SOURCE METER

Source Measurement Unit (SMU) Instruments

KEITHLEY

NUBICOM
키슬리 공식 채널파트너

Source Measurement Unit (SMU) Instruments

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Technical Information

Source Measurement Unit (SMU) Instruments

All of Keithley's source measurement unit (SMU) instruments can source voltage while measuring current and source current while measuring voltage. Some also measure resistance. All are fully programmable instruments that can stand alone as complete source, measurement, and automation solutions. They are also easy to integrate into larger systems.

Keithley's SMU instruments are faster, easier to use, and more economical than using individual power supplies and measurement instruments that are harnessed together. Additionally, they provide more accurate and repeatable results. Keithley's SMU instruments are ideal for production and automation, yet precise and sensitive enough for laboratory applications.

Keithley's SMU instruments include our Series 2400 SourceMeter® instruments, Series 2600A System SourceMeter instruments, Model 237 High-Voltage Source-Measure unit, and Model 4200-SCS Semiconductor Characterization System.

How does an SMU instrument work?

SMU instruments can be used as stand-alone constant voltage or constant current sources and as stand-alone voltmeters or ammeters. However, their real strength is their ability to simultaneously source and measure—applying voltage to a device under test (load) and measuring the current flowing through it, or supplying current to a load and measuring the voltage drop across it.

The SMU instrument topology (**Figure 1**) protects the device under test (DUT) from damage due to accidental overloads, thermal runaway, and other problems. Both the current and voltage source are programmable with readback to maximize device measurement integrity. If the readback reaches a programmed compliance limit, then the source is clamped at the limit, providing fault protection.

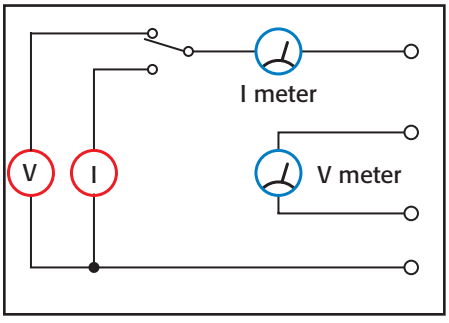


Figure 1. Basic SMU instrument topology

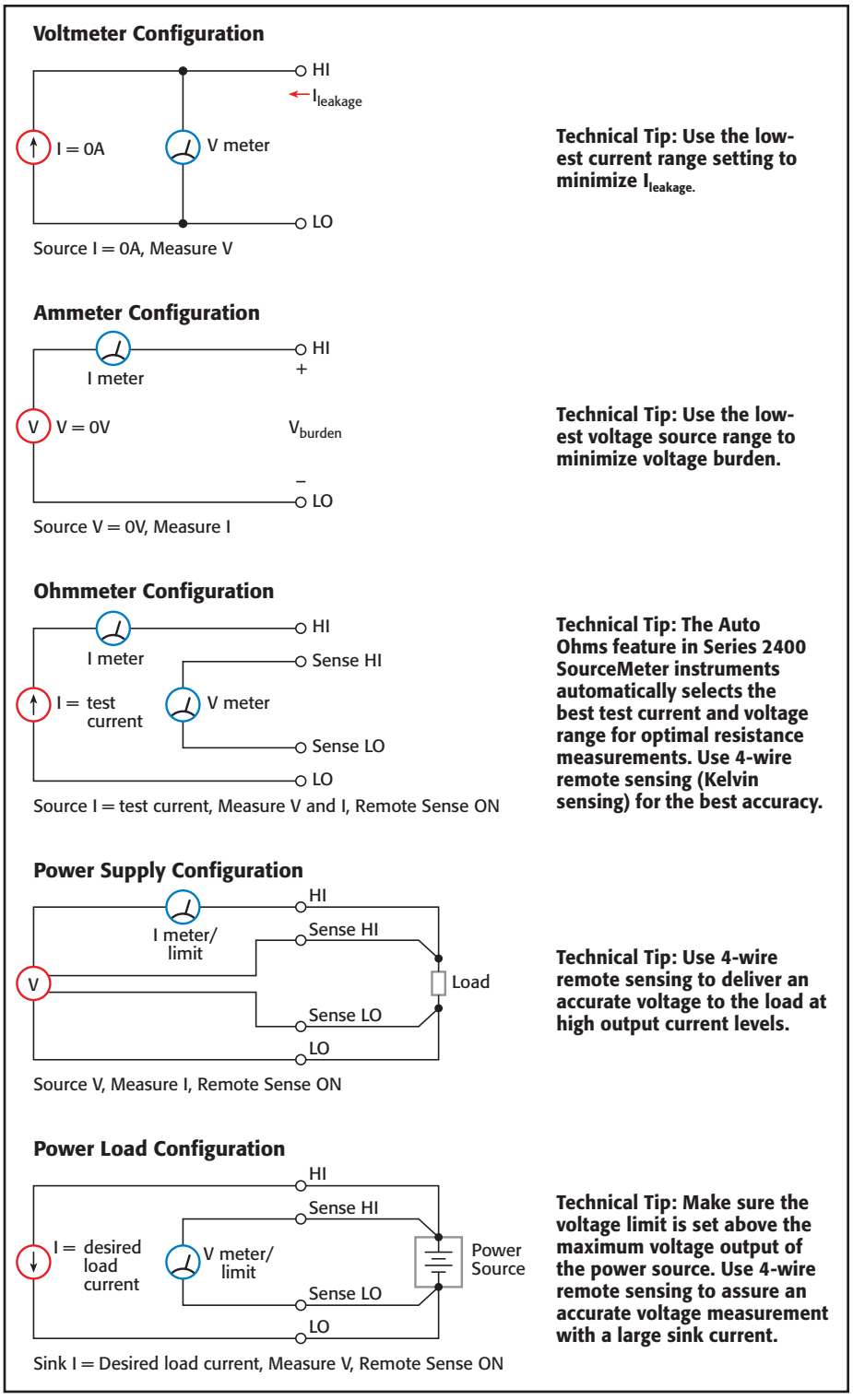


Figure 2. SMU instrument configurations

Source Measurement Unit (SMU) Instruments

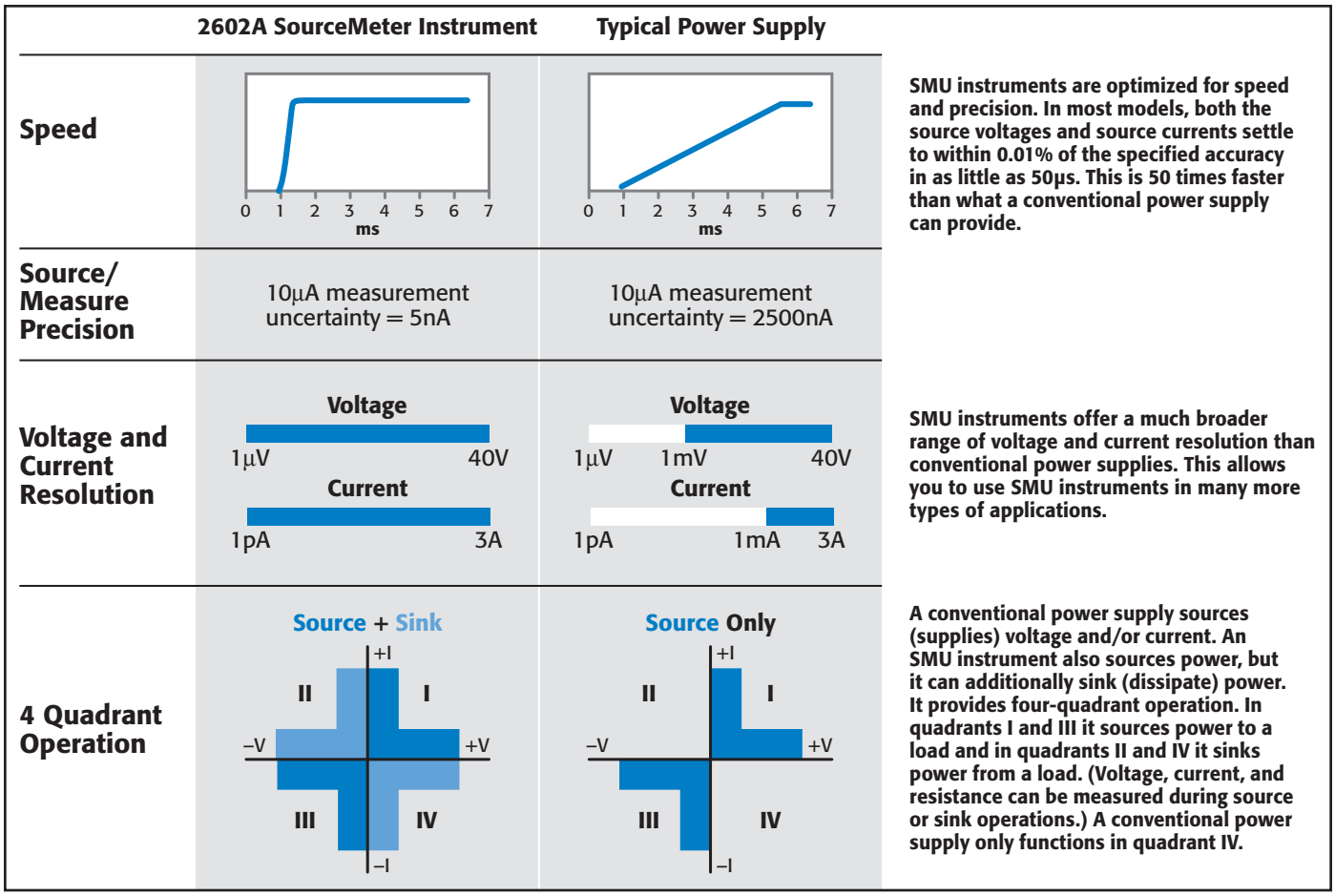


Figure 3. Precision power supplies vs. SMUs

Advantages

Many advantages are achieved by combining source and measurement circuitry into a single unit:

- Supports faster test times with improved accuracy and repeatability
- Allows you to source voltage or current while making time-stamped voltage, current, and resistance measurements without changing connections
- Eliminates many of the complex synchronization, connection, and programming issues associated with using multiple instruments
- Minimizes the time required for test station development, setup, and maintenance
- Lowers the overall cost of system ownership

What are the most popular SMU instrument configurations?

The fully isolated, floating configuration of Keithley's SMU instruments provide maximum flexibility in configuring test setups. SMU instruments can be configured as many different instruments (**Figure 2**). This makes them invaluable tools in flexible product test racks and in R&D test bench tools.

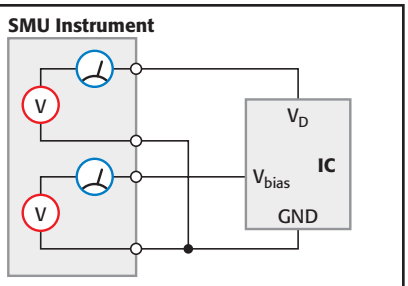
How does an SMU instrument compare to a precision power supply?

The power supply capabilities of Keithley's SMU instruments surpass those provided by conventional power supplies. This is illustrated in **Figure 3**. In addition to the highly stable DC power source, low noise, and readback, Keithley's SMU instruments include other features not usually available on conventional power supplies. For example, most SMU instruments offer a Pulse mode, include programmable delays, and provide a test sequencer that allows you to set up and execute tests without PC intervention. **Figure 4** illustrates a typical precision power supply test that uses an SMU instrument.

I-V characterization

Keithley's SMU instruments are core instruments for I-V characterization tests. Their ability to source voltage while simultaneously measuring current or source current while simultaneously measuring voltage can be combined with both DC and sweep operations to perform measurements such as forward voltage (V_F), reverse leakage, and reverse breakdown voltage (V_B) without changing a single connection to the device under test (**Figure 5**).

Built-in features allow multiple SMU instruments to be synchronized for parametric measure-



Test	Description	Reading
Idd ON (5V)	Power supply current, V_D = 5V, device active	14.294 mA
Idd OFF (5V)	Power supply current, V_D = 5V, device in standby	50.361 nA
Idd ON (3.3V)	Power supply current, V_D = 3.3V, device active	12.871 mA
Idd ON (3.3V)	Power supply current, V_D = 3.3V, device in standby	42.198 nA
I_{IL}	Input leakage current	1.2358 μA

Figure 4. Typical precision power supply tests

ments like threshold voltage, beta, and transconductance. Output interlocks provide controlled access to a test fixture, which is particularly important for the extended voltage range of the Model 237 (up to 1100V). Guarded 4-wire connections provide high quality measurements over a wide range (1fA to 10A).

A family of semiconductor curves can be obtained with just two SMU instruments (**Figure 6**). At each step of base current from SMU1, SMU2 sweeps V_{CE} and measures I_C. An SMU instrument can store data from a sweep in its buffer, thus reducing data transfer time to a computer. A family of curves could also be produced using pulse-sweeps to reduce power dissipation within a device.

Built-In Sweeps

Keithley's SMU instruments simplify capturing the data needed to characterize a wide range of devices with the SMU instruments' built-in pulsed and DC sweeps, including linear staircase, logarithmic staircase, and custom sweeps (**Figure 7**). Sweeps coupled with other throughput enhancements like built-in limit inspection, digital I/O, and a component handling interface are ideal for high speed, nonstop production environments. All sweep configurations can be programmed for single-event or continuous operation.

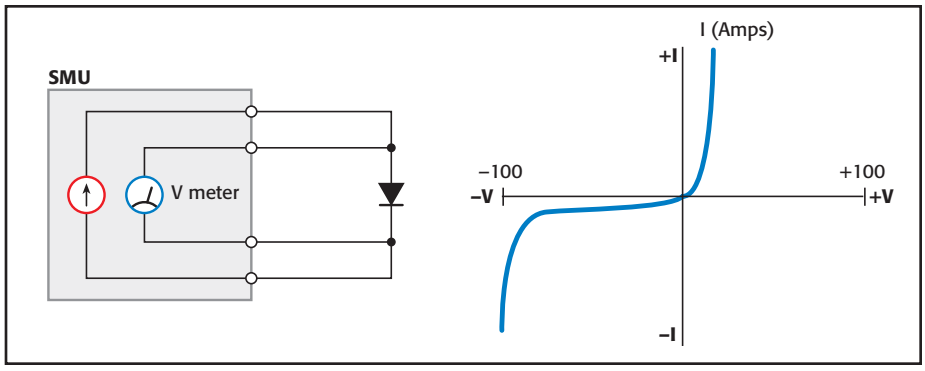


Figure 5. Typical diode characterization

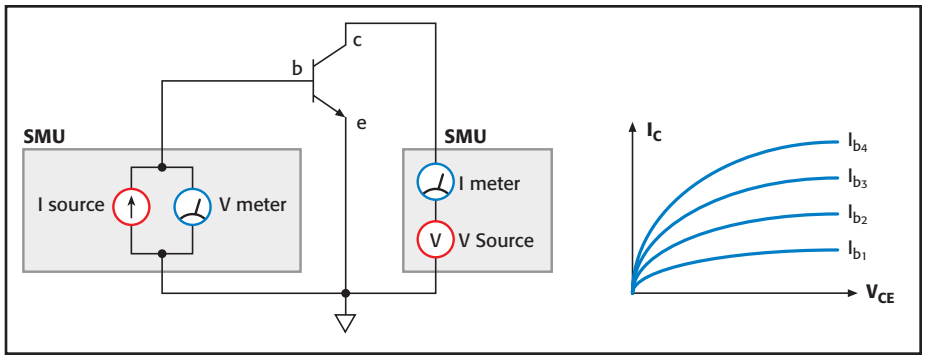


Figure 6. Typical family of curves for transistors

Instrumentation and software solutions for I-V characterization

Figure 8 illustrates various hardware and software solutions for I-V characterization. In the first example, Series 2400 SourceMeter instruments are connected to a PC.

In the second example, Series 2600A SourceMeter instruments are connected to a PC with TSP-Link® technology. TSP-Link technology seamlessly integrates multiple Series 2600A instruments into a single system that can be programmed and controlled as a single instrument through the master 2600A instrument or the PC.

The third example is the Model 4200-SCS Semiconductor Characterization System. This system includes an embedded PC, Windows® operating system, and mass storage. It is a complete DC characterization solution for semiconductor devices and test structures. It supports up to nine SMU modules and provides an array of Windows based software that is so intuitive that even a novice can use the system with ease. This point-and-click software supplies a full range of functionality, including: managing tests, generating reports, automating test sequencing, and creating user libraries. The Model 4200-SCS is a complete one box solution that combines sub-femtoamp resolution with real-time plotting and analysis. Key capabilities include instrument and prober drivers, interfaces to popular modeling/circuit simulation software, and WLR test capabilities.

High-Speed I-V Functional Testing

Keithley's SMU instruments are designed for maximum throughput on the production floor. Each SMU instrument provides high-speed measurements, an internal pass/fail comparator, programmable test sequencing, and digital I/O to control material handlers (**Figure 9**). Single- or multi-point pass/fail testing can be performed on a wide range of components, such as: network devices, circuit protection devices, active discrete devices, and sensors. The onboard pass/fail comparator simplifies high-speed pass/fail tests by avoiding the delay caused by computer and GPIB bus interaction. The buffer memory stores results, again avoiding the computer/GPIB bus interaction delay.

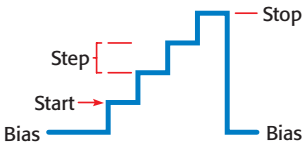
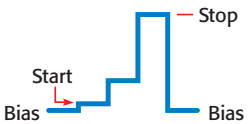
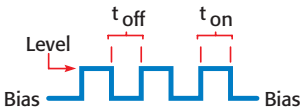
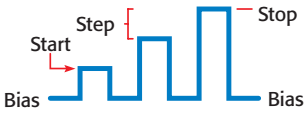
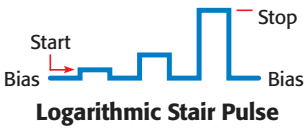
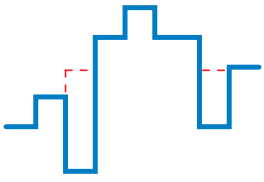
 **Fixed Level**	LEVEL, COUNT (number of DELAY-MEASURE cycles), DELAY, BIAS	**A fixed level sweep outputs a single level of voltage and current with multiple measurements to bias and/or stress devices.**
 **Linear Stair**	START, STOP, STEP, DELAY, BIAS	**The linear staircase sweep goes from the start level to the stop level in equal linear steps.**
 **Logarithmic Stair**	START, STOP, POINTS/DECADE (5, 10, 25, or 50), DELAY, BIAS	**The logarithmic staircase sweep is similar to the linear staircase sweep, but it is done on a log scale with a specified number of steps per decade.**
 **Pulse**	LEVEL, COUNT, t_{on}, t_{off}, BIAS	
 **Linear Stair Pulse**	START, STOP, STEP, t_{on}, t_{off}, BIAS	**Pulsed sweeps greatly reduce the power dissipation within a device, so the effects of temperature (drift, device failure, etc.) are virtually eliminated.**
 **Logarithmic Stair Pulse**	START, STOP, POINTS/DECADE (5, 10, 25, or 50), t_{on}, t_{off}, BIAS	
 **Custom**	Custom sweeps allow the user to program individual steps to create waveforms	**The custom sweep allows you to construct special sweeps by specifying the number of measurement points and the source level at each point.**

Figure 7. Various sweeps supported by SMU instruments.

Technical Information

Source Measurement Unit (SMU) Instruments

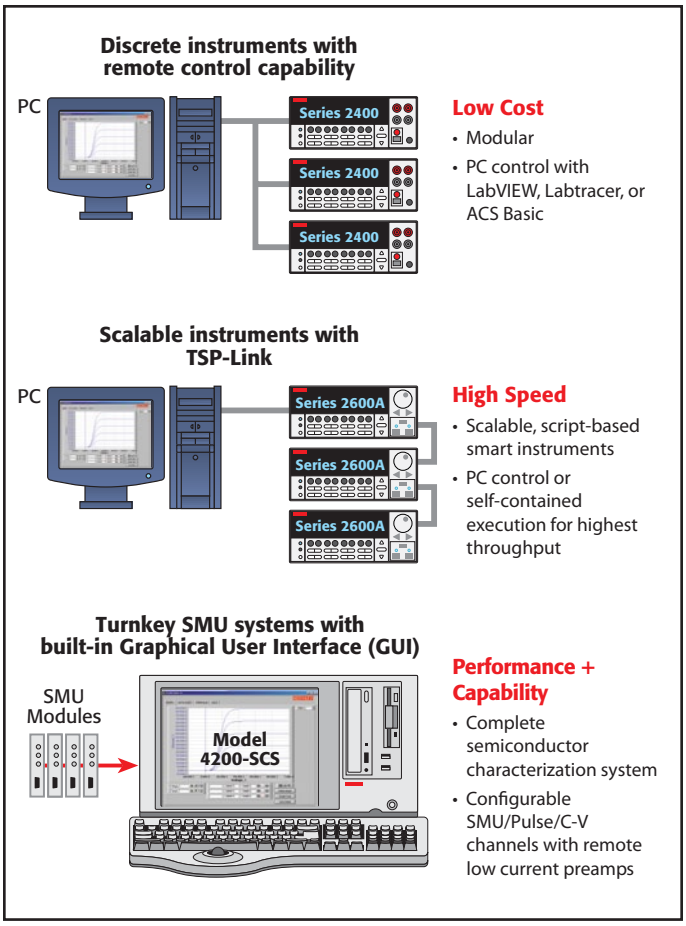


Figure 8. Examples of I-V characterization solutions

Need more test pins?

Keithley's new TSP-Link technology is a high speed interface for system expansion. It allows you to connect a virtually unlimited number of Series 2600A SourceMeter instruments in a master/slave configuration (**Figure 10**). All connected Series 2600A instruments can be programmed and operated under the control of the master instrument. TSP-Link technology provides an easy way to scale your system's channel count up or down to match changing application needs. There is no chassis involved.

In Series 2400 SourceMeter instruments, Trigger Link can be used to coordinate multiple instruments with hardware triggers.

Parallel test capability

Series 2600A instruments support true parallel testing. Each 2600A in a system can run its own test sequences, so the number of devices that can be tested in parallel is equivalent to the number of 2600A instruments in the system. Parallel testing coupled with the 20,000 rdgs/s of each 2600A creates a system that offers extremely high throughput.

Advanced automation for system throughput

Series 2600A TSP® Technology

Any Series 2600A instrument or 2600A-based system can run high speed, embedded test scripts with Test Script Processor (TSP) technology. The test sequence is processed and run on the embedded computer in the instrument, rather than from an external PC controller, so delays due to GPIB traffic congestion are eliminated (**Figure 11**). TSP test scripts allow throughput gains of up to 10x over equivalent PC-based programs controlling the same instruments via GPIB. TSP test scripts can be loaded and run from the front panel or over the system's GPIB interface. A single TSP test script, running on the master 2600A unit, can control all Series 2600A channels and acquire data from any Series 2600A instrument connected to the system with TSP-Link technology.

A Series 2600A-based system can stand alone as a complete measurement and automation solution for semiconductor device or component testing with the master 2600A unit controlling sourcing, measurements, pass/fail decisions, test sequence flow control, binning, the component handler, prober, and much more.

Series 2400 Source-Memory List

The Source-Memory List in Series 2400 SourceMeter instruments is a key feature for production testing. This programmable sequencer lets you set up a complete sequence of up to 100 tests. Each test can contain totally different test conditions, measurements, math, pass/fail, and binning criteria. The tests are executed sequentially without additional external commands. Conditional branching leads to different points on the test list, depending on the results.

The Source-Memory Sweep feature allows you to store up to 100 unique source and measure configurations in nonvolatile memory. This feature makes it possible to sweep through a group of source memory locations and execute a complete test sequence all at one time.

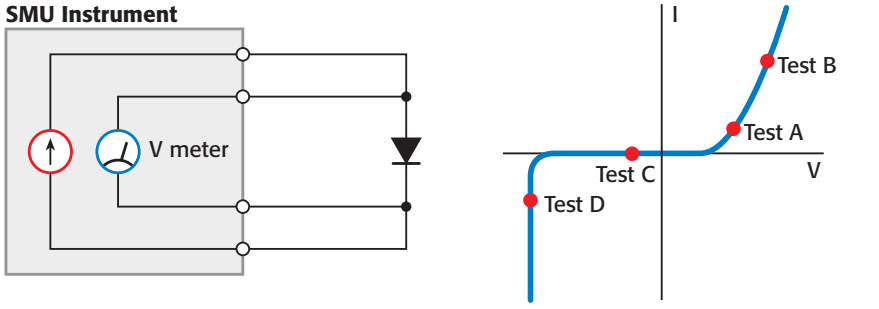
Digital I/O

Digital communication is one of the most common requirements of a production test system because of the need to communicate with handlers, binning equipment, and user controls. The SMU instruments' digital I/O can also be used to interact with racks of instruments to trigger events, start readings, and collect results. Digital triggering and response enable fast and reliable results that are not dependent on the communication bus in use. (Digital I/O is not available on the Model 2401.)

Contact check

The optional Contact Check function eliminates measurement errors and false product failures by verifying good connections to the DUT quickly and easily before testing begins. In just 350μs (Series 2400) or 1ms (Series 2600A), this function's verification and notification routine ensures that you have good contact to a device before sending energy through it and spending time testing it (**Figure 12**). (The Contact Check function is not available on the Model 2401.)

Some of the problems this function can detect while verifying connector, fixture, and test harness integrity are contact fatigue, breakage, contamination, corrosion, loose or broken connections, and relay failures. If a bad contact is detected, it can abort the measurement, protecting the DUT. Three methods of fault notification are provided.



	Pass/Fail Test	Description	Reading	Test Time	If Passes Test	If A Test Fails
Test A	Check Vf(A) at 100mA against pass/fail limits	Forward voltage test at 0.1A	0.6534 V	300 µs	Go to Test B	1. Bin part to bad bin. 2. Transmit data to computer while handler is placing new part. 3. Return to Test A.
Test B	Check Vf(B) at 1A against pass/fail limits	Forward voltage test at 1.0A	0.7268 V	300 µs	Go to Test C	
Test C	Check leakage current, Ir(C), at –10V and test against pass/fail limits	Reverse leakage current at –10V bias	10.122 nA	5 ms	Go to Test D	
Test D	Check Vbr(D)	Breakdown voltage	146.12 V	1 ms	1. Bin part to good bin. 2. Transmit readings to computer while handler is placing new part. 3. Return to Test A.	

Figure 9. Typical high speed I-V functional test

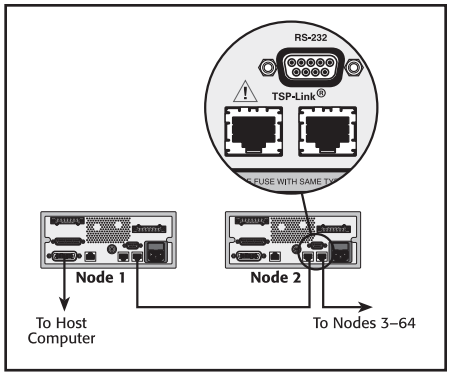


Figure 10. Series 2600A back panel

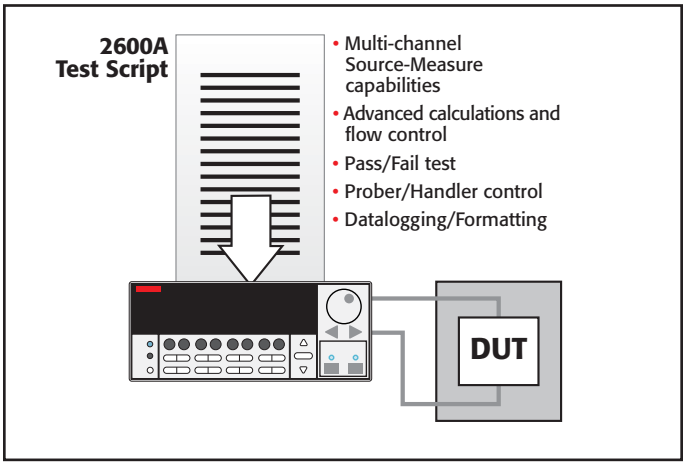


Figure 11. Series 2600A test script

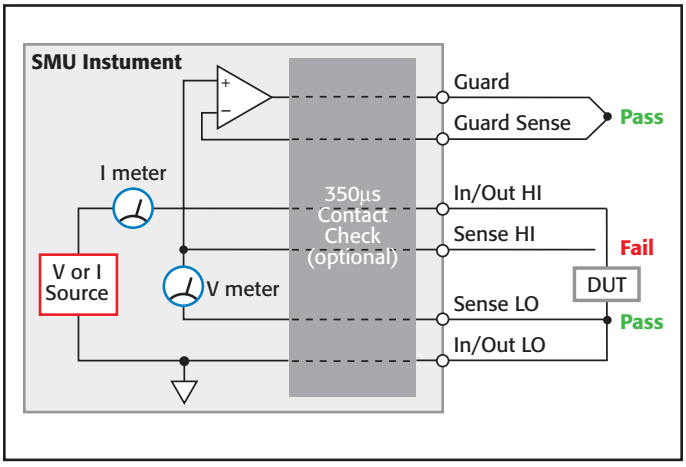


Figure 12. Series 2400 contact check

The Contact Check function was designed for high throughput 4-wire and 6-wire test applications. In Series 2400 SourceMeter instruments, three reference value choices (2Ω, 15Ω, and 50Ω) are supplied. If the resistance of good connections normally exceeds 50Ω, then the built-in contact check function is not suitable for that application and alternative approaches should be considered. Series 2600A instruments provide more flexibility with programmable values.

