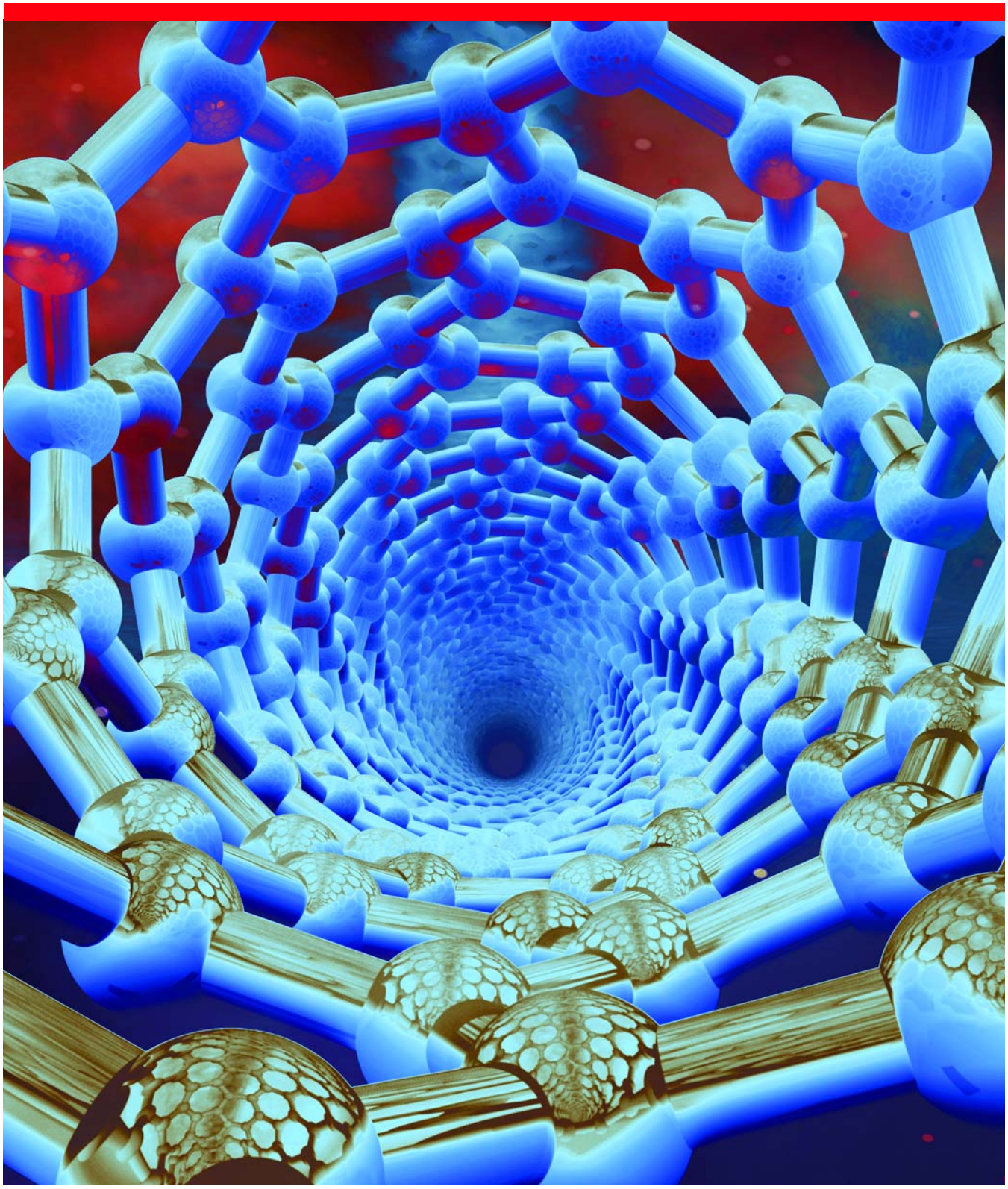
www.keithley.com

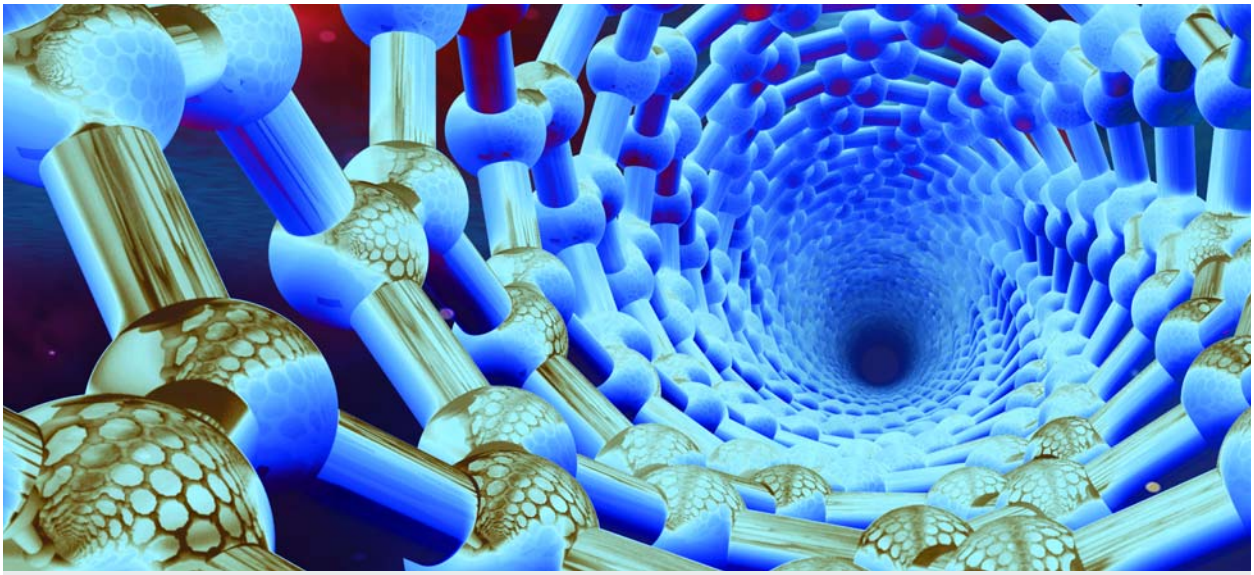


Discover Today's Solutions for Tomorrow's
Nano Characterization Challenges

A GREATER MEASURE OF CONFIDENCE

KEITHLEY

The leader in nanotechnology measurement solutions



Keithley is **helping advance the state of the art** in a growing list of nanotechnology applications—yours may be one of them. **Six decades of experience in designing ultra-sensitive measurement tools** allow us to provide university, corporate, and government labs around the world with solutions for investigating new material and device properties. Just as important, these solutions are designed for intuitive operation, so you'll get the results you need quickly and simply. That means you can focus on your research, not on your test hardware.

We partner with organizations like the Institute of Electrical and Electronics Engineers (**IEEE**), leading Nanotechnology Centers of Excellence, Keithley **customers**, and other leading nanotechnology measurement tool vendors to create more complete solutions. The **insight into emerging needs** these working partnerships provide helps us deliver new capabilities faster.

