

2450 SourceMeter® SMU Instrument

DATASHEET



The 2450 is Keithley's next-generation SourceMeter source measure unit (SMU) instrument that truly brings Ohm's law (current, voltage, and resistance) testing right to your fingertips. Its innovative graphical user interface (GUI) and advanced, capacitive touchscreen technology allow intuitive usage and minimize the learning curve to enable engineers and scientists to learn faster, work smarter, and invent easier. The 2450 is the SMU for everyone: a versatile instrument, particularly well-suited for characterizing modern scaled semiconductors, nano-scale devices and materials, organic semiconductors, printed electronics, and other small-geometry and low-power devices. All this combined with Keithley SMU precision and accuracy allows users to Touch, Test, Invent® with the new favorite go-to instrument in the lab for years to come.

Key Features

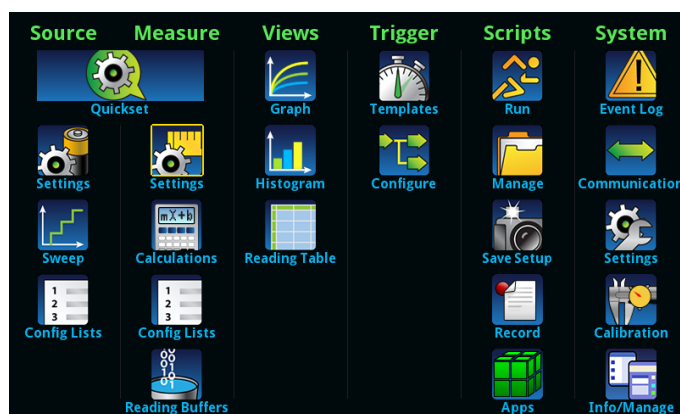
- Capabilities of analyzers, curve tracers, and I-V systems at a fraction of their cost
- Five-inch, high-resolution capacitive touchscreen GUI
- 0.012% basic measure accuracy with 6½-digit resolution
- Enhanced sensitivity with new 20 mV and 10 nA source/measure ranges
- Source and sink (four-quadrant) operation
- Four Quickset modes for fast setup and measurements
- Built-in, context-sensitive front panel help
- Front panel input banana jacks; rear panel input triaxial connections
- 2450 SCPI and TSP® scripting programming modes
- 2400 SCPI-compatible programming mode
- Front panel USB memory port for storing data, programming, instrument configurations, and to upgrade the unit



2450 main home screen.

Learn Faster, Work Smarter, and Invent Easier

Unlike conventional instruments with dedicated push-button technology and small, obscure, limited-character displays, the 2450 features a five-inch, full-color, high-resolution touchscreen that facilitates ease of use, learning, and optimizes overall speed and productivity. A simple icon-based menu structure reduces configuration steps by as much as 50 percent and eliminates the cumbersome multi-layer menu structures typically used on soft-key instruments. Built-in, context-sensitive help enables intuitive operation and minimizes the need to review a separate manual. These capabilities combined with its application versatility make the 2450 the SMU instrument that is inherently easy to use for basic and advanced measurement applications, regardless of your experience level with SMU instruments.

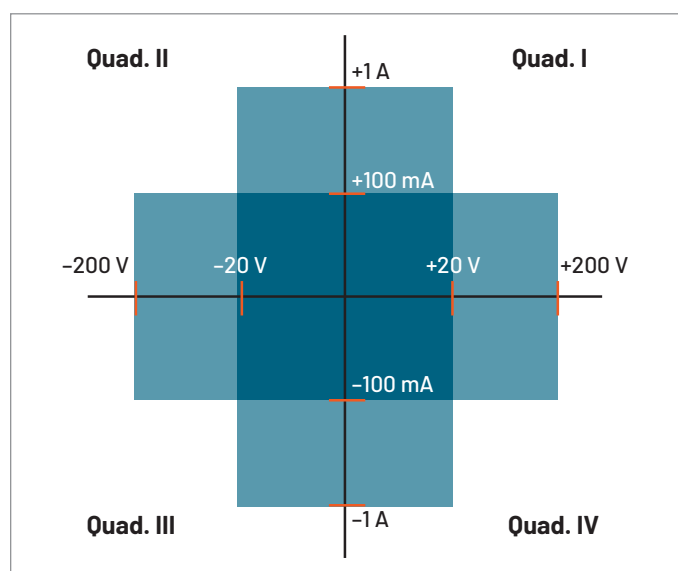


2450 icon-based menu.