Selector Guide

Source Measurement Unit (SMU) Instruments

	20–100W BENCH SMU INSTRUMENTS					20–100W SYSTEM SMU INSTRUMENTS
MODEL	**2400, 2401 2400-C 2400-LV**	**2410 2410-C**	**2420 2420-C**	**2425 2425-C**	**2440 2440-C**	**2601A 2602A**
Page	33	33	33	33	33	10
POWER OUTPUT	22 W	22 W	66 W	110W	55 W	40.4 W/channel
CURRENT CAPABILITY						
Min. (default)	±10 pA	±10 pA	±100 pA	±100 pA	±100 pA	±1 pA
Max	±1.05 A	±1.05 A	±3.15 A	±3.15 A	±5.25 A	±3.03 A DC and pulsed/10 A pulsed per channel
VOLTAGE CAPABILITY						
Min. (default)	±1 μV	±1 μV	±1 μV	±1 μV	±1 μV	±1 μV
Max.	±21/±210 V[2]	±1100 V	±63 V	±105 V	±42 V	±40.4 V/channel
OHMS RANGE	<0.2 Ω to >200 MΩ	<0.2 Ω to >200 MΩ	<0.2 Ω to >200 MΩ	<0.2 Ω to >200 MΩ	<2.0 Ω to >200 MΩ	
BASIC ACCURACY						
I	0.035%	0.035%	0.035%	0.035%	0.035%	0.02 %
V	0.015%	0.015%	0.015%	0.015%	0.015%	0.015%
Ω	0.06 %	0.07 %	0.06 %	0.06 %	0.06 %	
FEATURE SUMMARY						
Pulse Mode	No	No	No	No	No	Yes
Linear/Log/Custom Sweeps	Yes	Yes	Yes	Yes	Yes	Yes
Embedded Execution	Yes	Yes	Yes	Yes	Yes	Yes
Embedded Scripting	No	No	No	No	No	Yes
Contact Check	Optional	Optional	Optional	Optional	Optional	Yes
Selectable Front/Rear Inputs	Yes	Yes	Yes	Yes	Yes	Rear only
Connections	Banana	Banana	Banana	Banana	Banana	Screw terminal, adapters for banana and/or triax
Limit Inspection	Yes	Yes	Yes	Yes	Yes	Yes
Selectable Output-Off Impedance State	Yes	Yes	Yes	Yes	Yes	Yes
Remote or 4W Voltage Sense	Yes	Yes	Yes	Yes	Yes	Yes
Source Readback	Yes	Yes	Yes	Yes	Yes	Yes
Command Language Protocol	SCPI	SCPI	SCPI	SCPI	SCPI	ICL
Programming	IEEE-488, RS-232	IEEE-488, RS-232	IEEE-488, RS-232	IEEE-488, RS-232	IEEE-488, RS-232	Ethernet/LXI, IEEE-488, RS-232 communication with embedded Test Script Processor (TSP) capability
Memory/Buffer	5000 point, 2500 point reading buffer	5000 point, 2500 point reading buffer	5000 point, 2500 point reading buffer	5000 point, 2500 point reading buffer	5000 point, 2500 point reading buffer	>100,000 rdgs/buffer
Trigger	Trigger Link with 6 In/Out	Trigger Link with 6 In/Out	Trigger Link with 6 In/Out	Trigger Link with 6 In/Out	Trigger Link with 6 In/Out	14 digital I/O-trigger lines, 3 TSP-Link trigger lines
Guard	Ohms (high current) and cable	Ohms (high current) and cable	Ohms (high current) and cable	Ohms (high current) and cable	Ohms (high current) and cable	Cable
Digital I/O	1 In/4 Out with built-in component handler interfaces (except Model 2401).	1 In/4 Out with built-in component handler interfaces.	1 In/4 Out with built-in component handler interfaces.	1 In/4 Out with built-in component handler interfaces.	1 In/4 Out with built-in component handler interfaces.	14 digital I/O-trigger lines
Other	6½-digit measurement resolution. Handler interface. 500μs pass/fail test. Optional contact check capability (except Model 2401).	6½-digit measurement resolution. Handler interface. 500μs pass/fail test. Optional contact check capability.	6½-digit measurement resolution. Handler interface. 500μs pass/fail test. Optional contact check capability.	6½-digit measurement resolution. Handler interface. 500μs pass/fail test. Optional contact check capability.	6½-digit measurement resolution. Handler interface. 500μs pass/fail test. Optional contact check capability.	6½-digit measurement resolution. Scalable to 64+ channels with TSP-Link®. Built-in Web-based characterization software.
Compliance	CE, UL	CE	CE	CE	CE	CE, UL

1. In pulse mode.
2. Models 2401 and 2400-LV 21V max.

Selector Guide

Source Measurement Unit (SMU) Instruments

	20–100W SYSTEM SMU INSTRUMENTS	>200W POWER SMU INSTRUMENTS		20W LOW CURRENT SMU INSTRUMENTS		
	2611A 2612A	**2430 2430-C**	**2651A**	**2635A 2636A**	**6430**	**237**
	10	33	26	10	48	53
	30.3 W/channel	1100 W [1]	2,000W pulsed/200W DC	30.3 W/channel	2 W	11 W
	±1 pA	±100 pA	±1 pA	±1 fA	±10 aA	±100 fA
	±1.5 A DC and pulsed/10 A pulsed per channel	±10.5 A [1]	±50A (±100 A when two units are connected in parallel)	±1.5 A DC and pulsed/10 A pulsed per channel	±105 mA	±100 mA
	±1 μV	±1 μV	±1 μV	±1 μV	±1 μV	±100 μV
	±202 V	±105 V	±40 V (±80 V when two units are connected in series)	±202 V	±210 V	±1100 V
		<0.2 Ω to >200 MΩ			<2.0 Ω to >20 TΩ	
	0.02 %	0.035%	±0.02 %	0.02 %	0.035%	0.05%
	0.015%	0.015%	±0.015%	0.015%	0.012%	0.03%
		0.06 %			0.063%	
	Yes	Yes	Yes	Yes	No	Yes
	Yes	Yes	Yes	Yes	Yes	Yes (linear/log/pulse, fixed, stair, custom)
	Yes	Yes	Yes	Yes	Yes	No
	Yes	No	Yes	Yes	No	No
	Yes	Optional	Yes	Yes	No	No
	Rear only	Yes	Rear only	Rear only	Rear and Preamp	Rear only
	Screw terminal, adapters for banana and/or triax	Banana	Screw terminal, adapters for banana and/or triax	Screw terminal, adapters for banana	Triax	Triax
	Yes	Yes	Yes	Yes	Yes	No
	Yes	Yes	Yes	Yes	Yes	
	Yes	Yes	Yes	Yes	Yes	Yes
	Yes	Yes	Yes	Yes	Yes	No
	ICL	SCPI	ICL	ICL	SCPI	DDC
	Ethernet/LXI, IEEE-488, RS-232 communication with embedded Test Script Processor (TSP) capability	IEEE-488, RS-232	Ethernet/LXI, IEEE-488, RS-232 communication with embedded Test Script Processor (TSP) capability	Ethernet/LXI, IEEE-488, RS-232 communication with embedded Test Script Processor (TSP) capability	IEEE-488, RS-232	IEEE-488
	>100,000 rdgs/buffer	5000 point, 2500 point reading buffer	>100,000 rdgs/buffer	>100,000 rdgs/buffer	5000 point, 2500 point reading buffer	1000 pt.
	14 digital I/O-trigger lines, 3 TSP-Link trigger lines	Trigger Link with 6 In/Out	14 digital I/O-trigger lines, 3 TSP-Link trigger lines	14 digital I/O-trigger lines, 3 TSP-Link trigger lines	Trigger Link with 6 In/Out	In/Out
	Cable	Ohms (high current) and cable	Cable	Cable	Ohms (high current) and cable	Cable
	14 digital I/O-trigger lines	1 In/4 Out with built-in component handler interfaces (except Model 2401).	14 digital I/O-trigger lines	14 digital I/O-trigger lines	1 In/4 Out with built-in component handler interfaces	No
	6½-digit measurement resolution. Scalable to 64+ channels with TSP-Link®. Built-in Web-based characterization software.	6½-digit measurement resolution. Handler interface. 500μs pass/fail test. Optional contact check capability.	6½-digit measurement resolution. 1% to 100% pulse duty cycle. 1μs per point measurements.	6½-digit measurement resolution. Scalable to 64+ channels with TSP-Link®. Built-in Web-based characterization software.	6½-digit measurement resolution. Handler interface. 500μs pass/fail test.	
	CE, UL	CE	CE, UL	CE, UL	CE	CE

Series 2600A

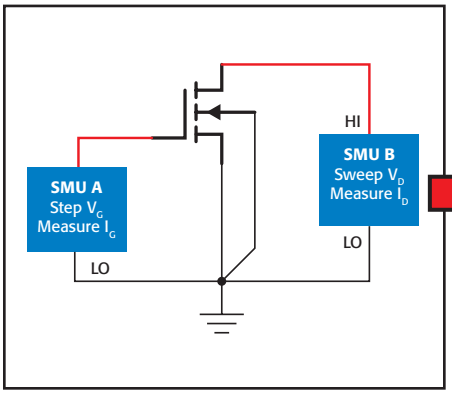
System SourceMeter® Instruments

See page 26 for Model 2651A Single-Channel System SourceMeter Instrument (High Power)

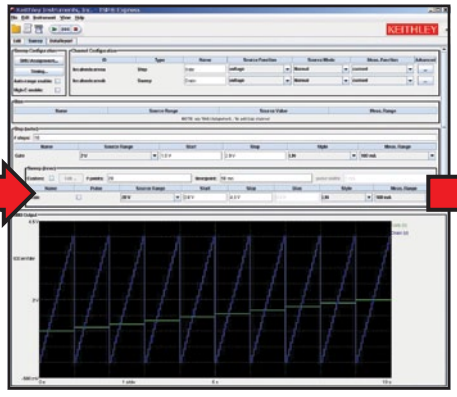
- **Combines a power supply, true current source, 6½-digit DMM, arbitrary waveform generator, V or I pulse generator with measurement, electronic load, and trigger controller – all in one instrument**
- **Family of products offers wide dynamic range: 1fA to 50A and 1µV to 200V**
- **20,000 rdg/s provides faster test times and ability to capture transient device behavior**
- **Precision timing and channel synchronization (<500ns)**
- **USB port for saving data and test scripts**
- **LXI Class C compliance supports high speed data transfer and enables quick and easy remote testing, monitoring, and troubleshooting**
- **Software:**
  - **TSP® Express for quick and easy I-V test (embedded)**
  - **ACS Basic Edition for semiconductor component characterization (optional)**

Series 2600A System SourceMeter instruments are Keithley's latest I-V source measurement unit (SMU) instruments for use as either bench-top I-V characterization tools or as building block components of multi-channel I-V test systems. For bench-top use, Series 2600A instruments feature an embedded TSP Express Software Tool that allows users to quickly and easily perform common I-V tests without programming or installing software. For system level applications, the Series 2600A's Test Script Processor (TSP) architecture, along with other new capabilities such as parallel test execution and precision timing, provides the highest throughput in the industry, lowering the cost of test. To simplify the testing, verification, and analysis of semiconductor components, the optional ACS Basic Edition software is also available.

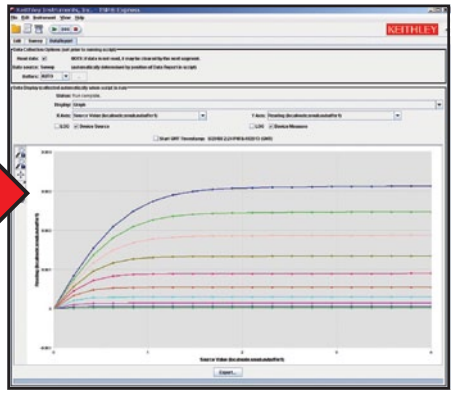
CONNECT DUT



CONFIGURE Test



COLLECT Data



Performing nested sweeps to characterize a transistor with TSP Express is quick and easy. Data can be exported to a .csv file for use with spreadsheet applications such as Excel.

Quick and Easy Lab and Bench-Top Use

Each Series 2600A SourceMeter instrument is a complete I-V measurement solution with unmatched ease of use, capability, and flexibility. They simplify the process of making high-performance measurements.

The TSP Express Software Tool quickly sets up and runs basic and advanced tests, including: nested step/sweeps, pulse sweeps, and custom sweeps for device characterization applications. The resulting data can be viewed in graphical or tabular format and exported to a .csv file for use with spreadsheet applications.

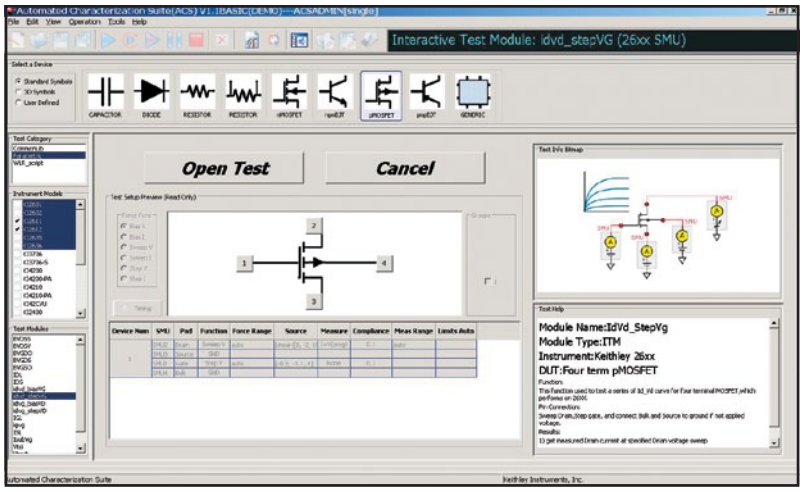
TSP Express runs on a PC connected to the SourceMeter instrument via an Ethernet cable (provided with the instrument). The intuitive user interface resides on the built-in LXI web page, so no software installation is needed.

Simplify Semiconductor Component Test, Verification, and Analysis

The optional ACS Basic Edition software maximizes the productivity of customers who perform packaged part characterization during development, quality verification, or failure analysis, with:

- Rich set of easy-to-access test libraries
- Script editor for fast customization of existing tests
- Data tool for comparing results quickly
- Formulator tool that analyzes captured curves and provides a wide range of math functions

For more information about the ACS Basic Edition software, please refer to the ACS Basic Edition data sheet.



When you need to acquire data on a packaged part quickly, the wizard-based user interface of ACS Basic Edition makes it easy to find and run the test you want, like this common FET curve trace test.

Unmatched Throughput and Flexibility for High Performance I-V Test Systems

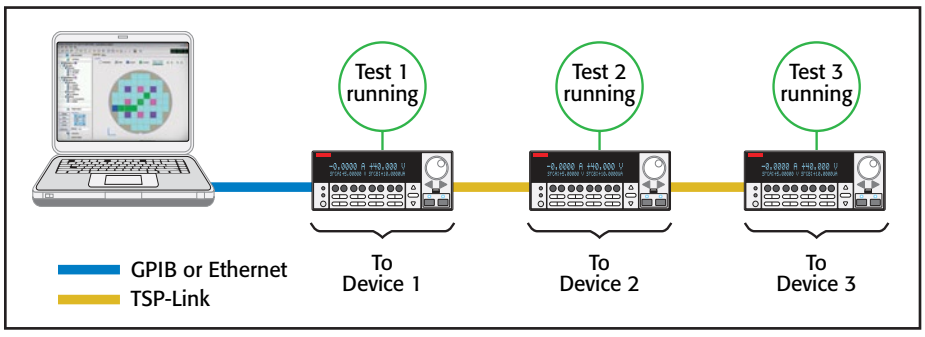
TSP technology provides remarkable capabilities when a Series 2600A is integrated as part of a multi-channel I-V test system. For example, the embedded scripting capability allows test scripts to be run by the instrument. Test scripts are complete test programs based on an easy to use but highly efficient and compact scripting language called Lua <www.lua.org>. Since test scripts can contain any sequence of routines that are executable by conventional programming languages (including decision making algorithms), this feature allows entire tests to be managed by the instrument without sending readings back to a PC for decision making. This eliminates the delays caused by GPIB traffic congestion and greatly improves overall test times.

Also, TSP technology offers "mainframe-less channel expansion." The TSP-Link channel expansion bus (which uses a 100 Base T Ethernet cable) allows multiple Series 2600A and other TSP instruments to be connected in a master-slave configuration and behave as one integrated system. TSP-Link technology supports up to 32 units or 64 SMU instrument channels per GPIB or IP address, making it easy to scale a system to fit the particular requirements of an application.

Parallel Test Capability

The Series 2600A takes system level performance to a new height with parallel testing capability. This feature tests multiple devices in parallel to meet the high throughput requirements of production test and advanced semiconductor lab applications.

This parallel testing capability enables each instrument in the system to run its own complete test sequence, creating a fully multi-threaded test environment. Hence, the number of tests that can be running in parallel on a Series 2600A system can be as many as the number of instruments in the system. In contrast, most conventional test systems run a single thread test, usually on the controller PC instead of the instrument itself. Testing multiple devices at the same time means dramatically improved test throughput and reduced overall cost of test.

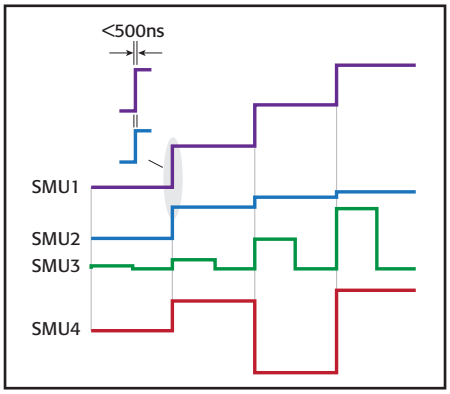


Parallel testing with the Series 2600A

When all or some of your test requirements change, your Series 2600A system can be reconfigured via software without rewiring. The internal software can match the different pin layouts of the devices-under-test to the appropriate SMU instrument-per-pin configurations.

Tight Timing and Synchronization

Today's test engineers are challenged with testing increasingly more complex and more sensitive devices that require precise timing and synchronization. Whether you need to synchronize electrical and optical tests for an



All channels in the system are synchronized to under 500ns.

Series 2600A

System SourceMeter® Instruments

Ordering Information

2601A Single-channel System SourceMeter Instrument (3A DC, 10A Pulse)

2602A Dual-channel System SourceMeter Instrument (3A DC, 10A Pulse)

2611A Single-channel System SourceMeter Instrument (200V, 10A Pulse)

2612A Dual-channel System SourceMeter Instrument (200V, 10A Pulse)

2635A Single-channel System SourceMeter Instrument (1fA, 10A Pulse)

2636A Dual-channel System SourceMeter Instrument (1fA, 10A Pulse)

2651A Single-channel System SourceMeter Instrument (2000W, 50A Pulse)

Accessories Supplied

2600-ALG-2 Low Noise Triax Cable with Alligator Clips, 2m (6.6 ft.) (two supplied with 2636A, one with 2635A)

2600-Kit Mating Screw Terminal Connectors with strain relief and covers (2601A/2602A/2611A/2612A)

CA-180-3A TSP-Link/Ethernet Cable (two per unit)

TSP Express Software Tool (embedded)

Test Script Builder Software (supplied on CD)

ACS Basic Edition Software (optional)

optoelectronic component or ensure that the same stress times are applied to the different pins of an advanced semiconductor device, providing precision timing and synchronization between SMU instrument channels (and external instruments) has become a critical requirement.

A high performance trigger model that is hardware driven allows timing at each source-measure step to be tightly controlled. It also synchronizes the operations between SMU instrument channels and/or external instrumentation at hardware speeds of <500ns.

Third-generation SMU Instrument Design Ensures Faster Test Times

Based on the proven architecture of earlier Series 2600 instruments, the Series 2600A's new SMU instrument design enhances test speed in several ways. For example, while earlier designs used a parallel current ranging topology, the Series 2600A uses a patented series ranging topology, which provides faster and smoother range changes and outputs that settle more quickly.

The Series 2600A SMU instrument design supports two modes of operation for use with a variety of loads. In normal mode, the SMU instrument provides high bandwidth performance for maximum throughput. In high capacitance (high-C) mode, the SMU instrument uses a slower bandwidth to provide robust performance with higher capacitive loads.

Each Series 2600A SMU instrument channel offers a highly flexible, four-quadrant source coupled with precision voltage and current meters. Each channel can be configured as a:

- Precision power supply
- True current source
- DMM (DCV, DCI, ohms, and power with 6½-digit resolution)
- Electronic load (with sink mode capability)
- V or I pulse generator (Pulse width: 100µs and longer)
- V or I waveform generator

Current arbitrary waveforms maximum output update rates: 12,500 samples/second.

Voltage arbitrary waveforms maximum output update rates: 20,000 samples/second.

All analog-to-digital (A/D) converters in Series 2600A instruments are both high speed and high precision for maximum flexibility. The two A/D converters per channel (one for I, one for V) can run simultaneously, providing precise source-readback without sacrificing test throughput. These A/D converters offer the versatility of programmable integration rates, allowing you to optimize for either high speed (>20,000 rdgs/s at 0.001 NPLC setting) or for high resolution (up to 24 bits at 10 NPLC setting) measurements.

In addition to the high speed or high resolution modes, the Model 2651A offers a digitizing measurement mode that enables 1µs per point sampling. See the Model 2651A on page 26 for more information.

Digital I/O Interface

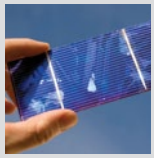
A back panel port on every Series 2600A instrument provides 14 bits of universal digital I/O to link the instrument to a variety of popular component handlers and/or probe stations. These digital I/O lines are compatible with the triggering technology of Keithley's earlier Trigger-Link instruments. These lines simplify integrating Series 2600A instruments into systems that employ other electrical, mechanical, optical, or RF equipment.

TSP-Link Trigger Lines

The TSP-Link bus supports dedicated trigger lines that provide synchronous operations between multiple Series 2600A instruments (and other TSP instruments, such as Series 3700 DMM/Switch Systems) without the need for additional trigger connections.

TYPICAL APPLICATIONS

I-V functional test and characterization of a wide range of devices, including:



- **Discrete and passive components**
  - **Two-leaded – Sensors, disk drive heads, metal oxide varistors (MOVs), diodes, zener diodes, sensors, capacitors, thermistors**
  - **Three-leaded – Small signal bipolar junction transistors (BJTs), field-effect transistors (FETs), and more**
- **Simple ICs – Optos, drivers, switches, sensors**
- **Integrated devices – small scale integrated (SSI) and large scale integrated (LSI)**
  - **Analog ICs**
  - **Radio frequency integrated circuits (RFICs)**
  - **Application specific integrated circuits (ASICs)**
  - **System on a chip (SOC) devices**
- **Optoelectronic devices such as light-emitting diodes (LEDs), laser diodes, high brightness LEDs (HBLEDs), vertical cavity surface-emitting lasers (VCSELs), displays**
- **Wafer level reliability**
  - **NBTI, TDDB, HCI, electromigration**
- **Solar Cells**
- **Batteries**

Built-in Contact Check Function

The Contact Check function makes it simple to verify good device-under-test connections quickly and easily before an automated test sequence begins. This eliminates the measurement errors and false product failures associated with contact fatigue, breakage, contamination, loose or broken connections, relay failures, etc.

Powerful Software Tools

In addition to the embedded TSP Express and optional ACS Basic Edition software, the free Test Script Builder software tool is provided to help users create, modify, debug, and store TSP test scripts. **Table 1** describes key features of Series 2600A software tools.

Complete Automated System Solutions

While the ACS Basic Edition software only supports component characterization tests, wafer and cassette level testing can be performed by Keithley's ACS Integrated Test Systems. ACS systems are highly configurable, instrument-based systems that generally include a number of Series 2600A instruments. These systems are designed for semiconductor device characterization, reliability/WLR, parametric, and component functional testing.

The flexible software architecture of ACS Basic Edition allows configuring systems with a wide range of controllers and test fixtures, as well as the exact number of SourceMeter instruments the application requires.

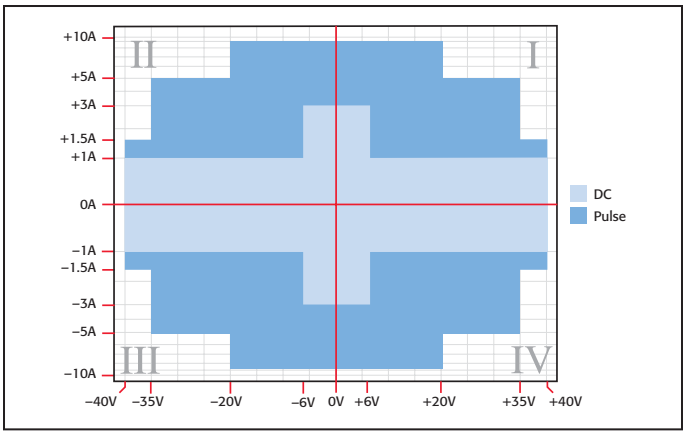
Example ACS Integrated Test System

Table 1. Series 2600A software tools

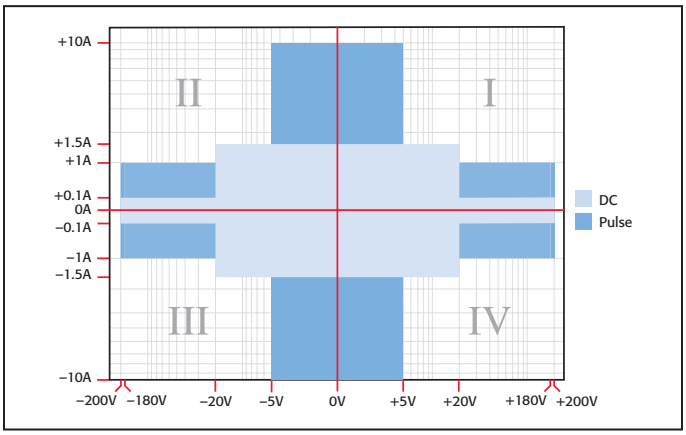
Feature/ Functionality	ACS Basic Edition	TSP Express	Test Script Builder (TSB)
Description	Semiconductor characterization software for component test, verification, and analysis	Quick Start Tool for fast and easy I-V testing, primarily for bench and lab users	Custom script writing tool for TSP instruments
Supported hardware	24xx, 26xxA, 4200-SCS, 237	26xxA	26xxA, 37xx
Supported buses	GPIB, Ethernet	Ethernet only	GPIB, RS-232, Ethernet
Functionality	Intuitive, wizard-based GUI, Rich set of test libraries	Linear/Log Sweeps, Pulsing, Custom sweeps, Single point source-measures. Note: Uses new 2600A's new API's for precision timing and channel synchronization	Custom scripts with total flexibility
Data management	Formulator tool with wide range of math functions	.csv export, basic curve tracing (no math formula or analysis support)	N/A
Installation	Optional purchase	Not necessary. Embedded in the instrument.	Free Download or CD Install on PC.

Series 2600A System SourceMeter® Instruments

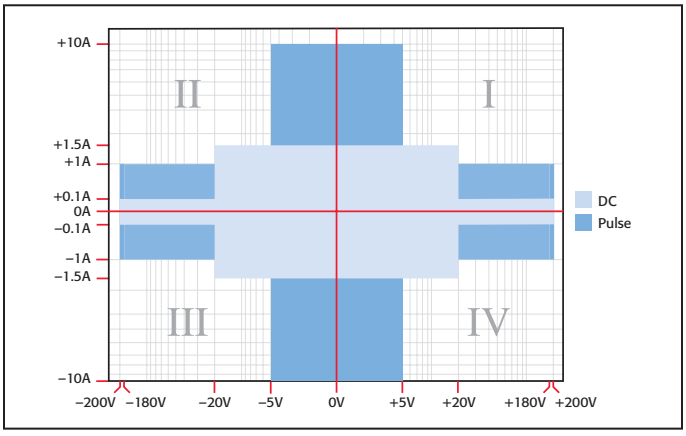
In the first and third quadrants, Series 2600A instruments operate as a source, delivering power to a load. In the second and fourth quadrants, they operate as a sink, dissipating power internally.



Models 2601A and 2602A I-V capability



Models 2611A and 2612A I-V capability



Models 2635A and 2636A I-V capability

ACCESSORIES AVAILABLE*

CABLES AND CONNECTORS

2600-BAN	Banana Test Leads/Adapter Cable. For a single 2601A/2602A/2611A/2612A SMU instrument channel
2600-KIT	Extra screw terminal connector, strain relief, and cover for a single SourceMeter channel (one supplied with 2601A/2611A, two with 2602A/2612A)
2600-TRIAX	Triax Adapter. For a single 2601A/2602A/2611A/2612A SMU instrument channel
7078-TRX-*	3-Slot, Low Noise Triax Cable. For use with 2600-TRIAX Adapter
7078-TRX-GND	3-Slot male triax to BNC adapter (guard removed)
8606	High Performance Modular Probe Kit. For use with 2600A-BAN
SC-200	Shielded Twisted Pair Cable. Recommended for general-purpose use with Series 2600A System SourceMeter instruments

DIGITAL I/O, TRIGGER LINK, AND TSP-LINK

2600-TLINK	Digital I/O to TLINK Adapter Cable, 1m
CA-126-1	Digital I/O and Trigger Cable, 1.5m
CA-180-3A	CAT5 Crossover Cable for TSP-Link and direct Ethernet connection (two supplied)

GPIB INTERFACES AND CABLES

7007-1	Double Shielded GPIB Cable, 1m (3.3 ft.)
7007-2	Double Shielded GPIB Cable, 2m (6.6 ft.)
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KPXI-488	IEEE-488 Interface Board for the PXI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

SWITCHING

Series 3700	DMM/Switch Systems
707A	Semiconductor Switching Matrix Mainframe
7001	Switch Control Mainframe

RACK MOUNT KITS

4299-1	Single Rack Mount Kit with front and rear support
4299-2	Dual Rack Mount Kit with front and rear support
4299-5	1U Vent Panel

SOFTWARE

ACS-BASIC	Component Characterization Software

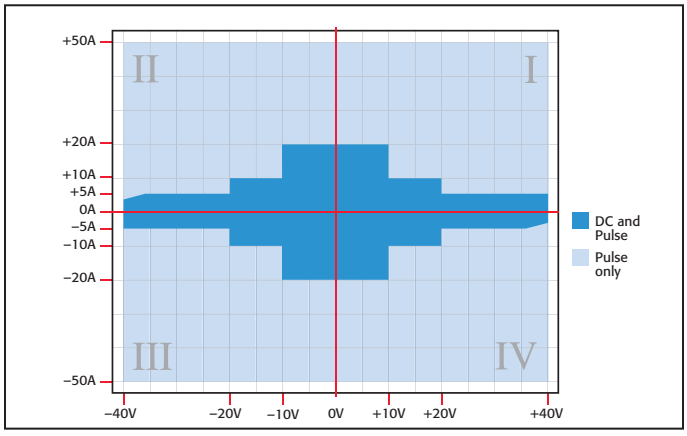
EXTENDED WARRANTIES

2601A-EW	1 Year Extended Warranty for Model 2601A
2602A-EW	1 Year Extended Warranty for Model 2602A
2611A-EW	1 Year Extended Warranty for Model 2611A
2612A-EW	1 Year Extended Warranty for Model 2612A
2635A-EW	1 Year Extended Warranty for Model 2635A
2636A-EW	1 Year Extended Warranty for Model 2636A

CALIBRATION AND VERIFICATION

2600-STD-RES	Calibration Standard 1GΩ Resistor for Models 2635A and 2636A

*See page 27 for Model 2651A accessories.



Model 2651A I-V capability

SPECIFICATION CONDITIONS

This document contains specifications and supplemental information for the Models 2601A and 2602A System SourceMeter® instruments. Specifications are the standards against which the Models 2601A and 2602A are tested. Upon leaving the factory, the 2601A and 2602A meet these specifications. Supplemental and typical values are non-warranted, apply at 23°C, and are provided solely as useful information.

Accuracy specifications are applicable for both normal and high capacitance modes.

The source and measurement accuracies are specified at the SourceMeter CHANNEL A (2601A and 2602A) or SourceMeter CHANNEL B (2602A) terminals under the following conditions:

1. 23°C ± 5°C, <70% relative humidity
2. After 2 hour warm-up
3. Speed normal (1 NPLC)
4. A/D auto-zero enabled
5. Remote sense operation or properly zeroed local operation
6. Calibration period = 1 year

SOURCE SPECIFICATIONS

VOLTAGE SOURCE SPECIFICATIONS

VOLTAGE PROGRAMMING ACCURACY[1]

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Typical Noise (peak-peak) 0.1Hz–10Hz
100.000 mV	5 µV	0.02% + 250 µV	20 µV
1.00000 V	50 µV	0.02% + 400 µV	50 µV
6.00000 V	50 µV	0.02% + 1.8 mV	100 µV
40.0000 V	500 µV	0.02% + 12 mV	500 µV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C)[2]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

MAXIMUM OUTPUT POWER AND SOURCE/SINK LIMITS[3]: 40.4W per channel maximum. ±40.4V @ ±1.0A, ±6.06V @ ±3.0A, four quadrant source or sink operation.

VOLTAGE REGULATION: Line: 0.01% of range. **Load:** ±(0.01% of range + 100µV).

NOISE 10Hz–20MHz: <20mV peak-peak (typical), <3mV RMS (typical), 6V range.

CURRENT LIMIT/COMPLIANCE[4]: Bipolar current limit (compliance) set with single value. Minimum value is 10nA. Accuracy same as current source.

OVERSHOOT: <±(0.1% + 10mV) typical. Step size = 10% to 90% of range, resistive load, maximum current limit/compliance.

GUARD OFFSET VOLTAGE: <4mV typical. Current <10mA.

CURRENT SOURCE SPECIFICATIONS

CURRENT PROGRAMMING ACCURACY

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)	Typical Noise (peak-peak) 0.1Hz–10Hz
100.000 nA	1 pA	0.06% + 100 pA	5 pA
1.00000 µA	10 pA	0.03% + 800 pA	25 pA
10.0000 µA	100 pA	0.03% + 5 nA	60 pA
100.000 µA	1 nA	0.03% + 60 nA	3 nA
1.00000 mA	10 nA	0.03% + 300 nA	6 nA
10.0000 mA	100 nA	0.03% + 6 µA	200 nA
100.000 mA	1 µA	0.03% + 30 µA	600 nA
1.00000 A[5]	10 µA	0.05% + 1.8 mA	70 µA
3.00000 A[5]	10 µA	0.06% + 4 mA	150 µA
10.0000 A[5,6]	100 µA	0.5 % + 40 mA (typical)	

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C)[7]: ±(0.15 × accuracy specification)/°C.

MAXIMUM OUTPUT POWER AND SOURCE/SINK LIMITS[8]: 40.4W per channel maximum. ±1.01A @ ±40.0V, ±3.03A @ ±6.0V, four quadrant source or sink operation.

CURRENT REGULATION: Line: 0.01% of range. **Load:** ±(0.01% of range + 100pA).

VOLTAGE LIMIT/COMPLIANCE[9]: Bipolar voltage limit (compliance) set with a single value. Minimum value is 10mV. Accuracy is the same as voltage source.

OVERSHOOT: <±0.1% typical (step size = 10% to 90% of range, resistive load; see Current Source Output Settling Time for additional test conditions).

ADDITIONAL SOURCE SPECIFICATIONS

TRANSIENT RESPONSE TIME: <70µs for the output to recover to within 0.1% for a 10% to 90% step change in load.

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range.

100mV, 1V Ranges: <50µs typical.

6V Range: <100µs typical.

40V Range[10]: <150µs typical.

CURRENT SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values below for $I_{out} \times R_{load} = 1V$ unless noted.

3A Range: <80µs typical (current less than 2.5A, R_{load} >2Ω).

1A–10mA Ranges: <80µs typical (R_{load} >6Ω).

1mA Range: <100µs typical.

100µA Range: <150µs typical.

10µA Range: <500µs typical.

1µA Range: <2.5ms typical.

100nA Range: <25ms typical.

DC FLOATING VOLTAGE: Output can be floated up to ±250VDC from chassis ground.

REMOTE SENSE OPERATING RANGE[11]:
Maximum voltage between HI and SENSE HI = 3V.
Maximum voltage between LO and SENSE LO = 3V.

VOLTAGE OUTPUT HEADROOM:

40V Range: Max. output voltage = 42V – total voltage drop across source leads (maximum 1Ω per source lead).

6V Range: Max. output voltage = 8V – total voltage drop across source leads (maximum 1Ω per source lead).

OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT: <300mV + 0.1% of larger range (typical). Overshoot into an 100kΩ load, 20MHz BW.

CURRENT SOURCE RANGE CHANGE OVERSHOOT: <5% of larger range + 300mV/R_{load} (typical with source settling set to SETTLE_SMOOTH_100NA). See Current Source Output Settling Time for additional test conditions.

NOTES

1. Add 50µV to source accuracy specifications per volt of HI lead drop.
2. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
3. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
4. For sink mode operation (quadrants II and IV), add 0.06% of limit range to the corresponding current limit accuracy specifications. Specifications apply with sink mode operation enabled.
5. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
6. 10A range accessible only in pulse mode.
7. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
8. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
9. For sink mode operation (quadrants II and IV), add 10% of compliance range and ±0.02% of limit setting to corresponding voltage source specification. For 100mV range add an additional 60mV of uncertainty.
10. Add 150µs when measuring on the 1A range.
11. Add 50µV to source accuracy specifications per volt of HI lead drop.

SOURCE SPECIFICATIONS (continued)

PULSE SPECIFICATIONS

Region	Maximum Current Limit	Maximum Pulse Width [12]	Maximum Duty Cycle [13]
1	1 A @ 40 V	DC, no limit	100%
1	3 A @ 6 V	DC, no limit	100%
2	1.5 A @ 40 V	100 ms	25%
3	5 A @ 35 V	4 ms	4%
4	10 A @ 20 V	1.8 ms	1%

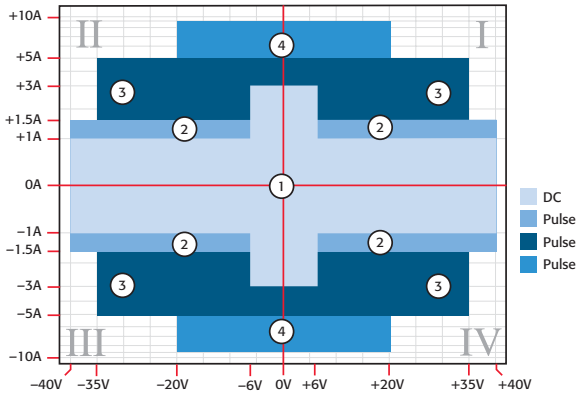
MINIMUM PROGRAMMABLE PULSE WIDTH [14, 15]: 100µs. NOTE: Minimum pulse width for settled source at a given I/V output and load can be longer than 100µs.