Which Keithley nanotechnology solution is best for your sourcing or measurement application?

Keithley instrumentation is being used in a growing list of nanotechnology research and production test settings. The applications shown here are only a sampling of the nanotechnology test and measurement tasks for which our instruments and systems are suitable. If your tests require sourcing or measuring low level signals, Keithley instrumentation can help you perform them more accurately and cost-effectively.

Want seamless control over current pulse sourcing and measurement?

When linked together, the **Model 6221 AC+DC Current Source** and **Model 2182A Nanovoltmeter** are designed to operate like a single instrument to make high speed pulse mode measurements. **Learn more on pages 9, 13, and 14.**

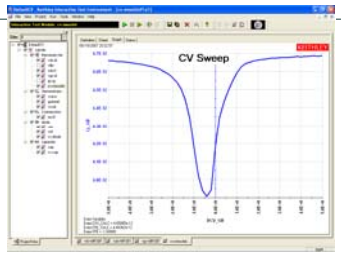
Polymer Nanofibers/ Nanowires	Semiconductor Nanowires	Carbon Nanotubes	Single Electron Devices/Transistors	Carbon Nanotube Field Effect Transistors
High R/Low I, 1MΩ to 10^{14}Ω	Low Power, R<10MΩ, Pulse	Low Power, R < 100kΩ	Low I, Low V	Low I, Pulse

Want multiple channels of sourcing and measurement?