Fourth-Generation, All-in-One SMU Instrument

The 2450 is the fourth-generation member of Keithley's award-winning SourceMeter family of SMU instruments and leverages the proven capabilities of the 2400 SourceMeter SMU Instrument. It offers a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current meters. This all-in-one instrument gives you the capabilities of a:

- Precision power supply with V and I readback
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load
- Trigger controller



2450 power envelope.

Comparison Table: 2400 vs 2450

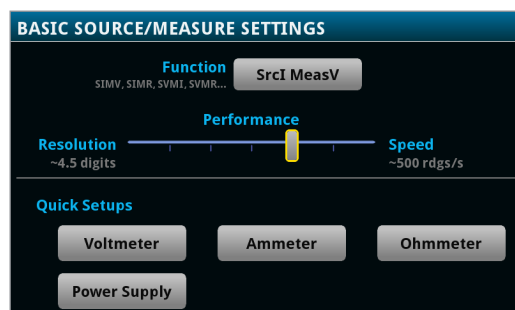
2400	2450
V-Ranges: 200 mV – 200 V	V-Ranges: 20 mV – 200 V
I-Ranges: 1 μ A – 1 A	I-Ranges: 10 nA – 1 A
0.012% Basic Accuracy	0.012% Basic Accuracy
Wideband Noise: 4 mV _{rms} Typ.	Wideband Noise: 2 mV _{rms} Typ.
Sweep Types: Linear, Log, Custom, Source-Memory	Sweep Types: Linear, Log, Dual Linear, Dual Log, Custom, Source-Memory (SCPI 2400 Mode)
5000 Point Reading Buffer	>250,000 Point Reading Buffer
>2000 Readings/Second	>3000 Readings/Second
SCPI Programming	SCPI (2400 + 2450) + TSP Programming
GPIO	GPIO, USB, Ethernet (LXI)
Front/Rear Banana Jacks	Front: Banana Jacks, Rear: Triax

Ease of Use Beyond the Touchscreen

In addition to its five-inch, color touchscreen, the 2450 front panel has many features that supplement its speed, user-friendliness, and learnability, including a USB 2.0 memory I/O port, a HELP key, a rotary navigation/control knob, a front/rear input selector button, and banana jacks for basic bench applications. The USB 2.0 memory port supports easy data storing, saving instrument configurations, loading test scripts, and system upgrades. Plus, all front panel buttons are backlit to enhance visibility in low-light environments.



2450 front panel with high-resolution, capacitive touchscreen.

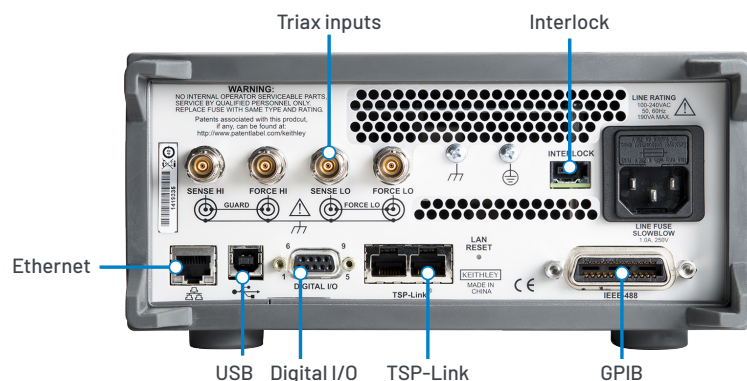


Four "Quickset" modes simplify user setup. With one touch, the instrument can be quickly configured for various operating modes without the need to configure the instrument indirectly for this operation.

Quickset modes enable fast setup and time to measurements.