PULSE WIDTH PROGRAMMING RESOLUTION: 1µs.

PULSE WIDTH PROGRAMMING ACCURACY [15]: ±5µs.

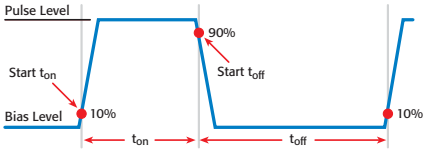
PULSE WIDTH JITTER: 2µs (typical).

QUADRANT DIAGRAM:



NOTES

12. Times measured from the start of pulse to the start off-time; see figure below.

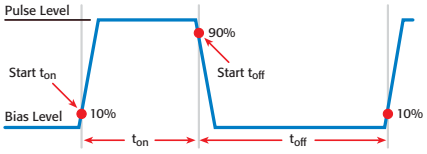


13. Thermally limited in sink mode (quadrants II and IV) and ambient temperatures above 30°C. See power equations in the reference manual for more information.
14. Typical performance for minimum settled pulse widths:

Source Value	Load	Source Settling (% of range)	Min. Pulse Width
6 V	2 Ω	0.2%	150 µs
20 V	2 Ω	1%	200 µs
35 V	7 Ω	0.5%	500 µs
40 V	27 Ω	0.1%	400 µs
1.5 A	27 Ω	0.1%	1.5 ms
3 A	2 Ω	0.2%	150 µs
5 A	7 Ω	0.5%	500 µs
10 A	2 Ω	0.5%	200 µs

Typical tests were performed using remote operation, 4W sense, and best, fixed measurement range. For more information on pulse scripts, see the Series 2600A Reference Manual.

15. Times measured from the start of pulse to the start off-time; see figure below.



METER SPECIFICATIONS

VOLTAGE MEASUREMENT ACCURACY [16, 17]

Range	Default Display Resolution [18]	Input Resistance	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)
100.000 mV	1 µV	>10 GΩ	0.015% + 150 µV
1.00000 V	10 µV	>10 GΩ	0.015% + 200 µV
6.00000 V	10 µV	>10 GΩ	0.015% + 1 mV
40.0000 V	100 µV	>10 GΩ	0.015% + 8 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C) [19]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

CURRENT MEASUREMENT ACCURACY [17]

Range	Default Display Resolution [20]	Voltage Burden [21]	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)
100.000 nA	1 pA	<1 mV	0.05% + 100 pA
1.00000 µA	10 pA	<1 mV	0.025% + 500 pA
10.0000 µA	100 pA	<1 mV	0.025% + 1.5 nA
100.000 µA	1 nA	<1 mV	0.02% + 25 nA
1.00000 mA	10 nA	<1 mV	0.02% + 200 nA
10.0000 mA	100 nA	<1 mV	0.02% + 2.5 µA
100.000 mA	1 µA	<1 mV	0.02% + 20 µA
1.00000 A	10 µA	<1 mV	0.03% + 1.5 mA
3.00000 A	10 µA	<1 mV	0.05% + 3.5 mA
10.0000 A [22]	100 µA	<1 mV	0.4% + 25 mA (typical)

CURRENT MEASURE SETTLING TIME (Time for measurement to settle after a V_{step}) [23]: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values for V_{out} = 1V unless noted. **Current Range:** 1mA. **Settling Time:** <100µs (typical).

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C) [24]: ±(0.15 × accuracy specification/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

CONTACT CHECK [25]

Speed	Maximum Measurement Time To Memory For 60Hz (50Hz)	Accuracy (1 Year) 23°C ±5°C ±(%rdg. + ohms)
FAST	1 (1.2) ms	5% + 10 Ω
MEDIUM	4 (5) ms	5% + 1 Ω
SLOW	36 (42) ms	5% + 0.3 Ω

ADDITIONAL METER SPECIFICATIONS

MAXIMUM LOAD IMPEDANCE:
Normal Mode: 10nF (typical). **High Capacitance Mode:** 50µF (typical).

COMMON MODE VOLTAGE: 250VDC.

COMMON MODE ISOLATION: >1GΩ, <4500pF.

OVERRANGE: 101% of source range, 102% of measure range.

MAXIMUM SENSE LEAD RESISTANCE: 1kΩ for rated accuracy.

SENSE INPUT IMPEDANCE: >10GΩ.

NOTES

16. Add 50µV to source accuracy specifications per volt of HI lead drop.
17. De-rate accuracy specifications for NPLC setting < 1 by increasing error term. Add appropriate % of range term using table below.

NPLC Setting	100mV Range	1V–40V Ranges	100nA Range	1µA–100mA Ranges	1A–3A Ranges
0.1	0.01%	0.01%	0.01%	0.01%	0.01%
0.01	0.08%	0.07%	0.1%	0.05%	0.05%
0.001	0.8 %	0.6 %	1%	0.5 %	1.1 %

18. Applies when in single channel display mode.
19. High Capacitance Mode accuracy is applicable for 23°C ±5°C only.
20. Applies when in single channel display mode.
21. Four-wire remote sense only with current meter mode selected. Voltage measure set to 100mV or 1V range only.
22. 10A range accessible only in pulse mode.
23. Compliance equal to 100mA.
24. High Capacitance Mode accuracy is applicable for 23°C ±5°C only.
25. Includes measurement of SENSE HI to HI and SENSE LO to LO contact resistances.

HIGH CAPACITANCE MODE[26, 27, 28]

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach 0.1% of final value after source level command is processed on a fixed range. Current limit = 1A.

Voltage Source Range	Settling Time with C_{load} = 4.7µF
100 mV	200 µs (typical)
1 V	200 µs (typical)
6 V	200 µs (typical)
40 V	7 ms (typical)

CURRENT MEASURE SETTLING TIME: Time required to reach 0.1% of final value after voltage source is stabilized on a fixed range. Values below for V_{out} = 1V unless noted.

Current Measure Range	Settling Time
3 A – 1 A	<120 µs (typical) (R_{load} > 2Ω)
100 mA – 10 mA	<100 µs (typical)
1 mA	< 3 ms (typical)
100 µA	< 3 ms (typical)
10 µA	< 230 ms (typical)
1 µA	< 230 ms (typical)

CAPACITOR LEAKAGE PERFORMANCE USING HIGH-C SCRIPTS[29]: Load = 5µF||10MΩ. Test: 5V step and measure. 200ms (typical) @ 50nA.

MODE CHANGE DELAY:

100µA Current Range and Above:
Delay into High Capacitance Mode: 10ms.
Delay out of High Capacitance Mode: 10ms.

1µA and 10µA Current Ranges:
Delay into High Capacitance Mode: 230ms.
Delay out of High Capacitance Mode: 10ms.

VOLTMETER INPUT IMPEDANCE: 10GΩ in parallel with 3300pF.

NOISE, 10Hz–20MHz (6V Range): <30mV peak-peak (typical).

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT: <400mV + 0.1% of larger range (typical). Overshoot into a 100kΩ load, 20MHz BW.

NOTES

26. High Capacitance Mode specifications are for DC measurements only.
27. 100nA range is not available in High Capacitance Mode.
28. High Capacitance Mode utilizes locked ranges. Auto Range is disabled.
29. Part of KI Factory scripts. See reference manual for details.

GENERAL

IEEE-488: IEEE-488.1 compliant. Supports IEEE-488.2 common commands and status model topology.

RS-232: Baud rates from 300bps to 115200bps. Programmable number of data bits, parity type, and flow control (RTS/CTS hardware or none). When not programmed as the active host interface, the SourceMeter instrument can use the RS-232 interface to control other instrumentation.

ETHERNET: RJ-45 connector, LXI Class C, 10/100BT, no auto MDIX.

EXPANSION INTERFACE: The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.

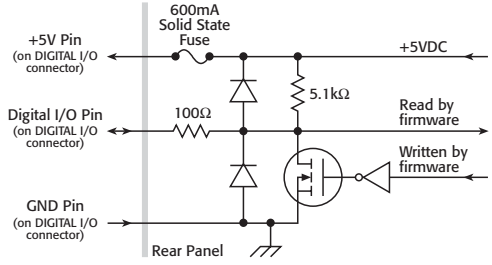
Cable Type: Category 5e or higher LAN crossover cable.

Length: 3 meters maximum between each TSP enabled instrument.

LXI COMPLIANCE: LXI Class C 1.2.

LXI TIMING: Total Output Trigger Response Time: 245µs min., 280µs typ., (not specified) max. **Receive LAN[0-7] Event Delay:** Unknown. **Generate LAN[0-7] Event Delay:** Unknown.

DIGITAL I/O INTERFACE:



Connector: 25-pin female D.

Input/Output Pins: 14 open drain I/O bits.

Absolute Maximum Input Voltage: 5.25V.

Absolute Minimum Input Voltage: –0.25V.

Maximum Logic Low Input Voltage: 0.7V, +850µA max.

Minimum Logic High Input Voltage: 2.1V, +570µA.

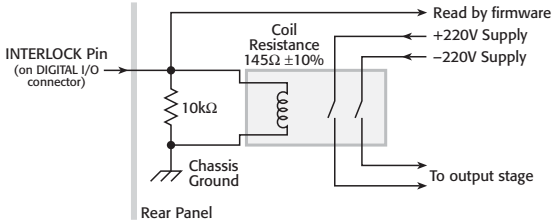
Maximum Source Current (flowing out of Digital I/O bit): +960µA.

Maximum Sink Current @ Maximum Logic Low Voltage (0.7V): –5.0mA.

Absolute Maximum Sink Current (flowing into Digital I/O pin): –11mA.

5V Power Supply Pin: Limited to 600mA, solid state fuse protected.

Safety Interlock Pin: Active high input. >3.4V @ 24mA (absolute maximum of 6V) must be externally applied to this pin to ensure 200V operation. This signal is pulled down to chassis ground with a 10kΩ resistor. 200V operation will be blocked when the INTERLOCK signal is <0.4V (absolute minimum –0.4V). See figure below:



USB: USB 1.0 Host Controller (Memory Stick I/O).

POWER SUPPLY: 100V to 250VAC, 50–60Hz (auto sensing), 240VA max.

COOLING: Forced air. Side intake and rear exhaust. One side must be unobstructed when rack mounted.

EMC: Conforms to European Union Directive 2004/108/EEC, EN 61326-1.

SAFETY: Conforms to European Union Directive 73/23/EEC, EN 61010-1, and UL 61010-1.

DIMENSIONS: 89mm high × 213mm wide × 460mm deep (3½ in × 8⅜ in × 17½ in). Bench Configuration (with handle and feet): 104mm high × 238mm wide × 460mm deep (4⅛ in × 9⅜ in × 17½ in).

WEIGHT: 2601A: 4.75kg (10.4 lbs). **2602A:** 5.50kg (12.0 lbs).

ENVIRONMENT: For indoor use only.

Altitude: Maximum 2000 meters above sea level.

Operating: 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C.

Storage: –25°C to 65°C.

SEE PAGES 24 AND 25 FOR MEASUREMENT SPEEDS AND OTHER SPECIFICATIONS.

2611A
2612A

System SourceMeter® Instruments

SPECIFICATION CONDITIONS

This document contains specifications and supplemental information for the Models 2611A and 2612A System SourceMeter® instruments. Specifications are the standards against which the Models 2611A and 2612A are tested. Upon leaving the factory the 2611A and 2612A meet these specifications. Supplemental and typical values are non-warranted, apply at 23°C, and are provided solely as useful information.

Accuracy specifications are applicable for both normal and high capacitance modes.

The source and measurement accuracies are specified at the SourceMeter CHANNEL A (2611A and 2612A) or SourceMeter CHANNEL B (2612A) terminals under the following conditions:

1. 23°C ± 5°C, <70% relative humidity.
2. After 2 hour warm-up.
3. Speed normal (1 NPLC).
4. A/D auto-zero enabled.
5. Remote sense operation or properly zeroed local sense operation.
6. Calibration period = 1 year.

SOURCE SPECIFICATIONS

VOLTAGE SOURCE SPECIFICATIONS

VOLTAGE PROGRAMMING ACCURACY[1]

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Typical Noise (Peak-Peak) 0.1Hz–10Hz
200.000 mV	5 µV	0.02% + 375 µV	20 µV
2.00000 V	50 µV	0.02% + 600 µV	50 µV
20.0000 V	500 µV	0.02% + 5 mV	300 µV
200.000 V	5 mV	0.02% + 50 mV	2 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C)[2]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

MAXIMUM OUTPUT POWER AND SOURCE/SINK LIMITS[3]: 30.3W per channel maximum. ±20.2V @ ±1.5A, ±202V @ ±100mA, four quadrant source or sink operation.

VOLTAGE REGULATION: Line: 0.01% of range. **Load:** ±(0.01% of range + 100µV).

NOISE 10Hz–20MHz: <20mV peak-peak (typical), <3mV RMS (typical), 20V range.

CURRENT LIMIT/COMPLIANCE[4]: Bipolar current limit (compliance) set with single value. Minimum value is 10nA. Accuracy is the same as current source.

OVERSHOOT: <±(0.1% + 10mV) (typical). Step size = 10% to 90% of range, resistive load, maximum current limit/compliance.

GUARD OFFSET VOLTAGE: <4mV (current <10mA).

CURRENT SOURCE SPECIFICATIONS

CURRENT PROGRAMMING ACCURACY[5]

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)	Typical Noise (Peak-Peak) 0.1Hz–10Hz
100.000 nA	2 pA	0.06% + 100 pA	5 pA
1.00000 µA	20 pA	0.03% + 800 pA	25 pA
10.0000 µA	200 pA	0.03% + 5 nA	60 pA
100.000 µA	2 nA	0.03% + 60 nA	3 nA
1.00000 mA	20 nA	0.03% + 300 nA	6 nA
10.0000 mA	200 nA	0.03% + 6 µA	200 nA
100.000 mA	2 µA	0.03% + 30 µA	600 nA
1.00000 A[6]	20 µA	0.05% + 1.8 mA	70 µA
1.50000 A[6]	50 µA	0.06% + 4 mA	150 µA
10.0000 A[6,7]	200 µA	0.5% + 40 mA (typical)	

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C)[8]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

MAXIMUM OUTPUT POWER AND SOURCE/SINK LIMITS[9]: 30.3W per channel maximum. ±1.515A @ ±20V , ±101mA @ ±200V , four quadrant source or sink operation.

CURRENT REGULATION: Line: 0.01% of range. **Load:** ±(0.01% of range + 100pA).

VOLTAGE LIMIT/COMPLIANCE[10]: Bipolar voltage limit (compliance) set with a single value. Minimum value is 20mV. Accuracy is the same as voltage source.

OVERSHOOT: <±0.1% (typical). Step size = 10% to 90% of range, resistive load; see Current Source Output Settling Time for additional test conditions.

ADDITIONAL SOURCE SPECIFICATIONS

TRANSIENT RESPONSE TIME: <70µs for the output to recover to within 0.1% for a 10% to 90% step change in load.

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to within reach 0.1% of final value after source level command is processed on a fixed range.

Range	Settling Time
200 mV	<50 µs (typical)
2 V	<50 µs (typical)
20 V	<110 µs (typical)
200 V	<700 µs (typical)

CURRENT SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values below for $I_{out} \cdot R_{load} = 2V$ unless noted.

Current Range	Settling Time
1.5 A – 1 A	<120 µs (typical) (R_{load} > 6Ω)
100 mA – 10 mA	<80 µs (typical)
1 mA	<100 µs (typical)
100 µA	<150 µs (typical)
10 µA	<500 µs (typical)
1 µA	<2 ms (typical)
100 nA	<20 ms (typical)

DC FLOATING VOLTAGE: Output can be floated up to ±250VDC from chassis ground.

REMOTE SENSE OPERATING RANGE[11]: Maximum voltage between HI and SENSE HI = 3V . Maximum voltage between LO and SENSE LO = 3V .

VOLTAGE OUTPUT HEADROOM:

200V Range: Max. output voltage = 202.3V – total voltage drop across source leads (maximum 1Ω per source lead).

20V Range: Max. output voltage = 23.3V – total voltage drop across source leads (maximum 1Ω per source lead).

OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT: <300mV + 0.1% of larger range (typical). Overshoot into a 200kΩ load, 20MHz BW.

CURRENT SOURCE RANGE CHANGE OVERSHOOT: <5% of larger range + 300mV/R_{load} (typical – With source settling set to SETTLE_SMOOTH_100NA). See Current Source Output Settling Time for additional test conditions.

NOTES

1. Add 50µV to source accuracy specifications per volt of HI lead drop.
2. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
3. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
4. For sink mode operation (quadrants II and IV), add 0.06% of limit range to the corresponding current limit accuracy specifications. Specifications apply with sink mode operation enabled.
5. Accuracy specifications do not include connector leakage. Derate accuracy by V_{out}/2E11 per °C when operating between 18°–28°C. Derate accuracy by V_{out}/2E11 + (0.15·V_{out}/2E11) per °C when operating <18°C and >28°C.
6. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
7. 10A range accessible only in pulse mode.
8. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
9. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
10. For sink mode operation (quadrants II and IV), add 10% of compliance range and ±0.02% of limit setting to corresponding voltage source specification. For 200mV range add an additional 120mV of uncertainty.
11. Add 50µV to source accuracy specifications per volt of HI lead drop.

PULSE SPECIFICATIONS

Region	Maximum Current Limit	Maximum Pulse Width[12]	Maximum Duty Cycle[13]
1	100 mA @ 200 V	DC, no limit	100%
1	1.5 A @ 20 V	DC, no limit	100%
2	1 A @ 180 V	8.5 ms	1%
3[14]	1 A @ 200 V	2.2 ms	1%
4	10 A @ 5 V	1 ms	2.2%

MINIMUM PROGRAMMABLE PULSE WIDTH[15,16]: 100µs. NOTE: Minimum pulse width for settled source at a given I/V output and load can be longer than 100µs.

PULSE WIDTH PROGRAMMING RESOLUTION: 1µs.

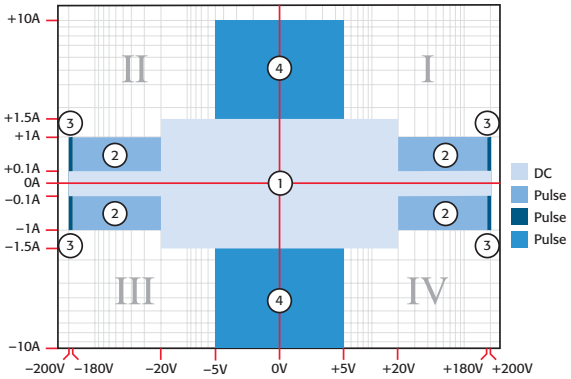
PULSE WIDTH PROGRAMMING ACCURACY[16]: ±5µs.

PULSE WIDTH JITTER: 2µs (typical).

SOURCE SPECIFICATIONS (continued)

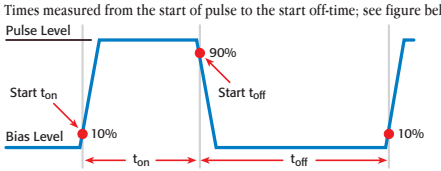
PULSE SPECIFICATIONS (continued)

QUADRANT DIAGRAM:



NOTES

12. Times measured from the start of pulse to the start off-time; see figure below.

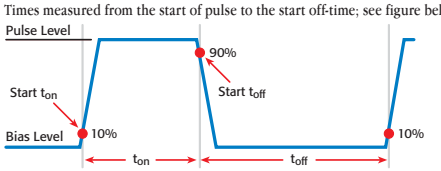


13. Thermally limited in sink mode (quadrants II and IV) and ambient temperatures above 30°C. See power equations in the reference manual for more information.
14. Voltage source operation with 1.5 A current limit.
15. Typical performance for minimum settled pulse widths:

Source Value	Load	Source Settling (% of range)	Min. Pulse Width
5 V	0.5 Ω	1%	300 µs
20 V	200 Ω	0.2%	200 µs
180 V	180 Ω	0.2%	5 ms
200 V (1.5 A Limit)	200 Ω	0.2%	1.5 ms
100 mA	200 Ω	1%	200 µs
1 A	200 Ω	1%	500 µs
1 A	180 Ω	0.2%	5 ms
10 A	0.5 Ω	0.5%	300 µs

Typical tests were performed using remote operation, 4W sense, and best, fixed measurement range. For more information on pulse scripts, see the Series 2600A Reference Manual.

16. Times measured from the start of pulse to the start off-time; see figure below.



METER SPECIFICATIONS

VOLTAGE MEASUREMENT ACCURACY [17, 18]

Range	Default Display Resolution [19]	Input Resistance	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)
200.000 mV	1 µV	>10 GΩ	0.015% + 225 µV
2.00000 V	10 µV	>10 GΩ	0.02% + 350 µV
20.0000 V	100 µV	>10 GΩ	0.015% + 5 mV
200.000 V	1 mV	>10 GΩ	0.015% + 50 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C) [20]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

CURRENT MEASUREMENT ACCURACY [18, 21]

Range	Default Display Resolution [22]	Voltage Burden [23]	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)
100.000 nA	1 pA	<1 mV	0.06% + 100 pA
1.00000 µA	10 pA	<1 mV	0.025% + 500 pA
10.0000 µA	100 pA	<1 mV	0.025% + 1.5 nA
100.000 µA	1 nA	<1 mV	0.02% + 25 nA
1.00000 mA	10 nA	<1 mV	0.02% + 200 nA
10.0000 mA	100 nA	<1 mV	0.02% + 2.5 µA
100.000 mA	1 µA	<1 mV	0.02% + 20 µA
1.00000 A	10 µA	<1 mV	0.03% + 1.5 mA
1.50000 A	10 µA	<1 mV	0.05% + 3.5 mA
10.0000 A [24]	100 µA	<1 mV	0.4% + 25 mA (typical)

CURRENT MEASURE SETTLING TIME (Time for measurement to settle after a Vstep) [25]: Time required to reach 0.1% of final value after source level command is processed on a fixed range. Values for V_{out} = 2V unless noted. **Current Range:** 1mA. **Settling Time:** <100µs (typical).

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C) [26]: ±(0.15 × accuracy specfication)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

CONTACT CHECK [27]

Speed	Maximum Measurement Time to Memory For 60Hz (50Hz)	Accuracy (1 Year) 23°C ±5°C ±(%rdg. + ohms)
FAST	1 (1.2) ms	5% + 10 Ω
MEDIUM	4 (5) ms	5% + 1 Ω
SLOW	36 (42) ms	5% + 0.3 Ω

ADDITIONAL METER SPECIFICATIONS

MAXIMUM LOAD IMPEDANCE:
Normal Mode: 10nF (typical). **High Capacitance Mode:** 50µF (typical).

COMMON MODE VOLTAGE: 250VDC.

COMMON MODE ISOLATION: >1GΩ, <4500pF.

OVERRANGE: 101% of source range, 102% of measure range.

MAXIMUM SENSE LEAD RESISTANCE: 1kΩ for rated accuracy.

SENSE INPUT IMPEDANCE: >10GΩ.

METER SPECIFICATIONS (continued)

NOTES

17. Add 50µV to source accuracy specifications per volt of HI lead drop.
18. De-rate accuracy specifications for NPLC setting <1 by increasing error term. Add appropriate % of range term using table below.

NPLC Setting	200mV Range	2V–200V Ranges	100nA Range	1µA–100mA Ranges	1A–1.5A Ranges
0.1	0.01%	0.01%	0.01%	0.01%	0.01%
0.01	0.08%	0.07%	0.1%	0.05%	0.05%
0.001	0.8 %	0.6 %	1%	0.5 %	1.1 %

19. Applies when in single channel display mode.
20. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
21. Accuracy specifications do not include connector leakage. De-rate accuracy by V_{out}/2E11 per °C when operating between 18°–28°C. Derate accuracy by V_{out}/2E11 + (0.15 * V_{out}/2E11) per °C when operating <18° and >28°C.
22. Applies when in single channel display mode.
23. Four-wire remote sense only and with current meter mode selected. Voltage measure set to 200mV or 2V range only.
24. 10A range accessible only in pulse mode.
25. Compliance equal to 100mA.
26. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
27. Includes measurement of SENSE HI to HI and SENSE LO to LO contact resistances.

HIGH CAPACITANCE MODE [28, 29, 30]

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Current limit = 1A.

Voltage Source Range	Settling Time with C_{load} = 4.7µF
200 mV	600 µs (typical)
2 V	600 µs (typical)
20 V	1.5 ms (typical)
200 V	20 ms (typical)

CURRENT MEASURE SETTLING TIME: Time required to reach within 0.1% of final value after voltage source is stabilized on a fixed range. Values below for V_{out} = 2V unless noted.

Current Measure Range	Settling Time
1.5 A – 1 A	<120 µs (typical) (R_{load} >6Ω)
100 mA – 10 mA	<100 µs (typical)
1 mA	< 3 ms (typical)
100 µA	< 3 ms (typical)
10 µA	< 230 ms (typical)
1 µA	< 230 ms (typical)

CAPACITOR LEAKAGE PERFORMANCE USING HIGH-C SCRIPTS [31]: Load = 5µF||10MΩ. Test: 5V step and measure. 200ms (typical) @ 50nA.

MODE CHANGE DELAY:

100µA Current Range and Above:
Delay into High Capacitance Mode: 10ms.
Delay out of High Capacitance Mode: 10ms.

1µA and 10µA Current Ranges:
Delay into High Capacitance Mode: 230ms.
Delay out of High Capacitance Mode: 10ms.

VOLTMETER INPUT IMPEDANCE: 30GΩ in parallel with 3300pF.

NOISE, 10Hz–20MHz (20V Range): <30mV peak-peak (typical).

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT (for 20V range and below): <400mV + 0.1% of larger range (typical). Overshoot into a 200kΩ load, 20MHz BW.

NOTES

28. High Capacitance Mode specifications are for DC measurements only.
29. 100nA range is not available in High Capacitance Mode.
30. High Capacitance Mode utilizes locked ranges. Auto Range is disabled.
31. Part of KI Factory scripts, See reference manual for details.

SEE PAGES 24 AND 25 FOR MEASUREMENT SPEEDS AND OTHER SPECIFICATIONS.

GENERAL

IEEE-488: IEEE-488.1 compliant. Supports IEEE-488.2 common commands and status model topology.

RS-232: Baud rates from 300bps to 115200bps. Programmable number of data bits, parity type, and flow control (RTS/CTS hardware or none). When not programmed as the active host interface, the SourceMeter instrument can use the RS-232 interface to control other instrumentation.

ETHERNET: RJ-45 connector, LXI Class C, 10/100BT, no auto MDIX.

EXPANSION INTERFACE: The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.

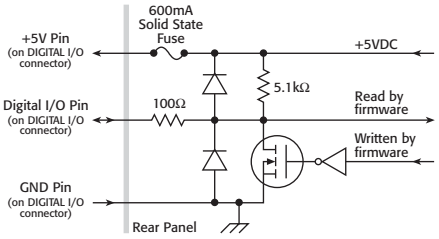
Cable Type: Category 5e or higher LAN crossover cable.

Length: 3 meters maximum between each TSP enabled instrument.

LXI COMPLIANCE: LXI Class C 1.2.

LXI TIMING: Total Output Trigger Response Time: 245µs min., 280µs typ., (not specified) max. **Receive LAN[0-7] Event Delay:** Unknown. **Generate LAN[0-7] Event Delay:** Unknown.

DIGITAL I/O INTERFACE:



Connector: 25-pin female D.

Input/Output Pins: 14 open drain I/O bits.

Absolute Maximum Input Voltage: 5.25V.

Absolute Minimum Input Voltage: –0.25V.

Maximum Logic Low Input Voltage: 0.7V, +850µA max.

Minimum Logic High Input Voltage: 2.1V, +570µA.

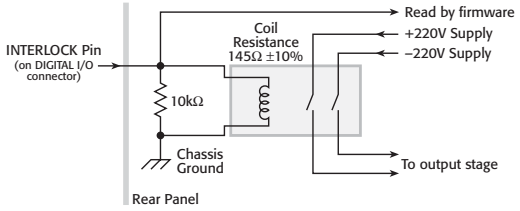
Maximum Source Current (flowing out of Digital I/O bit): +960µA.

Maximum Sink Current @ Maximum Logic Low Voltage (0.7V): –5.0mA.

Absolute Maximum Sink Current (flowing into Digital I/O pin): –11mA.

5V Power Supply Pin: Limited to 600mA, solid state fuse protected.

Safety Interlock Pin: Active high input. >3.4V @ 24mA (absolute maximum of 6V) must be externally applied to this pin to ensure 200V operation. This signal is pulled down to chassis ground with a 10kΩ resistor. 200V operation will be blocked when the INTERLOCK signal is <0.4V (absolute minimum –0.4V). See figure below:



USB: USB 1.0 Host Controller (Memory Stick I/O).

POWER SUPPLY: 100V to 250VAC, 50–60Hz (auto sensing), 240VA max.

COOLING: Forced air. Side intake and rear exhaust. One side must be unobstructed when rack mounted.

EMC: Conforms to European Union Directive 2004/108/EEC, EN 61326-1.

SAFETY: Conforms to European Union Directive 73/23/EEC, EN 61010-1, and UL 61010-1.

DIMENSIONS: 89mm high × 213mm wide × 460mm deep (3½ in × 8⅜ in × 17½ in). Bench Configuration (with handle and feet): 104mm high × 238mm wide × 460mm deep (4⅛ in × 9⅜ in × 17½ in).

WEIGHT: 2611A: 4.75kg (10.4 lbs). **2612A:** 5.50kg (12.0 lbs).

ENVIRONMENT: For indoor use only. **Altitude:** Maximum 2000 meters above sea level.

Operating: 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C.

Storage: –25°C to 65°C.

SPECIFICATION CONDITIONS

This document contains specifications and supplemental information for the Models 2635A and 2636A System SourceMeter® instruments. Specifications are the standards against which the Models 2635A and 2636A are tested. Upon leaving the factory the 2635A and 2636A meet these specifications. Supplemental and typical values are non-warranted, apply at 23°C, and are provided solely as useful information.

Accuracy specifications are applicable for both normal and high capacitance modes.

The source and measurement accuracies are specified at the SourceMeter CHANNEL A (2635A and 2636A) or SourceMeter CHANNEL B (2636A) terminals under the following conditions:

1. 23°C ± 5°C, <70% relative humidity.
2. After 2 hour warm-up
3. Speed normal (1 NPLC)
4. A/D auto-zero enabled
5. Remote sense operation or properly zeroed local sense operation
6. Calibration period = 1 year

SOURCE SPECIFICATIONS

VOLTAGE SOURCE SPECIFICATIONS

VOLTAGE PROGRAMMING ACCURACY[1]

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Typical Noise (peak-peak) 0.1Hz–10Hz
200.000 mV	5 µV	0.02% + 375 µV	20 µV
2.00000 V	50 µV	0.02% + 600 µV	50 µV
20.0000 V	500 µV	0.02% + 5 mV	300 µV
200.000 V	5 mV	0.02% + 50 mV	2 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C)[2]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

MAXIMUM OUTPUT POWER AND SOURCE/SINK LIMITS[3]: 30.3W per channel maximum. ±20.2V @ ±1.5A, ±202V @ ±100mA, four quadrant source or sink operation.

VOLTAGE REGULATION: Line: 0.01% of range. **Load:** ±(0.01% of range + 100µV).

NOISE 10Hz–20MHz: <20mV pk-pk (typical), <3mV rms (typical), 20V range.

CURRENT LIMIT/COMPLIANCE[4]: Bipolar current limit (compliance) set with single value. Minimum value is 100pA. Accuracy is the same as current source.

OVERSHOOT: <±(0.1% + 10mV) typical (step size = 10% to 90% of range, resistive load, maximum current limit/compliance).

GUARD OFFSET VOLTAGE: <4mV (current <10mA).

CURRENT SOURCE SPECIFICATIONS

CURRENT PROGRAMMING ACCURACY

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)	Typical Noise (peak-peak) 0.1Hz–10Hz
1.00000 nA	20 fA	0.15% + 2 pA	800 fA
10.0000 nA	200 fA	0.15% + 5 pA	2 pA
100.000 nA	2 pA	0.06% + 50 pA	5 pA
1.00000 µA	20 pA	0.03% + 700 pA	25 pA
10.0000 µA	200 pA	0.03% + 5 nA	60 pA
100.000 µA	2 nA	0.03% + 60 nA	3 nA
1.00000 mA	20 nA	0.03% + 300 nA	6 nA
10.0000 mA	200 nA	0.03% + 6 µA	200 nA
100.000 mA	2 µA	0.03% + 30 µA	600 nA
1.00000 A[5]	20 µA	0.05% + 1.8 mA	70 µA
1.50000 A[5]	50 µA	0.06% + 4 mA	150 µA
10.0000 A[5,6]	200 µA	0.5 % + 40 mA (typical)	

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C)[7]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

MAXIMUM OUTPUT POWER AND SOURCE/SINK LIMITS[8]: 30.3W per channel maximum. ±1.515A @ ±20V, ±101mA @ ±200V, four quadrant source or sink operation.

CURRENT REGULATION: Line: 0.01% of range. **Load:** ±(0.01% of range + 100pA).

VOLTAGE LIMIT/COMPLIANCE[9]: Bipolar voltage limit (compliance) set with a single value. Minimum value is 20mV. Accuracy is the same as voltage source.

OVERSHOOT: <±0.1% typical (step size = 10% to 90% of range, resistive load, maximum current limit/compliance; see Current Source Output Settling Time for additional test conditions).

ADDITIONAL SOURCE SPECIFICATIONS

TRANSIENT RESPONSE TIME: <70µs for the output to recover to within 0.1% for a 10% to 90% step change in load.

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range.