The fully integrated **Model 4200 Semiconductor Characterization System** brings together up to eight channels in one easy-to-operate package. It's used in many phases of nano research, development, characterization, and production. **Learn more on pages 6, 7, 10, and 11.**

Need to characterize mobility, carrier density, and device speed?

The **Model 4200-CVU Option** takes the guesswork out of obtaining valid capacitance-voltage (C-V) measurements quickly and easily, with intuitive point-and-click setup, complete cabling, and built-in element models. **Learn more on page 11.**



Need tighter control over your pulses?

Our newest pulse generation solutions, **Series 3400 Pulse/Pattern Generators**, can output voltage pulses with widths as short as 3ns, with independently adjustable rise and fall times as short as 2ns. **Learn more on pages 9 and 18.**

The Model 4200-SCS conforms to and supports the new IEEE Standard 1650™-2005: "IEEE Standard Test Methods for Measurement of Electrical Properties of Carbon Nanotubes," the world's first electrical measurement standard for these devices.

Model 4200-SCS: Tackle both today's ultra-precise measurements and tomorrow's evolving nano challenges

Keithley originally developed the Model 4200 Semiconductor Characterization System for the semiconductor industry, but nanotechnology researchers and production test experts soon discovered its effectiveness for developing and studying nanoscale materials and devices. Today, this powerful characterization system is the industry-standard tool used in nanotechnology labs around the world in applications ranging from materials research and nanostructure development to I-V characterization of nanoelectronic devices. The system's popularity is due in part to our commitment to enhancing its hardware and software to meet emerging test needs. Our ongoing commitment to the Model 4200-SCS ensures we'll continue to provide you with a cost-effective system upgrade path to new measurement capabilities.

- Start testing productively right out of the box. The Model 4200-SCS's intuitive Windows®-based interface minimizes the system-specific training needed and allows even novice users to begin taking data almost immediately. Whether your background is in biology, chemistry, physics, semiconductor engineering, or some other discipline, the Model 4200-SCS delivers the test results you need faster.
- Organize your tests with the built-in Project Navigator, which automates test sequencing and often eliminates the need to write code.
- Customize and modify your test parameters easily using the system's point-and-click interface. Less time spent on test development allows more time to focus on your research.
- Take advantage of the powerful scripting language to create more advanced tests as new testing needs arise.

"The Model 4200-SCS makes it simple to obtain and analyze data, so we can learn the electronic characteristics of nanodevices almost immediately. It's a very user-friendly design – it's easy to set up and operate with no training needed."

- Dr. Iwao Ohdomari, Professor of Science & Engineering, Waseda University, Japan

Keep your finger on the pulse of new nano testing technologies

New materials, miniscule device dimensions, and higher operating speeds have all combined to make characterizing nanostructures more challenging than ever. Traditional DC I-V techniques can lead to joule heating of the device, affecting device response and masking the phenomenon of interest, or even destroying priceless experimental devices. By minimizing the amount of energy pumped into a device, Keithley's growing line of pulse testing solutions offers valuable alternatives to DC characterization methods.

