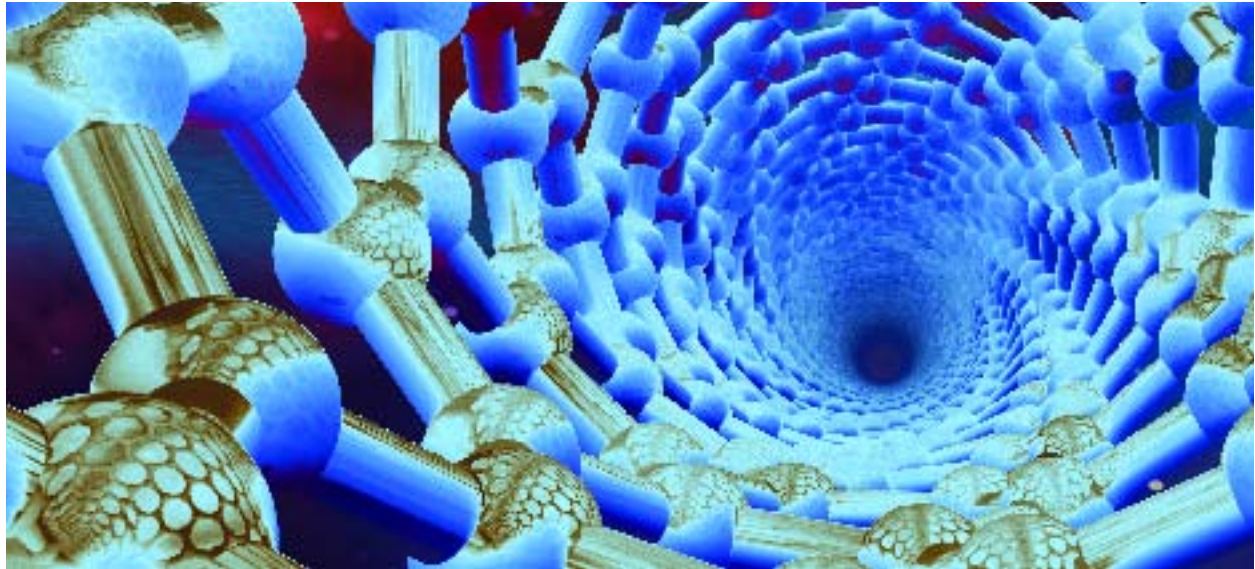


**Discover Today's Solutions for Tomorrow's**  
Nano Characterization Challenges

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.

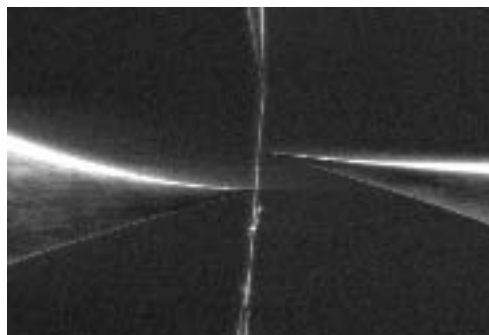


## What kinds of measurement challenges do your nanotechnology applications present?

Nanotechnology research is advancing so rapidly that many scientists find that their existing measurement tools simply lack the sensitivity or resolution needed to characterize low level signals effectively. Others are scrambling to keep up with the rapid changes in measurement requirements that new discoveries create. No matter which challenge you're facing, Keithley can help.

### Need wider ranges for your nanoscale materials research?

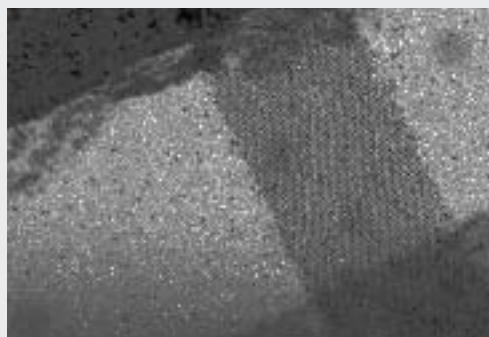
Understanding how building block materials like nanocrystals, nanotubes, nanowires, and nanofibers will perform in tomorrow's electronics demands instrumentation that can characterize resistance and conductivity over wide ranges. Keithley combines all the necessary sourcing and measurement tools into a variety of easy-to-use test solutions. Many are designed for easy integration with other instruments to extend system ranges and capabilities even further.



A four-wire connection to a carbon nanotube. Image reproduced here courtesy of Zyvex Corporation.

### Experimental nanostructures can't take the heat?

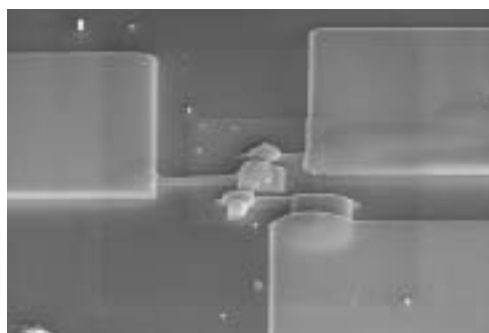
During device development, structures like single electron transistors (SETs), sensors, and other experimental devices often display unique properties. Characterizing these properties without damaging one-of-a-kind structures requires systems that provide tight control over sourcing to prevent device self-heating. Keithley instrumentation combines this tight control with exceptional measurement speed and sensitivity in flexible, modular architectures that make it easy to adapt to changing test requirements.



A device formed by an array of gold nanoparticles. Photo courtesy of K. Elteto and X.M. Lin, the University of Chicago.

### Preparing to make the leap into production?

Our growing line of I-V characterization tools can help you make the jump from the lab into commercial production sooner. Their wide sourcing and measurement ranges allow you to study how next-generation nanoelectronics like carbon nanotube field-effect transistors (CNTFETs), SETs, and other exotic devices will perform under a variety of conditions.