Range	Settling Time
200 mV	<50 µs (typical)
2 V	<50 µs (typical)
20 V	<110 µs (typical)
200 V	<700 µs (typical)

CURRENT SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values below for $I_{out} \cdot R_{load}$ = 2V unless noted.

Current Range	Settling Time
1.5 A – 1 A	<120 µs (typical) (R_{load} > 6Ω)
100 mA – 10 mA	<80 µs (typical)
1 mA	<100 µs (typical)
100 µA	<150 µs (typical)
10 µA	<500 µs (typical)
1 µA	<2 ms (typical)
100 nA	<20 ms (typical)
10 nA	<40 ms (typical)
1 nA	<150 ms (typical)

DC FLOATING VOLTAGE: Output can be floated up to ±250VDC.

REMOTE SENSE OPERATING RANGE[10]: Maximum voltage between HI and SENSE HI = 3V. Maximum voltage between LO and SENSE LO = 3V.

VOLTAGE OUTPUT HEADROOM:

200V Range: Max. output voltage = 202.3V – total voltage drop across source leads (maximum 1Ω per source lead).

20V Range: Max. output voltage = 23.3V – total voltage drop across source leads (maximum 1Ω per source lead).

OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT: <300mV + 0.1% of larger range (typical). Overshoot into a 200kΩ load, 20MHz BW.

CURRENT SOURCE RANGE CHANGE OVERSHOOT: <5% of larger range + 300mV/R_{load} (typical – With source settling set to SETTLE_SMOOTH_100NA). See Current Source Output Settling Time for additional test condtions.

PULSE SPECIFICATIONS

Region	Maximum Current Limit	Maximum Pulse Width[11]	Maximum Duty Cycle[12]
1	100 mA @ 200 V	DC, no limit	100%
1	1.5 A @ 20 V	DC, no limit	100%
2	1 A @ 180 V	8.5 ms	1%
3[13]	1 A @ 200 V	2.2 ms	1%
4	10 A @ 5 V	1 ms	2.2%

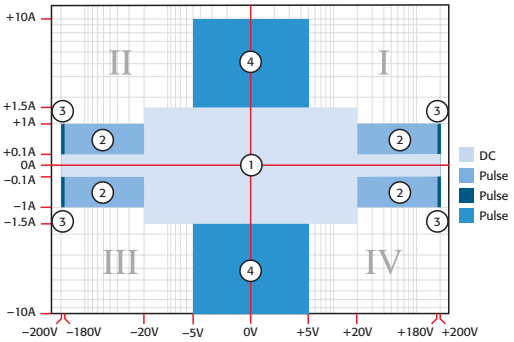
MINIMUM PROGRAMMABLE PULSE WIDTH[14,15]: 100µs. NOTE: Minimum pulse width for settled source at a given I/V output and load can be longer than 100µs.

PULSE WIDTH PROGRAMMING RESOLUTION: 1µs.

PULSE WIDTH PROGRAMMING ACCURACY[15]: ±5µs.

PULSE WIDTH JITTER: 50µs (typical).

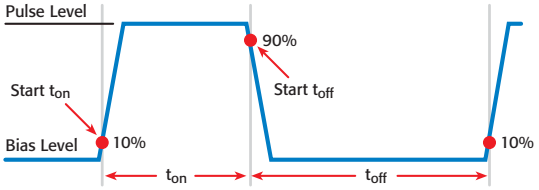
QUADRANT DIAGRAM:



SOURCE SPECIFICATIONS (continued)

NOTES

1. Add 50µV to source accuracy specifications per volt of HI lead drop.
2. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
3. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
4. For sink mode operation (quadrants II and IV), add 0.06% of limit range to the corresponding current limit accuracy specifications. Specifications apply with sink mode operation enabled.
5. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
6. 10A range accessible only in pulse mode.
7. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
8. Full power source operation regardless of load to 30°C ambient. Above 30°C and/or power sink operation, refer to "Operating Boundaries" in the Series 2600A Reference Manual for additional power derating information.
9. For sink mode operation (quadrants II and IV), add 10% of compliance range and ±0.02% of limit setting to corresponding voltage source specification. For 200mV range add an additional 120mV of uncertainty.
10. Add 50µV to source accuracy specifications per volt of HI lead drop.
11. Times measured from the start of pulse to the start off-time; see figure below.

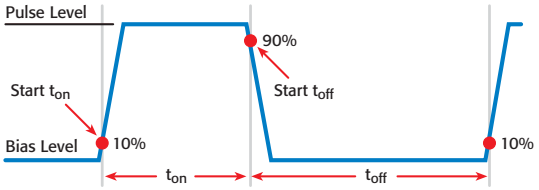


12. Thermally limited in sink mode (quadrants II and IV) and ambient temperatures above 30°C. See power equations in the Reference Manual for more information.
13. Voltage source operation with 1.5 A current limit.
14. Typical performance for minimum settled pulse widths:

Source Value	Load	Source Settling (% of range)	Min. Pulse Width
5 V	0.5 Ω	1%	300 µs
20 V	200 Ω	0.2%	200 µs
180 V	180 Ω	0.2%	5 ms
200 V (1.5 A Limit)	200 Ω	0.2%	1.5 ms
100 mA	200 Ω	1%	200 µs
1 A	200 Ω	1%	500 µs
1 A	180 Ω	0.2%	5 ms
10 A	0.5 Ω	0.5%	300 µs

Typical tests were performed using remote operation, 4W sense, and best, fixed measurement range. For more information on pulse scripts, see the Series 2600A Reference Manual.

15. Times measured from the start of pulse to the start off-time; see figure below.



METER SPECIFICATIONS

VOLTAGE MEASUREMENT ACCURACY [16, 17]

Range	Default Display Resolution [18]	Input Resistance	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)
200.000 mV	1 µV	>10^{14} Ω	0.015% + 225 µV
2.00000 V	10 µV	>10^{14} Ω	0.02% + 350 µV
20.0000 V	100 µV	>10^{14} Ω	0.015% + 5 mV
200.000 V	1 mV	>10^{14} Ω	0.015% + 50 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C) [19]: ±(0.15 × accuracy specification)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

CURRENT MEASUREMENT ACCURACY [17]

Range	Default Display Resolution [20]	Voltage Burden [21]	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)
100.00 pA [22, 23]	1 fA	<1 mV	0.15% + 120 fA
1.00000 nA [22, 24]	10 fA	<1 mV	0.15% + 240 fA
10.0000 nA	100 fA	<1 mV	0.15% + 3 pA
100.000 nA	1 pA	<1 mV	0.06% + 40 pA
1.00000 µA	10 pA	<1 mV	0.025% + 400 pA
10.0000 µA	100 pA	<1 mV	0.025% + 1.5 nA
100.000 µA	1 nA	<1 mV	0.02% + 25 nA
1.00000 mA	10 nA	<1 mV	0.02% + 200 nA
10.0000 mA	100 nA	<1 mV	0.02% + 2.5 µA
100.000 mA	1 µA	<1 mV	0.02% + 20 µA
1.00000 A	10 µA	<1 mV	0.03% + 1.5 mA
1.50000 A	10 µA	<1 mV	0.05% + 3.5 mA
10.0000 A [25]	100 µA	<1 mV	0.4 % + 25 mA

CURRENT MEASURE SETTLING TIME (Time for measurement to settle after a Vstep) [26]: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values for V_{out} = 2V unless noted. **Current Range:** 1mA. **Settling Time:** <100µs (typical).

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C) [27]: ±(0.15 × accuracy specfication)/°C. Applicable for normal mode only. Not applicable for high capacitance mode.

CONTACT CHECK [28]

Speed	Maximum Measurement Time to Memory For 60Hz (50Hz)	Accuracy (1 Year) 23°C ±5°C ±(%rdg. + ohms)
FAST	1 (1.2) ms	5% + 10 Ω
MEDIUM	4 (5) ms	5% + 1 Ω
SLOW	36 (42) ms	5% + 0.3 Ω

ADDITIONAL METER SPECIFICATIONS

MAXIMUM LOAD IMPEDANCE:
Normal Mode: 10nF (typical). **High Capacitance Mode:** 50µF (typical).

COMMON MODE VOLTAGE: 250VDC.

COMMON MODE ISOLATION: >1GΩ, <4500pF.

OVERRANGE: 101% of source range, 102% of measure range.

MAXIMUM SENSE LEAD RESISTANCE: 1kΩ for rated accuracy.

SENSE INPUT IMPEDANCE: >10^{14}Ω.

METER SPECIFICATIONS (continued)

NOTES

16. Add 50μV to source accuracy specifications per volt of HI lead drop.
17. De-rate accuracy specifications for NPLC setting <1 by increasing error term. Add appropriate % of range term using table below.

NPLC Setting	200mV Range	2V–200V Ranges	100nA Range	1μA–100mA Ranges	1A–1.5A Ranges
0.1	0.01%	0.01%	0.01%	0.01%	0.01%
0.01	0.08%	0.07%	0.1%	0.05%	0.05%
0.001	0.8 %	0.6 %	1%	0.5 %	1.1 %

18. Applies when in single channel display mode.
19. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
20. Applies when in single channel display mode.
21. Four-wire remote sense only and with current meter mode selected. Voltage measure set to 200mV or 2V range only.
22. 10-NPLC, 11-Point Median Filter, <200V range, measurements made within 1 hour after zeroing. 23°C ± 1°C
23. Under default specification conditions: ±(0.15% + 750fA).
24. Under default specification conditions: ±(0.15% + 1pA).
25. 10A range accessible only in pulse mode.
26. Delay factor set to 1. Compliance equal to 100mA.
27. High Capacitance Mode accuracy is applicable at 23°C ±5°C only.
28. Includes measurement of SENSE HI to HI and SENSE LO to LO contact resistances.

HIGH CAPACITANCE MODE [29, 30, 31]

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Current limit = 1A.

Voltage Source Range	Settling Time with C_{load} = 4.7μF
200 mV	600 μs (typical)
2 V	600 μs (typical)
20 V	1.5 ms (typical)
200 V	20 ms (typical)

CURRENT MEASURE SETTLING TIME: Time required to reach within 0.1% of final value after voltage source is stabilized on a fixed range. Values below for V_{out} = 2V unless noted.

Current Measure Range	Settling Time
1.5 A – 1 A	<120 μs (typical) (R_{load} >6Ω)
100 mA – 10 mA	<100 μs (typical)
1 mA	< 3 ms (typical)
100 μA	< 3 ms (typical)
10 μA	< 230 ms (typical)
1 μA	< 230 ms (typical)

CAPACITOR LEAKAGE PERFORMANCE USING HIGH-C SCRIPTS [32]: Load = 5μF||10MΩ. Test: 5V step and measure. 200ms (typical) @ 50nA.

MODE CHANGE DELAY:

100μA Current Range and Above:
Delay into High Capacitance Mode: 10ms.
Delay out of High Capacitance Mode: 10ms.

1μA and 10μA Current Ranges:
Delay into High Capacitance Mode: 230ms.
Delay out of High Capacitance Mode: 10ms.

VOLTMETER INPUT IMPEDANCE: 30GΩ in parallel with 3300pF.

NOISE, 10Hz–20MHz (20V Range): <30mV peak-peak (typical).

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT (for 20V range and below): <400mV + 0.1% of larger range (typical). Overshoot into a 200kΩ load, 20MHz BW.

NOTES

29. High Capacitance Mode specifications are for DC measurements only.
30. 100nA range and below are not available in high capacitance mode.
31. High Capacitance Mode utilizes locked ranges. Auto Range is disabled.
32. Part of KI Factory scripts. See reference manual for details.

SEE PAGES 24 AND 25 FOR MEASUREMENT SPEEDS AND OTHER SPECIFICATIONS.

GENERAL

IEEE-488: IEEE-488.1 compliant. Supports IEEE-488.2 common commands and status model topology.

RS-232: Baud rates from 300bps to 115200bps. Programmable number of data bits, parity type, and flow control (RTS/CTS hardware or none). When not programmed as the active host interface, the SourceMeter instrument can use the RS-232 interface to control other instrumentation.

ETHERNET: RJ-45 connector, LXI Class C, 10/100BT, no auto MDIX.

EXPANSION INTERFACE: The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.

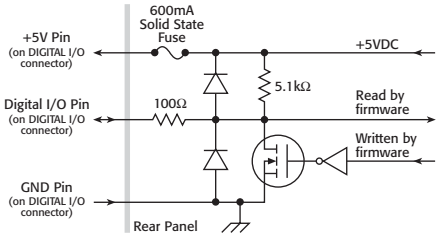
Cable Type: Category 5e or higher LAN crossover cable.

Length: 3 meters maximum between each TSP enabled instrument.

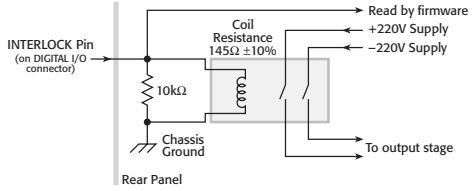
LXI COMPLIANCE: LXI Class C 1.2.

LXI TIMING: Total Output Trigger Response Time: 245μs min., 280μs typ., (not specified) max. **Receive LAN[0-7] Event Delay:** Unknown. **Generate LAN[0-7] Event Delay:** Unknown.

DIGITAL I/O INTERFACE:



Connector: 25-pin female D.
Input/Output Pins: 14 open drain I/O bits.
Absolute Maximum Input Voltage: 5.25V.
Absolute Minimum Input Voltage: –0.25V.
Maximum Logic Low Input Voltage: 0.7V, +850μA max.
Minimum Logic High Input Voltage: 2.1V, +570μA.
Maximum Source Current (flowing out of Digital I/O bit): +960μA.
Maximum Sink Current @ Maximum Logic Low Voltage (0.7V): –5.0mA.
Absolute Maximum Sink Current (flowing into Digital I/O pin): –11mA.
5V Power Supply Pin: Limited to 600mA, solid state fuse protected.
Safety Interlock Pin: Active high input. >3.4V @ 24mA (absolute maximum of 6V) must be externally applied to this pin to ensure 200V operation. This signal is pulled down to chassis ground with a 10kΩ resistor. 200V operation will be blocked when the INTERLOCK signal is <0.4V (absolute minimum –0.4V). See figure below:



USB: USB 1.0 Host Controller (Memory Stick I/O).

POWER SUPPLY: 100V to 250VAC, 50–60Hz (auto sensing), 240VA max.

COOLING: Forced air. Side intake and rear exhaust. One side must be unobstructed when rack mounted.

EMC: Conforms to European Union Directive 2004/108/EEC, EN 61326-1.

SAFETY: Conforms to European Union Directive 73/23/EEC, EN 61010-1, and UL 61010-1.

DIMENSIONS: 89mm high × 213mm wide × 460mm deep (3½ in × 8⅜ in × 17½ in). Bench Configuration (with handle and feet): 104mm high × 238mm wide × 460mm deep (4⅛ in × 9⅜ in × 17½ in).

WEIGHT: 2635A: 4.75kg (10.4 lbs). **2636A:** 5.50kg (12.0 lbs).

ENVIRONMENT: For indoor use only. **Altitude:** Maximum 2000 meters above sea level.
Operating: 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C.
Storage: –25°C to 65°C.

Series 2600A System SourceMeter® Instruments

Applicable to Models 2601A, 2602A, 2611A, 2612A, 2635A, and 2636A.
See page 28 for Model 2651A specifications.

MEASUREMENT SPEED SPECIFICATIONS [1, 2, 3]

MAXIMUM SWEEP OPERATION RATES (operations per second) FOR 60Hz (50Hz):

A/D Converter Speed	Trigger Origin	Measure To Memory Using User Scripts	Measure To GPIB Using User Scripts	Source Measure To Memory Using User Scripts	Source Measure To GPIB Using User Scripts	Source Measure To Memory Using Sweep API	Source Measure To GPIB Using Sweep API
0.001 NPLC	Internal	20000 (20000)	10500 (10500)	7000 (7000)	6200 (6200)	12000 (12000)	5900 (5900)
0.001 NPLC	Digital I/O	8100 (8100)	7100 (7100)	5500 (5500)	5100 (5100)	11200 (11200)	5700 (5700)
0.01 NPLC	Internal	5000 (4000)	4000 (3500)	3400 (3000)	3200 (2900)	4200 (3700)	3100 (2800)
0.01 NPLC	Digital I/O	3650 (3200)	3400 (3000)	3000 (2700)	2900 (2600)	4150 (3650)	3050 (2775)
0.1 NPLC	Internal	580 (490)	560 (475)	550 (465)	550 (460)	575 (480)	545 (460)
0.1 NPLC	Digital I/O	560 (470)	450 (460)	545 (460)	540 (450)	570 (480)	545 (460)
1.0 NPLC	Internal	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)
1.0 NPLC	Digital I/O	58 (48)	58 (49)	59 (49)	59 (49)	59 (49)	59 (49)

MAXIMUM SINGLE MEASUREMENT RATES (operations per second) FOR 60Hz (50Hz):

A/D Converter Speed	Trigger Origin	Measure To GPIB	Source Measure To GPIB	Source Measure Pass/Fail To GPIB
0.001 NPLC	Internal	1900 (1800)	1400 (1400)	1400 (1400)
0.01 NPLC	Internal	1450 (1400)	1200 (1100)	1100 (1100)
0.1 NPLC	Internal	450 (390)	425 (370)	425 (375)
1.0 NPLC	Internal	58 (48)	57 (48)	57 (48)

MAXIMUM MEASUREMENT RANGE CHANGE RATE: <150µs for ranges >10µA, typical. When changing to or from a range ≥1A, maximum rate is <450µs, typical.

MAXIMUM SOURCE RANGE CHANGE RATE: <2.5ms for ranges >10µA, typical. When changing to or from a range ≥1A, maximum rate is <5.2ms, typical.

MAXIMUM SOURCE FUNCTION CHANGE RATE: <1ms, typical.

COMMAND PROCESSING TIME: Maximum time required for the output to begin to change following the receipt of the smux.source.levelv or smux.source.leveli command. <1ms typical.

NOTES

1. Tests performed with a 2602A, 2612A, or 2636A on Channel A using the following equipment: PC Hardware (Pentium® 4 2.4GHz, 512MB RAM, National Instruments PCI-GPIB). Driver (NI-486.2 Version 2.2 PCI-GPIB). Software (Microsoft® Windows® 2000, Microsoft Visual Studio 2005, VISA version 4.1).
2. Exclude current measurement ranges less than 1mA.
3. 2635A/2636A with default measurement delays and filters disabled.

TRIGGERING AND SYNCHRONIZATION SPECIFICATIONS

TRIGGERING:

Trigger in to trigger out: 0.5µs, typical.
Trigger in to source change:[4] 10 µs, typical.
Trigger Timer accuracy: ±2µs, typical.
Source change[4] **after LXI Trigger:** 280µs, typical.

SYNCHRONIZATION:

Single-node synchronized source change:[4] <0.5µs, typical.
Multi-node synchronized source change:[4] <0.5µs, typical.

NOTES

4. Fixed source range, with no polarity change.

Series 2600A System SourceMeter® Instruments

Applicable to Models 2601A, 2602A, 2611A, 2612A, 2635A, and 2636A.
See page 28 for Model 2651A specifications.

SUPPLEMENTAL INFORMATION

FRONT PANEL INTERFACE: Two-line vacuum fluorescent display (VFD) with keypad and rotary knob.

Display:
- Show error messages and user defined messages
- Display source and limit settings
- Show current and voltage measurements
- View measurements stored in dedicated reading buffers

Keypad Operations:
- Change host interface settings
- Save and restore instrument setups
- Load and run factory and user defined test scripts (i.e. sequences) that prompt for input and send results to the display
- Store measurements into dedicated reading buffers

PROGRAMMING: Embedded Test Script Processor (TSP) accessible from any host interface. Responds to individual instrument control commands. Responds to high speed test scripts comprised of instrument control commands and Test Script Language (TSL) statements (e.g. branching, looping, math, etc.). Able to execute high speed test scripts stored in memory without host intervention.

Minimum Memory Available: 16MB (approximately 250,000 lines of TSL code).

Test Script Builder: Integrated development environment for building, running, and managing TSP scripts. Includes an instrument console for communicating with any TSP enabled instrument in an interactive manner. Requires:
- VISA (NI-VISA included on CD)
- Microsoft .NET Framework (included on CD)
- Keithley I/O Layer (included on CD)
- Pentium III 800MHz or faster personal computer
- Microsoft Windows 98, NT, 2000, or XP

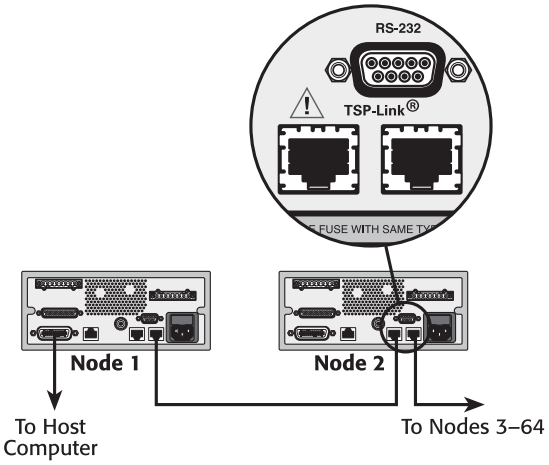
Software Interface: TSP Express (embedded), Direct GPIB/VISA, READ/WRITE for VB, VC/C++, LabVIEW, LabWindows/CVI, etc.

READING BUFFERS: Dedicated storage area(s) reserved for measurement data. Reading buffers are arrays of measurement elements. Each element can hold the following items:
- Measurement
- Measurement status
- Timestamp
- Source setting (at the time the measurement was taken)
- Range information

Two reading buffers are reserved for each SourceMeter channel. Reading buffers can be filled using the front panel STORE key and retrieved using the RECALL key or host interface.

Buffer Size, with timestamp and source setting: >60,000 samples.
Buffer Size, without timestamp and source setting: >140,000 samples.

SYSTEM EXPANSION: The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other. See figure below:



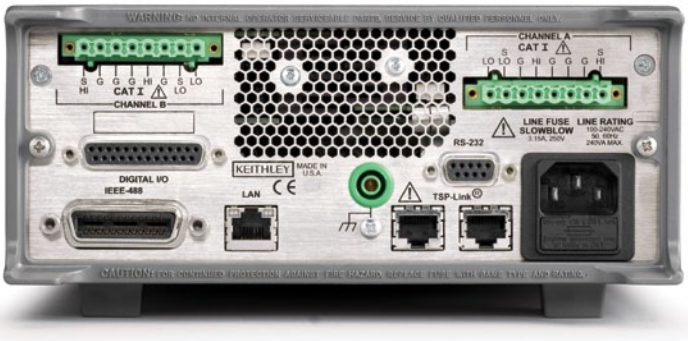
Each SourceMeter instrument has two TSP-Link connectors to facilitate chaining instruments together.
- Once SourceMeter instruments are interconnected via TSP-Link, a computer can access all of the resources of each SourceMeter instrument via the host interface of any SourceMeter instrument.
- A maximum of 32 TSP-Link nodes can be interconnected. Each SourceMeter instrument consumes one TSP-Link node.

TIMER: Free running 47-bit counter with 1MHz clock input. Reset each time instrument powers up. Rolls over every 4 years.

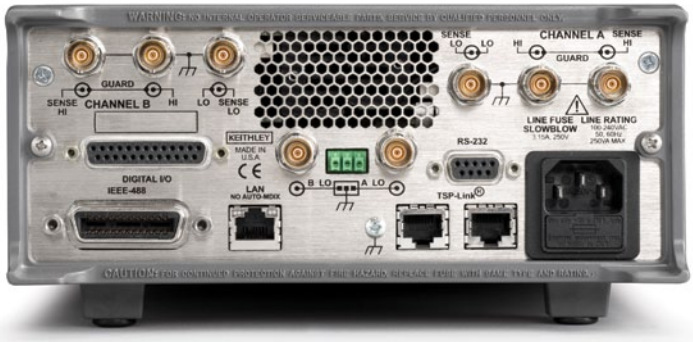
Timestamp: TIMER value automatically saved when each measurement is triggered.

Resolution: 1µs.

Accuracy: ±100ppm.



Model 2602A/2612A rear panel
(Single channels 2601A, 2611A, 2635A not shown)



Model 2636A rear panel

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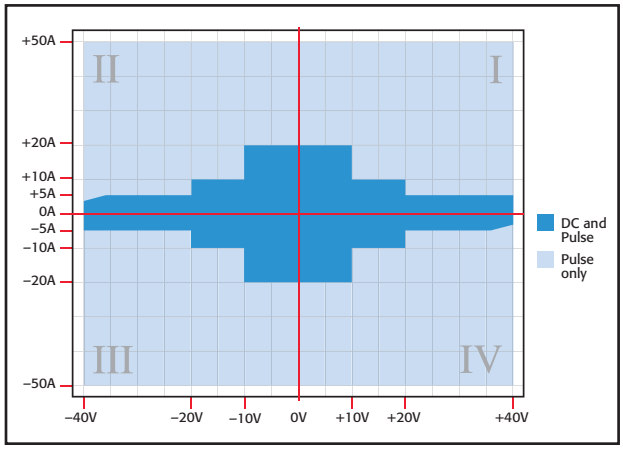
50A, High Power System SourceMeter® Instrument

- **Source or sink:**
  - **2,000W of pulsed power (±40V, ±50A)**
  - **200W of DC power (±10V@±20A, ±20V@±10A, ±40V@±5A)**
- **Easily connect two units (in series or parallel) to create solutions up to ±100A or ±80V**
- **1pA resolution enables precise measurement of very low leakage currents**
- **1µs per point (1MHz), 18-bit sampling, accurately characterizes transient behavior**
- **1% to 100% pulse duty cycle for pulse width modulated (PWM) drive schemes and device-specific drive stimulus**
- **Combines a precision power supply, current source, DMM, arbitrary waveform generator, V or I pulse generator with measurement, electronic load, and trigger controller—all in one instrument**
- **Includes TSP® Express I-V characterization software, LabVIEW® driver, and Keithley's Test Script Builder software development environment**

The high power Model 2651A is the newest addition to the Series 2600A family of System SourceMeter instruments. Specifically designed to characterize and test high power electronics, these source measurement unit (SMU) instruments can help you improve productivity in applications across the R&D, reliability, and production spectrums, including high brightness LEDs, power semiconductors, DC-DC converters, batteries, and other high power materials, components, modules, and subassemblies.

The Model 2651A, like every Series 2600A SourceMeter instrument, offers a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current meters. It can be used as a:

- Semiconductor characterization instrument
- V or I waveform generator
- V or I pulse generator
- Precision power supply
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load



The Model 2651A can source or sink up to ±40V and ±50A.

Two Measurement Modes: Digitizing or Integrating

Precisely characterize transient and steady-state behavior, including rapidly changing thermal effects, with the two measurement modes in the Model 2651A. Each mode is defined by its independent analog-to-digital (A/D) converters.

The Digitizing Measurement mode enables 1µs per point measurements. Its 18-bit A/D converters allow you to precisely measure transient characteristics. For more accurate measurements, use its Integrating Measurement mode, which is based on 22-bit A/D converters. The Integrating Measurement mode is provided in all Series 2600A instruments.

APPLICATIONS

- **Power semiconductor, HBLED, and optical device characterization and testing**
- **Characterization of GaN, SiC, and other compound materials and devices**
- **Semiconductor junction temperature characterization**
- **High speed, high precision digitization**
- **Electromigration studies**
- **High current, high power device testing**

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Ordering information

2651A **High Power System SourceMeter® Instrument**

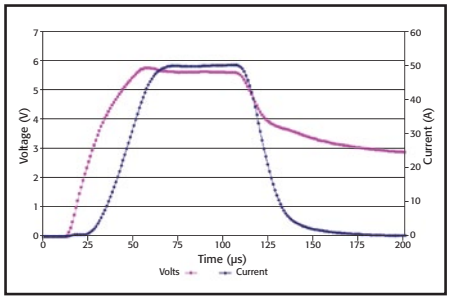
Accessories Supplied

2651A-KIT-1A: Low Impedance Cable Assembly (1m)
CS-1592-2: High Current Phoenix Connector (male)
CS-1626-2: High Current Phoenix Connector (female)
CA-557-1: Sense Line Cable Assembly (1m)
7709-308A: Digital I/O Connector
CA-180-3A: TSP-Link/Ethernet Cable
Documentation CD
Software Tools and Drivers CD

ACCESSORIES AVAILABLE

2600-KIT	Low Impedance CAble Assemble, 1m (3.3 ft)
ACS-BASIC	Component Charaterization Software
4299-6	Rack Mount Kit
8011	Test Socket Kit

Two A/D converters are used with each measurement mode (one for current and the other for voltage), which run simultaneously for accurate source readback that does not sacrifice test throughput.



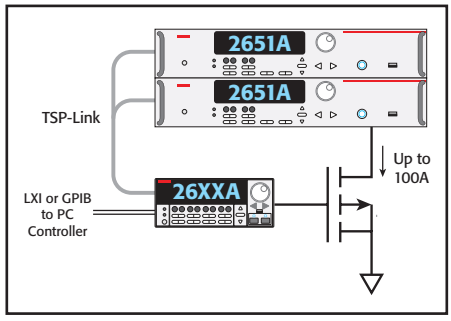
The dual digitizing A/D converters sample at up to 1µs/point, enabling full simultaneous characterization of both current and voltage waveforms.

High Speed Pulsing

The Model 2651A minimizes the unwanted effects of self heating during tests by accurately sourcing and measuring pulses as short as 100μs. Additional control flexibility enables you to program the pulse width from 100μs to DC and the duty cycle from 1% to 100%. A single unit can pulse up to 50A; combine two units to pulse up to 100A.

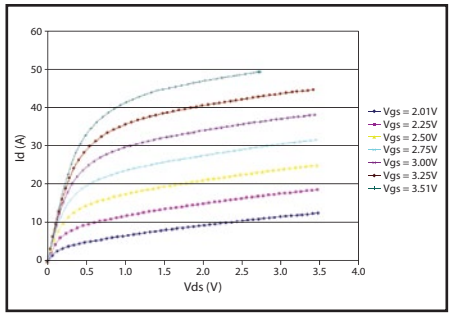
Expansion Capabilities

Through TSP-Link® technology, multiple Model 2651As and other Series 2600A instruments can be combined to form a larger integrated system with up to 64 channels. Precision timing and tight channel synchronization are guaranteed with built-in 500ns trigger controllers. True SMU instrument-per-pin testing is assured with the fully isolated, independent channels of the SourceMeter instruments.

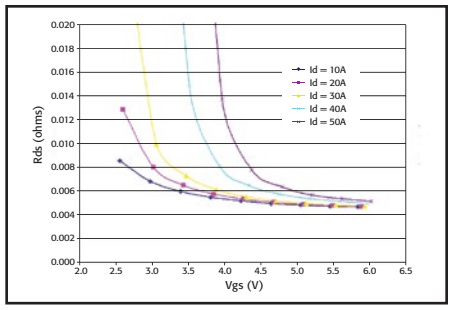


Keithley's TSP and TSP-Link technology enables true SMU-per-pin testing without the power and/or channel limitations of a mainframe-based system.

Also, when two Model 2651As are connected in parallel with TSP-Link technology, the current range is expanded from 50A to 100A. When two units are connected in series, the voltage range is expanded from 40V to 80V. Built-in intelligence simplifies testing by enabling the units to be addressed as a single instrument, thus creating an industry-best dynamic range (100A to 1pA). This capability enables you to test a much wider range of power semiconductors and other devices.



Precision measurements to 50A (100A with two units) enable a more complete and accurate characterization.



1µV measurement resolution and current sourcing up to 50A (100A with two units) enable low-level Rds measurements to support next-generation devices.

Standard Capabilities of Series 2600A Instruments

Each Model 2651A includes all the features and capabilities provided in the other Series 2600A instruments, such as:

- Ability to be used as either a bench-top I-V characterization tool or as a building block component of multiple-channel I-V test systems
- TSP Express software to quickly and easily perform common I-V tests without programming or installing software
- ACS Basic Edition software for semiconductor component characterization (optional). ACS Basic now features a Trace mode for generating a suite of characteristic curves.
- Keithley's Test Script Processor (TSP®), which enables creation of custom user test scripts to further automate testing, and also supports the creation of programming sequences that allow the instrument to operate asynchronously without direct PC control.
- Parallel test execution and precision timing when multiple Series 2600A instruments are connected together in a system
- LXI Class C compliance
- 14 digital I/O lines for direct interaction with probe stations, component handlers, or other automation tools
- USB port for extra data and test program storage via USB memory device

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Specification Conditions

This document contains specifications and supplemental information for the Model 2651A High Power System SourceMeter instrument. Specifications are the standards against which the Model 2651A is tested. Upon leaving the factory, the Model 2651A meets these specifications. Supplemental and typical values are non-warranted, apply at 23°C, and are provided solely as useful information.

Accuracy specifications are applicable for both normal and high-capacitance modes.