Save time and money with the Model 4200-PIV

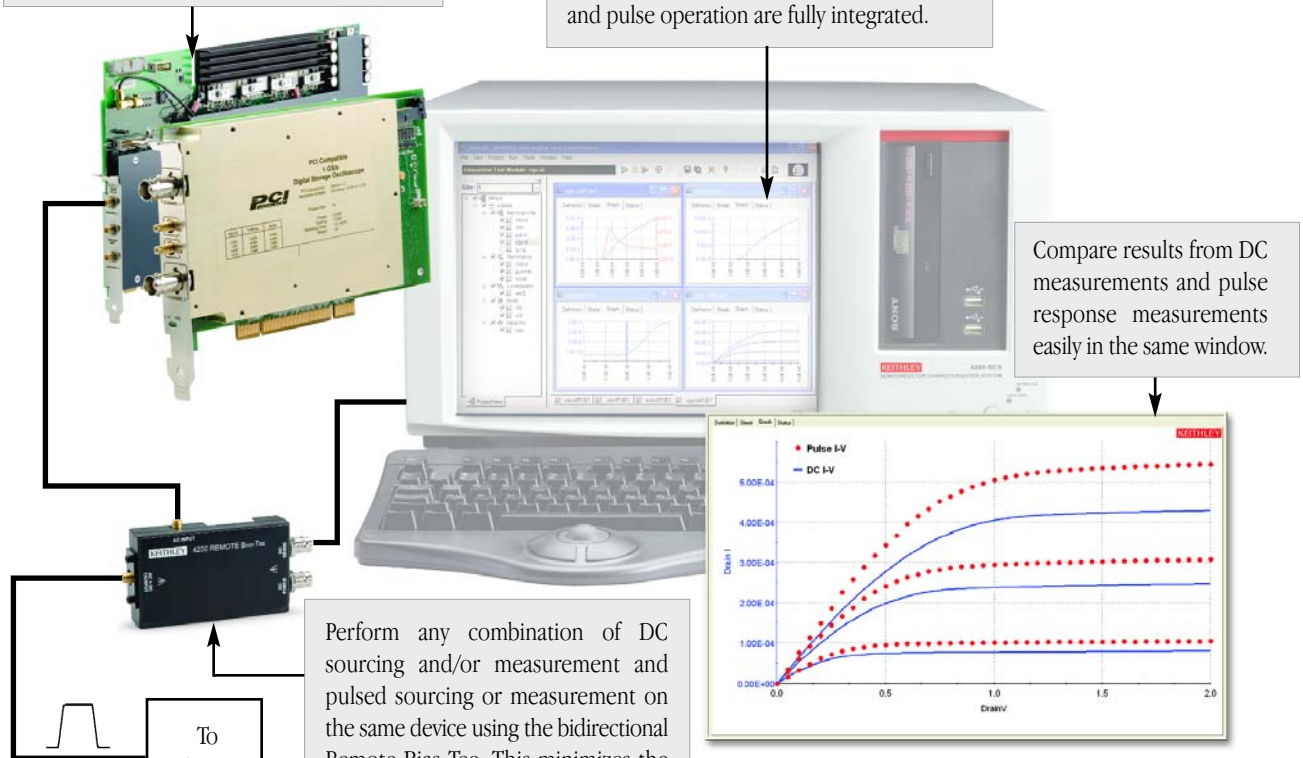
Now, incorporating a pulse I-V characterization system into your nano lab is no longer a "do-it-yourself" project or a major strain on the capital equipment budget. Our new 4200-PIV bundle is a comprehensive package of hardware and software (including patent pending cable and load-line compensation utilities), designed to integrate seamlessly with the Model 4200-SCS workstation. It includes everything you need to implement a turnkey system for pulsed I-V testing of nanostructures:

- Integrated dual-channel pulse generator
- Dual-channel digital oscilloscope
- Control software
- Interconnect fixture that minimizes the signal reflections common to pulse I-V testing
- All required connectors and cables
- Pulse I-V sample project created for isothermal testing