TiO<sub>2</sub> nanotube image courtesy of Dr. Jiyoung Kim, University of Texas at Dallas

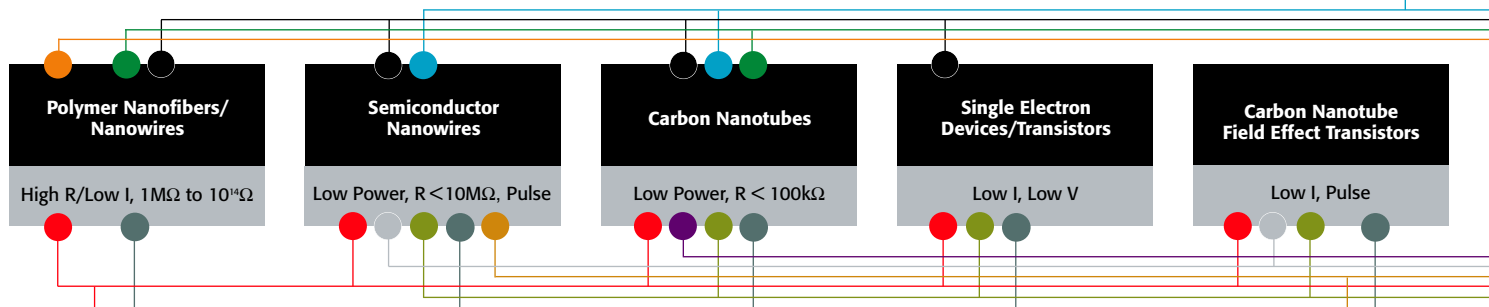
**Visit [www.keithley.com/nano](http://www.keithley.com/nano) to learn more about why we're leading the industry in the development of measurement solutions for nanotechnology research and production test.**

# 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.**



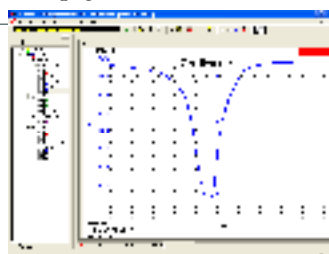
## Want multiple channels of sourcing and measurement?

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.**

### Studying highly resistive nanowires?

The **Model 6430 Sub-Femtoamp Remote SourceMeter®** instrument's low noise and drift performance make it ideal. It measures currents with 400aA ( $400 \times 10^{-18}$ A) sensitivity. **Learn more on page 12.**



### Trying to characterize high resistance nanomaterials?

The **Model 6517A Electrometer/High Resistance Meter's** built-in 1kV source, 200TΩ input resistance, and low current sensitivity make it an ideal solution. **Learn more on page 15.**



### Want low current measurements without the high price tag?

With  $<200\mu\text{V}$  burden voltage, the cost-effective **Model 6485 Picoammeter** ensures accurate low current measurements, even in circuits with very low source voltages. The **Model 6487 Picoammeter/Voltage Source** adds a 500V bias source for high resistance and resistivity measurements. **Learn more on page 16.**



#### Nanobatteries

Low I, Low Power

#### Nanophotonics

Low I, Pulse

#### Synthesized Molecular Electronics/Wires

Low I, Low Power

#### Nanosensors & Arrays

Low I, Low V

#### Thermal Transport

Low I, Low Power, Pulse

### Troubled by overheating problems?

The **Model 4200-PIV Option** for the Model 4200-SCS combines a pulse generator, an oscilloscope, a specialized interconnect, and powerful software to control pulse IV testing of devices with self-heating issues. **Learn more on page 8.**



### Testing lots of devices?

**Series 2600 System SourceMeter®** instruments let you make precision DC, pulse, and low frequency AC source-measure tests quickly, easily, and economically. They offer virtually unlimited flexibility to scale the system's channel count up or down to match changing application needs. **Learn more on page 17.**



### Looking for just a single channel?

Each **Series 2400 SourceMeter** instrument is a complete, single-channel DC parametric tester. Choose from a variety of ranges and functions to suit specific application needs. The Model 2430 can be programmed to produce individual pulses or pulse trains up to 5ms wide. **Learn more on page 18.**

### Want to characterize nanoscale RF components?

Our **Series 2800 Vector Signal Analyzers** and **Series 2900 Vector Signal Generators** offer an ideal combination of solutions for characterizing RF components such as nano-oscillators, nanofilters, and nanotransistors. **Learn more on page 19.**



To discuss how we can work with you to configure a solution for a specific nanotechnology application, contact Keithley's Applications Engineering department and ask to speak with one of our nano measurements experts. In the U.S., call us toll free at 1-888-KEITHLEY (534-8453). Or contact one of the sales offices listed on the back cover for guidance.

# 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



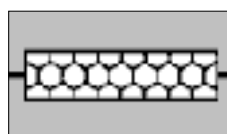
## Explore nanotechnology applications

With 16 Interactive Test Modules (ITMs) for characterizing the seven most common nanodevice structures, the sample project and sample tests included in the Model 4200-SCS bring together the capabilities you need to create powerful nanotech R&D software applications. They can help you to focus on your research by slashing the time needed to develop new applications or to refine them as new test requirements emerge. 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.