Source and measurement accuracies are specified at the Model 2651A terminals under these conditions:

- 23° ±5°C, <70 percent relative humidity
- After two-hour warm-up
- Speed normal (1 NPLC)
- A/D autozero enabled
- Remote sense operation or properly zeroed local operation
- Calibration period: One year

VOLTAGE ACCURACY SPECIFICATIONS [1, 2]

	SOURCE			MEASURE		
Range	Programming Resolution	Accuracy ±(% reading + volts)	Noise (Vpp) (typical) 0.1 Hz to 10 Hz	Default Display Resolution	Integrating ADC Accuracy [3] ±(% reading + volts)	High-Speed ADC Accuracy [4] ±(% reading + volts)
100.000 mV	5 µV	0.02% + 500 µV	100 µV	1 µV	0.02% + 300 µV	0.05% + 600 µV
1.00000 V	50 µV	0.02% + 500 µV	500 µV	10 µV	0.02% + 300 µV	0.05% + 600 µV
10.0000 V	500 µV	0.02% + 5 mV	1 mV	100 µV	0.02% + 3 mV	0.05% + 8 mV
20.0000 V	500 µV	0.02% + 5 mV	1 mV	100 µV	0.02% + 5 mV	0.05% + 8 mV
40.0000 V	500 µV	0.02% + 12 mV	2 mV	100 µV	0.02% + 12 mV	0.05% + 15 mV

CURRENT ACCURACY SPECIFICATIONS [5]

	SOURCE			MEASURE		
Range	Programming Resolution	Accuracy ±(% reading + amps)	Noise (Ipp) (typical) 0.1Hz to 10Hz	Default Display Resolution	Integrating ADC Accuracy [3] ±(% reading + amps)	High-Speed ADC Accuracy [4] ±(% reading + amps)
100.000 nA	2 pA	0.1 % + 500 pA	50 pA	1 pA	0.08% + 500 pA	0.08% + 800 pA
1.00000 µA	20 pA	0.1 % + 2 nA	250 pA	10 pA	0.08% + 2 nA	0.08% + 4 nA
10.0000 µA	200 pA	0.1 % + 10 nA	500 pA	100 pA	0.08% + 8 nA	0.08% + 10 nA
100.000 µA	2 nA	0.03% + 60 nA	5 nA	1 nA	0.02% + 25 nA	0.05% + 60 nA
1.00000 mA	20 nA	0.03% + 300 nA	10 nA	10 nA	0.02% + 200 nA	0.05% + 500 nA
10.0000 mA	200 nA	0.03% + 8 µA	500 nA	100 nA	0.02% + 2.5 µA	0.05% + 10 µA
100.000 mA	2 µA	0.03% + 30 µA	1 µA	1 µA	0.02% + 20 µA	0.05% + 50 µA
1.00000 A	200 µA	0.08% + 3.5 mA	300 µA	10 µA	0.05% + 3 mA	0.05% + 5 mA
5.00000 A	200 µA	0.08% + 3.5 mA	300 µA	10 µA	0.05% + 3 mA	0.05% + 5 mA
10.0000 A	500 µA	0.15% + 6 mA	500 µA	100 µA	0.12% + 6 mA	0.12% + 12 mA
20.0000 A	500 µA	0.15% + 8 mA	500 µA	100 µA	0.08% + 8 mA	0.08% + 15 mA
50.0000 A [6]	2 mA	0.15% + 80 mA	N/A	100 µA	0.05% + 50 mA [7]	0.05% + 90 mA [8]

NOTES

1. Add 50µV to source accuracy specifications per volt of HI lead drop.
2. For temperatures 0° to 18°C and 28° to 50°C, accuracy is degraded by ±(0.15 × accuracy specification)/°C. High-capacitance mode accuracy is applicable at 23° ±5°C only.
3. Derate accuracy specification for NPLC setting <1 by increasing error term. Add appropriate typical percent of range term for resistive loads using the table below.

NPLC Setting	100mV Range	1V to 40V Ranges	100nA Range	1µA to 100mA Ranges	1A to 20A Ranges
0.1	0.01%	0.01%	0.01%	0.01%	0.01%
0.01	0.08%	0.07%	0.1 %	0.05%	0.1 %
0.001	0.8 %	0.6 %	1 %	0.5 %	1.8 %

4. 18-bit ADC. Average of 1000 samples taken at 1µs intervals.
5. At temperatures 0° to 18°C and 28° to 50°C; 100nA to 10µA accuracy is degraded by ±(0.35 × accuracy specification)/°C. 100µA to 50A accuracy is degraded by ±(0.15 × accuracy specification)/°C. High-capacitance mode accuracy is applicable at 23° ±5°C only.
6. 50A range accessible only in pulse mode.
7. 50A range accuracy measurements are taken at 0.008 NPLC.
8. Average of 100 samples taken at 1µs intervals.

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DC POWER SPECIFICATIONS

MAXIMUM OUTPUT POWER: 202W maximum.

SOURCE/SINK LIMITS [1]:

Voltage: ±10.1V at ±20.0A, ±20.2V at ±10.0A, ±40.4V at ±5.0A [2].
Four-quadrant source or sink operation.

Current: ±5.05A at ±40V [2], ±10.1A at ±20V, ±20.2A at ±10V
Four-quadrant source or sink operation.

CAUTION: Carefully consider and configure the appropriate output-off state and source and compliance levels before connecting the Model 2651A to a device that can deliver energy. Failure to consider the output-off state and source and compliance levels may result in damage to the instrument or to the device under test.

PULSE SPECIFICATIONS

MINIMUM PROGRAMMABLE PULSE WIDTH [3]: 100µs. Note: Minimum pulse width for settled source at a given I/V output and load can be longer than 100µs.

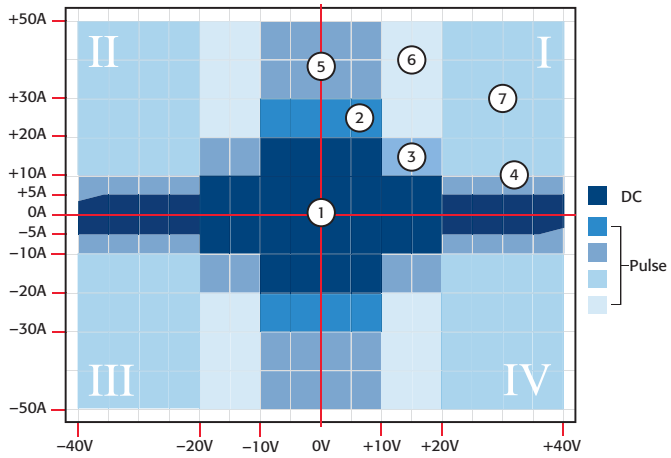
PULSE WIDTH PROGRAMMING RESOLUTION: 1µs.

PULSE WIDTH PROGRAMMING ACCURACY [3]: ±5µs.

PULSE WIDTH JITTER: 2µs (typical).

PULSE RISE TIME (TYPICAL):

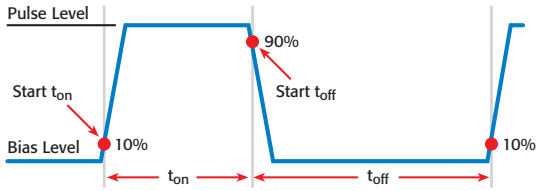
Current Range	R_{load}	Rise Time (typical)
50 A	0.05 Ω	26 µs
50 A	0.2 Ω	57 µs
50 A	0.4 Ω	85 µs
20 A	0.5 Ω	95 µs
50 A	0.8 Ω	130 µs
20 A	1 Ω	180 µs
10 A	2 Ω	330 µs
5 A	8.2 Ω	400 µs



Region	Region Maximums	Maximum Pulse Width [3]	Maximum Duty Cycle [4]
1	5 A at 40 V	DC, no limit	100%
1	10 A at 20 V	DC, no limit	100%
1	20 A at 10 V	DC, no limit	100%
2	30 A at 10 V	1 ms	50%
3	20 A at 20 V	1.5 ms	40%
4	10 A at 40 V	1.5 ms	40%
5	50 A at 10 V	1 ms	35%
6	50 A at 20 V	330 µs	10%
7	50 A at 40 V	300 µs	1%

NOTES

1. Full power source operation regardless of load to 30°C ambient. Above 30°C or power sink operation, refer to "Operating Boundaries" in the Model 2651A Reference manual for additional power derating information.
2. Quadrants 2 and 4 power envelope is trimmed at 36V and 4.5A.
3. Times measured from the start of pulse to the start off-time; see figure below.



4. Thermally limited in sink mode (quadrants 2 and 4) and ambient temperatures above 30°C. See power equations in the Model 2651A Reference Manual for more information.

The Model 2651A supports GPIB, LXI, Digital I/O, and Keithley's TSP-Link for multi-channel synchronization.

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ADDITIONAL SOURCE SPECIFICATIONS

NOISE (10Hz to 20MHz): <100mV peak-peak (typical), <30mV RMS (typical), 10V range with a 20A limit.

OVERSHOOT:

Voltage: <±(0.1% + 10mV) (typical). Step size = 10% to 90% of range, resistive load, maximum current limit/compliance.

Current: <±(0.1% + 10mV) (typical). Step Size = 10% to 90% of range, resistive load. See Current Source Output Settling Time specifications for additional test conditions.

RANGE CHANGE OVERSHOOT:

Voltage: <300mV + 0.1% of larger range (for <20V ranges) (typical).
<400mV + 0.1% of larger range (for ≥20V ranges) (typical).
Overshoot into a 100kΩ load, 20MHz bandwidth.

Current: <5% of larger range + 360mV/R_{load} (for >10μA ranges) (typical). $I_{out} \times R_{load}$ = 1V.

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. [1]

Range	Settling Time (typical)
1 V	< 70 μs
10 V	<160 μs
20 V	<190 μs
40 V	<175 μs

CURRENT SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1% of final value after source level command is processed on a fixed range. Values below for $I_{out} \times R_{load}$.

Current Range	R_{load}	Settling time (typical)
20 A	0.5 Ω	<195 μs
10 A	1.5 Ω	<540 μs
5 A	5 Ω	<560 μs
1 A	1 Ω	< 80 μs
100 mA	10 Ω	< 80 μs
10 mA	100 Ω	<210 μs
1 mA	1 kΩ	<300 μs
100 μA	10 kΩ	<500 μs
10 μA	100 kΩ	< 15 ms
1 μA	1 MΩ	< 35 ms
100 nA	10 MΩ	<110 ms

TRANSIENT RESPONSE TIME:

10V and 20V Ranges: <70μs for the output to recover to within 0.1% for a 10% to 90% step change in load.

40V Range: <110μs for the output to recover to within 0.1% for a 10% to 90% step change in load.

GUARD OFFSET VOLTAGE: <4mV, current <10mA.

REMOTE SENSE OPERATING RANGE [2]:

Maximum Voltage between HI and SENSE HI: 3V.
Maximum Voltage between LO and SENSE LO: 3V.

MAXIMUM IMPEDANCE PER SOURCE LEAD:

Maximum impedance limited by 3V drop by remote sense operating range.

Maximum resistance = 3V/source current value (amperes) (maximum of 1Ω per source lead).

3V = L di/dt.

VOLTAGE OUTPUT HEADROOM:

5A Range: Maximum output voltage = 48.5V – (Total voltage drop across source leads).

10A Range: Maximum output voltage = 24.5V – (Total voltage drop across source leads).

20A Range: Maximum output voltage = 15.9V – (Total voltage drop across source leads).

OVERTEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

LIMIT/COMPLIANCE: Bipolar limit (compliance) set with single value.

Voltage [3]: Minimum value is 10mV; accuracy is the same as voltage source.

Current [4]: Minimum value is 10nA; accuracy is the same as current source.

NOTES

1. With measure and compliance set to the maximum current for the specified voltage range.
2. Add 50 μV to source accuracy specifications per volt of HI lead drop.
3. For sink mode operation (quadrants II and IV), add 0.6% of limit range to the corresponding voltage source accuracy specifications. For 100mV range add an additional 60mV of uncertainty. Specifications apply with sink mode enabled.
4. For sink mode operation (quadrants II and IV), add 0.6% of limit range to the corresponding current limit accuracy specifications. Specifications apply with sink mode enabled.

ADDITIONAL MEASUREMENT SPECIFICATIONS

CONTACT CHECK [1]

Speed	Maximum Measurement Time to Memory for 60Hz (50Hz)	Accuracy (1 Year) 23° ±5°C ±(% reading + ohms)
Fast	1.1 ms (1.2 ms)	5% + 15 Ω
Medium	4.1 ms (5 ms)	5% + 5 Ω
Slow	36 ms (42 ms)	5% + 3 Ω

NOTES

1. Includes measurement of SENSE HI to HI and SENSE LO to LO contact resistances.

ADDITIONAL METER SPECIFICATIONS

MAXIMUM LOAD IMPEDANCE:

Normal Mode: 10nF (typical), 3μH (typical).
High-Capacitance Mode: 50μF (typical), 3μH (typical).

COMMON MODE VOLTAGE: 250V DC.

COMMON MODE ISOLATION: >1GΩ, <4500pF.

MEASURE INPUT IMPEDANCE: >10GΩ.

SENSE HIGH INPUT IMPEDANCE: >10GΩ.

MAXIMUM SENSE LEAD RESISTANCE: 1kΩ for rated accuracy.

OVERRANGE: 101% of source range, 102% of measure range.

HIGH-CAPACITANCE MODE [1,2]

ACCURACY SPECIFICATIONS [3]: Accuracy specifications are applicable in both normal and high-capacitance modes.

VOLTAGE SOURCE OUTPUT SETTLING TIME: Time required to reach within 0.1 % of final value after source level command is processed on a fixed range. [4]

Voltage Source Range	Settling Time with C_{load} = 4.7μF (typical)
1 V	75 μs
10 V	170 μs
20 V	200 μs
40 V	180 μs

MODE CHANGE DELAY:

100 μA Current Range and Above:
Delay into High-Capacitance Mode: 11ms.
Delay out of High-Capacitance Mode: 11ms.

1 μA and 10 μA Current Ranges:
Delay into High-Capacitance Mode: 250ms.
Delay out of High-Capacitance Mode: 11ms.

MEASURE INPUT IMPEDANCE: >10GΩ in parallel with 25nF.

VOLTAGE SOURCE RANGE CHANGE OVERSHOOT: <400mV + 0.1% of larger range (typical). Overshoot into a 100kΩ load, 20MHz bandwidth.

NOTES

1. High-capacitance mode specifications are for DC measurements only and use locked ranges. Autorange is disabled.
2. 100nA range is not available in high-capacitance mode.
3. Add an additional 2nA to the source current accuracy and measure current accuracy offset for the 1μA range.
4. With measure and compliance set to the maximum current for the specified voltage range.

MEASUREMENT SPEED SPECIFICATIONS [1, 2]

MAXIMUM SWEEP OPERATION RATES (operations per second) FOR 60Hz (50Hz):

A/D Converter Speed	Trigger Origin	Measure To Memory Using User Scripts	Measure To GPIB Using User Scripts	Source Measure To Memory Using User Scripts	Source Measure To GPIB Using User Scripts	Source Measure To Memory Using Sweep API	Source Measure To GPIB Using Sweep API
0.001 NPLC	Internal	20000 (20000)	9800 (9800)	7000 (7000)	6200 (6200)	12000 (12000)	5900 (5900)
0.001 NPLC	Digital I/O	8100 (8100)	7100 (7100)	5500 (5500)	5100 (5100)	11200 (11200)	5700 (5700)
0.01 NPLC	Internal	4900 (4000)	3900 (3400)	3400 (3000)	3200 (2900)	4200 (3700)	4000 (3500)
0.01 NPLC	Digital I/O	3500 (3100)	3400 (3000)	3000 (2700)	2900 (2600)	4150 (3650)	3800 (3400)
0.1 NPLC	Internal	580 (480)	560 (470)	550 (465)	550 (460)	560 (470)	545 (460)
0.1 NPLC	Digital I/O	550 (460)	550 (460)	540 (450)	540 (450)	560 (470)	545 (460)
1.0 NPLC	Internal	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)	59 (49)
1.0 NPLC	Digital I/O	58 (48)	58 (49)	59 (49)	59 (49)	59 (49)	59 (49)
HS ADC	Internal	38500 (38500)	18000 (18000)	10000 (10000)	9500 (9500)	14300 (14300)	6300 (6300)
HS ADC	Digital I/O	12500 (12500)	11500 (11500)	7500 (7500)	7000 (7000)	13200 (13200)	6000 (6000)

HIGH SPEED ADC BURST MEASUREMENT RATES [3]

Burst Length (readings)	Readings per Second	Bursts per Second
100	1,000,000	400
500	1,000,000	80
1000	1,000,000	40
2500	1,000,000	16
5000	1,000,000	8

MAXIMUM SINGLE MEASUREMENT RATES (operations per second) FOR 60Hz (50Hz)

A/D Converter Speed	Trigger Origin	Measure To GPIB	Source Measure To GPIB	Source Measure Pass/Fail To GPIB
0.001 NPLC	Internal	1900 (1800)	1400 (1400)	1400 (1400)
0.01 NPLC	Internal	1450 (1400)	1200 (1100)	1100 (1100)
0.1 NPLC	Internal	450 (390)	425 (370)	425 (375)
1.0 NPLC	Internal	58 (48)	57 (48)	57 (48)

MAXIMUM MEASUREMENT RANGE CHANGE RATE: >4000 per second for >10µA (typical).

MAXIMUM SOURCE RANGE CHANGE RATE: >325 per second for >10µA, typical. When changing to or from a range ≥1A, maximum rate is >250 per second, typical.

COMMAND PROCESSING TIME: Maximum time required for the output to begin to change following the receipt of the smua.source.levelv or smua.source.leveli command. <1ms typical.

NOTES

1. Tests performed with a Model 2651A on channel A using the following equipment: Computer hardware (Intel® Pentium® 4 2.4GHz, 2GB RAM, National Instruments™ PCI-GPIB). Driver (NI-488.2 Version 2.2 PCI-GPIB). Software (Microsoft® Windows® XP, Microsoft Visual Studio® 2010, VISA™ version 4.1).
2. Exclude current measurement ranges less than 1mA.
3. `smua.measure.adc` has to be enabled and the smua.measure.count set to the burst length.

TRIGGERING AND SYNCHRONIZATION SPECIFICATIONS

TRIGGERING:

Trigger In to Trigger Out: 0.5µs (typical).
Trigger In to Source Change [1]: 10µs (typical).
Trigger Timer Accuracy: ±2µs (typical).
Source Change [1] After LXI Trigger: 280µs (typical).

SYNCHRONIZATION:

Single-Node Synchronized Source Change [1]: <0.5µs (typical).
Multi-Node Synchronized Source Change [1]: <0.5µs (typical).

NOTES

1. Fixed source range with no polarity change.

2651A

50A, High Power System SourceMeter® Instrument

SUPPLEMENTAL INFORMATION

FRONT PANEL INTERFACE: Two-line vacuum fluorescent display (VFD) with keypad and navigation wheel.

DISPLAY:

- Show error messages and user defined messages
- Show current and voltage measurements (6½-digit to 4½-digit)
- Display source and limit settings
- View measurements stored in dedicated reading buffers

KEYPAD OPERATIONS:

- Change host interface settings
- Save and restore instrument setups
- Load and run factory and user defined test scripts that prompt for input and send results to the display
- Store measurements into dedicated reading buffers

PROGRAMMING: Embedded Test Script Processor (TSP®) scripting engine is accessible from any host interface.

- Responds to individual instrument control commands.
- Responds to high speed test scripts comprised of instrument control commands and Test Script Language (TSL) statements (for example, branching, looping, and math).
- Able to execute high speed test scripts stored in memory without host intervention.

MINIMUM USER MEMORY AVAILABLE: 16MB (approximately 250,000 lines of TSP code).

TEST SCRIPT BUILDER: Integrated development environment for building, running, and managing TSP scripts. Includes an instrument console for communicating with any TSP enabled instrument in an interactive manner. Requires:

- VISA (NI-VISA included on CD)
- Microsoft® .NET Framework (included on CD)
- Keithley I/O Layer (included on CD)
- Intel® Pentium III 800MHz or faster personal computer
- Microsoft Windows® 2000, XP, Vista®, or 7

TSP EXPRESS (embedded): Tool that allows users to quickly and easily perform common I-V tests without programming or installing software. To run TSP Express, you need:

- Java™ Platform, Standard Edition 6
- Microsoft Internet Explorer®, Mozilla® Firefox®, or another Java-compatible web browser

SOFTWARE INTERFACE: TSP Express (embedded), direct GPIB/VISA, read/write with Microsoft Visual Basic®, Visual C/C++®, Visual C#®, LabVIEW™, CEC TestPoint™ Data Acquisition Software Package, NI LabWindows™/CVI, etc.

READING BUFFERS: Nonvolatile memory uses dedicated storage areas reserved for measurement data. Reading buffers are arrays of measurement elements. Each element can hold the following items:

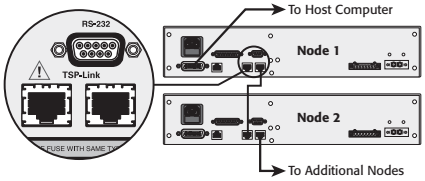
- Measurement
- Measurement status
- Timestamp
- Source setting (at the time the measurement was taken)
- Range information

Two reading buffers are reserved for each Model 2651A channel. Reading buffers can be filled using the front panel STORE key and retrieved using the RECALL key or host interface.

Buffer Size, with timestamp and source setting: >60,000 samples.

Buffer Size, without timestamp and source setting: >140,000 samples.

SYSTEM EXPANSION: The TSP-Link expansion interface allows TSP-enabled instruments to trigger and communicate with each other. See figure below.



Each Model 2651A has two TSP-Link connectors to make it easier to connect instruments together in sequence.

- Once source-measure instruments are interconnected through the TSP-Link expansion interface, a computer can access all of the resources of each source-measure instrument through the host interface of any Model 2651A
- A maximum of 32 TSP-Link nodes can be interconnected. Each source-measure instrument consumes one TSP-Link node.

TIMER: Free-running 47-bit counter with 1MHz clock input. Resets each time instrument power is turned on. If the instrument is not turned off, the timer is reset to zero every 4 years.

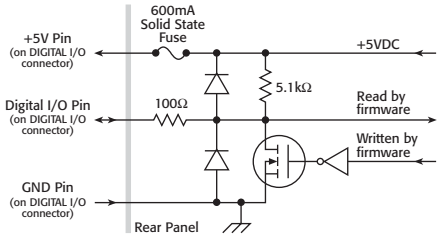
Timestamp: TIMER value is automatically saved when each measurement is triggered.

Resolution: 1µs.

Timestamp Accuracy: ±100ppm.

GENERAL

DIGITAL I/O INTERFACE:



Connector: 25-pin female D.

Input/Output Pins: 14 open drain I/O bits.

Absolute Maximum Input Voltage: 5.25V.

Absolute Minimum Input Voltage: –0.25V.

Maximum Logic Low Input Voltage: 0.7V, +850µA max.

Minimum Logic High Input Voltage: 2.1V, +570µA.

Maximum Source Current (flowing out of digital I/O bit): +960µA.

Maximum Sink Current At Maximum Logic Low Voltage (0.7): –5.0mA.

Absolute Maximum Sink Current (flowing into digital I/O pin): –11mA.

5V Power Supply Pin: Limited to 250mA, solid-state fuse protected.

Output Enable Pin: Active high input pulled down internally to ground with a 10kΩ resistor; when the output enable input function has been activated, the Model 2651A channel will not turn on unless the output enable pin is driven to >2.1V (nominal current = 2.1V/10kΩ = 210µA).

IEEE-488: IEEE Std 488.1 compliant. Supports IEEE Std 488.2 common commands and status model topology.

RS-232: Baud rates from 300bps to 115200bps. Programmable number of data bits, parity type, and flow control (RTS/CTS hardware or none). When not programmed as the active host interface, the Model 2651A can use the RS-232 interface to control other instrumentation.

ETHERNET: RJ-45 connector, LXI Class C, 10/100BT, Auto MDIX.

LXI COMPLIANCE: LXI Class C 1.2.

Total Output Trigger Response Time: 245µs minimum, 280µs (typical), (not specified) maximum.

Receive Lan[0-7] Event Delay: Unknown.

Generate Lan[0-7] Event Delay: Unknown.

EXPANSION INTERFACE: The TSP-Link® expansion interface allows TSP-enabled instruments to trigger and communicate with each other.

Cable Type: Category 5e or higher LAN crossover cable. 3 meters maximum between each TSP-enabled instrument.

USB: USB 2.0 host controller.

POWER SUPPLY: 100V to 250V AC, 50Hz to 60Hz (autosensing), 550VA maximum.

COOLING: Forced air; side and top intake and rear exhaust.

WARRANTY: 1 year.

EMC: Conforms to European Union EMC Directive.

SAFETY: UL listed to UL61010-1:2004. Conforms to European Union Low Voltage Directive.

DIMENSIONS: 89mm high × 435mm wide × 549mm deep (3.5 in. × 17.1 in. × 21.6 in.).

BENCH CONFIGURATION (with handle and feet): 104mm high × 483mm wide × 620mm deep (4.1 in. × 19 in. × 24.4 in.).

WEIGHT: 9.98kg (22 lb).

ENVIRONMENT: For indoor use only.

ALTITUDE: Maximum 2000 meters above sea level.

OPERATING: 0° to 50° C, 70 % relative humidity up to 35°C. Derate 3% relative humidity/°C, 35° to 50°C.

STORAGE: –25° to 65°C.

Series 2400 SourceMeter® Line

- **Five instruments in one (IV Source, IVR Measure)**
- **Seven models: 20–100W DC, 1000W pulsed, 1100V to 1µV, 10A to 10pA**
- **Source and sink (4-quadrant) operation**
- **0.012% basic measure accuracy with 6½-digit resolution**
- **2-, 4-, and 6-wire remote V-source and measure sensing**
- **1700 readings/second at 4½ digits via GPIB**
- **Pass/Fail comparator for fast sorting/binning**
- **Available high speed sense lead contact check function**
- **Programmable DIO port for automation/handler/prober control (except Model 2401)**
- **Standard SCPI GPIB, RS-232 and Keithley Trigger Link interfaces**
- **Keithley LabTracer 2.0 I-V curve tracing application software (download)**

Keithley's SourceMeter family are source measurement unit (SMU) instruments designed specifically for test applications that demand tightly coupled sourcing and measurement. All SourceMeter models provide precision voltage and current sourcing as well as measurement capabilities. Each SourceMeter instrument is both a highly stable DC power source and a true instrument-grade 6½-digit multimeter. The power source characteristics include low noise, precision, and readback. The multimeter capabilities include high repeatability and low noise. The result is a compact, single-channel, DC parametric tester. In operation, these instruments can act as a voltage source, a current source, a voltage meter, a current meter, and an ohmmeter. Manufacturers of components and modules for the communications, semiconductor, computer, automotive, and medical industries will find the SourceMeter instruments invaluable for a wide range of characterization and production test applications.

Advantages of a Tightly Integrated Instrument

By linking source and measurement circuitry in a single unit, these instruments offer a variety of advantages over systems configured with separate source and measurement instruments. For example, they minimize the time required for test station development, setup, and maintenance, while lowering the overall cost of system ownership. They simplify the test process itself by eliminating many of the complex synchronization and connection issues associated with using multiple instruments. And, their compact half-rack size conserves precious "real estate" in the test rack or bench.

Power of Five Instruments in One (IV Source, IVR Measure)

The tightly coupled nature of a SourceMeter instrument provides many advantages over solutions configured from separate instruments, such as a precision power supply and a digital multimeter. For example, it provides faster test times by reducing GPIB traffic and simplifies the remote programming interface. It also protects the device under test from damage due to accidental overloads, thermal runaway, etc. Both the current and voltage source are programmable with readback to help maximize device measurement integrity. If the readback reaches a programmed compliance limit, then the source is clamped at the limit, providing fault protection.

ACCESSORIES AVAILABLE

TEST LEADS AND PROBES

1754	2-Wire Universal 10-Piece Test Lead Kit
5804	Kelvin (4-Wire) Universal 10-Piece Test Lead Kit
5805	Kelvin (4-Wire) Spring-Loaded Probes
5808	Low Cost Single-pin Kelvin Probe Set
5809	Low Cost Kelvin Clip Lead Set
8607	2-Wire, 1000V Banana Cables, 1m (3.3 ft)
CA-18-1	Shielded Dual Banana Cable, 1.2m (4 ft)

SWITCHING HARDWARE

7001	Two-Slot Switch System
7002	Ten-Slot Switch System
7019-C	6-Wire Ohms Switch Card
7053	High-Current Switch Card

CABLES/ADAPTERS

7007-1	Shielded GPIB Cable, 1m (3.3 ft)
7007-2	Shielded GPIB Cable, 2m (6.6 ft)
7009-5	RS-232 Cable
8620	Shorting Plug

COMMUNICATION INTERFACE

KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

TRIGGERING AND CONTROL

2499-DIGIO	Digital I/O Expander Assembly (not for Model 2401)
8501-1	Trigger Link Cable, DIN-to-DIN, 1m (3.3 ft)
8501-2	Trigger Link Cable, DIN-to-DIN, 2m (6.6 ft)
8502	Trigger Link to BNC Breakout Box
8503	Trigger Link Cable, DIN-to-Dual BNC, 1m (3.3 ft)
8505	Male to 2-Female Y-DIN Cable for Trigger Link

RACK MOUNT KITS

4288-1	Single Fixed Rack Mount Kit
4288-2	Dual Fixed Rack Mount Kit
4288-4	Dual Fixed Rack Mount Kit
4288-5	Shelf Type Side by Side Rack Mounting Kit
4288-9	Dual Fixed Rack Mounting Kit

SOFTWARE

LabTracer 2.0	Curve Tracing Software (downloadable)

Series 2400

SourceMeter® Line

Ordering Information

2400	200V, 1A, 20W SourceMeter Instrument
2400-C	200V, 1A, 20W SourceMeter Instrument with Contact Check
2401	20V, 1A, 20W SourceMeter Instrument
2410	1100V, 1A, 20W SourceMeter Instrument
2410-C	1100V, 1A, 20W SourceMeter Instrument with Contact Check
2420	60V, 3A, 60W SourceMeter Instrument
2420-C	60V, 3A, 60W SourceMeter Instrument with Contact Check
2425	100V, 3A, 100W SourceMeter Instrument
2425-C	100V, 3A, 100W SourceMeter Instrument with Contact Check
2430	100V, 10A, 1000W Pulse Mode SourceMeter Instrument
2430-C	100V, 10A, 1000W Pulse Mode SourceMeter Instrument with Contact Check
2440	40V, 5A, 50W SourceMeter Instrument
2440-C	40V, 5A, 50W SourceMeter Instrument with Contact Check

Accessories Supplied

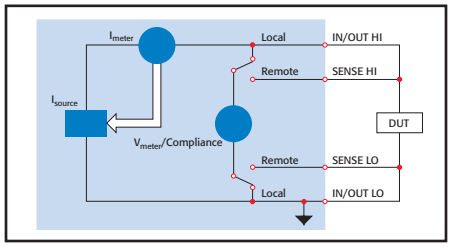
Model 8605 Test Leads

LabVIEW Software Driver (downloadable)

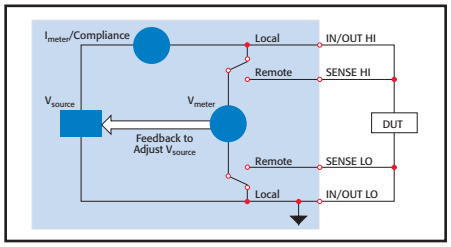
LabTracer Software (downloadable)

I-V Characteristics

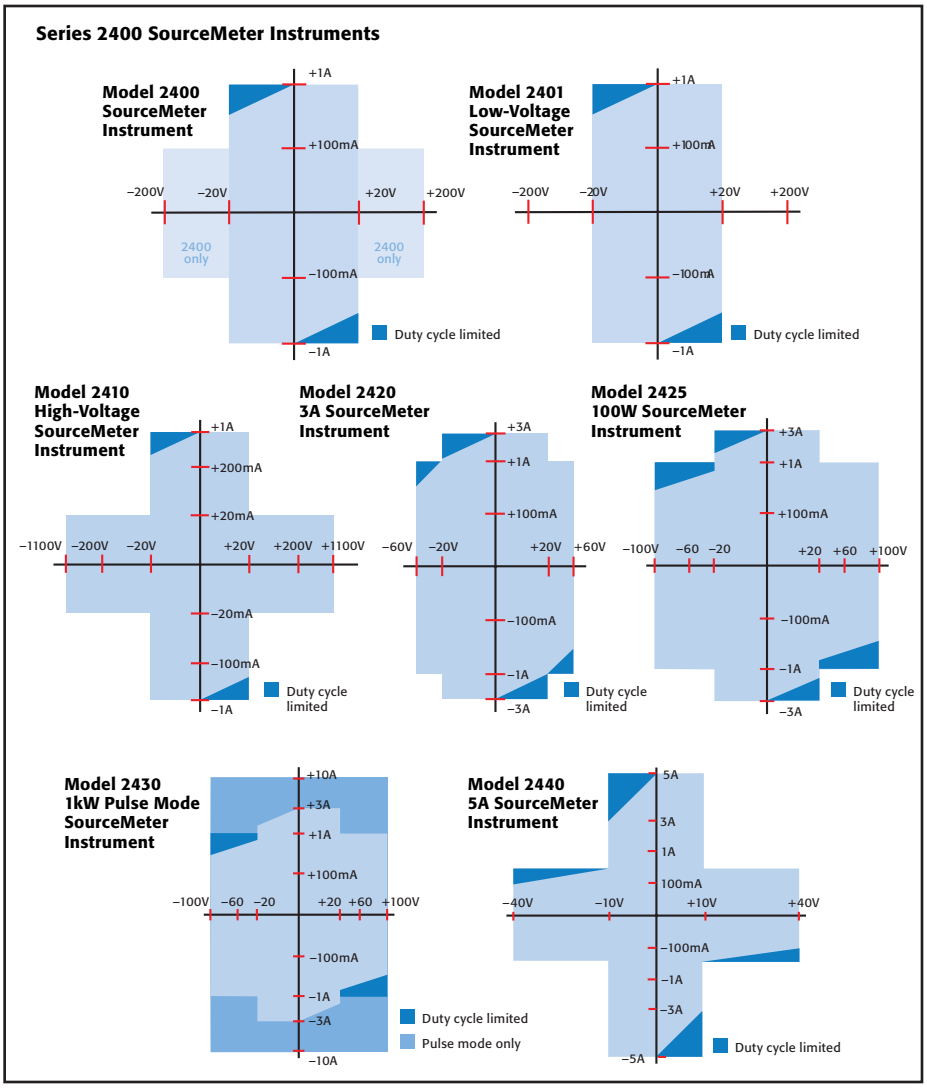
All SourceMeter instruments provide four-quadrant operation. In the first and third quadrants they operate as a source, delivering power to a load. In the second and fourth quadrants they operate as a sink, dissipating power internally. Voltage, current, and resistance can be measured during source or sink operation.