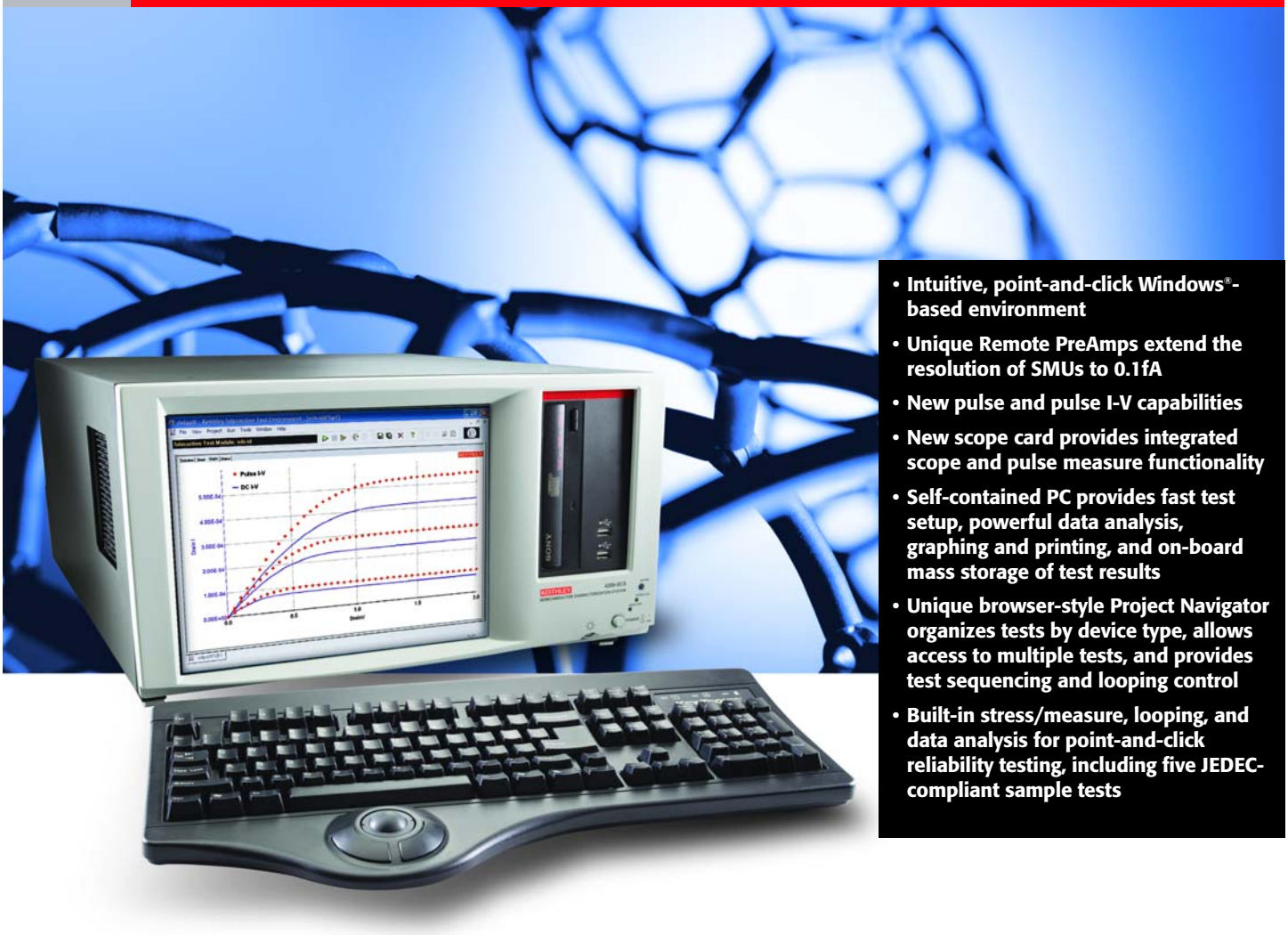
Control the amount of energy transmitted to the device precisely with independently controllable pulse rise and fall times. Source pulses as short as 40ns.

View results in the way that's best suited to your application—V or I vs. time, DC bias current vs. pulse voltage response, etc. DC and pulse operation are fully integrated.

Compare results from DC measurements and pulse response measurements easily in the same window.



Perform any combination of DC sourcing and/or measurement and pulsed sourcing or measurement on the same device using the bidirectional Remote Bias Tee. This minimizes the signal reflections due to poor impedance matching that often plague custom-built pulse testing systems.



- Intuitive, point-and-click Windows®-based environment
- Unique Remote PreAmps extend the resolution of SMUs to 0.1fA
- New pulse and pulse I-V capabilities
- New scope card provides integrated scope and pulse measure functionality
- Self-contained PC provides fast test setup, powerful data analysis, graphing and printing, and on-board mass storage of test results
- Unique browser-style Project Navigator organizes tests by device type, allows access to multiple tests, and provides test sequencing and looping control
- Built-in stress/measure, looping, and data analysis for point-and-click reliability testing, including five JEDEC-compliant sample tests

Complete pulse and DC solution

Model 4200-SCS Semiconductor Characterization System

The easy-to-use Model 4200-SCS Semiconductor Characterization System performs lab-grade DC and pulse device characterization, real-time plotting, and analysis with high precision and sub-femtoamp resolution. It offers the most advanced capabilities available in a fully integrated characterization system, including a complete, embedded PC with Windows operating system and mass storage. Its self-documenting, point-and-click interface speeds and simplifies the process of taking data, so users can begin analyzing their results sooner. The powerful test library management tools included allow standardizing test methods and extractions to ensure consistent test results. The 4200-SCS offers tremendous flexibility, with hardware options that include four different switch matrix configurations, a variety of LCR meters, and pulse generators.