### Supported nanodevices and their associated Interactive Test Modules:

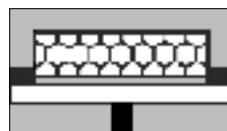
- Carbon Nanotube
  - I-V characteristics
- BioComponent
  - I-V characteristics
- Carbon Nanotube FET
  - +Drain Voltage vs. Drain Current
  - -Drain Voltage vs. Drain Current
  - Linear Threshold Voltage Sweep
  - Gate Voltage vs. Drain Current
  - Sub-Threshold Voltage Sweep
  - Threshold Voltage Max GM Sweep
  - Gate Leakage vs. Voltage Sweep
- Nanowire
  - Low Resistance Nanowire Sweep
  - Low Resistance Nanowire Differential Conductance Sweep
  - High Resistance Nanowire Sweep
  - High Resistance Nanowire Differential Conductance Sweep
- Molecular Wire
  - Current, Conductance vs. Voltage I-V Sweep
- Molecular Transistor
  - Drain Voltage vs. Drain Current Sweep
- Multi-Pin Nanocell
  - Input/Output Characteristics Sweep



Carbon Nanotube



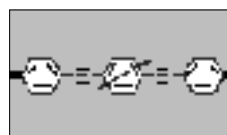
BioComponent



Carbon Nanotube FET



Nanowire



Molecular Wire



Molecular Transistor

**Learn more by downloading “I-V Measurements of Nanoscale Wires and Tubes with the Model 4200-SCS and Zyvex S100 Nanomanipulator” at [www.keithley.com/nano](http://www.keithley.com/nano).**

# 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

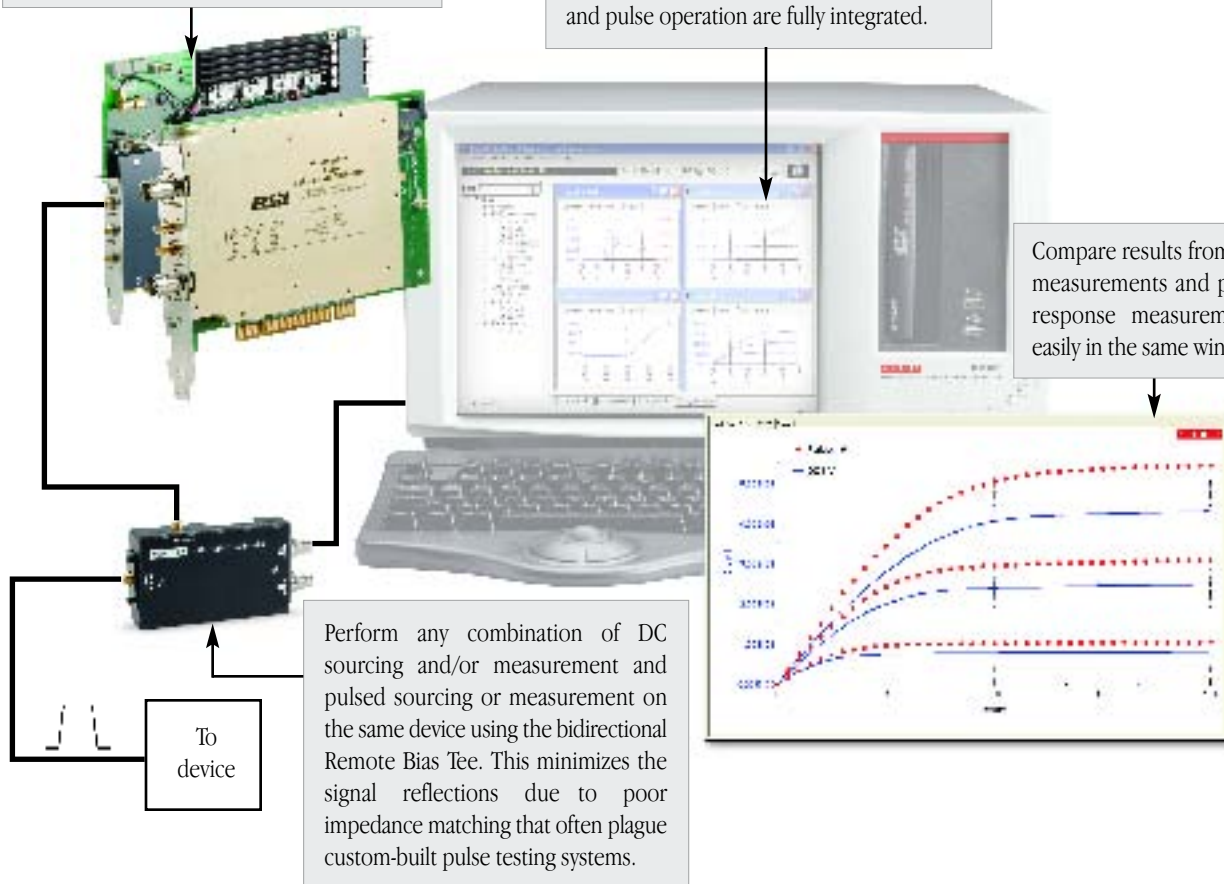
Now, incorporating a pulse I-V characterization system into your nano lab is no longer a "do-it-yourself" project or a major strain on the capital equipment budget. Our new 4200-PIV bundle is a comprehensive package of hardware and software (including patent pending cable and load-line compensation utilities), 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.

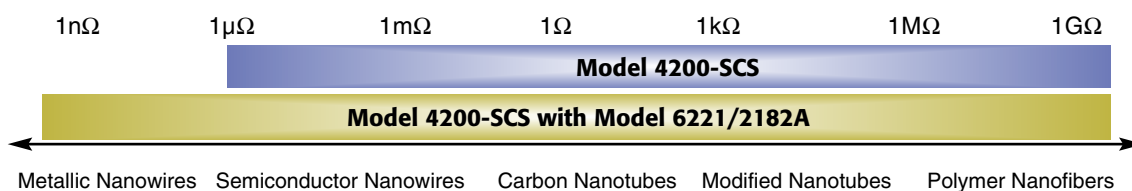
Compare results from DC measurements and pulse response measurements easily in the same window.