Source I, Measure V, I, or Ω configuration



Source V, Measure I, V, or Ω configuration



Series 2400 SourceMeter® Line

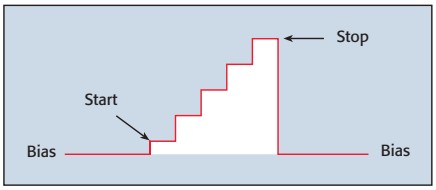
Automation for Speed

A SourceMeter instrument streamlines production testing. It sources voltage or current while making measurements without needing to change connections. It is designed for reliable operation in non-stop production environments. To provide the throughput demanded by production applications, the SourceMeter instrument offers many built-in features that allow it to run complex test sequences without computer control or GPIB communications slowing things down.

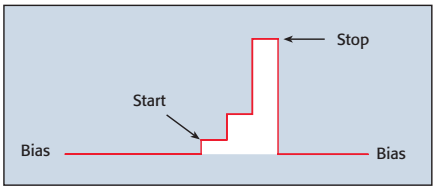
Standard and Custom Sweeps

Sweep solutions greatly accelerate testing with automation hooks. Three basic sweep waveforms are provided that can be programmed for single-event or continuous operation. They are ideal for I/V, I/R, V/I, and V/R characterization.

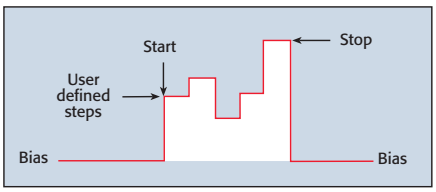
- Linear Staircase Sweep: Moves from the start level to the stop level in equal linear steps
- Logarithmic Staircase Sweep: Done on a log scale with a specified number of steps per decade
- Custom Sweep: Allows construction of special sweeps by specifying the number of measurement points and the source level at each point
- Up to 1700 readings/second at 4½ digits to the GPIB bus
- 5000 readings can be stored in the non-volatile buffer memory



Linear staircase sweep



Logarithmic staircase sweep



Custom sweep

Built-In Test Sequencer (Source Memory List)

The Source Memory list provides faster and easier testing by allowing you to setup and execute up to 100 different tests that run without PC intervention.

- Stores up to 100 instrument configurations, each containing source settings, measurement settings, pass/fail criteria, etc.
- Pass/fail limit test as fast as 500µs per point
- Onboard comparator eliminates the delay caused when sending data to the computer for analysis
- Built-in, user definable math functions to calculate derived parameters

TYPICAL APPLICATIONS

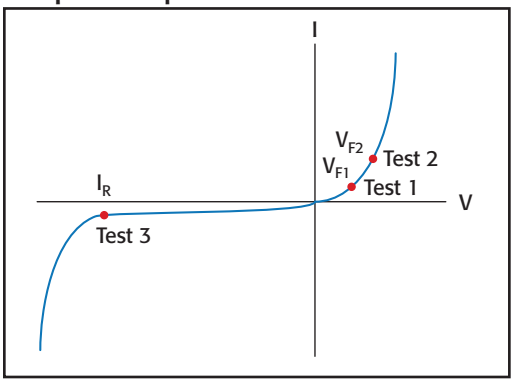
Devices:

- **Discrete semiconductor devices**
- **Passive devices**
- **Transient suppression devices**
- **ICs, RFICs, MMICs**
- **Laser diodes, laser diode modules, LEDs, photodetectors**
- **Circuit protection devices: TVS, MOV, Fuses, etc.**
- **Airbags**
- **Connectors, switches, relays**
- **High brightness LEDs (DC and pulse)**

Tests:

- **Leakage**
- **Low voltage/resistances**
- **LIV**
- **IDDQ**
- **I-V characterization**
- **Isolation and trace resistance**
- **Temperature coefficient**
- **Forward voltage, reverse breakdown, leakage current**
- **DC parametric test**
- **DC power source**
- **HIPOT**
- **Photovoltaic cell efficiency (source and sink)**
- **Dielectric withstanding**

Example Test Sequence



Test	Pass/Fail Test	If Passes Test	If Fails Test
Test 1	Check V_{F1} at 100mA against pass/fail limits	Go to Test 2	1. Bin part to bad bin 2. Transmit data to computer while handler is placing new part 3. Return to Test 1
Test 2	Check V_{F2} at 1A against pass/fail limits	Go to Test 3	
Test 3	Check leakage current at –500V and test against pass/fail limits	1. Bin part to good bin 2. Transmit readings to computer while handler is placing new part 3. Return to Test 1	

Digital I/O Interface

The digital I/O interface can link the SourceMeter instrument to many popular component handlers, including Aetrium, Aeco, and Robotronics. Other capabilities of the interface include:

- Tight systems integration for applications such as binning and sorting
- Built-in component handler interface
- Start of test and end of test signals
- 5V, 300mA power supply
- Optional expander accessory (Model 2499-DIGIO) adds 16 digital I/O lines

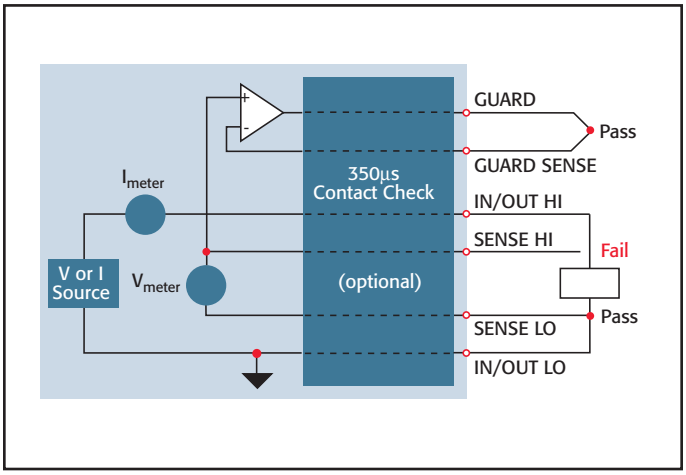
Trigger Link Interface

All SourceMeter instruments include Keithley's unique Trigger Link interface which provides high-speed, seamless communications with many of Keithley's other instruments. For example, use the Trigger Link interface to connect a SourceMeter instrument with a Series 7000 Switching System for a complete multi-point test solution. With Trigger Link, the 7000 Series Switching Systems can be controlled by a SourceMeter instrument during a high-speed test sequence independent of a computer and GPIB.

Optional Contact Check Function

The Contact Check function makes it simple to verify good connections quickly and easily before an automated test sequence begins. This eliminates measurement errors and false product failures associated with contact fatigue, breakage, contamination, loose or broken connection, relay failures, etc. Some capabilities of this function are:

- 350μs verification and notification process time
- The output of the SourceMeter instrument is automatically shut off after a fault and is not re-activated until good contact is verified, protecting the device under test from damage and the operator from potential safety hazards
- 3 pass/fail threshold values: 2Ω, 15Ω, and 50Ω
- No energy passes through the device under test during the operation
- Enabled either from the front panel or remotely over the GPIB
- 3 fault notification methods

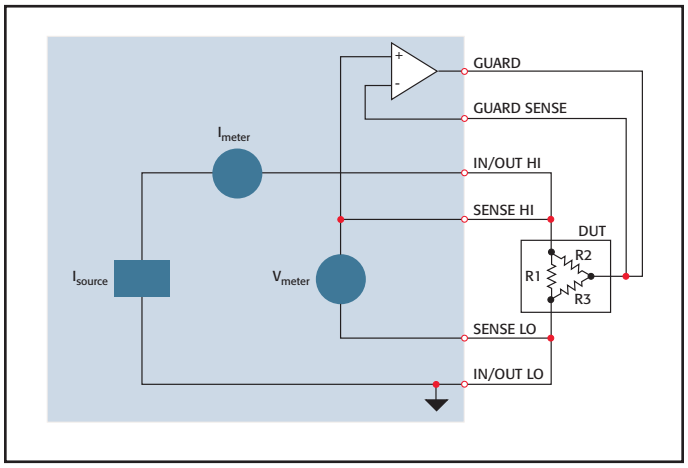


Contact check option for 4-wire or 6-wire applications

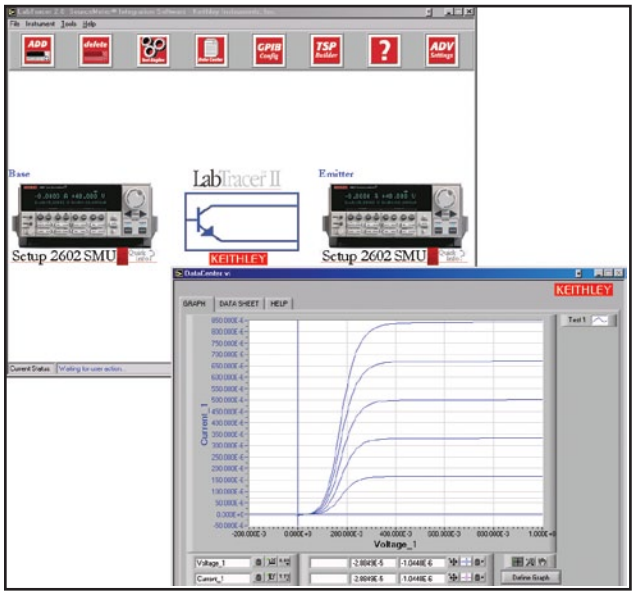
Unique 6-Wire Ohms Technique

SourceMeter instruments can make standard 4-wire, split Kelvin, and 6-wire, guarded ohms measurements and can be configured for either the constant current or constant voltage method. The 6-wire ohms technique:

- Uses guard and guard sense leads in addition to the 4-wire sense and source leads
- Locks out parallel current paths when measuring resistor networks or hybrid circuits to isolate the component under test
- Allows users to configure and plot data easily from Series 2400 SourceMeter instruments, making characterization of two, three, and four terminal devices a snap



6-Wire Ohms Circuit. All test current flows through R1 because the high current guard drives the voltage across R2 to 0V.



Free LabTracer 2.0 device characterization software (downloadable)

Voltage Accuracy (Local or Remote Sense)

Model	Range	Programming Resolution	Source[1] Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Default Measurement Resolution	Measurement[2, 3, 4] Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Output Slew Rate (±30%)	Source/Sink Limit
2400, 2400-C, 2401	200.000 mV	5 µV	0.02% + 600 µV	1 µV	0.012% + 300 µV		±21 V @ ±1.05 A ±210 V @ ±105 mA*
	2.00000 V	50 µV	0.02% + 600 µV	10 µV	0.012% + 300 µV		
	20.0000 V	500 µV	0.02% + 2.4 mV	100 µV	0.015% + 1.5 mV	0.08 V/µs	
	200.000 V*	5 mV	0.02% + 24 mV	1 mV	0.015% + 10 mV	0.5 V/µs	
2410, 2410-C	200.000 mV	5 µV	0.02% + 600 µV	1 µV	0.012% + 300 µV		±21 V @ ±1.05 A ±1100 V @ ±21 mA
	2.00000 V	50 µV	0.02% + 600 µV	10 µV	0.012% + 300 µV		
	20.0000 V	500 µV	0.02% + 2.4 mV	100 µV	0.015% + 1 mV	0.15 V/µs	
	1000.00 V	50 mV	0.02% + 100 mV	10 mV	0.015% + 50 mV	0.5 V/µs	
2420, 2420-C	200.000 mV	5 µV	0.02% + 600 µV	1 µV	0.012% + 300 µV		±21 V @ ±3.15 A ±63 V @ ±1.05 A
	2.00000 V	50 µV	0.02% + 600 µV	10 µV	0.012% + 300 µV		
	20.0000 V	500 µV	0.02% + 2.4 mV	100 µV	0.015% + 1 mV	0.08 V/µs	
	60.0000 V	1.5 mV	0.02% + 7.2 mV	1 mV	0.015% + 3 mV	0.14 V/µs	
2425, 2425-C	200.000 mV	5 µV	0.02% + 600 µV	1 µV	0.012% + 300 µV		±21 V @ ±3.15 A ±105 V @ ±1.05 A
	2.00000 V	50 µV	0.02% + 600 µV	10 µV	0.012% + 300 µV		
	20.0000 V	500 µV	0.02% + 2.4 mV	100 µV	0.015% + 1 mV	0.08 V/µs	
	100.0000 V	2.5 mV	0.02% + 12 mV	1 mV	0.015% + 5 mV	0.25 V/µs	
2430, 2430-C	200.000 mV	5 µV	0.02% + 600 µV	1 µV	0.012% + 300 µV		±105 V @ ±1.05 A ±105 V @ ±10.5 A (pulse mode only)
	2.00000 V	50 µV	0.02% + 600 µV	10 µV	0.012% + 300 µV		
	20.0000 V	500 µV	0.02% + 2.4 mV	100 µV	0.015% + 1 mV	0.08 V/µs	
	100.0000 V	2.5 mV	0.02% + 12 mV	1 mV	0.015% + 5 mV	0.25 V/µs	
2440, 2440-C	200.000 mV	5 µV	0.02% + 600 µV	1 µV	0.012% + 300 µV		±10.5 V @ ±5.25 A ±42 V @ ±1.05 A
	2.00000 V	50 µV	0.02% + 600 µV	10 µV	0.012% + 300 µV		
	10.0000 V	500 µV	0.02% + 1.2 mV	100 µV	0.015% + 750 µV	0.08 V/µs	
	40.0000 V	5 mV	0.02% + 4.8 mV	1 mV	0.015% + 3 mV	0.25 V/µs	

***Not available on Model 2401.**

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.15 × accuracy specification)/°C.
VOLTAGE REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 100µV.
OVER VOLTAGE PROTECTION: User selectable values, 5% tolerance. Factory default = none.
CURRENT LIMIT: Bipolar current limit (compliance) set with single value. Min. 0.1% of range.
OVERSHOOT: <0.1% typical (full scale step, resistive load, 10mA range).

ADDITIONAL SOURCE SPECIFICATIONS (All Models)

TRANSIENT RESPONSE TIME: 30µs minimum for the output to recover to its spec. following a step change in load.
COMMAND PROCESSING TIME: Maximum time required for the output to begin to change following the receipt of :SOURce:VOLTage|CURRent <nrf> command. **Autorange On:** 10ms. **Autorange Off:** 7ms.
OUTPUT SETTLING TIME: Time required to reach 0.1% of final value after command is processed. 100µs typical. Resistive load. 10µA to 100mA range.
DC FLOATING VOLTAGE: Output can be floated up to ±250VDC (Model 2440 ±40VDC) from chassis ground.
REMOTE SENSE: Up to 1V drop per load lead.
COMPLIANCE ACCURACY: Add 0.3% of range and ±0.02% of reading to base specification.
OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.
RANGE CHANGE OVERSHOOT: Overshoot into a fully resistive 100kΩ load, 10Hz to 1MHz BW, adjacent ranges: 100mV typical, except 20V/200V (20V/60V on Model 2420), 20V/100V on Model 2425 and 2430, range boundary, and Model 2440.
MINIMUM COMPLIANCE VALUE: 0.1% of range.

ADDITIONAL PULSE MODE SOURCE SPECIFICATIONS (2430 and 2430-C only)

MAXIMUM DUTY CYCLE: 8%, hardware limited, 10A range only. All other ranges 100%.
MAXIMUM PULSE WIDTH: 5ms from 90% rising to 90% falling edge, 2.5ms 10A range.
MINIMUM PULSE WIDTH: 150µs.
MINIMUM PULSE RESOLUTION: 50µs typical, 70µs max., limited by system jitter.
SOURCE ACCURACY: Determined by settling time and source range specifications.
OUTPUT SETTLING TIME 0.1%:
800µs typ., source I = 10A into 10Ω, limited by voltage slew rate.
500µs typ., source I = 10A into 1Ω, limited by voltage slew rate.
OUTPUT SLEW RATE:
Voltage (10Ω load): 0.25V/µs ±30% on 100V range. 0.08V/µs ±30% on 20V range, 10A range.
Current (0Ω load): 0.25A/µs ±30% on 100V range. 0.08A/µs ±30% on 20V range, 10A range.

NOTES

1. **2400, 2401, 2410 Only:** Specifications valid for continuous output currents below 105mA. For operation above 105mA continuous for >1 minute, derate accuracy 10%/35mA above 105mA.
2. Speed = Normal (1 PLC). For 0.1 PLC, add 0.005% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.05%. For 0.01 PLC, add 0.05% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.5%.
3. Accuracies apply to 2- or 4-wire mode when properly zeroed.
4. In pulse mode, limited to 0.1 PLC measurement.

Current Accuracy (Local or Remote Sense)

Model	Range	Programming Resolution	Source[1, 3] Accuracy (1 Year)[3] 23°C ±5°C ±(% rdg. + amps)	Default Measurement Resolution	Measurement[5, 6, 7] Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)	Source/Sink Limit
2400, 2400-C, 2401	1.00000 µA	50 pA	0.035% + 600 pA	10 pA	0.029% + 300 pA	±1.05A @ ±21 V ±105 mA @ ±210 V[8]
	10.0000 µA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	
	100.000 µA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	10.0000 mA	500 nA	0.045% + 2 µA	100 nA	0.035% + 600 nA	
	100.000 mA	5 µA	0.066% + 20 µA	1 µA	0.055% + 6 µA	
	1.00000 A[2]	50 µA	0.27 % + 900 µA	10 µA	0.22 % + 570 µA	
2410, 2410-C	1.00000 µA	50 pA	0.035% + 600 pA	10 pA	0.029% + 300 pA	±1.05A @ ±21 V ±21 mA @ ±1100 V
	10.0000 µA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	
	100.000 µA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	20.0000 mA	500 nA	0.045% + 4 µA	100 nA	0.035% + 1.2 µA	
	100.000 mA	5 µA	0.066% + 20 µA	1 µA	0.055% + 6 µA	
	1.00000 A[2]	50 µA	0.27 % + 900 µA	10 µA	0.22 % + 570 µA	
2420, 2420-C	10.0000 µA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	±3.15A @ ±21 V ±1.05 A @ ±63 V
	100.000 µA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	10.0000 mA	500 nA	0.045% + 2 µA	100 nA	0.035% + 600 nA	
	100.000 mA	5 µA	0.066% + 20 µA	1 µA	0.055% + 6 µA	
	1.00000 A[2]	50 µA	0.067% + 900 µA	10 µA	0.066% + 570 µA	
	3.00000 A[2]	50 µA	0.059% + 2.7 mA	10 µA	0.052% + 1.71 mA	
2425, 2425-C	10.0000 µA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	±3.15A @ ±21 V ±1.05 A @ ±105 V
	100.000 µA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	10.0000 mA	500 nA	0.045% + 2 µA	100 nA	0.035% + 600 nA	
	100.000 mA	5 µA	0.066% + 20 µA	1 µA	0.055% + 6 µA	
	1.00000 A[2]	50 µA	0.067% + 900 µA	10 µA	0.060% + 570 µA	
	3.00000 A[2]	50 µA	0.059% + 2.8 mA	10 µA	0.052% + 1.71 mA	
2430, 2430-C	10.0000 µA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	±1.05A @ ±105 V ±10.5 A @ ±105 V (pulse mode only)
	100.000 µA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	10.0000 mA	500 nA	0.045% + 2 µA	100 nA	0.035% + 600 nA	
	100.000 mA	5 µA	0.066% + 20 µA	1 µA	0.055% + 6 µA	
	1.00000 A	50 µA	0.067% + 900 µA	10 µA	0.060% + 570 µA	
	3.00000 A[2]	500 µA	0.059% + 2.8 mA	10 µA	0.052% + 1.71 mA	
	10.00000 A[4]	500 µA	0.089% + 5.9 mA	10 µA	0.082% + 1.71 mA	
2440, 2440-C	10.0000 µA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	±5.25A @ ±10.5 V ±1.05 A @ ±42 V
	100.000 µA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	10.0000 mA	500 nA	0.045% + 2 µA	100 nA	0.035% + 600 nA	
	100.000 mA	5 µA	0.066% + 20 µA	1 µA	0.055% + 6 µA	
	1.00000 A	50 µA	0.067% + 900 µA	10 µA	0.060% + 570 µA	
	5.00000 A	50 µA	0.10 % + 5.4 mA	10 µA	0.10 % + 3.42 mA	

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.15 × accuracy specification)/°C.

CURRENT REGULATION: Line: 0.01% of range. **Load:** 0.01% of range (except Model 2440 5A range 0.05%) + 100pA.

VOLTAGE LIMIT: Bipolar voltage limit (compliance) set with single value. Min. 0.1% of range.

OVERSHOOT: <0.1% typical (1mA step, RL = 10kΩ, 20V range for Model 2400, 2401, 2410, 2420, 2425, 2430), (10V range for Model 2440).

CONTACT CHECK SPECIFICATIONS (requires -C version)

(Not available for Model 2401)

SPEED: 350µs for verification and notification.

CONTACT CHECK:	2 Ω	15 Ω	50 Ω
No contact check failure	<1.00 Ω	<13.5 Ω	<47.5 Ω
Always contact check failure	>3.00 Ω	>16.5 Ω	>52.5 Ω

NOTES

1. **2400, 2401, 2410 Only:** Specifications valid for continuous output currents below 105mA. For operation above 105mA continuous for >1 minute, derate accuracy 10%/35mA above 105mA.
2. Full operation (1A) regardless of load to 30°C (50°C for Model 2420 and 2440). Above 30°C (50°C for Model 2420 and 2440) ambient, derate 35mA/°C and prorate 35mA/Ω load. 4-wire mode. For current sink operation on 1A, 3A, or 5A ranges, maximum continuous power is limited to approximately 1/2 rated power or less, depending on current, up to 30°C ambient. See power equations in the User's Manual to calculate allowable duty cycle for specific conditions.
3. For sink mode, 1µA to 100mA range, accuracy is:
   Model 2400, 2401: ±(0.15% + offset*4). **Models 2410, 2420, 2425, 2430, 2440:** ±(0.5% + offset*3).
   For 1A range, accuracy is:
   Model 2400, 2401: ±(1.5% + offset*8). **Models 2410, 2420, 2425, 2430, 2440:** ±(1.5% + offset*3).
4. 10A range only in pulse mode. Limited to 2.5ms pulse width maximum. 10% duty cycle maximum.
5. Speed = Normal (1 PLC). For 0.1 PLC, add 0.005% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.05%. For 0.01 PLC, add 0.05% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.5%.
6. Accuracies apply to 2- or 4-wire mode when properly zeroed.
7. In pulse mode, limited to 0.1 PLC measurement.
8. Model 2400 and 2400-C only.

Resistance Measurement Accuracy (Local or Remote Sense)[1, 2, 5]

Range	Default Resolution	Default Test Current 2400, 2401, 2410	Default Test Current 2420, 2425, 2430, 2440	Normal Accuracy (23°C ±5°C) 1 Year, ±(% rdg. + ohms) 2400, 2401	2410	2420, 2425, 2430, 2440	Enhanced Accuracy (23°C ±5°C)[4] 1 Year, ±(% rdg. + ohms) 2400, 2401
<0.20000 Ω[3]	–	–	–	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}
2.00000 Ω[3]	10 μΩ	–	1 A	Source I_{ACC} + Meas V_{ACC}	Source I_{ACC} + Meas. V_{ACC}	0.17% + 0.0003Ω	Source I_{ACC} + Meas. V_{ACC}
20.0000 Ω	100 μΩ	100 mA	100 mA	0.10% + 0.003 Ω	0.11% + 0.006 Ω	0.10% + 0.003 Ω	0.07% + 0.001 Ω
200.000 Ω	1 mΩ	10 mA	10 mA	0.08% + 0.03 Ω	0.09% + 0.1 Ω	0.08% + 0.03 Ω	0.05% + 0.01 Ω
2.00000 kΩ	10 mΩ	1 mA	1 mA	0.07% + 0.3 Ω	0.08% + 0.6 Ω	0.07% + 0.3 Ω	0.05% + 0.1 Ω
20.0000 kΩ	100 mΩ	100 μA	100 μA	0.06% + 3 Ω	0.07% + 6 Ω	0.06% + 3 Ω	0.04% + 1 Ω
200.000 kΩ	1 Ω	10 μA	10 μA	0.07% + 30 Ω	0.07% + 60 Ω	0.07% + 30 Ω	0.05% + 10 Ω
2.00000 MΩ[6]	10 Ω	1 μA	1 μA	0.11% + 300 Ω	0.12% + 600 Ω	0.11% + 300 Ω	0.05% + 100 Ω
20.0000 MΩ[7]	100 Ω	1 μA	1 μA	0.11% + 1 kΩ	0.12% + 2.4 kΩ	0.11% + 1 kΩ	0.05% + 500 Ω
200.000 MΩ[3]	1 kΩ	100 nA	–	0.66% + 10 kΩ	0.66% + 24 kΩ	Source I_{ACC} + Meas. V_{ACC}	0.35% + 5 kΩ
>200.000 MΩ[3]	–	–	–	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.15 × accuracy specification)/°C.

SOURCE I MODE, MANUAL OHMS: Total uncertainty = I source accuracy + V measure accuracy (4-wire remote sense).

SOURCE V MODE, MANUAL OHMS: Total uncertainty = V source accuracy + I measure accuracy (4-wire remote sense).

6-WIRE OHMS MODE: Available using active ohms guard and guard sense. Max. Guard Output Current: 50mA (except 1A range). Accuracy is load dependent. Refer to White Paper no. 2033 for calculation formula.

GUARD OUTPUT IMPEDANCE: <0.1Ω in ohms mode.

NOTES

1. Speed = Normal (1 PLC). For 0.1 PLC, add 0.005% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.05%. For 0.01 PLC, add 0.05% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.5%.
2. Accuracies apply to 2- or 4-wire mode when properly zeroed.
3. Manual ohms only – except 2420, 2425, 2430, 2440 for 2Ω range and 2400, 2401 or 2410 for 200MΩ range.
4. Source readback enabled, offset compensation ON. Also available on 2410, 2420, 2425, 2430, and 2440 with similar accuracy enhancement.
5. In pulse mode, limited to 0.1 PLC measurement.
6. Except 2440; default test current is 5μA.
7. Except 2440; default test current is 0.5μA.

SERVICES AVAILABLE

2400-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2400-C-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2401-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2410-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2410-C-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2420-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2420-C-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2425-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2425-C-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2430-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2430-C-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2440-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2440-C-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
C/2400-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Models 2400, 2400-C, 2400-LV*
C/2401-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Model 2401*
C/2410-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Models 2410, 2410-C*
C/2420-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Models 2420, 2420-C*
C/2425-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Models 2425, 2425-C*
C/2430-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Models 2430, 2430-C*
C/2440-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase for Models 2440, 2440-C*
TRN-2400-1-C	Course: Unleashing the Power of Your SourceMeter Instrument

*Not available in all countries

Series 2400 SourceMeter® Line

System Speeds

MEASUREMENT[1]

MAXIMUM RANGE CHANGE RATE: 75/second.

MAXIMUM MEASURE AUTORANGE TIME: 40ms (fixed source).[2]

Sweep Operation[3] Reading Rates (rdg./second) for 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To Mem.	Measure To GPIB	Source-Measure To Mem.	Source-Measure To GPIB	Source-Measure Pass/Fail Test[4, 5] To Mem.	Source-Measure Pass/Fail Test[4, 5] To GPIB	Source-Memory[4] To Mem.	Source-Memory[4] To GPIB
Fast	0.01 / internal	2081 (2030)	1754	1551 (1515)	1369	902 (900)	981	165 (162)	165
IEEE-488.1 Mode	0.01 / external	1239 (1200)	1254	1018 (990)	1035	830 (830)	886	163 (160)	163
Fast	0.01 / internal	2081 (2030)	1198 (1210)	1551 (1515)	1000 (900)	902 (900)	809 (840)	165 (162)	164 (162)
IEEE-488.2 Mode	0.01 / external	1239 (1200)	1079 (1050)	1018 (990)	916 (835)	830 (830)	756 (780)	163 (160)	162 (160)
Medium	0.10 / internal	510 (433)	509 (433)	470 (405)	470 (410)	389 (343)	388 (343)	133 (126)	132 (126)
IEEE-488.2 Mode	0.10 / external	438 (380)	438 (380)	409 (360)	409 (365)	374 (333)	374 (333)	131 (125)	131 (125)
Normal	1.00 / internal	59 (49)	59 (49)	58 (48)	58 (48)	56 (47)	56 (47)	44 (38)	44 (38)
IEEE-488.2 Mode	1.00 / external	57 (48)	57 (48)	57 (48)	57 (47)	56 (47)	56 (47)	44 (38)	44 (38)

Single Reading Operation Reading Rates (rdg./second) for 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To GPIB	Source-Measure[5] To GPIB	Source-Measure Pass/Fail Test[4,5] To GPIB
Fast (488.1)	0.01 / internal	537	140	135
Fast (488.2)	0.01 / internal	256 (256)	79 (83)	79 (83)
Medium (488.2)	0.10 / internal	167 (166)	72 (70)	69 (70)
Normal (488.2)	1.00 / internal	49 (42)	34 (31)	35 (30)

Component for 60Hz (50Hz):[4, 6]

Speed	NPLC/Trigger Origin	Measure To GPIB	Source Pass/Fail Test	Source-Measure Pass/Fail Test[5, 7] To GPIB
Fast	0.01 / external	1.04 ms (1.08 ms)	0.5 ms (0.5 ms)	4.82 ms (5.3 ms)
Medium	0.10 / external	2.55 ms (2.9 ms)	0.5 ms (0.5 ms)	6.27 ms (7.1 ms)
Normal	1.00 / external	17.53 ms (20.9 ms)	0.5 ms (0.5 ms)	21.31 ms (25.0 ms)

NOTES

[1] Reading rates applicable for voltage or current measurements. Auto zero off, autorange off, filter off, display off, trigger delay = 0, and binary reading format.

[2] Purely resistive lead. 1μA and 10μA ranges <65ms.

[3] 1000 point sweep was characterized with the source on a fixed range.

[4] Pass/Fail test performed using one high limit and one low math limit.

[5] Includes time to re-program source to a new level before making measurement.

[6] Time from falling edge of START OF TEST signal to falling edge of END OF TEST signal.

[7] Command processing time of :SOURce:VOLTage|CURRent:TRIGgered <nrf> command not included.

GENERAL

Noise Rejection:

	NPLC	NMRR	CMRR
Fast	0.01	—	80 dB
Medium	0.1	—	80 dB
Slow	1	60 dB	100 dB[1]

[1] Except lowest 2 current ranges = 90dB.

LOAD IMPEDANCE: Stable into 20,000pF typical.

COMMON MODE VOLTAGE: 250V DC (40V DC for Model 2440).

COMMON MODE ISOLATION: >10^9Ω, <1000pF.

OVERRANGE: 105% of range, source and measure.

MAX. VOLTAGE DROP BETWEEN INPUT/OUTPUT AND SENSE TERMINALS: 5V.

MAX. SENSE LEAD RESISTANCE: 1MΩ for rated accuracy.

SENSE INPUT IMPEDANCE: >10^{10}Ω.

GUARD OFFSET VOLTAGE: <150μV, typical (300μV for Models 2430, 2440).

SOURCE OUTPUT MODES:
Pulse (Model 2430 only)
Fixed DC level
Memory List (mixed function)
Stair (linear and log)

MEMORY BUFFER: 5,000 readings @ 5 digits (two 2,500 point buffers). Includes selected measured value(s) and time stamp. Lithium battery backup (3 yr+ battery life).

SOURCE MEMORY LIST: 100 points max.

PROGRAMMABILITY: IEEE-488 (SCPI-1995.0), RS-232, 5 user-definable power-up states plus factory default and *RST.

DIGITAL INTERFACE:
Interlock: Active low input.
Handler Interface: Start of test, end of test, 3 category bits. +5V@ 300mA supply.
Digital I/O: 1 trigger input, 4 TTL/Relay Drive outputs (33V @ 500mA, diode clamped).

POWER SUPPLY: 100V to 240V rms, 50–60Hz (automatically detected at power up). **Model 2400, 2401:** 190VA. **Model 2410:** 210VA. **Model 2420:** 220VA. **Model 2425, 2430:** 250VA. **Model 2440:** 240VA.

COOLING: Model 2401: Convection. **Model 2410, 2420, 2425, 2430, 2440:** Forced air, variable speed.

EMC: Conforms to European Union Directive 89/336/EEC, EN 61326-1.

SAFETY: UL listed to UL 61010B-1:2003: Conforms to European Union Low Voltage Directive.

VIBRATION: MIL-PRF-28800F Class 3 Random.

WARM-UP: 1 hour to rated accuracies.

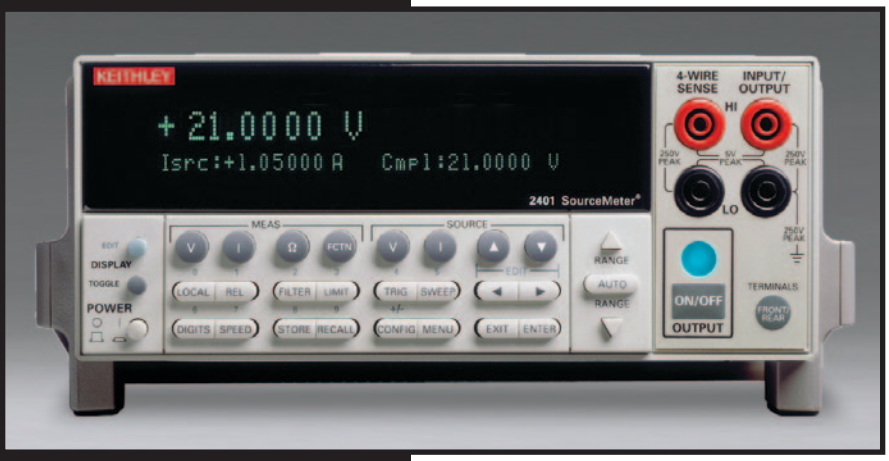
DIMENSIONS: 89mm high × 213mm wide × 370mm deep (3½ in × 8⅜ in × 14⅝ in). **Bench Configuration (with handle and feet):**104mm high × 238mm wide × 370mm deep (4⅛ in × 9⅜ in × 14⅝ in).

WEIGHT: 3.21kg (7.08 lbs) (Model 2425, 2430, 2440: 4.1kg, 9.0 lbs).

ENVIRONMENT: Operating: 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C. **Storage:** –25°C to 65°C.