Comprehensive Built-in Connectivity

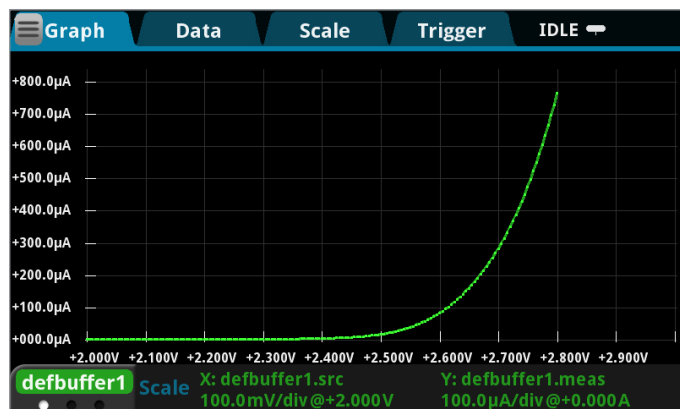
Rear panel access to rear-input triax connectors, remote control interfaces (GPIB, USB 2.0, and LXI/Ethernet), D-sub 9-pin digital I/O port (for internal/external trigger signals and handler control), instrument interlock control, and TSP-Link® jacks enables easy configuration of multiple instrument test solutions and eliminates the need to invest in additional adapter accessories.



Rear panel connections are optimized for signal integrity.

Convert Raw Data to Information

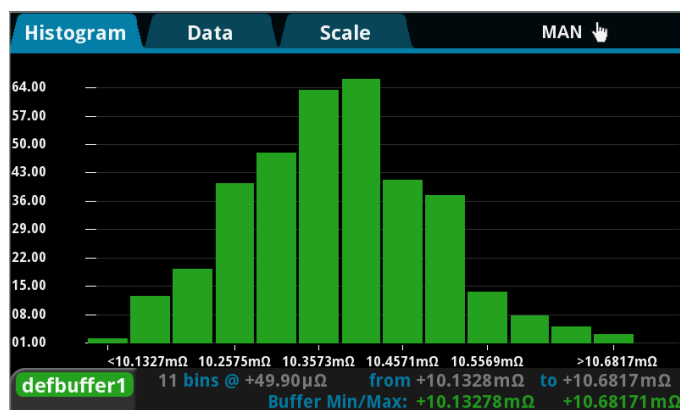
The 2450 provides a full plotting and sheet view to display sweeps, measurement data, and charting right on the screen. It also supports exporting to a spreadsheet for further analysis, dramatically improving productivity for research, bench-top testing, device qualification, and debugging.



READING TABLE

Buffer: Active (defbuffer1)

Index	Time	Reading	Source
62	11/14 11:30:49.891111	+0.08693 mA	+1.84858 V
63	11/14 11:30:49.962316	+0.08913 mA	+1.87886 V
64	11/14 11:30:50.033464	+0.09134 mA	+1.90919 V
65	11/14 11:30:50.104618	+0.09355 mA	+1.93952 V
66	11/14 11:30:50.175782	+0.09576 mA	+1.96982 V
67	11/14 11:30:50.246938	+0.09797 mA	+2.00013 V
68	11/14 11:30:50.318112	+0.10018 mA	+2.03042 V
69	11/14 11:30:50.389283	+0.10239 mA	+2.06071 V
70	11/14 11:30:50.460450	+0.10460 mA	+2.09100 V
71	11/14 11:30:50.531604	+0.10682 mA	+2.12133 V

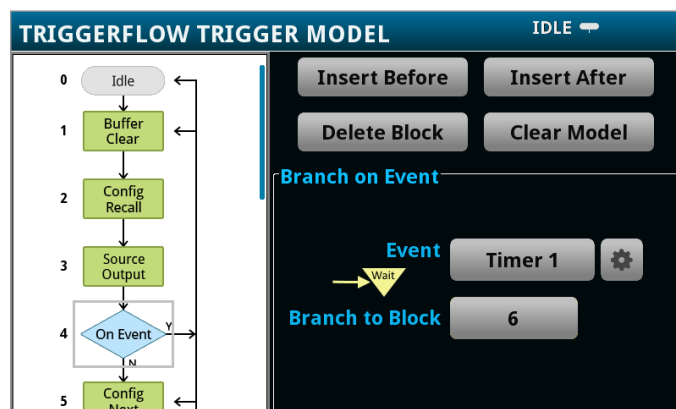


Full data display, charting, and export to a spreadsheet lets you convert raw data to useful information.