## Model 6221/2182A AC+DC Current Source/ Nanovoltmeter Combination

These instruments are natural measurement partners for applications such as characterizing nanotubes and nanowires. The Model 6221 current source can produce current pulses as short as  $5\mu\text{s}$  when used as a stand-alone pulse source or as short as  $50\mu\text{s}$  when used with the Model 2182A. This high speed pulsing capability reduces the power dissipated in the device, minimizing device self-heating and preventing device damage. The Model 2182A nanovoltmeter combines low noise, thermoelectric EMF cancellation, fast measurement rates, and 2ppm accuracy. When linked together and operated in pulse mode, the current source configures the nanovoltmeter over the RS-232 interface, controls it through the Trigger Link interface, and then automatically retrieves the data for calculation.

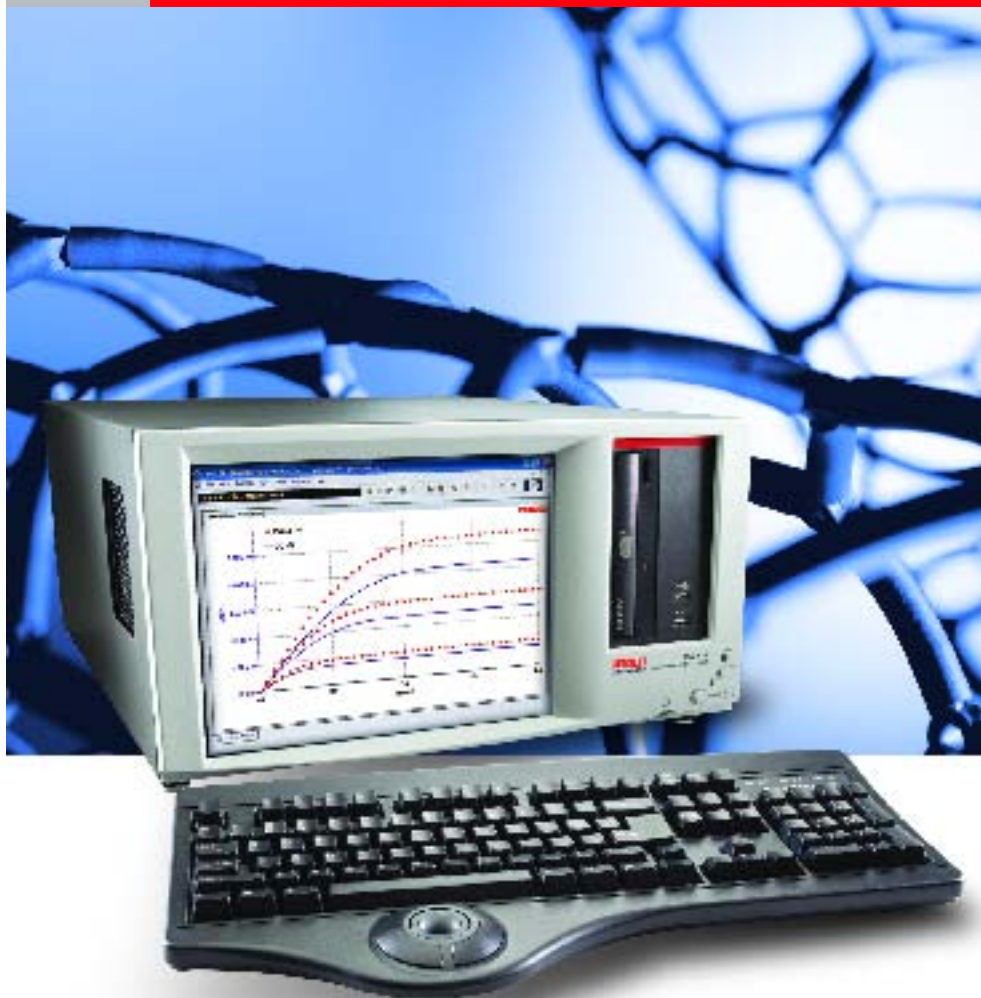


## Series 3400 Pulse/Pattern Generators



Voltage pulsing can produce much narrower pulse widths than current pulsing, so it's often used in experiments such as thermal transport, in which the timeframe of interest is shorter than a few hundred nanoseconds. High amplitude accuracy and programmable rise and fall times are necessary to control the amount of energy delivered to a nanodevice. Series 3400 Pulse/Pattern Generators can simplify simulating serial data patterns for use in testing devices to characterize their performance when operated under sub-optimal conditions like low supply voltage, propagation delay, and slow edge slew.

Both the single-channel Model 3401 and the dual-channel Model 3402 can output voltage pulses with pulse widths as short as 3ns, with independently adjustable rise and fall times. The Model 3402's dual outputs allow tight synchronization of pulses to multi-pin devices. For applications that require generating multi-step pulses, the Series 3400 makes it easy to combine multiple channels, with fully independent control over each channel. Trigger outputs simplify synchronizing the operation of multiple units.



- 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."*

## Model 4200-SCS Semiconductor Characterization System

### Options that Expand the Model 4200-SCS's Applications

A variety of hardware options integrate directly into the Model 4200-SCS chassis. They can be purchased as upgrades to existing systems or as options for new systems.

**Pulse I-V Package:** The optional Pulse I-V package provides dual-channel pulse generation and measurement. Pulsed I-V testing offers a new approach to characterization testing. Its high speed pulses allow you to characterize materials and devices in nano applications.

**Dual-Channel Pulse Generator:** The optional integrated dual-channel pulse generator adds pulsing to the Model 4200-SCS's DC source and measure

capabilities. It supports voltage pulses as short as 20ns in high speed mode or up to +20V (into 50 $\Omega$ ) in high voltage mode. With two pulse generators on one card, you have the flexibility to apply pulses to two points on a device under test, such as the gate and the drain, simultaneously.