2401

Low Voltage SourceMeter® Instrument



The economical Model 2401 is the latest member of Keithley's Series 2400 SourceMeter family, designed specifically for low voltage test applications that demand tightly coupled sourcing and measurement. Like all Series 2400 SourceMeter models, the Model 2401 provides precision voltage and current sourcing and measurement capabilities (1μV–20V and 10pA–1A). It is both a highly stable DC power source and a true instrument-grade 6½-digit multimeter. The power source characteristics include low noise, precision, and readback. The multimeter capabilities include high repeatability and low noise. The result is a compact, single-channel, DC parametric tester. In operation, it can act as a voltage source, a current source, a voltage meter, a current meter, and an ohmmeter.

- **1μV–20V and 10pA–1A precision voltage and current sourcing and measurement capabilities**
- **Five instruments in one (IV Source, IVR Measure)**
- **Source and sink (4-quadrant) operation**
- **0.012% basic measure accuracy with 6½-digit resolution**
- **2-, 4-, and 6-wire remote V-source and measure sensing**
- **1700 readings/second at 4½ digits via GPIB**
- **Standard SCPI GPIB, RS-232, and Keithley Trigger Link interfaces**
- **Keithley LabTracer 2.0 I-V curve tracing application software (download)**

The Lowest Cost Precision Source Measurement Unit (SMU) Instrument on the Market

The Model 2401 is the lowest cost precision SMU instrument on the market, offering an economical 20W I-V source/measure alternative to configuring systems and test benches with separate programmable power supplies and digital multimeters. The Model 2401 also offers an economical alternative for applications for which precision programmable power supplies cannot deliver sufficient accuracy, signal range, source setting, or readback resolution.

The Model 2401 offers users all the same accuracy, speed, and measurement functions as the other instruments in the Series 2400 family. It shares a common operating code base with the rest of the family, so it can be operated and programmed within its range boundaries just like any other Series 2400 instrument. The only functional differences between the Model 2401 and the Model 2400 are that the Model 2401 does not include 200V source and measure ranges or back panel Digital I/O port capabilities. (However, the DB-9 connector is still provided to provide test fixture interlock signals.)

Model 2401 Applications

Manufacturers of components and modules for the communications, semiconductor, computer, automotive, and medical industries will find the Model 2401 invaluable for a wide range of characterization and production test applications. Its 20V@1A output makes it ideal for characterizing the current-voltage (I-V) performance of photovoltaic (solar) cells, high brightness LEDs (HBLEDs), low voltage materials, CMOS circuits and low-power semiconductor devices, as well as resistance measurements on these devices.

The Model 2401 is well suited for use as a gate bias in applications involving devices with three or more terminals such as HBLEDs and photovoltaic cells, reducing total system hardware costs. It also provides sufficient range for characterizing low voltage materials and devices (including graphene and other nano- and MEMs-type structures), which are inherently low voltage oriented.

TYPICAL APPLICATIONS

- **High brightness LEDs (DC and pulse)**
- **Photovoltaic cell efficiency (source and sink)**
- **Precision DC power supply/ current measure**
- **Discrete semiconductor devices**
- **Passive devices**
- **Laser diodes, laser diode modules, LEDs, photodetectors**
- **Connectors, switches, relays**
- **Low voltages/resistances**
- **LIV**
- **IDDQ**
- **I-V characterization**

2401

Low Voltage SourceMeter® Instrument

Ordering Information

2401 Low Voltage SourceMeter® Instrument

Accessories Supplied

Model 8605 Test Leads

LabVIEW Software Driver (downloadable)

ACCESSORIES AVAILABLE

TEST LEADS AND PROBES

1754	2-Wire Universal 10-Piece Test Lead Kit
5804	Kelvin (4-Wire) Universal 10-Piece Test Lead Kit
5805	Kelvin (4-Wire) Spring-Loaded Probes
5808	Low Cost Single-pin Kelvin Probe Set
5809	Low Cost Kelvin Clip Lead Set
8607	2-Wire, 1000V Banana Cables, 1m (3.3 ft)
CA-18-1	Shielded Dual Banana Cable, 1.2m (4 ft)

SWITCHING HARDWARE

7001	Two-Slot Switch System
7002	Ten-Slot Switch System
7019-C	6-Wire Ohms Switch Card
7053	High-Current Switch Card

CABLES/ADAPTERS

7007-1	Shielded GPIB Cable, 1m (3.3 ft)
7007-2	Shielded GPIB Cable, 2m (6.6 ft)
7009-5	RS-232 Cable
8620	Shorting Plug

COMMUNICATION INTERFACE

KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

TRIGGERING AND CONTROL

8501-1	Trigger Link Cable, DIN-to-DIN, 1m (3.3 ft)
8501-2	Trigger Link Cable, DIN-to-DIN, 2m (6.6 ft)
8502	Trigger Link to BNC Breakout Box
8503	Trigger Link Cable, DIN-to-Dual BNC, 1m (3.3 ft)
8505	Male to 2-Female Y-DIN Cable for Trigger Link

RACK MOUNT KITS

4288-1	Single Fixed Rack Mount Kit
4288-2	Dual Fixed Rack Mount Kit
4288-4	Dual Fixed Rack Mount Kit
4288-5	Shelf Type Side by Side Rack Mounting Kit
4288-9	Dual Fixed Rack Mounting Kit

SOFTWARE

LabTracer 2.0	Curve Tracing Software (downloadable)

SERVICES AVAILABLE

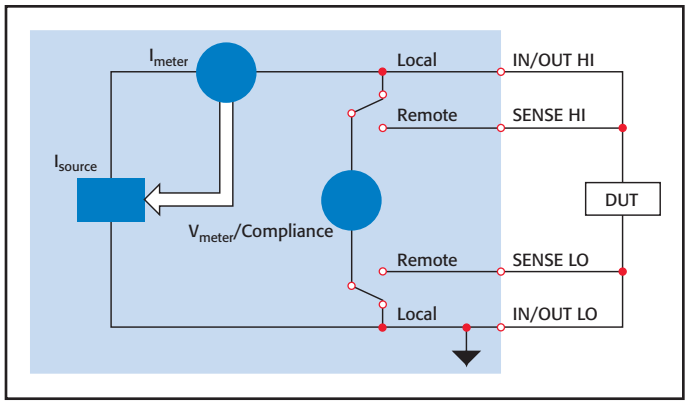
2401-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
C/2401-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase
TRN-2400-1C	Course: Unleashing the Power of Your SourceMeter Instrument

Advantages of a Tightly Integrated Instrument

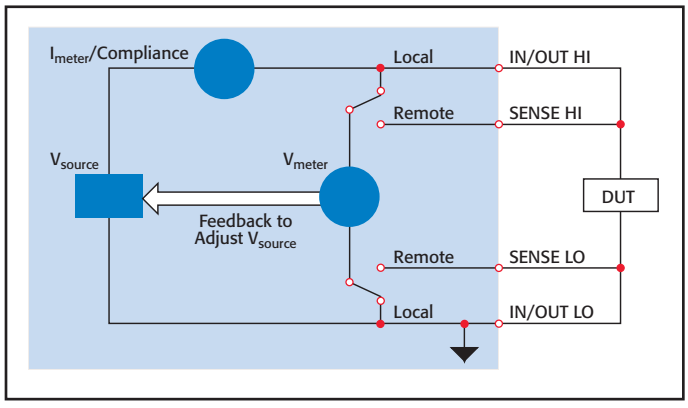
By linking source and measurement circuitry in a single unit, the Model 2401 offers a variety of advantages over systems configured with separate source and measurement instruments. For example, it minimizes the time required for test station development, setup, and maintenance, while lowering the overall cost of system ownership. It simplifies the test process itself by eliminating many of the complex synchronization and connection issues associated with using multiple instruments. Its compact half-rack size conserves precious "real estate" in the test rack or bench.

Much More than a Power Supply

The tightly coupled nature of a SourceMeter instrument provides many advantages over solutions configured from separate instruments such as a precision power supply and a digital multimeter. For example, the Model 2401 provides faster test times by reducing GPIB traffic and simplifies the remote programming interface. It also protects the device under test from damage due to accidental overloads, thermal runaway, etc. Both the Model 2401's current and voltage source are programmable with readback to help maximize device measurement integrity. If the readback reaches a programmed compliance limit, then the source is clamped at the limit, providing fault protection.



Source I, Measure V, I, or Ω configuration

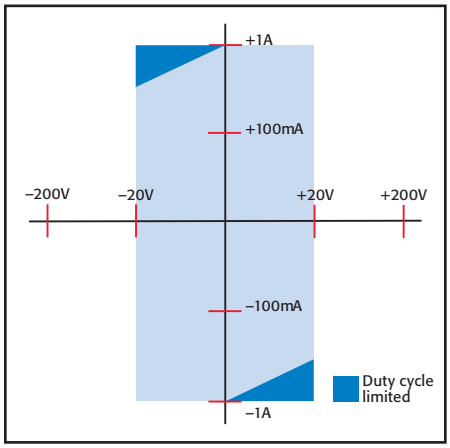


Source V, Measure I, V, or Ω configuration

2401 Low Voltage SourceMeter® Instrument

I-V Characteristics

Like all Series 2400 SourceMeter instruments, the Model 2401 provides four-quadrant operation. In the first and third quadrants, it operates as a source, delivering power to a load. In the second and fourth quadrants, it operates as a sink, dissipating power internally. Voltage, current, and resistance can be measured during source or sink operation.



Model 2401 four-quadrant operation

Built-In Test Sequencer (Source Memory List)

The Source Memory list provides faster and easier testing by allowing you to set up and execute up to 100 different tests that run without PC intervention.

- Stores up to 100 instrument configurations, each containing source settings, measurement settings, pass/fail criteria, etc.
- Pass/fail limit test as fast as 500μs per point
- Onboard comparator eliminates the delay caused when sending data to the computer for analysis
- Built-in, user-definable math functions to calculate derived parameters

Example Test Sequence

Test	Pass/Fail Test	If Passes Test	If Fails Test
Test 1	Check V_{F1} at 100mA against pass/fail limits	Go to Test 2	1. Bin part to bad bin 2. Transmit data to computer while handler is placing new part 3. Return to Test 1
Test 2	Check V_{F2} at 1A against pass/fail limits	Go to Test 3	
Test 3	Check leakage current at –500V and test against pass/fail limits	1. Bin part to good bin 2. Transmit readings to computer while handler is placing new part 3. Return to Test 1	

Trigger Link Interface

All SourceMeter instruments include Keithley's unique Trigger Link interface, which provides high speed, seamless communications with many of Keithley's other instruments. For example, use the Trigger Link interface to connect a SourceMeter instrument with a Series 7000 Switching System for a complete multipoint test solution. With Trigger Link, Series 7000 Switching Systems can be controlled by a SourceMeter instrument during a high speed test sequence independent of a computer and GPIB.

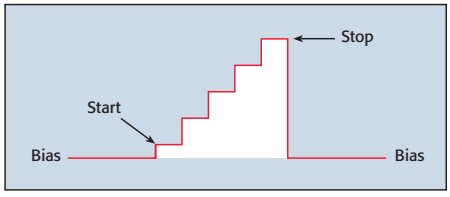
Automation for Speed

A SourceMeter instrument streamlines production testing. It sources voltage or current while making measurements without needing to change connections. It is designed for reliable operation in non-stop production environments. To provide the throughput demanded by production applications, the SourceMeter instrument offers many built-in features that allow it to run complex test sequences without computer control or GPIB communications slowing things down.

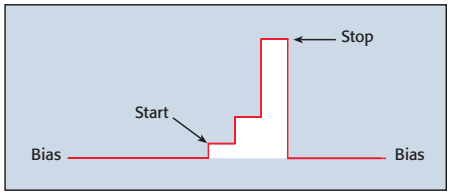
Standard and Custom Sweeps

Sweep solutions greatly accelerate testing with automation hooks. Three basic sweep waveforms are provided that can be programmed for single-event or continuous operation. They are ideal for I/V, I/R, V/I, and V/R characterization.

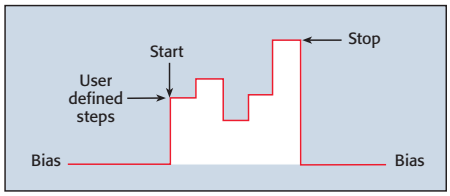
- Linear Staircase Sweep: Moves from the start level to the stop level in equal linear steps
- Logarithmic Staircase Sweep: Done on a log scale with a specified number of steps per decade
- Custom Sweep: Allows construction of special sweeps by specifying the number of measurement points and the source level at each point
- Up to 1700 readings/second at 4½ digits to the GPIB bus
- 5000 5½-digit readings can be stored in the non-volatile buffer memory



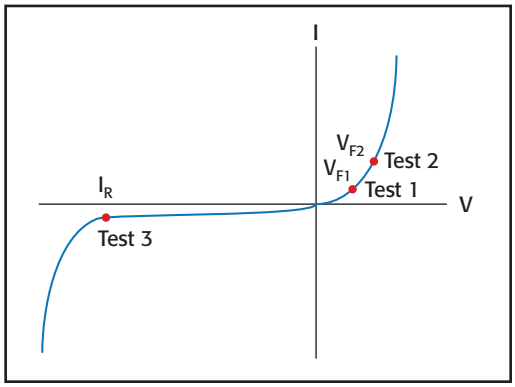
Linear staircase sweep



Logarithmic staircase sweep



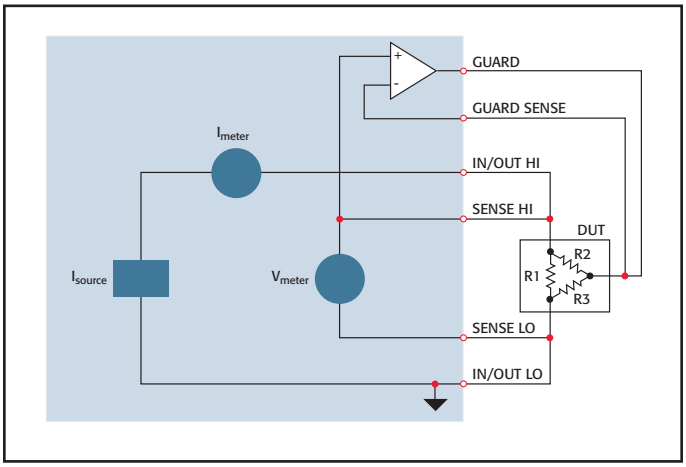
Custom sweep



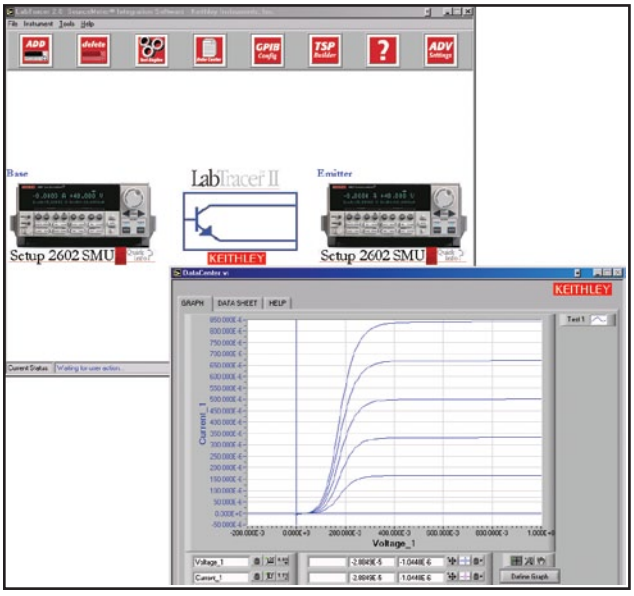
Unique 6-Wire Ohms Technique

The Model 2401 can make standard 4-wire, split Kelvin, and 6-wire, guarded ohms measurements and can be configured for either the constant current or constant voltage method. The 6-wire ohms technique:

- Uses guard and guard sense leads in addition to the 4-wire sense and source leads
- Locks out parallel current paths when measuring resistor networks or hybrid circuits to isolate the component under test
- Allows users to configure and plot data easily from Series 2400 SourceMeter instruments, making characterization of 2-, 3-, and 4-terminal devices a snap



6-Wire Ohms Circuit. All test current flows through R1 because the high current guard drives the voltage across R2 to 0V.



Free LabTracer 2.0 device characterization software (downloadable).

Advantages of a Tightly Integrated Instrument

By linking source and measurement circuitry in a single unit, these instruments offer a variety of advantages over systems configured with separate source and measurement instruments. For example, they minimize the time required for test station development, setup, and maintenance, while lowering the overall cost of system ownership. They simplify the test process itself by eliminating many of the complex synchronization and connection issues associated with using multiple instruments. And, their compact half-rack size conserves precious "real estate" in the test rack or bench.

Power of Five Instruments in One (IV Source, IVR Measure)

The tightly coupled nature of a SourceMeter instrument provides many advantages over separate instruments. For example, it provides faster test times by reducing GPIB traffic and simplifies the remote programming interface. It also protects the device under test from damage due to accidental overloads, thermal runaway, etc. Both the current and voltage source are programmable with readback to help maximize device measurement integrity. If the readback reaches a programmed compliance limit, then the source is clamped at the limit, providing fault protection.

Unlike narrow-performance SMU platforms, including board-level products, which often deliver sub-optimal analog measurements due to significant loss in signal integrity, accuracy, power, and/or speed due to interconnect, thermal management, and other issues, all Series 2400 SourceMeter instruments combine the industry's widest dynamic range with uncompromising throughput and superior measurement integrity.

Other Series 2400 SourceMeter Instruments

If your application requires a wider sourcing or measurement range than the Model 2401 can provide, other Series 2400 instruments (page 33) likely offer the range you need. Consult the range graphs shown here or the instrument specifications for details. Series 2600A System SourceMeter instruments (page 10) are also available to address applications that require integrating multiple source and measure channels and/or pulsing capabilities.

Voltage Accuracy (Local or Remote Sense)

Model	Range	Programming Resolution	Source[1] Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Default Measurement Resolution	Measurement[2, 3, 4] Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Output Slew Rate (±30%)	Source/Sink Limit
2400, 2400-C	200.000 mV	5 μV	0.02% + 600 μV	1 μV	0.012% + 300 μV		±21 V @ ±1.05 A ±210 V @ ±105 mA
	2.00000 V	50 μV	0.02% + 600 μV	10 μV	0.012% + 300 μV		
	20.0000 V	500 μV	0.02% + 2.4 mV	100 μV	0.015% + 1.5 mV	0.08 V/μs	
	200.000 V	5 mV	0.02% + 24 mV	1 mV	0.015% + 10 mV	0.5 V/μs	
2401	200.000 mV	5 μV	0.02% + 600 μV	1 μV	0.012% + 300 μV		±21 V @ ±1.05 A
	2.00000 V	50 μV	0.02% + 600 μV	10 μV	0.012% + 300 μV		
	20.0000 V	500 μV	0.02% + 2.4 mV	100 μV	0.015% + 1.5 mV	0.08 V/μs	

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.15 × accuracy specification)/°C.

VOLTAGE REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 100μV.

OVER VOLTAGE PROTECTION: User selectable values, 5% tolerance. Factory default = none.

CURRENT LIMIT: Bipolar current limit (compliance) set with single value. Min. 0.1% of range.

OVERSHOOT: <0.1% typical (full scale step, resistive load, 10mA range).

NOTES

1. **2400, 2401, 2410 Only:** Specifications valid for continuous output currents below 105mA. For operation above 105mA continuous for >1 minute, derate accuracy 10%/35mA above 105mA.
2. Speed = Normal (1 PLC). For 0.1 PLC, add 0.005% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.05%. For 0.01 PLC, add 0.05% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.5%.
3. Accuracies apply to 2- or 4-wire mode when properly zeroed.
4. In pulse mode, limited to 0.1 PLC measurement.

ADDITIONAL SOURCE SPECIFICATIONS (All Models)

TRANSIENT RESPONSE TIME: 30μs minimum for the output to recover to its spec. following a step change in load.

COMMAND PROCESSING TIME: Maximum time required for the output to begin to change following the receipt of :SOURce:VOLTage|CURRent <nrf> command. **Autorange On:** 10ms. **Autorange Off:** 7ms.

OUTPUT SETTLING TIME: Time required to reach 0.1% of final value after command is processed. 100μs typical. Resistive load. 10μA to 100mA range.

DC FLOATING VOLTAGE: Output can be floated up to ±250VDC (Model 2440 ±40VDC) from chassis ground.

REMOTE SENSE: Up to 1V drop per load lead.

COMPLIANCE ACCURACY: Add 0.3% of range and ±0.02% of reading to base specification.

OVER TEMPERATURE PROTECTION: Internally sensed temperature overload puts unit in standby mode.

RANGE CHANGE OVERSHOOT: Overshoot into a fully resistive 100kΩ load, 10Hz to 1MHz BW, adjacent ranges: 100mV typical, except 20V/200V (20V/60V on Model 2420), 20V/100V on Model 2425 and 2430, range boundary, and Model 2440.

MINIMUM COMPLIANCE VALUE: 0.1% of range.

Current Accuracy (Local or Remote Sense)

Model	Range	Programming Resolution	Source [1, 3] Accuracy (1 Year)[3] 23°C ±5°C ±(% rdg. + amps)	Default Measurement Resolution	Measurement [4, 5, 6] Accuracy (1 Year) 23°C ±5°C ±(% rdg. + amps)	Source/Sink Limit
2400, 2400-C, 2401	1.00000 μA	50 pA	0.035% + 600 pA	10 pA	0.029% + 300 pA	±1.05A @ ±21 V
	10.0000 μA	500 pA	0.033% + 2 nA	100 pA	0.027% + 700 pA	
	100.000 μA	5 nA	0.031% + 20 nA	1 nA	0.025% + 6 nA	
	1.00000 mA	50 nA	0.034% + 200 nA	10 nA	0.027% + 60 nA	
	10.0000 mA	500 nA	0.045% + 2 μA	100 nA	0.035% + 600 nA	
	100.000 mA	5 μA	0.066% + 20 μA	1 μA	0.055% + 6 μA	
	1.00000 A[2]	50 μA	0.27 % + 900 μA	10 μA	0.22 % + 570 μA	

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.15 × accuracy specification)/°C.

CURRENT REGULATION: Line: 0.01% of range. **Load:** 0.01% of range (except Model 2440 5A range 0.05%) + 100pA.

VOLTAGE LIMIT: Bipolar voltage limit (compliance) set with single value. Min. 0.1% of range.

OVERSHOOT: <0.1% typical (1mA step, RL = 10kΩ, 20V range for Model 2400, 2401, 2410, 2420, 2425, 2430), (10V range for Model 2440).

CONTACT CHECK SPECIFICATIONS (requires -C version)

(Not available for Model 2401)

SPEED: 350μs for verification and notification.

CONTACT CHECK:	2 Ω	15 Ω	50 Ω
No contact check failure	<1.00 Ω	<13.5 Ω	<47.5 Ω
Always contact check failure	>3.00 Ω	>16.5 Ω	>52.5 Ω

NOTES

1. **2400, 2401, 2410 Only:** Specifications valid for continuous output currents below 105mA. For operation above 105mA continuous for >1 minute, derate accuracy 10%/35mA above 105mA.
2. Full operation (1A) regardless of load to 30°C (50°C for Model 2420 and 2440). Above 30°C (50°C for Model 2420 and 2440) ambient, derate 35mA/°C and prorate 35mA/Ω load. 4-wire mode. For current sink operation on 1A, 3A, or 5A ranges, maximum continuous power is limited to approximately 1/2 rated power or less, depending on current, up to 30°C ambient. See power equations in the User's Manual to calculate allowable duty cycle for specific conditions.
3. For sink mode, 1μA to 100mA range, accuracy is:
   Model 2400, 2401: ±(0.15% + offset*4). **Models 2410, 2420, 2425, 2430, 2440:** ±(0.5% + offset*3).
   For 1A range, accuracy is:
   Model 2400, 2401: ±(1.5% + offset*8). **Models 2410, 2420, 2425, 2430, 2440:** ±(1.5% + offset*3).
4. Speed = Normal (1 PLC). For 0.1 PLC, add 0.005% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.05%. For 0.01 PLC, add 0.05% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.5%.
5. Accuracies apply to 2- or 4-wire mode when properly zeroed.
6. In pulse mode, limited to 0.1 PLC measurement.

Resistance Measurement Accuracy (Local or Remote Sense)[1, 2, 5]

Range	Default Resolution	Default Test Current 2400, 2401, 2410	Normal Accuracy (23°C ±5°C) 1 Year, ±(% rdg. + ohms) 2400, 2401	Enhanced Accuracy (23°C ±5°C)[4] 1 Year, ±(% rdg. + ohms) 2400, 2401
<0.20000 Ω[3]	–	–	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}
2.00000 Ω[3]	10 μΩ	–	Source I_{ACC} + Meas V_{ACC}	Source I_{ACC} + Meas. V_{ACC}
20.0000 Ω	100 μΩ	100 mA	0.10% + 0.003 Ω	0.07% + 0.001 Ω
200.000 Ω	1 mΩ	10 mA	0.08% + 0.03 Ω	0.05% + 0.01 Ω
2.00000 kΩ	10 mΩ	1 mA	0.07% + 0.3 Ω	0.05% + 0.1 Ω
20.0000 kΩ	100 mΩ	100 μA	0.06% + 3 Ω	0.04% + 1 Ω
200.000 kΩ	1 Ω	10 μA	0.07% + 30 Ω	0.05% + 10 Ω
2.00000 MΩ[6]	10 Ω	1 μA	0.11% + 300 Ω	0.05% + 100 Ω
20.0000 MΩ[7]	100 Ω	1 μA	0.11% + 1 kΩ	0.05% + 500 Ω
200.000 MΩ[3]	1 kΩ	100 nA	0.66% + 10 kΩ	0.35% + 5 kΩ
>200.000 MΩ[3]	–	–	Source I_{ACC} + Meas. V_{ACC}	Source I_{ACC} + Meas. V_{ACC}

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.15 × accuracy specification)/°C.

SOURCE I MODE, MANUAL OHMS: Total uncertainty = I source accuracy + V measure accuracy (4-wire remote sense).

SOURCE V MODE, MANUAL OHMS: Total uncertainty = V source accuracy + I measure accuracy (4-wire remote sense).

6-WIRE OHMS MODE: Available using active ohms guard and guard sense. Max. Guard Output Current: 50mA (except 1A range). Accuracy is load dependent. Refer to White Paper no. 2033 for calculation formula.

GUARD OUTPUT IMPEDANCE: <0.1Ω in ohms mode.

NOTES

1. Speed = Normal (1 PLC). For 0.1 PLC, add 0.005% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.05%. For 0.01 PLC, add 0.05% of range to offset specifications, except 200mV, 1A, 10A ranges, add 0.5%.
2. Accuracies apply to 2- or 4-wire mode when properly zeroed.
3. Manual ohms only – except 2420, 2425, 2430, 2440 for 2Ω range and 2400, 2401, or 2410 for 200MΩ range.
4. Source readback enabled, offset compensation ON. Also available on 2410, 2420, 2425, 2430, and 2440 with similar accuracy enhancement.
5. In pulse mode, limited to 0.1 PLC measurement.
6. Except 2440; default test current is 5μA.
7. Except 2440; default test current is 0.5μA.

System Speeds

MEASUREMENT[1]

MAXIMUM RANGE CHANGE RATE: 75/second.

MAXIMUM MEASURE AUTORANGE TIME: 40ms (fixed source).[2]

Sweep Operation[3] Reading Rates (rdg./second) for 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To Mem.	Measure To GPIB	Source-Measure To Mem.	Source-Measure To GPIB	Source-Measure Pass/Fail Test[4, 5] To Mem.	Source-Measure Pass/Fail Test[4, 5] To GPIB	Source-Memory[4] To Mem.	Source-Memory[4] To GPIB
Fast	0.01 / internal	2081 (2030)	1754	1551 (1515)	1369	902 (900)	981	165 (162)	165
IEEE-488.1 Mode	0.01 / external	1239 (1200)	1254	1018 (990)	1035	830 (830)	886	163 (160)	163
Fast	0.01 / internal	2081 (2030)	1198 (1210)	1551 (1515)	1000 (900)	902 (900)	809 (840)	165 (162)	164 (162)
IEEE-488.2 Mode	0.01 / external	1239 (1200)	1079 (1050)	1018 (990)	916 (835)	830 (830)	756 (780)	163 (160)	162 (160)
Medium	0.10 / internal	510 (433)	509 (433)	470 (405)	470 (410)	389 (343)	388 (343)	133 (126)	132 (126)
IEEE-488.2 Mode	0.10 / external	438 (380)	438 (380)	409 (360)	409 (365)	374 (333)	374 (333)	131 (125)	131 (125)
Normal	1.00 / internal	59 (49)	59 (49)	58 (48)	58 (48)	56 (47)	56 (47)	44 (38)	44 (38)
IEEE-488.2 Mode	1.00 / external	57 (48)	57 (48)	57 (48)	57 (47)	56 (47)	56 (47)	44 (38)	44 (38)

Single Reading Operation Reading Rates (rdg./second) for 60Hz (50Hz):

Speed	NPLC/Trigger Origin	Measure To GPIB	Source-Measure[5] To GPIB	Source-Measure Pass/Fail Test[4,5] To GPIB
Fast (488.1)	0.01 / internal	537	140	135
Fast (488.2)	0.01 / internal	256 (256)	79 (83)	79 (83)
Medium (488.2)	0.10 / internal	167 (166)	72 (70)	69 (70)
Normal (488.2)	1.00 / internal	49 (42)	34 (31)	35 (30)

Component for 60Hz (50Hz):[4, 6]

Speed	NPLC/Trigger Origin	Measure To GPIB	Source Pass/Fail Test	Source-Measure Pass/Fail Test[5, 7] To GPIB
Fast	0.01 / external	1.04 ms (1.08 ms)	0.5 ms (0.5 ms)	4.82 ms (5.3 ms)
Medium	0.10 / external	2.55 ms (2.9 ms)	0.5 ms (0.5 ms)	6.27 ms (7.1 ms)
Normal	1.00 / external	17.53 ms (20.9 ms)	0.5 ms (0.5 ms)	21.31 ms (25.0 ms)

NOTES

1. Reading rates applicable for voltage or current measurements. Auto zero off, autorange off, filter off, display off, trigger delay = 0, and binary reading format.
2. Purely resistive lead. 1μA and 10μA ranges <65ms.
3. 1000 point sweep was characterized with the source on a fixed range.
4. Pass/Fail test performed using one high limit and one low math limit.
5. Includes time to re-program source to a new level before making measurement.
6. Time from falling edge of START OF TEST signal to falling edge of END OF TEST signal.
7. Command processing time of :SOURce:VOLTage|CURRent:TRIGgered <nrf> command not included.

GENERAL

Noise Rejection:

	NPLC	NMRR	CMRR
Fast	0.01	—	80 dB
Medium	0.1	—	80 dB
Slow	1	60 dB	100 dB[1]

[1] Except lowest 2 current ranges = 90dB.

LOAD IMPEDANCE: Stable into 20,000pF typical.

COMMON MODE VOLTAGE: 250V DC (40V DC for Model 2440).

COMMON MODE ISOLATION: $>10^9\Omega$, <1000pF.

OVERRANGE: 105% of range, source and measure.

MAX. VOLTAGE DROP BETWEEN INPUT/OUTPUT AND SENSE TERMINALS: 5V.

MAX. SENSE LEAD RESISTANCE: 1MΩ for rated accuracy.

SENSE INPUT IMPEDANCE: $>10^{10}\Omega$.

GUARD OFFSET VOLTAGE: <150μV, typical (300μV for Models 2430, 2440).

SOURCE OUTPUT MODES:
Fixed DC level
Memory List (mixed function)
Stair (linear and log)

MEMORY BUFFER: 5,000 readings @ 5 digits (two 2,500 point buffers). Includes selected measured value(s) and time stamp. Lithium battery backup (3 yr+ battery life).

SOURCE MEMORY LIST: 100 points max.

PROGRAMMABILITY: IEEE-488 (SCPI-1995.0), RS-232, 5 user-definable power-up states plus factory default and *RST.

DIGITAL INTERFACE: Interlock: Active low input. **Note:** DIO Post N/A.

POWER SUPPLY: 100V to 240V rms, 50–60Hz (automatically detected at power up). **Model 2400, 2401:** 190VA.

COOLING: Convection.

EMC: Conforms to European Union Directive 89/336/EEC, EN 61326-1.

SAFETY: UL listed to UL 61010B-1:2003: Conforms to European Union Low Voltage Directive.

VIBRATION: MIL-PRF-28800F Class 3 Random.

WARM-UP: 1 hour to rated accuracies.

DIMENSIONS: 89mm high × 213mm wide × 370mm deep (3½ in × 8⅜ in × 14⅝ in). **Bench Configuration (with handle and feet):**104mm high × 238mm wide × 370mm deep (4⅛ in × 9⅜ in × 14⅝ in).

WEIGHT: 3.21kg (7.08 lbs) (Model 2425, 2430, 2440: 4.1kg, 9.0 lbs).

ENVIRONMENT: Operating: 0°–50°C, 70% R.H. up to 35°C. Derate 3% R.H./°C, 35°–50°C. **Storage:** –25°C to 65°C.

6430

Sub-femtoamp Remote SourceMeter® Instrument

- **0.4fA p-p (4E–16A) noise (typical)**
- **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 Sub-Femtoamp Remote SourceMeter combines the voltage and current sourcing and measurement functions of Keithley's popular SourceMeter and source measurement unit (SMU) instruments 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 high level signals output by the Remote PreAmp are sent to the controlling mainframe via a two-meter cable. This allows the user to make a direct or very short connection to the signal, minimizing the effects of cable noise.

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.