TriggerFlow® Building Blocks for Instrument Control and Execution

The 2450 incorporates Keithley's new TriggerFlow triggering system that allows user control of instrument execution. Similar to developing a flow chart, TriggerFlow diagrams are created using four fundamental building blocks:

- **Wait** – Waits for an event to occur before the flow continues
- **Branch** – Branches when a condition has been satisfied
- **Action** – Initiates an action in the instrument, for example, measure, source, delay, set digital I/O, etc.
- **Notify** – Notifies other equipment that an event has occurred



TriggerFlow building blocks let users create very simple to very complex triggering models.

A TriggerFlow model using a combination of these building blocks can be created from the front panel or by sending remote commands. With the TriggerFlow system, users can build triggering models from very simple to complex with up to 63 block levels. The 2450 also includes basic triggering functions, including immediate, timer, and manual triggering.

Unmatched System Integration and Programming Flexibility

When the 2450 is integrated as part of a multi-channel I-V test system, the Test Script Processor (TSP) embedded scripting capability allows test scripts to be run by the instrument, enabling the user to create powerful measurement applications with significantly reduced development times. TSP technology also offers channel expansion without a mainframe. Keithley's TSP-Link® channel expansion bus, which uses a 100 Base T Ethernet cable, connects multiple 2450 instruments and other TSP instruments such as Keithley's Series 2600B SourceMeter SMU instruments and Series 3700A Switch/Multimeter systems in a master-subordinate configuration that behaves as one integrated system. The TSP-Link expansion bus supports up to 32 units per GPIB or IP address, making it easy to scale a system to fit an application's particular requirements.

The 2450 also includes a SCPI programming mode that optimizes the instrument's new features, as well as a SCPI 2400 mode that provides backwards compatibility with the existing 2400 SourceMeter instrument. Not only does this preserve your 2400 investment but it also eliminates re-work normally associated with upgrading to a new instrument with new capabilities.

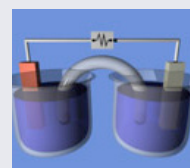
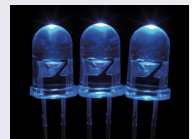
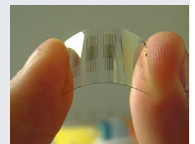
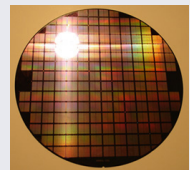
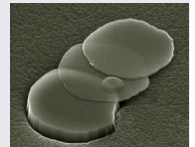
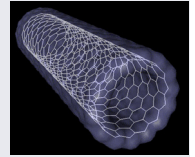
Parallel Test Capability