**Dual-Channel Digital Oscilloscope:** The optional dual-channel digital oscilloscope integrates more than the performance of a bench-top oscilloscope into your 4200-SCS. It also supports time-domain measurements of pulse waveforms and monitors the reactions of devices under test to those pulses. Some of the features of this oscilloscope include: a broad selection of acquisition modes, triggers, measurements, calculations, and up to four reference waveforms.

## Integrated C-V Option Speeds and Simplifies Device and Materials Characterization

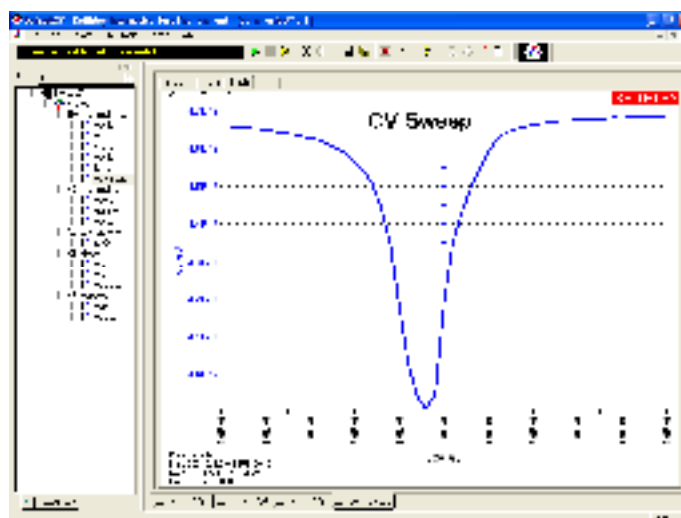
The Model 4200-CVU Integrated C-V Option is designed for integration with the Model 4200-SCS, so it brings together DC I-V, C-V, and pulse testing capabilities in one easy-to-use tool that can support all of a lab's characterization, modeling, and reliability testing needs.

### Now, C-V is as simple as I-V

When combined with the Model 4200-SCS's intuitive point-and-click interface and powerful Keithley Interactive Test Environment (KITE), the Model 4200-CVU and its supporting software make C-V tests as easy to set up and run as I-V tests. The system's flexible, powerful test execution engine makes it simple to combine I-V, C-V, and pulsed tests into the same test sequence, so the Model 4200-SCS can replace a variety of electrical test tools with a single, tightly integrated characterization solution.

### Powerful C-V test libraries and parameter extraction examples

There's much more to the Model 4200-CVU than hardware and interface software. By building on decades of experience in C-V test technology, Keithley is backing up the Model 4200-CVU with an extensive set of sample programs, test libraries, and built-in parameter extraction examples. The sample tests included range from simple capacitance measurements to capacitance vs. frequency sweeps. Parameter extraction algorithms such as doping profiles and oxide thickness are provided ready to run right out of the box. The open source code for these algorithms is included, allowing easy user customization.





## 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
- $>10^{15}\Omega$  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 Current/High Resistance Measurements



## New sources simplify device characterization

Model 6220 DC current source

Model 6221 AC and DC current source

The Model 6220 DC Current Source and the Model 6221 AC and DC Current Source combine ease of use with exceptionally low current noise. Low current sourcing is critical to applications in test environments ranging from R&D to production, especially in the semiconductor, nanotechnology, and superconductor industries. High sourcing accuracy and built-in control functions make the Models 6220 and 6221 ideal for applications like Hall measurements, resistance measurements using delta mode, pulsed measurements, and differential conductance measurements.

The Model 6221 is the only AC current source on the market and provides better accuracy, consistency, reliability, and robustness than the homemade solutions that were previously necessary. The Model 6221 is also the only commercially available current source waveform generator, which greatly simplifies creating and outputting complex waveforms.

For many applications, the Model 6220 or 6221 can be combined with the Model 2182A low voltage, low resistance nanovoltmeter to create a powerful source and measure system. This combination is easy to use because the two instruments can be treated as a single instrument. Their simple connections eliminate the isolation and noise current problems that plague other options. Working together, the Model 6220/6221 and the Model 2182A are the most complete solution for differential conductance measurements. They are also the fastest, providing 10× the speed and lower noise than other options. The 622x/2182A combination also performs the new three-step delta technique, which eliminates errors due to changing thermoelectric voltages, and provides pulsed resistance and pulsed I-V measurements down to 50μs.



- **Low DC current range:** 2nA to 100mA (full scale)
- **Extremely low current noise:** down to 400fA p-p
- **RS-232, GPIB, Trigger Link, Digital I/O, and Ethernet (6221 only)**
- **Reconfigurable triax output simplifies matching the application's guarding requirements**
- **Model 220 programming compatibility mode**
- **Versatile example software**

### 6221 only:

- **AC current range:** 1pA to 100mA
- **Very short pulse widths:** less than 5μs
- **Frequency range:** 1mHz to 100kHz
- **Arbitrary waveform generator**

### 6220/6221 with 2182A

- **Measurement range:** 10nΩ to 100MΩ
- **Differential conductance mode:** 10× faster and lower noise than other solutions
- **Delta mode:** improves resistance measurements up to 1000×
- **Pulse mode (6221 only):** coordinated pulse and measurement down to 50μs
- **Easy to set up, easy to use (push two buttons)**

To read "Low-Level Pulsed Electrical Characterization with the Model 6221/2182A Combination," visit [www.keithley.com/nano](http://www.keithley.com/nano).