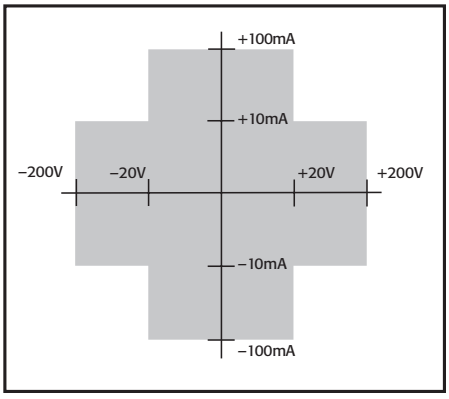
The Model 6430's distinguishing features include its excellent low current sensitivity and the Remote PreAmp, which makes this sensitivity useful by eliminating long input cables. The Remote PreAmp is an integral part of the Model 6430's feedback measuring system that cannot be operated independently from the measurement mainframe, although it can be separated from the mainframe by up to two meters of connection cable carrying high level signals.

Applications

The Model 6430's capabilities make it equally useful for research work and for evaluating sophisticated components in test labs for low-current, high-resistance, or sensitive semiconductor measurements. The low noise and drift performance of the Model 6430 also makes it well suited for research studies in single electron devices, highly resistive nanowires and nanotubes, polymers, highly resistive nanomaterials, and electrochemical amperometry applications.

High Speed Data Handling

The Model 6430 can read more than 2000 readings per second into its internal memory buffer. The IEEE-488 bus output can transmit up to 75 source/measure readings per second to an external computer controller, including pass/fail indication.



The Model 6430 provides four-quadrant sourcing of up to 2.2W, as well as measurement sensitivity down to sub-femtoamp and microvolt levels. It can measure currents from the 1pA range (with just 0.4fA p-p noise typical) up to the 100mA range at up to 20V. Voltage ranges from 200mV to 200V are available. Current and voltage range settings define the maximum source or sink voltage or current.

6430

Sub-Femtoamp Remote SourceMeter® Instrument

Ordering Information

6430 Sub-femtoamp Remote SourceMeter

Accessories Supplied

6430-322-1B Low Noise Triax Cable, 3-slot triax to alligator clips, 20cm (8 in)

8607 Safety High Voltage Dual Test Leads

CA-176-1E PreAmp Cable, 2m (6.6 ft)

CA-186-1B Banana Lead to Screw Terminal Adapter

CAP-31 3-lug Protective Cap (2)

Instruction Manual

ACCESSORIES AVAILABLE

7007-1	Shielded GPIB Cable, 1m (3.3 ft)
7007-2	Shielded GPIB Cable, 2m (6.6 ft)
7007-4	Shielded GPIB Cable, 4m (13.1 ft)
7007-05	Shielded GPIB Cable, 0.5m (1.6 ft)
7078-TRX-6IN	3-slot, Low Noise, 0.15m (0.5 ft) Guarded Triax Cable
8501-1	Trigger Link Cable, 1m (3.3 ft.)
8501-2	Trigger Link Cable, 2m (6.6 ft.)
8502	Trigger Link Adapter Box
8503	Trigger Link DIN-to-BNC Trigger Cable
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

SERVICES AVAILABLE

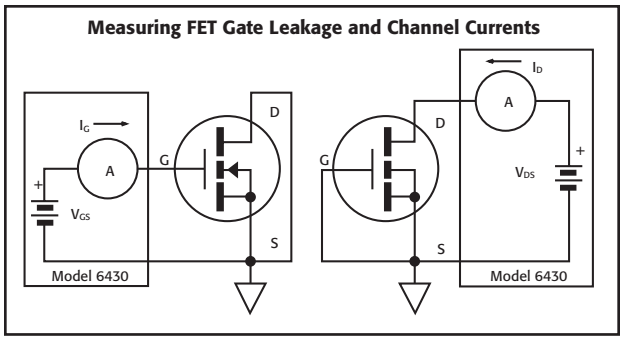
TRN-2400-1-C	Course: Unleashing the Power of Your SourceMeter Instrument
6430-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
C/6430-3Y-ISO	3 (ISO-17025 accredited) calibrations within 3 years of purchase*

*Not available in all countries

Typical applications:

Semiconductor measurements

Gate leakage or channel leakage in FET-based components can generate errors in MOSFETs, JFETs, analog switches, and many other circuits. By allowing researchers to measure extremely low-level currents and voltages, the Model 6430 can help them understand the design limitations of these components and investigate alternative device structures or materials.

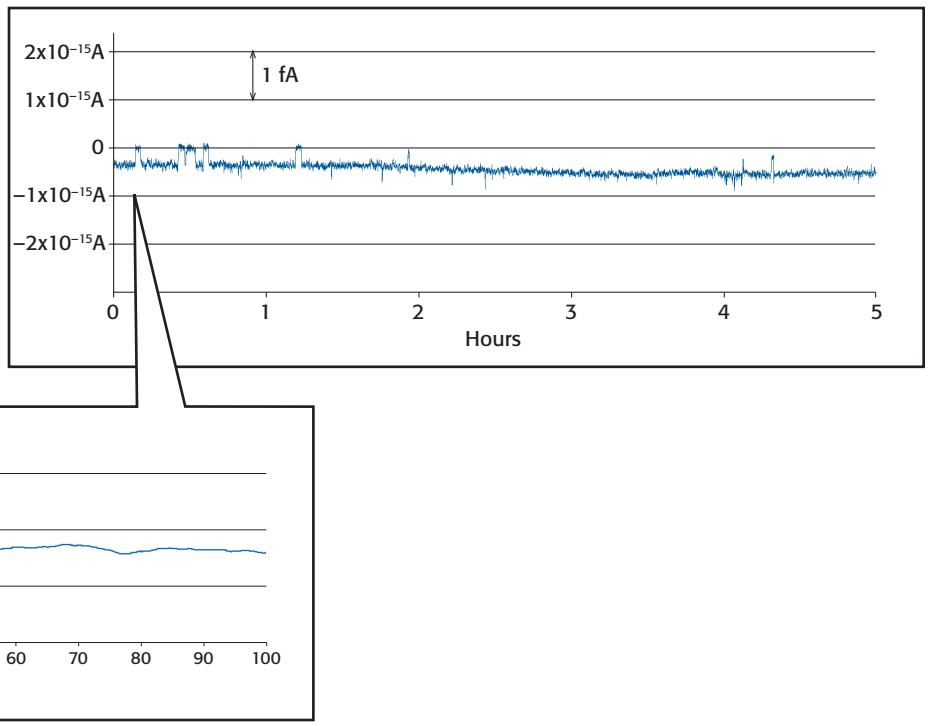


SET research

The Model 6430's superior low current measurement ability (0.4fA p-p noise typical) makes it extremely useful for single electron transistor (SET) and quantum-dot research. Using a technique similar to a lock-in, the 6430 can measure currents with 1aA sensitivity (10^{-18}A = 6 electrons/second).

The Measurement Industry's Lowest Noise and Drift

This data illustrates the Model 6430's impressive stability over a five-hour period, as well as its low short-term noise performance. This signal trace was acquired using the instrument's AUTOFILTER with a 5-second rise time on the 1pA range. The inset close-up is a snapshot of the filtered signal, showing the Model 6430's low noise during the first 100-second period. The data was taken in a laboratory environment where temperature varied about 1°C, with the instrument's IN/OUT HI and SENSE leads capped.



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Sub-Femtoamp Remote SourceMeter® Instrument

CONDENSED MEASURE SPECIFICATIONS [1]

VOLTAGE MEASUREMENT ACCURACY (4-WIRE SENSE)[3]

Range	Max. Resolution	Input[2] Resistance	Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + volts)
200.000 mV	1 μV	>10^{16}Ω	0.012% + 350 μV
2.00000 V	10 μV	>10^{16}Ω	0.012% + 350 μV
20.0000 V	100 μV	>10^{16}Ω	0.015% + 1.5 mV
200.000 V	1 mV	>10^{16}Ω	0.015% + 10 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–40°C): ±(0.15 × accuracy specification)/°C.

ADDITIONAL MEASURE SPECIFICATIONS

OUTPUT SETTLING TIME (typical to 10% of final value): <2s, 1pA and 10pA ranges; <50ms, 100pA through 10nA ranges; <5ms, 100nA through 100mA ranges.

CURRENT NOISE: When observed over 1 minute intervals, peak to peak noise will be within 400aA (typical) during 90% of the intervals using Autofilter (5s 10% to 90% rise time), with triax connectors capped, Autozero OFF, Source Delay = 0, on the 1pA range for at least 3 minutes.

CURRENT MEASUREMENT ACCURACY (2- OR 4-WIRE SENSE)[4]

Range	Max. Resolution	Voltage Burden[5]	Accuracy (23°C ± 5°C) 1 Year ±(%rdg + amps)
1.00000 pA	10 aA	< 1mV	1.0 % + 7 fA
10.0000 pA	100 aA	< 1mV	0.50 % + 7 fA
100.000 pA	1 fA	< 1mV	0.15 % + 30 fA
1.00000 nA	10 fA	< 1mV	0.050 % + 200 fA
10.0000 nA	100 fA	< 1mV	0.050 % + 2 pA
100.000 nA	1 pA	< 1mV	0.050 % + 20 pA
1.00000 μA	10 pA	< 1mV	0.050 % + 300 pA
10.0000 μA	100 pA	< 1mV	0.050 % + 2 nA
100.000 μA	1 nA	< 1mV	0.025 % + 6 nA
1.00000 mA	10 nA	< 1mV	0.027 % + 60 nA
10.0000 mA	100 nA	< 1mV	0.035 % + 600 nA
100.000 mA	1 μA	< 1mV	0.055 % + 6 μA

TEMPERATURE COEFFICIENT (0°–18°C and 28°–40°C): ±[(0.15 × accuracy specification) + 1fA]/°C.

INPUT CURRENT: <3fA at 23°C, <40% RH; typically ±0.5fA/°C around 23°C, <40% RH.

RESISTANCE MEASUREMENT ACCURACY (4-WIRE SENSE WITH REMOTE PREAMP)

Source I Mode, Auto Ohms

Range	Max. Resolution	Default Test Current	Normal Accuracy (23°C ± 5°C) 1 Year, ±(%rdg + ohms)	Enhanced Accuracy (23°C ± 5°C) [7] 1 Year, ±(%rdg + ohms)
<2.00000 Ω [6]	1 μΩ	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}
20.0000 Ω	100 μΩ	100 mA	0.098% + 0.003 Ω	0.068% + 0.001 Ω
200.000 Ω	1 mΩ	10 mA	0.077% + 0.03 Ω	0.048% + 0.01 Ω
2.00000 kΩ	10 mΩ	1 mA	0.066% + 0.3 Ω	0.040% + 0.1 Ω
20.0000 kΩ	100 mΩ	100 μA	0.063% + 3 Ω	0.038% + 1 Ω
200.000 kΩ	1 Ω	10 μA	0.082% + 30 Ω	0.064% + 10 Ω
2.00000 MΩ	10 Ω	1 μA	0.082% + 300 Ω	0.064% + 100 Ω
20.0000 MΩ	100 Ω	1 μA	0.085% + 1 kΩ	0.067% + 500 Ω
200.000 MΩ	1 kΩ	100 nA	0.085% + 10 kΩ	0.068% + 5 kΩ
2.00000 GΩ	10 kΩ	10 nA	0.085% + 100 kΩ	0.070% + 50 kΩ
20.0000 GΩ	100 kΩ	1 nA	0.085% + 1 MΩ	0.070% + 500 kΩ
200.000 GΩ	1 MΩ	100 pA	0.205% + 10 MΩ	0.185% + 5 MΩ
2.00000 TΩ	10 MΩ	10 pA	0.822% + 100 MΩ	0.619% + 50 MΩ
20.0000 TΩ	100 MΩ	1 pA	2.06% + 1 GΩ	1.54% + 500 MΩ
>20.0000 TΩ [6]	—	—	Source I_{ACC} + Measure V_{ACC}	Measure I_{ACC} + Measure V_{ACC}

TEMPERATURE COEFFICIENT (0°–18°C and 28°–40°C): ±(0.15 × accuracy specification)/°C.

SOURCE I MODE, MANUAL OHMS: Total uncertainty = I source accuracy + V measure accuracy (4-wire sense).

SOURCE V MODE: Total uncertainty = V source accuracy + I measure accuracy (4-wire sense).

6-WIRE OHMS MODE: Available using active ohms guard and guard sense (mainframe rear panel ONLY). **Max. Guard Output Current:** 50 mA. Accuracy is load dependent. Refer to manual for calculation formula.

MAINFRAME GUARD OUTPUT RESISTANCE: 0.1Ω in ohms mode.

NOTES

1. Speed = 10 PLC, Autofilter ON, properly zeroed and settled.
2. Source I mode, I = 0.
3. Voltage measurement accuracy is not affected by the remote preamp.
4. Current measurement accuracy is not affected by the remote preamp; however, the 1pA through 100nA ranges are available only when using a preamp.
5. 4-wire mode.
6. Manual ohms mode only.
7. Source readback enabled, offset compensation ON. Source delay must be programmed such that the source is fully settled for each reading.

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Sub-Femtoamp Remote SourceMeter® Instrument

CONDENSED SYSTEM SPEEDS

MEASUREMENT[1]

MAXIMUM RANGE CHANGE RATE: 75/second.

SINGLE READING OPERATION READING RATES (rdg/second) FOR 60Hz (50Hz):

Speed	NPLC/ Trigger Origin	Measure To GPIB	Source-Measure[3] To GPIB	Source-Measure Pass/Fail Test[2, 3] To GPIB
Fast	0.01 / internal	256 (256)	83 (83)	83 (83)
Medium	0.10 / internal	181 (166)	73 (70)	73 (70)
Normal	1.00 / internal	49 (42)	35 (31)	34 (30)

CONDENSED SOURCE SPECIFICATIONS[4]

VOLTAGE PROGRAMMING ACCURACY (4-WIRE SENSE)[5]

Range	Programming Resolution	Accuracy (1 Year) 23°C ±5°C ±(% rdg. + volts)	Noise (peak-peak) 0.1Hz – 10Hz
200.000 mV	5 µV	0.02% + 600 µV	5 µV
2.00000 V	50 µV	0.02% + 600 µV	50 µV
20.0000 V	500 µV	0.02% + 2.4 mV	500 µV
200.000 V	5 mV	0.02% + 24 mV	5 mV

TEMPERATURE COEFFICIENT (0°–18°C and 28°–40°C): ±(0.15 × accuracy specification)/°C.

MAX. OUTPUT POWER: 2.2W (four quadrant source or sink operation).

SOURCE/SINK LIMITS: ±21V @ ±105mA, ±210V @ ±10.5mA.

VOLTAGE REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 100µV.

NOISE 10Hz–1MHz (p-p): 10mV.

OVER VOLTAGE PROTECTION: User selectable values, 5% tolerance. Factory default = None.

CURRENT LIMIT: Bipolar current limit (compliance) set with single value. Min. 0.1% of range.

CURRENT PROGRAMMING ACCURACY (WITH REMOTE PREAMP)

Range	Programming Resolution	Accuracy (1 Year)[4] 23°C ±5°C ±(% rdg. + amps)	Noise (peak-peak) 0.1Hz – 10Hz
1.00000 pA	50 aA	1.0 % + 10 fA	5 fA
10.0000 pA	500 aA	0.50 % + 30 fA	10 fA
100.000 pA	5 fA	0.15 % + 40 fA	20 fA
1.00000 nA	50 fA	0.050 % + 200 f A	50 fA
10.0000 nA	500 fA	0.050 % + 2 pA	500 fA
100.000 nA	5 pA	0.050 % + 20 pA	3 pA
1.00000 µA	50 pA	0.050 % + 300 pA	20 pA
10.0000 µA	500 pA	0.050 % + 2 nA	200 pA
100.000 µA	5 nA	0.031 % + 20 nA	500 pA
1.00000 mA	50 nA	0.034 % + 200 nA	5 nA
10.0000 mA	500 nA	0.045 % + 2 µA	50 nA
100.000 mA	5 µA	0.066 % + 20 µA	500 nA

TEMPERATURE COEFFICIENT (0°–18°C and 28°–40°C): ±(0.15 × accuracy specification)/°C.

MAX. OUTPUT POWER: 2.2W (four quadrant source or sink operation).

SOURCE/SINK LIMITS: ±10.5mA @ ±210V, ±105mA @ ±21V.

CURRENT REGULATION: Line: 0.01% of range. **Load:** 0.01% of range + 1fA.

VOLTAGE LIMIT: Bipolar voltage limit (compliance) set with single value. Min. 0.1% of range.

NOTES

1. Reading rates applicable for voltage or current measurements. Auto zero off, autorange off, filter off, display off, trigger delay = 0, source auto clear off, and binary reading format.
2. Pass/Fail test performed using one high limit and one low math limit.
3. Includes time to re-program source to a new level before making measurement.
4. For sink mode, 1pA to 100mA range, accuracy is ±(0.15% + offset*4).
5. Voltage source accuracies are not affected by the remote preamp.

GENERAL

Noise Rejection:	NPLC	NMRR	CMRR
Fast	0.01	—	80 dB
Medium	0.1	—	80 dB
Normal	1	60 dB	90 dB

LOAD IMPEDANCE: Stable into 20,000pF on the 100mA through 100µA ranges, 470pF on the 10µA and 1µA ranges, and 100pF on the nA and pA ranges. Refer to the User's Manual for details on measuring large capacitive loads.

COMMON MODE VOLTAGE: ±42VDC maximum.

COMMON MODE ISOLATION: >10^9Ω, <1000pF.

OVERRANGE: 105% of range, source and measure.

MAX. VOLTAGE DROP BETWEEN INPUT/OUTPUT AND SENSE TERMINALS: 5V. (To meet specified accuracy with 4-wire sense, refer to the User's Manual.)

MAX. SENSE LEAD RESISTANCE: 10Ω for rated accuracy.

SENSE INPUT RESISTANCE: 1MΩ.

MAINFRAME GUARD OFFSET VOLTAGE: 300µV, typical.

PREAMP GUARD OFFSET VOLTAGE: 1mV, typical.

PREAMP GUARD OUTPUT RESISTANCE: 110kΩ.

SOURCE OUTPUT MODES: Fixed DC level, Memory List (mixed function), Stair (linear and log).

SOURCE MEMORY LIST: 100 points max.

MEMORY BUFFER: 5,000 readings @ 5½ digits (two 2,500 point buffers). Includes selected measured value(s) and time stamp. Lithium battery backup (3 yr+ battery life).

DIGITAL INTERFACE:

Safety Interlock: Active low input.

Handler Interface: Start of test, end of test, 3 category bits. +5V @ 300mA supply.

Digital I/O: 1 trigger input, 4 TTL/Relay Drive outputs (33V @ 500mA sink, diode clamped).

PROGRAMMABILITY: IEEE-488 (SCPI-1995.0), RS-232, 5 user-definable power-up states plus factory default and *RST.

POWER SUPPLY: 100V–240V rms, 50–60Hz (automatically detected at power up), 100VA max.

EMC: Conforms with European Union Directive 89/336/EEC EN 55011, EN 50082-1, EN 61000-3-2 and 61000-3-3, FCC part 15 class B.

SAFETY: Conforms with European Union Directive 73/23/EEC EN 61010-1.

VIBRATION: MIL-PRF-28800F, Class 3.

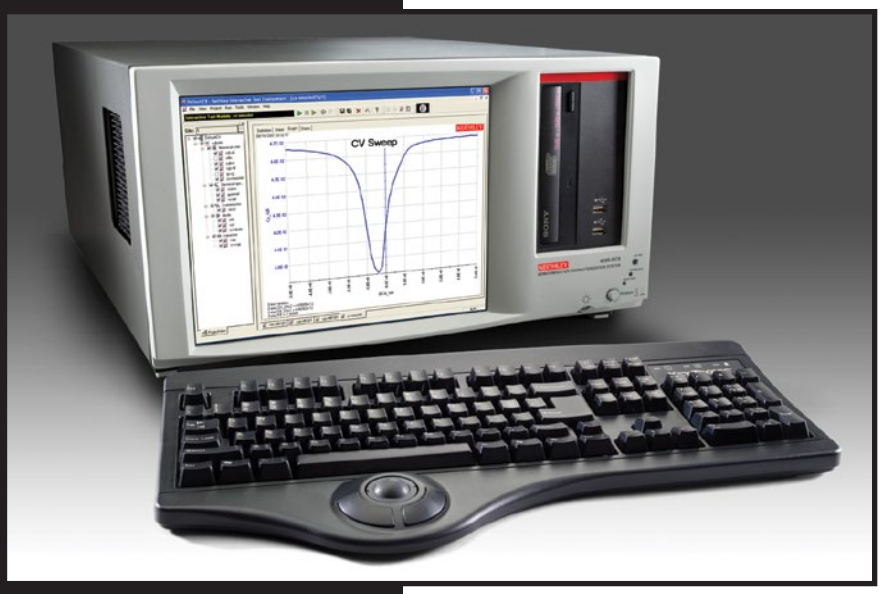
WARM-UP: 1 hour to rated accuracies.

DIMENSIONS: 89mm high × 213mm wide × 370mm deep (3½ in × 8⅜ in × 14⅝ in). Bench Configuration (with handle and feet): 104mm high × 238mm wide × 370mm deep (4⅛ in × 9⅜ in × 14⅝ in).
Amplifier: 20mm high × 57mm wide × 97mm deep (0.783 in × 2.225 in × 3.75 in).

WEIGHT: 5.9kg (13 lbs).

ENVIRONMENT: Operating: 0°–40°C, 60% R.H. (non-condensing) up to 35°C. Derate 5% R.H./°C, 35°–40°C. **Storage:** –25°C to 65°C. Non-condensing humidity.

4200-SCS Semiconductor Characterization System



- Characterize devices with up to 9 source-measure units
- Sub-femtoamp resolution measurements with optional preamps
- Ultra-fast I-V module for pulse and pulse I-V capabilities
- C-V instrument makes C-V measurements as easy as DC I-V
- Ultra low frequency C-V measurement capability
- Familiar, point-and-click Windows® environment and intuitive GUI
- Easy to use for both interactive and automated tests
- Real-time plotting and analysis allow users to view results before a test has completed and to take preemptive action as needed
- Embedded PC provides the additional benefits of a networked instrument including mapping network drives and making test results available to the corporate network
- Simultaneously acquires data, analyzes plots, and prints reports
- Ideal for device characterization, device modeling, reliability testing, and failure analysis
- Includes instrument and prober drivers as well as interfaces to popular modeling and circuit simulation software

APPLICATIONS:

Semiconductor Devices

- On-wafer parametric test
- Wafer level reliability
- Packaged device characterization
- High κ gate charge trapping
- Isothermal testing of devices and materials subject to self-heating effects
- Charge pumping to characterize interface state densities in MOSFET devices
- Resistive or capacitive MEMS drive characterization

Optoelectronic Devices

- Semiconductor laser diode DC/CW characterization
- DC/CW characterization of transceiver modules
- PIN and APD characterization

Technology Development

- Carbon nanotube characterization
- Materials research
- Electrochemistry

The easy-to-use Model 4200-SCS performs laboratory grade DC I-V, C-V, and pulse device characterization, real-time plotting, and analysis with high precision and sub-femtoamp resolution. It is the best tool available for interactive parametric analysis and device characterization. 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.

Its Keithley Interactive Test Environment (KITE) is so intuitive that even a novice can use the system with ease. This point-and-click software offers a full range of functionality, from managing tests, organizing results, and generating reports to creating user libraries. Sophisticated and simple test sequencing and external instrument drivers make it simple to perform automated testing with combined DC I-V, pulse, and C-V measurements.

The modular design of the Model 4200-SCS provides you with tremendous flexibility. It supports up to nine internal source measurement unit (SMUs) instruments and optional Remote Pre-Amps that extend the resolution of any SMU from 100fA to 0.1fA. Its hardware options also include four switch matrix configurations, meters, pulse generators, and more.

Optional instruments can be integrated into the Model 4200-SCS, such as dual-channel pulse generators, a dual-channel digital oscilloscope, and a C-V instrument, which is a capacitance-voltage instrument that performs capacitance measurements from fF to nF at frequencies from 1kHz to 10MHz.

The C-V option includes the new C-V Power package, which supports high power C-V measurements up to 400V and 300mA, up to 60V of differential DC bias, and quasistatic C-V measurements.

The exceptional low current performance of the Model 4200-SCS makes it the perfect solution for research studies of single electron transistors (SETs), molecular electronic devices, and other nanoelectronic devices that require I-V characterization. The 4200-SCS can also be used to make four-probe van der Pauw resistivity and Hall voltage measurements.

For more information on the Model 4200-SCS, see page 56.

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High Voltage Source-Measure Unit

- **Four instruments in one (voltage source, voltage measure, current source, current measure)**
- **10fA, 10µV measurement sensitivity**
- **1100V source and measure**
- **Standard and custom sweep capability including pulse**
- **1000 source/measurements per second**
- **Four quadrant source operation**
- **Internal 1000-reading memory**

Ordering Information

237 **High Voltage Source-Measure Unit**

Accessories Supplied

7078-TRX-10 3-Slot Low Noise Triax Cables, 3m (10 ft) (2)

236-ILC-3 Interlock Cable, 3m (10 ft)

237-ALG-2 Low Noise Triax Cable, 2m (6.6 ft)

ACCESSORIES AVAILABLE

237-TRX-NG	3-Slot Triax to 3-Lug Female Triax Connector
1938	Fixed Rack Mount Kit
1939	Slide Rack Mount Kit
7010	GPIB Shielded Extender
7007-1	Shielded GPIB Cable, 1m (3.3 ft.)
7007-2	Shielded GPIB Cable, 2m (6.6 ft.)
7078-TRX-3	3-Slot, Low Noise Triax Cable, 0.9m (3 ft)
7078-TRX-20	3-Slot, Low Noise Triax Cable, 6m (20 ft)
KPCI-488LPA	IEEE-488 Interface/Controller for the PCI Bus
KUSB-488B	USB-to-GPIB Interface Adapter for USB Port (requires 7010 Adapter)

SERVICES AVAILABLE

237-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
C/237-3Y-DATA	3 (Z540-1 compliant) calibrations within 3 years of purchase*

*Not available in all countries

The Model 237 Source-Measure Unit is a fully programmable instrument, capable of sourcing and measuring voltage or current simultaneously. This system is really four instruments in one: voltage source, current source, voltage measure, and current measure.

Applications

This SMU instrument addresses a wide variety of applications, including the characterization of semiconductor devices and the measurement of leakage currents or insulation resistance. It can be used standalone on a bench, in a test rack with PC control, or integrated with our Model 4200-SCS for high voltage semicconductor characterization.

Wide Dynamic Range

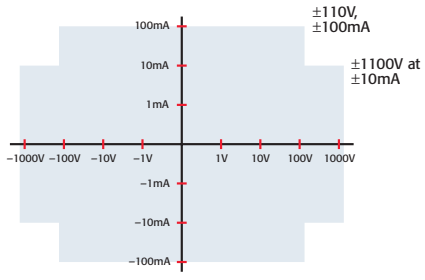
The Model 237 will source voltage from 100µV to 1100V, and current from 100fA to 100mA. It can also measure voltage from 10µV to 110V and current from 10fA to 100mA. In the higher voltage range, current source and measure is 10mA maximum.

Selectable Sweeps of Voltage and Current

The Model 237 can be programmed to perform source-measurements as a function of a stepped voltage or current. Voltage and current can be swept linearly, logarithmically, or pulsed. The START, STOP, STEP method of setting sweep parameters allows operators to become proficient at using the instrument very quickly. Sweep parameters may be appended (APPEND key) to obtain more complex test sequences.

Creating custom sweeps of voltage or current is facilitated by the use of three waveform operations: CREATE, APPEND, and MODIFY. These allow the user to select waveform parameters, combine multiple waveforms, and select and change any points in a waveform previously created or appended.

Model 237 Source Capability

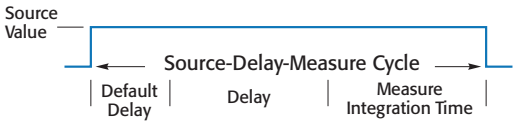


Fully-Guarded Four-Terminal Measurements

The Model 237 outputs and inputs are fully guarded, and the units are configured to allow four-terminal measurements. Two-terminal measurements are also available for more standard test procedures. These outputs can be floated up to ±200V from ground.

High Voltage Source-Measure Unit

SOURCE-DELAY-MEASURE CYCLE:



Default Delay: Fixed delay for instrument settling.

User Delay: Additional delay for device under test or system capacitance.

MEASURE:

Integration Time

Fast	416	µs	4-digit resolution
Medium	4	ms	5-digit resolution
Line Cycle	16.67	ms (60 Hz)	5-digit resolution
	20.00	ms (50 Hz)	

EXECUTION SPEED

MINIMUM SOURCE-DELAY-MEASURE CYCLE TIME: 1ms.

RESPONSE TO IEEE-488 COMMAND (as a source): 25ms.

MEASUREMENT RATE: 1ms per point into internal buffer.

CONTINUOUS MEASUREMENT SPEED (source DC value over IEEE-488 bus): 110 readings per second.

TRIGGER LATENCY TIME: <2ms.

GENERAL

LOAD CAPACITANCE: Stable into 20,000pF typical.

REMOTE SENSE: Corrects for up to 2V drop in each output lead. Maximum 1kΩ per sense lead for rated accuracy. Residual output resistance (as a voltage source) is 0.5Ω.

GUARD: Output Resistance: ≤12kΩ.

Maximum Output Current: ±2mA.

Offset Relative to Output HI: ±2mV max.

ISOLATION (Output LO to chassis): Typically >10^{10}Ω in parallel with 500pF.

MAXIMUM COMMON MODE VOLTAGE: 200V.

CONNECTORS: Outputs: 3-lug triax.

Trigger Input/Output: BNC.

Interlock: 3-pin miniature DIN.

TEMPERATURE COEFFICIENT (0°–18°C and 28°–50°C): ±(0.1 × applicable accuracy specification)/°C.

ENVIRONMENT:

Operating: 0°–50°C, 70% relative humidity up to 35°C. Linearly derate 3% R.H./°C, 35°–50°C.

Storage: –25° to 65°C.

EMC: Conforms to European Union Directive 89/336/EEC.

SAFETY: Conforms to European Union Directive 73/23/EEC (meets EN61010-1/IEC 1010).

WARM-UP: One hour to rated accuracy.

COOLING: Internal fan forced air cooling.

POWER: 105–125 or 210–250V AC (external switch selectable), 90–110V and 180–220V version available. 100VA max.

DIMENSIONS, WEIGHT: 89mm high × 435mm wide × 448mm deep (3½ in × 17⅛ in × 17⅜ in). Net weight 9kg (19.75 lb).

VOLTAGE

Source V			Measure V		
Range (Max. Value)	Step Size	Accuracy (1 Year, 18°–28°C)	Resolution 4-Digit	Resolution 5-Digit	Accuracy (1 Year, 18°–28°C)
±1.1000 V	100 µV	±(0.033% + 650 µV)	100 µV	10 µV	±(0.028% + 300 µV)
±11.000 V	1 mV	±(0.033% + 2.4 mV)	1 mV	100 µV	±(0.025% + 1 mV)
±110.00 V	10 mV	±(0.033% + 24 mV)	10 mV	1 mV	±(0.025% + 10 mV)
±1100.0 V	100 mV	±(0.04 % + 240 mV)	100 mV	10 mV	±(0.035% + 100 mV)

COMPLIANCE: Bipolar current limit set with single value.

Maximum: ±100mA (except ±10mA on 1100V range).

Minimum: ±1% of range, except 0.5% of 1.1V range.

Accuracy, Step Size: Same as current source.

NOISE (p-p):

Range	0.1–10Hz	DC–20MHz
110 V – 1100 V	< 3 ppm of range	40 mV
11 V	< 3 ppm of range	15 mV
1.1 V	<10 ppm of range	15 mV

WIDEBAND NOISE: 0.1 to 20MHz, 8mV p-p typical.

OVERSHOOT: <0.01% (110V step, 10mA range).

SETTLING TIME: <500µs to 0.01% (110V step, 10mA range).

NMRR: >60dB at 50 or 60Hz (LINE CYCLE integration time selected).

CMRR: >120dB at DC, 50 or 60Hz (LINE CYCLE integration time selected).

INPUT IMPEDANCE (as a voltmeter): >10^{14}Ω paralleled by <20pF.

CURRENT

Source I			Measure I		
Range (Max. Value)	Step Size	Accuracy (1 Year, 18°–28°C)	Resolution 4-Digit	Resolution 5-Digit	Accuracy (1 Year, 18°–28°C)
±1.0000 nA	100 fA	±(0.3 % + 450 fA)	100 fA	10 fA	±(0.3 % + 100 fA)[1]
±10.000 nA	1 pA	±(0.3 % + 2 pA)	1 pA	100 fA	±(0.3 % + 1 pA)
±100.00 nA	10 pA	±(0.21% + 20 pA)	10 pA	1 pA	±(0.21 % + 6 pA)
±1.0000 µA	100 pA	±(0.05% + 200 pA)	100 pA	10 pA	±(0.04 % + 60 pA)
±10.000 µA	1 nA	±(0.05% + 2 nA)	1 nA	100 pA	±(0.035 % + 700 pA)
±100.00 µA	10 nA	±(0.05% + 20 nA)	10 nA	1 nA	±(0.035 % + 6 nA)
±1.0000 mA	100 nA	±(0.05% + 200 nA)	100 nA	10 nA	±(0.035 % + 60 nA)
±10.000 mA	1 µA	±(0.05% + 2 µA)	1 µA	100 nA	±(0.038 % + 600 nA)
±100.00 mA	10 µA	±(0.1 % + 20 µA)	10 µA	1 µA	±(0.1 % + 6 µA)

COMPLIANCE: Bipolar voltage limit set with single value.

Maximum: ±1100V (except on 100mA range).

Minimum: ±0.1% of selected current range.

Accuracy, Step Size: Same as voltage source.

NOISE (p-p of range): 0.1–10Hz: <3ppm (<20ppm on 1nA and 10nA ranges).

OVERSHOOT: <0.01% typical (10mA step, R_L = 10kΩ).

SETTLING TIME: <500µs to 0.01% (10mA step, R_L = 10kΩ).

OUTPUT R, C: >10^{14}Ω paralleled by <20pF (on 1nA range).

NOTES

1. Offset specification applies for 23°C ±1°C with suppression. Temperature coefficient 50fA/°C.