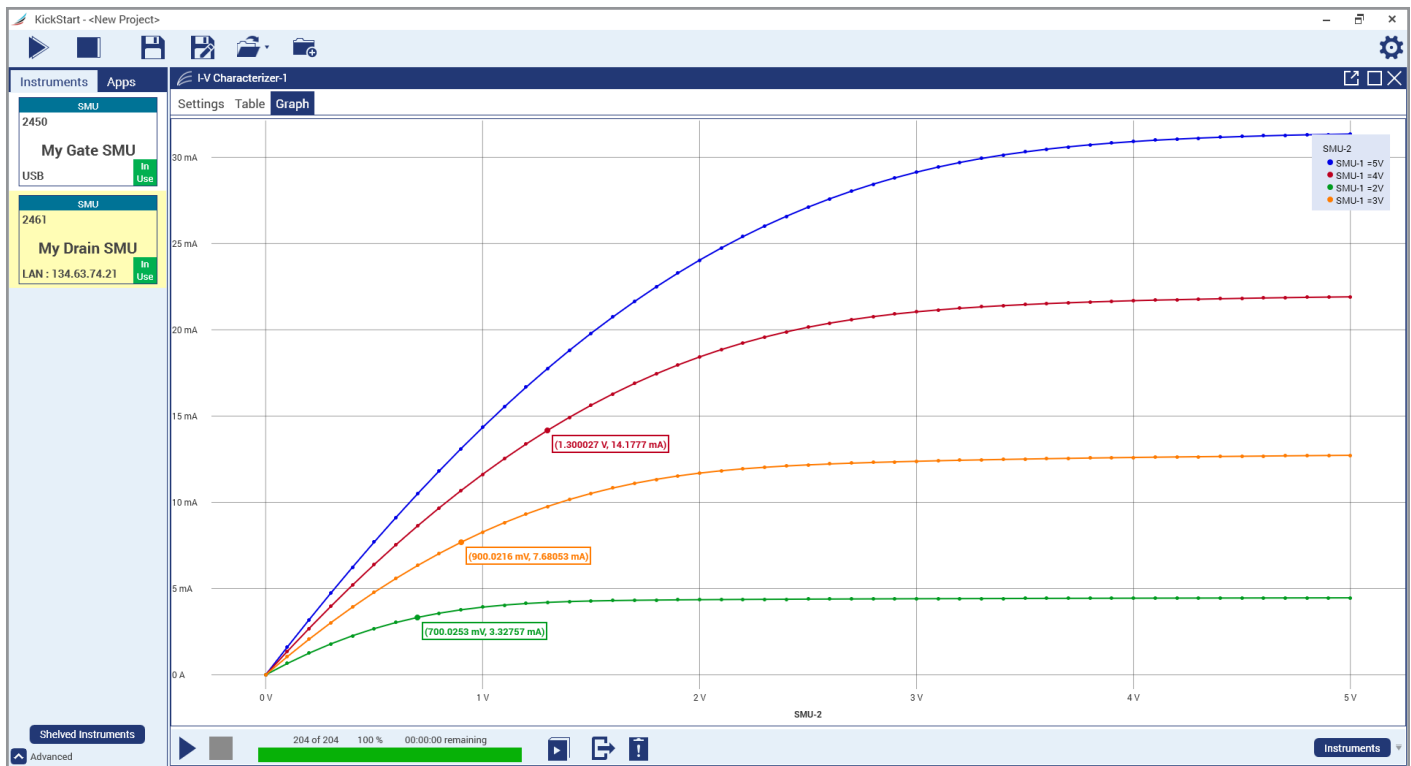
With the TSP technology in the 2450, multiple devices can be tested in parallel to meet the needs of device research, advanced semiconductor lab applications, and even high throughput production test. This parallel testing capability enables each instrument in the system to run its own complete test sequence, creating a fully multi-threaded test environment. The number of tests that can be run in parallel on a 2450 can be as high as the number of instruments in the system.

Typical Applications

Ideal for current/voltage characterization and functional test of a wide range of today's modern electronics and devices, including:

- Nanomaterials and Devices
 - Graphene
 - Carbon nanotubes
 - Nanowires
 - Low-power nanostructures
- Semiconductor Structures
 - Wafers
 - Thin films
- Organic Materials and Devices
 - E-inks
 - Printable electronics
- Energy Efficiency and Lighting
 - LEDs/AMOLEDs
 - Photovoltaics/Solar cells
 - Batteries
- Discrete and Passive Components
 - Two-leaded: Resistors, diodes, zener diodes, LEDs, disk drive heads, sensors
 - Three-leaded: Small signal bipolar junction transistors (BJTs), field effect transistors (FETs), and more
- Material Characterization
 - Resistivity
 - Hall Effect
 - High ohmic resistance (using triax connectors)
- Electrochemistry
 - Cyclic voltammetry
 - Battery charge/discharge cycling
 - Electro-deposition





KickStart start-up software lets users be ready to make measurements in minutes.