The 4200-SCS is modular and configurable. The system supports up to eight Source-Measure Units, including up to four high power SMUs with 1A/20W capability. An optional Remote PreAmp, the 4200-PA, extends the system's measurement resolution from 100fA to 0.1fA 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.

The Model 4200-SCS conforms to and supports the new IEEE Standard 1650™-2005: "IEEE Standard Test Methods for Measurement of Electrical Properties of Carbon Nanotubes."

Low Current/High Resistance Measurements

Sources and measures the lowest currents in the world

Model 6430 sub-femtoamp remote SourceMeter® instrument

- **0.4fA p-p (4E–16A) noise**
- **Remote PreAmp can be located at the signal source to minimize cable noise**
- **>$10^{16}\Omega$ input resistance on voltage measurements**
- **High speed—up to 2000 readings/second**
- **Up to 6½-digit resolution**
- **Fast characterization of components with programmable digital I/O and interfaces**

The Model 6430 combines the voltage and current sourcing and measurement functions of Keithley's SourceMeter and Source-Measure Unit (SMU) products with sensitivity, noise, and input resistance specifications superior to electrometers. This unique combination of broad functionality and exceptional measurement integrity is made possible by the Model 6430's Remote PreAmp, which offers a very sensitive bi-directional amplifier with sensitive feedback elements for measuring or sourcing currents at the device being tested. The Model 6430 makes voltage, current and resistance measurements at speeds no electrometer can match. It can read up to 2000 source/measure readings per second into internal memory. Currents can be measured in as little as 5ms on the 100nA range, decreasing to just a few hundred microseconds on the higher ranges.

"The capabilities of the 6430 allow us to measure with a resolution and ease that was previously unavailable in this type of experiment."