## 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 50 $\mu$ s with Model 6221
- Differential conductance with Model 6220 or 6221
- Resistances from 10n $\Omega$  to 100M $\Omega$
- Thermocouple temperatures from -200°C to 1820°C

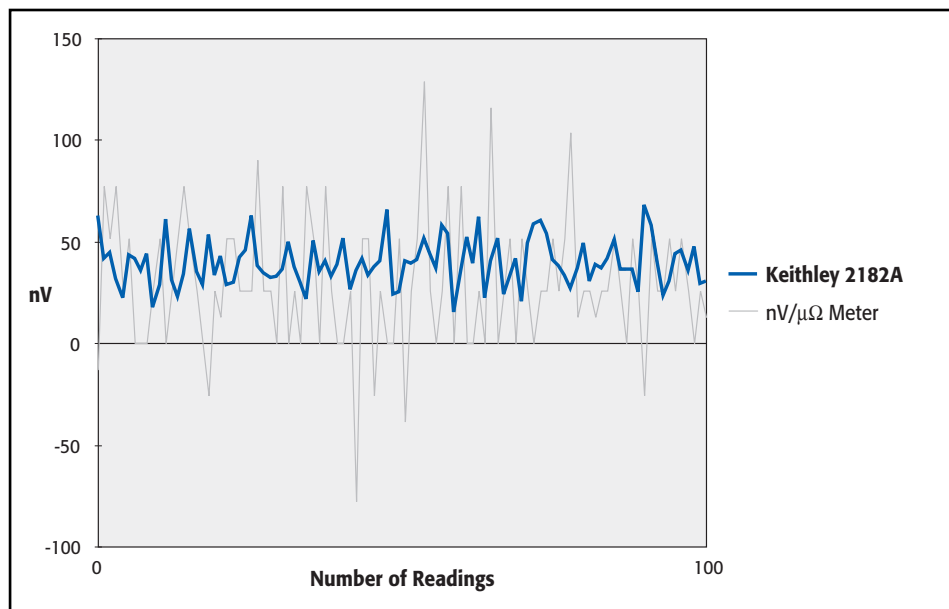
- Dual channels support measuring voltage, temperature, or the ratio of an unknown resistance to a reference resistor

- 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

# The ultimate tool for measuring low currents and high resistances

## Model 6517A electrometer/high resistance system



The Model 6517A Electrometer/High Resistance Meter combines exceptional accuracy and sensitivity with a variety of features that simplify measuring high resistances and the resistivity of insulating materials. With reading rates of up to 125 readings/second, it's also significantly faster than competitive electrometers. The Model 6517A's low current input amplifier has an input bias current of  $<3\text{fA}$  with just  $0.75\text{fA}$  p-p (peak-to-peak) noise and  $<20\mu\text{V}$  burden voltage on the lowest range. The input impedance for voltage and resistance measurements is  $200\text{T}\Omega$ , for near-ideal circuit loading. These specifications give the Model 6517A the accuracy and sensitivity needed for accurate low current and high impedance voltage, resistance, and charge measurements. A built-in  $\pm 1\text{kV}$  voltage source with a sweep capability simplifies leakage, breakdown, and resistance testing, as well as volume ( $\Omega\text{-cm}$ ) and surface resistivity ( $\Omega/\text{square}$ ) measurements on insulating materials.

Several instrument features help ensure the accuracy of high resistance measurement applications. For example, the built-in voltage source simplifies determining the relationship between an insulator's resistivity and the level of source voltage used. It is well suited for capacitor leakage and insulation resistance measurements, tests of the surface insulation resistance of printed circuit boards, voltage coefficient testing of resistors, and diode leakage characterization. A built-in test sequence incorporates a voltage reversal method for measuring very high resistances, especially in materials and devices where the inherent background currents in the sample once made accurate measurements impossible.



**Model 6521 and 6522 10-Channel Scanner Cards.** Plug either of these cards into the Model 6517A's back panel option slot for multipoint low current testing.

- Measures
  - Currents from  $1\text{fA}$  to  $20\text{mA}$
  - Voltages from  $10\mu\text{V}$  to  $200\text{V}$
  - Resistances up to  $10^{16}\Omega$
  - Charges from  $10\text{fC}$  to  $2\mu\text{C}$
- Simple, DMM-like interface
- $<20\mu\text{V}$  burden voltage on the lowest current ranges
- $200\text{T}\Omega$  input impedance
- $<3\text{fA}$  bias current
- $0.75\text{fA}$  p-p noise
- Built-in  $\pm 1\text{kV}$  source



**The Model 65 High Resistivity Measurement Package** includes the Model 6517A and Model 6524 software, which simplifies operating the 6517A via a computer controller and helps in optimizing the test parameters (delay time, voltage, etc.) for the specific material or device under test. The package also includes the Model 8009 Resistivity Test Fixture and all meter and fixture cables.

Want to learn more? Read "Achieving Accurate and Reliable Resistance Measurements in Low Power and Low Voltage Applications," available at [www.keithley.com/nano](http://www.keithley.com/nano).

## 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



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.

- 20fA lowest noise
- 5½-digit resolution
- <200μV burden voltage
- Alternating Voltage method ohms measurements
- Automated voltage sweeps for I-V characterization up to 10<sup>15</sup>Ω
- 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

#### 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<sup>15</sup>Ω
- 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



Measure low currents with  
1fA resolution with  
our newest  
Series 2600 instruments



- Combines a precision power supply, true current source, DMM, arbitrary waveform generator, V or I pulse generator with measurement, electronic load, and trigger controller—all in one instrument
- TSP-Link™ master/slave connection seamlessly integrates multiple Series 2600 SourceMeter channels into a system that can be programmed and controlled as a single instrument
- Free Test Script Builder software simplifies creating powerful test scripts for programming custom test functions
- Free LabTracer™ 2.0 software provides curve tracing and fast, easy startup