Instrument Control Start-up Software

KickStart instrument control/start-up software enables users to start making measurements in minutes without programming. In most cases, users merely need to make some quick measurements, graph the data, and store the data to disk for later analysis in software environments such as Excel. KickStart offers:

- Configure and control up to four SMU instruments for DC or Pulsed I-V test in either the same app, same project, or a combination of the two.
- Create tests by mixing any of these SMU instruments: 2400 Graphical Series, 2400 Standard Series (DC only), 2600B Series, 2651A, 2657A, and 6430 SourceMeter SMU (DC only) instruments.
- Differentiate SMU instrument channels and their measurement data using labels that are relevant to your device or module.
- Native X-Y graphing, panning, and zooming; screenshot capturing of graphs.

- Spreadsheet/tabular viewing of data; export data for further analysis.
- Annotating of tests; save test setups.
- GPIB, USB 2.0, Ethernet compliance.

Optional Apps Tailored for your Characterization Needs

The 2450 is an excellent tool to define nearly any DC test you choose for characterizing materials, electronic devices and modules. For more specific needs, Keithley offers on-instrument software apps that alter the 2450's behavior, fitting your instrument to your needs. These apps can be installed directly to your 2450 by connecting to Keithley's KickStart instrument control software and opening the relevant app in KickStart.

I-V Tracer App

Curve tracing analysis is a critical task for many users in the semiconductor development supply chain. Engineers and technicians both hold the traditional curve tracer as the simplest, fastest method for generating characteristic

I-V curves on a device. They are heavily used by engineers in failure analysis and incoming inspection to qualify parts, identify counterfeit devices, and to quickly identify the location of a failure on damaged devices. SMUs have typically been limited to predefined sweeps with longer set up times than curve tracers — until I-V Tracer.

Keithley's I-V Tracer app leverages the touchscreen and front-panel knob of the 2450 to allow precise, live control over the SMU output while viewing I-V results of 2 terminal devices. At each individual output level current and voltage are measured and plotted. The small footprint of the SMU enables portable benchtop use, reserving high power (kW) traditional curve tracers for special cases. The power envelope of the 2450 allows it to comfortably operate in the low-power range of traditional curve tracers like the Tektronix 576 and Tektronix 370A, while offering enhanced low current measurements.



I-V Tracer home screen

Once installed, I-V Tracer exists on the SMU itself, meaning I-V tracer can be used wherever your SMU can go, without a continuous remote connection. It can also integrate with KickStart to enable simple data collection and comparison on the PC, simplifying the preparation of reports used in failure analysis or teaching labs at colleges and universities.

I-V Tracer capabilities with the 2450:

- Use the full power envelope of the 2450 (max 200 V or 1 A)
- Trace by sourcing voltage or current, positive or negative
- 2 or 4-wire sense
- Compare mode for verifying against a reference device
- Reading table view to see exact measurements
- Easily copy curves and settings to your PC with KickStart

Simplified Programming with Ready-to-Use Instrument Drivers

For users who want to create their own customized application software, native National Instruments LabVIEW® drivers, IVI-C, and IVI-COM drivers are available at tek.com.

Specifications

Voltage Specifications^{1,2}

Source				Measure ³		
Range	Resolution	Accuracy (18°C to 28°C) 1 Year ±(% setting + volts)	Noise (RMS) (<10 Hz) ⁶	Resolution	Input Resistance	Accuracy (18°C to 28°C) 1 Year ±(% rdg. + volts)
20.00000 mV	500 nV	0.100% + 200 µV	1 µV	10 nV	>10 GΩ	0.100% + 150 µV
200.0000 mV	5 µV	0.015% + 200 µV	1 µV	100 nV	>10 GΩ	0.012% + 200 µV
2.000000 V	50 µV	0.020% + 300 µV	10 µV	1 µV	>10 GΩ	0.012% + 300 µV
20.00000 V	500 µV	0.015% + 2.4 mV	100 µV	10 µV	>10 GΩ	0.015% + 1 mV
200.0000 V	5 mV	0.015% + 24 mV	1 mV	100 µV	>10 GΩ	0.015% + 10 mV