—Heinrich Jaeger, Professor of Physics, The University of Chicago

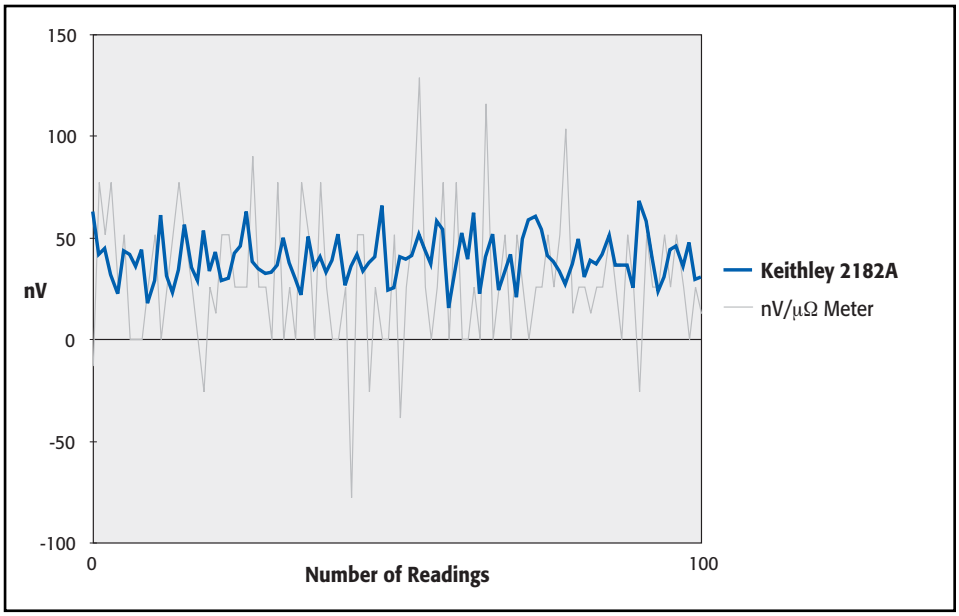
Low Voltage/Low Resistance Measurements

Makes pulsed I-V, resistance, and differential conductance measurements easy

Model 2182A nanovoltmeter

- **Measures:**
  - **Voltages from 10nV to 100V**
  - **Pulsed I-V down to 50µs with Model 6221**
  - **Differential conductance with Model 6220 or 6221**
  - **Resistances from 10nΩ to 100MΩ**
  - **Thermocouple temperatures from –200°C to 1820°C**
- **Dual channels support measuring voltage, temperature, or the ratio of an unknown resistance to a reference resistor**
- **Synchronization to line provides 110dB NMRR and minimizes the effect of AC common-mode currents**
- **In delta mode, coordinates measurements with a reversing current source at up to 24Hz and averages multiple readings for noise down to 1nV**

The two-channel Model 2182A Nanovoltmeter is optimized for making stable, low noise, voltage measurements and for characterizing low resistance materials and devices reliably and repeatably. It provides higher measurement speed and significantly better noise performance than alternative low voltage measurement solutions. The Model 2182A replaces Keithley's Model 2182 and offers enhanced capabilities, including pulse capability, lower measurement noise, and faster current reversals. It also offers a simplified delta mode for making resistance measurements in combination with a reversing current source, such as Keithley's Model 6220 or 6221.



Compare the Model 2182A's DC noise performance with a nanovolt/micro-ohmmeter's. All the data shown was taken at 10 readings per second with a low thermal short applied to the input.

Low Current/High Resistance Measurements

When you just need to measure current

- **Cost-effective low current measurement solution**
- **20fA lowest noise**
- **5½-digit resolution**
- **<200µV burden voltage**
- **Up to 1000 readings/second**
- **Built-in Model 485 emulation mode**
- **IEEE-488 and RS-232 interfaces**
- **Analog output**

Model 6485 picoammeter

The 5½-digit Model 6485 picoammeter is a cost-effective instrument that can measure currents from 20fA to 20mA, taking measurements at speeds up to 1000 readings per second. Its 10fA resolution and superior sensitivity make it well suited for characterizing low current phenomena, while its 20mA range lets it measure currents high enough for applications such as measuring 4–20mA sensor loops. Although it employs the latest current measurement technology, it is significantly less expensive than other instruments that perform similar functions, such as optical power meters, competitive picoammeters, or user-designed solutions. With a price that's comparable to a general purpose DMM, the Model 6485 makes picoamp-level measurements affordable for virtually any laboratory or production floor. While DMMs typically employ shunt ammeter circuitry to measure current, the Model 6485 is a feedback picoammeter. This design reduces voltage burden by several orders of magnitude, resulting in a voltage burden of less than 200µV on the lower measurement ranges. The low voltage burden makes the Model 6485 function much more like an ideal ammeter than a DMM, so it can make current measurements with high accuracy, even in circuits with very low source voltages.

Adds voltage sourcing and resistance measurement to the Model 6485's capabilities

Model 6487 picoammeter/voltage source

- **20fA lowest noise**
- **5½-digit resolution**
- **<200µV burden voltage**
- **Alternating Voltage method ohms measurements**
- **Automated voltage sweeps for I-V characterization up to $10^{15}\Omega$**
- **Floating measurements up to 500V**
- **Up to 1000 readings/second**
- **Built-in Model 486 and 487 emulation mode**
- **IEEE-488 and RS-232 interfaces**
- **Digital I/O**

With eight current measurement ranges and high speed autoranging, the Model 6487 Picoammeter/Voltage Source instrument can measure currents from 20fA to 20mA, take measurements at speeds up to 1000 readings per second, and source voltage from 200µV to 505V. Its 10fA resolution, superior sensitivity, voltage sweeping, and Alternating Voltage resistance measurements make it well suited for characterizing low current devices. Using the latest current measurement technology, it is significantly less expensive than other instruments that perform similar functions, such as optical power meters, tera-ohmmeters, competitive picoammeters, or user-designed solutions. With a price that's comparable to a high end DMM, the Model 6487 makes picoamp-level measurements affordable for virtually any laboratory or production floor.