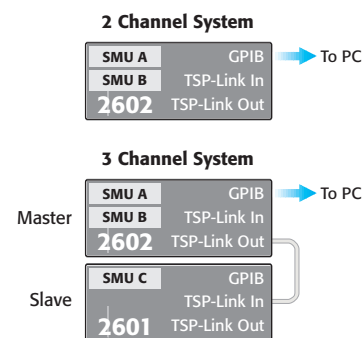
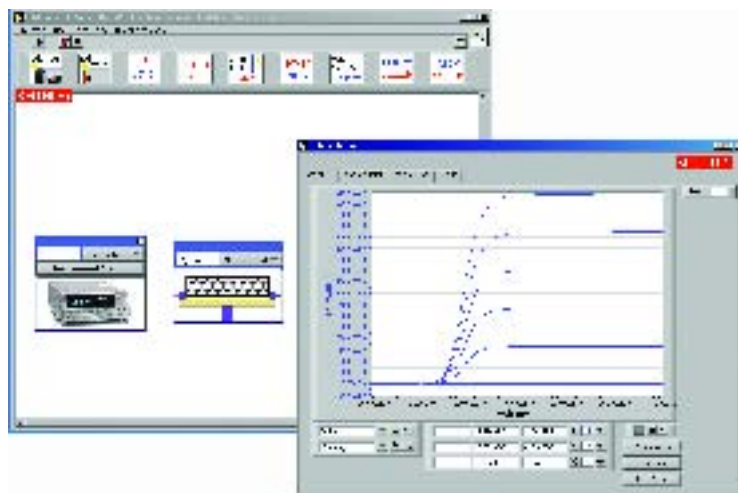
## Scalable solutions for high speed R&D and functional testing

### Series 2600 System SourceMeter® multi-channel I-V test solutions

The Series 2600 System SourceMeter instruments provide high speed source-measure capability plus advanced automation features and time-saving software tools, making them ideal solutions for I-V testing of a wide range of devices.

Each System 2600 combines all this functionality in one compact unit: precision power supply, true current source, digital multimeter, arbitrary waveform generator, V or I pulse generator, and electronic load and trigger controller.

Free LabTracer™ 2.0 software makes it simple to configure and control up to eight Series 2600 or 2400 SourceMeter channels for curve tracing or device characterization with a simple GUI for setup, control, data acquisition, and graphing of DUT data. Drop-down menus in the instrument setup window allow configuring any SourceMeter channel for fixed point or sweeping operation. No programming is required.



TSP-Link, a high speed system expansion interface, makes it easy to scale the system's channel count to match the application.

For further reading, download "Nanoscale Device and Material Electrical Measurements," from [www.keithley.com/nano](http://www.keithley.com/nano).



- Family of products offers wide dynamic range: 10pA to 10A, 1 $\mu$ V to 1100V, 20W to 1000W
- 4-quadrant operation
- 0.012% basic accuracy with 5½-digit resolution
- 6-wire  $\Omega$  measurement with programmable I source and V clamp
- 1700 readings/second at 4½ digits via GPIB
- Built-in comparator for fast pass/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](http://www.keithley.com/nano).

## Characterize nanoscale RF components

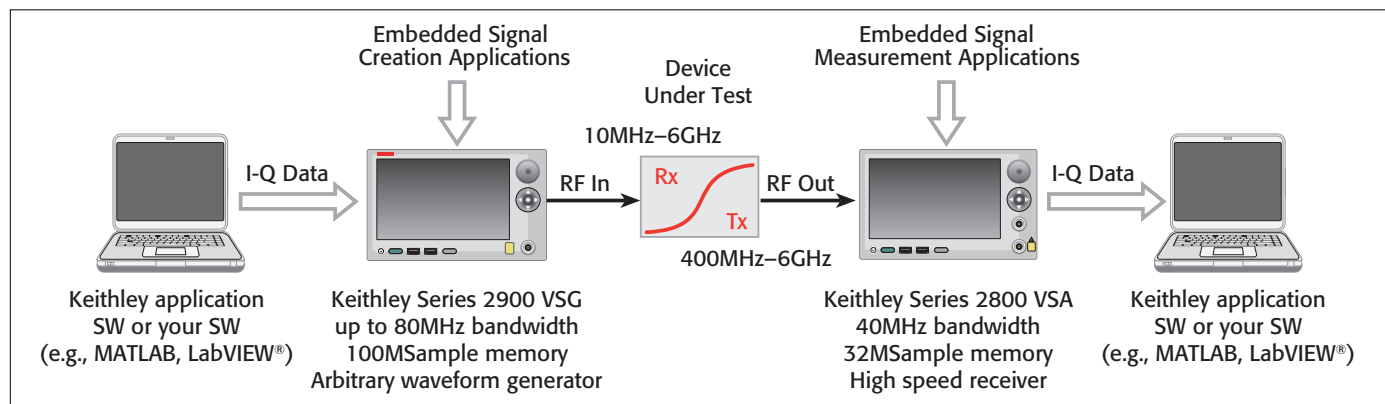


- **New Series 2900 RF Vector Signal Generators** with signal generation frequencies from 10MHz to 6GHz
- **New Series 2800 RF Vector Signal Analyzers** with 40MHz of measurement capture bandwidth as standard in 2.5GHz, 4GHz or 6GHz models
- **High speed embedded DSP measurements technology** for GSM, EDGE, W-CDMA, WLAN, and even the industry's most demanding signal, 802.11n MIMO with 40MHz of bandwidth
- **Patented single down/up conversion and digital processing techniques** reduce cost while maintaining performance

- Get flexible and fast remote connectivity with LAN (LXI), USB, and GPIB interfaces.
- Boost test speed with embedded DSP measurement technology.
- Apply 40MHz of bandwidth (or optional 80MHz arbitrary waveform generator bandwidth with 100M Samples of waveform memory option in the Model 2920) to test a vast array of commercial communications signals.
- Reduce cost while maintaining performance with patented single down/up conversion and digital processing techniques

