SEGMENTS ⁶: 2048.

MAX. NUMBER OF SEQUENCES ⁶: 512.

MAX. NUMBER OF SEQUENCE LOOPS: 10¹².

TIME PER SEGMENT: 20ns to 40s.

SEGMENT TIMING RESOLUTION: 10ns.

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.

4225-PMU 4225-RPM 4220-PGU

Ultra-Fast I-V Module for the Model 4200-SCS

VOLTAGE SOURCE ABSOLUTE BEST PERFORMANCE

When used only as a voltage source (that is, without measurements of voltage or current), the Model 4225-PMU can actually exceed the level of performance listed in these specifications. The following table is provided only to offer the user a clearer idea of the Model 4225-PMU's absolute best performance as achievable under optimal conditions. This should not be interpreted as a guarantee that the Model 4225-PMU will achieve this level of performance in typical use cases.

10V RANGE:

Rise Time: <10ns.

Pulse Width: 10ns (full width half maximum).

Period: 20ns.

Overshoot/Preshoot/Ringing: $\pm(2\% + 20\text{mV})$.

40V RANGE:

Rise Time: 50ns to 10V, 100ns to 40V.

Pulse Width: 50ns.

Period: 100ns.

Overshoot/Preshoot/Ringing: $\pm(0.5\% + 40\text{mV})$.

SOFTWARE TOOLS AND SUPPORT INCLUDED WITH KTEI 8.0

(Refer to the Model 4200-SCS Technical Data Sheet for details)

Interactive Test Modules (ITMs) for general ultra-fast IV, no programming required

User Test Modules (UTMs) for detailed programming of all 4225-PMU/4225-RPM/4220-PGU functions

KPulse (voltage source only) general-purpose pulse generator interface

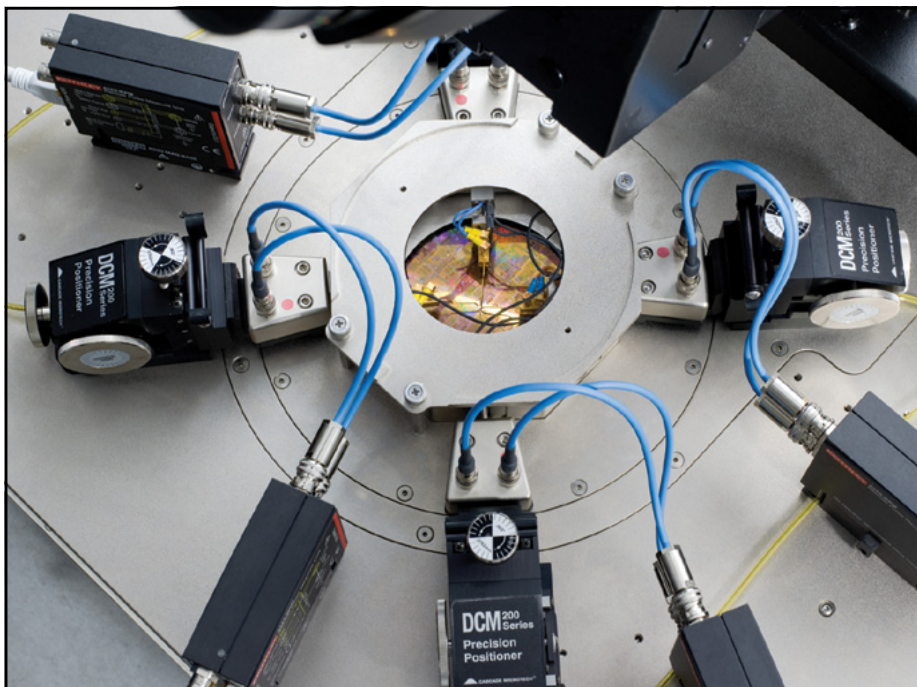
KXCI (UTM caller only) for external control via Ethernet/GPIB

OPTIONAL SOFTWARE

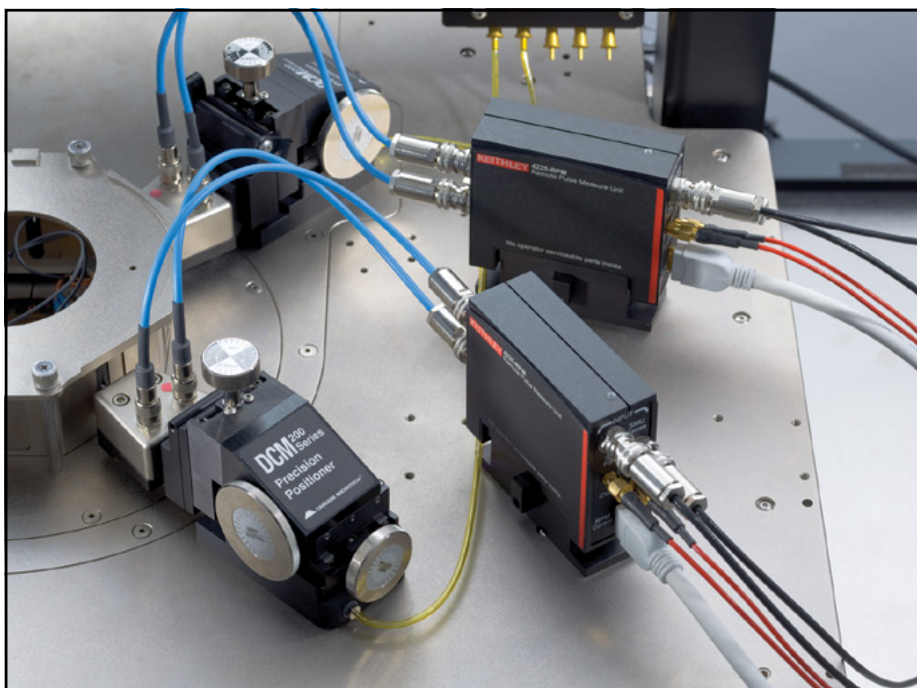
Automated Characterization Suite (ACS) V4.2 for reliability testing, general characterization, and lab automation. For more information on these capabilities, refer to the Model 4200-BTI-A data sheet.

4225-PMU
4225-RPM
4220-PGU

Ultra-Fast I-V Module for
the Model 4200-SCS



This top-down view of a Cascade Microtech analytical probe station illustrates best practices for interconnecting the Model 4225-RPM Remote Amplifier/Switch to the probe using the blue Multi-Measurement Performance cables.



This close-up of two Model 4225-RPMs highlights the DC SMU, C-V, and ultra-fast I-V cable connections.

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