Other Model 6487 features include:

- Direct resistance measurements using the Source Voltage/Measure Current method
- Alternating Voltage method, which improves resistance measurements on devices with high background current or high noise, and extends the measurable resistance range up to $10^{15}\Omega$
- 500V overload protection
- Scaled voltage analog output, which allows the Model 6487 to transmit measurement results to devices like DMMs, data acquisition cards, oscilloscopes, or strip chart recorders
- Display on/off switch for use in research on light-sensitive components

- **Family of products offers wide dynamic range: 10pA to 10A, 1µV to 1100V, 20W to 1000W**
- **4-quadrant operation**
- **0.012% basic accuracy with 5½-digit resolution**
- **6-wire Ω measurement with programmable I source and V clamp**
- **1700 readings/second at 4½ digits via GPIB**
- **Built-in comparator for fast pass/fail fail testing**
- **Optional contact check function**
- **Digital I/O for fast binning and connection to component handlers**
- **GPIB, RS-232, and Trigger Link interfaces**

Widest I-V dynamic range for high speed automated and benchtop testing

Series 2400 SourceMeter® line

The Series 2400 SourceMeter® instrument family is designed specifically for test applications that demand tightly coupled precision voltage and current sourcing and measurement. All SourceMeter models combine a precision, low noise, highly stable DC power supply with readback and a low noise, highly repeatable, high impedance, 5½-digit multimeter. The result is a compact, single-channel, DC parametric tester. In operation, these instruments can act as a V-Source, an I-Source, a V-Meter, an I-Meter, and an ohmmeter. They offer a variety of advantages over systems configured with separate source and measurement instruments. For example, their compact half-rack size conserves precious space in the test rack or bench. They also minimize the test station development, set-up, and maintenance time required, while lowering the overall cost of system ownership. In addition, SourceMeter instruments simplify the test process itself by eliminating many of the complex synchronization and connection issues associated with using multiple instruments. All SourceMeter instruments are suitable for making a wide range of DC measurements, including resistance at a specified current or voltage, breakdown voltage, leakage current, insulation resistance, and electrical characterization.

Control a wide range of pulse parameters

Series 3400 pulse/pattern generators

Series 3400 Pulse/Pattern Generators are the latest additions to Keithley's growing line of instrumentation with pulse generation functions. They offer users extensive control over a wide variety of pulse parameters, including pulse amplitude, rise time, fall time, width, and duty cycle via the instrument's flexible user interface or over the GPIB and USB interfaces. This operational flexibility makes Series 3400 instruments readily adaptable to the needs of a wide range of users, including nanotechnology researchers, research and education organizations, and semiconductor and RF device design and development departments. Built-in pattern generation capabilities simplify simulating serial data patterns when testing devices to characterize their performance when operated under sub-optimal conditions.

Series 3400 instruments offer users some important performance advantages over some of the best-selling pulse/pattern generators on the market, including:

- Clean transient response
- Less edge-to-edge jitter
- Simpler user interface
- Easier integration into existing test and measurement systems

To explore further, download the Series 3400 data sheet from **www.keithley.com/nano**.

Visit our online nano resource to discover what you've been missing

We've compiled all our nanotechnology resources in one convenient location: www.keithley.com/nano. There, you'll discover our growing library of low level measurement white papers, application notes, articles, and other literature. Even if you've visited our site previously, we encourage you to revisit it often because we're constantly developing and posting new materials on this topic. While there, you may want to request a copy of our ***Nanotechnology Measurement Handbook: A Guide to Electrical Measurements for Nanoscience Applications***. It is useful both as a reference and as an aid to understanding low level phenomena observed in the lab. It provides an overview of the theoretical and practical considerations involved in measuring low currents, high resistances, low voltages, and low resistances.

Talk to Keithley

There's a Keithley applications engineer ready with advice on configuring a test system tailored to your low current sourcing or measurement application. Call us toll free at **1-888-KEITHLEY (534-8453)** (US only) or call your local Keithley sales office (listed below) and ask to speak with one of our low level instrumentation specialists.

Visit www.keithley.com/nano to learn how to make measurements suited for nanotechnology applications.

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