Keithley's Series 2900 Vector Signal Generators and Series 2800 Vector Signal Analyzers can open a new world of nanoscale RF characterization capabilities. These rapidly expanding families of instruments combine state-of-the-art RF test signals with high accuracy and excellent repeatability, allowing you to switch frequencies, amplitudes, or modulation types rapidly, for more efficient device characterization. They simplify testing a wide range of wireless devices economically by generating and analyzing signals compatible with an array of RF communications standards. The Software-Defined Radio (SDR), DSP-based architecture on which Series 2900 instruments are built allows them to generate

virtually any RF signal with up to 80MHz of modulation bandwidth, without the need for hardware upgrades. This exceptional bandwidth provides the high signal generation flexibility that R&D applications demand. Series 2800 instruments, also based on SDR architecture, offers 40MHz bandwidth, which ensures its ability to measure today's RF signals and its flexibility to handle tomorrow's, too. As new wireless standards emerge, both instrument families are engineered for easy upgrades, which extend their useful lives and provide ongoing return on investment far longer than traditional instruments.



**Keithley's Series 2900 RF Vector Signal Generators and Series 2800 RF Vector Signal Analyzers are engineered for operating versatility. Use built-in applications or download I-Q waveform data from a connected PC and upload signal waveforms.**

For further information, such as related white papers, presentations and more, go to  
[www.keithley.com/rf](http://www.keithley.com/rf).

# 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](http://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](http://www.keithley.com/nano) to learn how to make measurements suited for nanotechnology applications.

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# KEITHLEY

A G R E A T E R M E A S U R E O F C O N F I D E N C E

KEITHLEY INSTRUMENTS, INC. ■ 28775 AURORA ROAD ■ CLEVELAND, OHIO 44139-1891 ■ 440-248-0400 ■ Fax: 440-248-6168 ■ 1-888-KEITHLEY ■ [www.keithley.com](http://www.keithley.com)

### BELGIUM

Sint-Pieters-Leeuw  
Ph: 02-3630040  
Fax: 02-3630064  
[info@keithley.nl](mailto:info@keithley.nl)  
[www.keithley.nl](http://www.keithley.nl)

### ITALY

Peschiera Borromeo(Mi)  
Ph: 02-5538421  
Fax: 02-55384228  
[info@keithley.it](mailto:info@keithley.it)  
[www.keithley.it](http://www.keithley.it)

### CHINA

Beijing  
Ph: 8610-82255010  
Fax: 8610-82255018  
[china@keithley.com](mailto:china@keithley.com)  
[www.keithley.com.cn](http://www.keithley.com.cn)

### JAPAN

Tokyo  
Ph: 81-3-5733-7555  
Fax: 81-3-5733-7556  
[info.jp@keithley.com](mailto:info.jp@keithley.com)  
[www.keithley.jp](http://www.keithley.jp)

### SWEDEN

Solna  
Ph: 08-50904600  
Fax: 08-6552610  
[sweden@keithley.com](mailto:sweden@keithley.com)  
[www.keithley.com](http://www.keithley.com)

### FINLAND

Espoo  
Ph: 09-88171661  
Fax: 09-88171662  
[finland@keithley.com](mailto:finland@keithley.com)  
[www.keithley.com](http://www.keithley.com)

### KOREA

Seoul  
Ph: 82-2-574-7778  
Fax: 82-2-574-7838  
[keithley@keithley.co.kr](mailto:keithley@keithley.co.kr)  
[www.keithley.co.kr](http://www.keithley.co.kr)

### SWITZERLAND

Zürich  
Ph: 044-8219444  
Fax: 044-8203081  
[info@keithley.ch](mailto:info@keithley.ch)  
[www.keithley.ch](http://www.keithley.ch)

### FRANCE

Saint-Aubin  
Ph: 01-64532020  
Fax: 01-60117726  
[info@keithley.fr](mailto:info@keithley.fr)  
[www.keithley.fr](http://www.keithley.fr)

### MALAYSIA

Penang  
Ph: 60-4-656-2592  
Fax: 60-4-656-3794  
[chan\\_patrick@keithley.com](mailto:chan_patrick@keithley.com)  
[www.keithley.com](http://www.keithley.com)

### TAIWAN

Hsinchu  
Ph: 886-3-572-9077  
Fax: 886-3-572-9031  
[info.kei@keithley.com.tw](mailto:info.kei@keithley.com.tw)  
[www.keithley.com.tw](http://www.keithley.com.tw)

### GERMANY

Germaring  
Ph: 089-84930740  
Fax: 089-84930734  
[info@keithley.de](mailto:info@keithley.de)  
[www.keithley.de](http://www.keithley.de)

### NETHERLANDS

Gorinchem  
Ph: 0183-635333  
Fax: 0183-630821  
[info@keithley.nl](mailto:info@keithley.nl)  
[www.keithley.nl](http://www.keithley.nl)

### UNITED KINGDOM

Theale  
Ph: 0118-9297500  
Fax: 0118-9297519  
[info@keithley.co.uk](mailto:info@keithley.co.uk)  
[www.keithley.co.uk](http://www.keithley.co.uk)

### INDIA

Bangalore  
Ph: 080-26771071, -72, -73  
Fax: 080-26771076  
[support\\_india@keithley.com](mailto:support_india@keithley.com)  
[www.keithley.com](http://www.keithley.com)

### SINGAPORE

Singapore  
Ph: 65-6747-9077  
Fax: 65-6747-2991  
[koh\\_william@keithley.com](mailto:koh_william@keithley.com)  
[www.keithley.com.sg](http://www.keithley.com.sg)