Current Specifications^{1,2}

Source				Measure ³		
Range	Resolution	Accuracy (18°C to 28°C) ⁴ 1 Year ±(% setting + amps)	Noise (RMS) (<10 Hz) ⁶	Resolution	Voltage Burden	Accuracy (18°C to 28°C) 1 Year ±(% rdg. + amps)
10.00000 nA ⁵	500 fA	0.100% + 100 pA	500 fA	10 fA	<100 µV	0.100% + 50 pA
100.0000 nA ⁵	5 pA	0.060% + 150 pA	500 fA	100 fA	<100 µV	0.060% + 100 pA
1.000000 µA	50 pA	0.025% + 400 pA	5 pA	1 pA	<100 µV	0.025% + 300 pA
10.00000 µA	500 pA	0.025% + 1.5 nA	40 pA	10 pA	<100 µV	0.025% + 700 pA
100.0000 µA	5 nA	0.020% + 15 nA	400 pA	100 pA	<100 µV	0.020% + 6 nA
1.000000 mA	50 nA	0.020% + 150 nA	5 nA	1 nA	<100 µV	0.020% + 60 nA
10.00000 mA	500 nA	0.020% + 1.5 µA	40 nA	10 nA	<100 µV	0.020% + 600 nA
100.0000 mA	5 µA	0.025% + 15 µA	100 nA	100 nA	<100 µV	0.025% + 6 µA
1.000000 A	50 µA	0.067% + 900 µA	3 µA	1 µA	<100 µV	0.030% + 500 µA

Temperature Coefficient
(0°C to 18°C and 28°C to 50°C) ±(0.15 × accuracy specification)/°C.

Notes

- Speed = 1 PLC.
- All specifications are guaranteed with output ON.
- Accuracies apply to 2- and 4-wire mode when properly zeroed.
- For sink mode, 1 µA to 100 mA range accuracy is ±(0.15% + offset × 4). For 1 A range, accuracy is ±(1.5% + offset × 8).
- Rear panel triax connections only.
- Typical noise (RMS) <10 Hz.

Resistance Measurement Accuracy (Local or Remote Sense)^{1, 2}

Range	Default Resolution ³	Default Test Current	Normal Accuracy (18°C to 28°C) 1 Year, $\pm(\% \text{ rdg.} + \text{ohms})$	Enhanced Accuracy ⁴ (18°C to 28°C) 1 Year, $\pm(\% \text{ rdg.} + \text{ohms})$
<2.000000 Ω ⁵	1 $\mu\Omega$	User defined	Source I_{ACC} + Meas. V_{ACC}	Meas. I_{ACC} + Meas. V_{ACC}
20.00000 Ω	10 $\mu\Omega$	100 mA	0.098% + 0.003 Ω	0.073% + 0.001 Ω
200.0000 Ω	100 $\mu\Omega$	10 mA	0.077% + 0.03 Ω	0.053% + 0.01 Ω
2.000000 k Ω	1 m Ω	1 mA	0.066% + 0.3 Ω	0.045% + 0.1 Ω
20.00000 k Ω	10 m Ω	100 μA	0.063% + 3 Ω	0.043% + 1 Ω
200.0000 k Ω	100 m Ω	10 μA	0.065% + 30 Ω	0.046% + 10 Ω
2.000000 M Ω	1 Ω	1 μA	0.110% + 300 Ω	0.049% + 100 Ω
20.00000 M Ω	10 Ω	1 μA	0.110% + 1 k Ω	0.052% + 500 Ω
200.0000 M Ω	100 Ω	100 nA	0.655% + 10 k Ω	0.349% + 5 k Ω
>200.0000 M Ω ⁵	—	User defined	Source I_{ACC} + Meas. V_{ACC}	Meas. I_{ACC} + Meas. V_{ACC}

Temperature Coefficient
(0°–18°C and 28°–50°C) $\pm(0.15 \times \text{accuracy specification})/^{\circ}\text{C}$.Source Current,
Measure Resistance ModeTotal uncertainty = I_{source} accuracy + V_{measure} accuracy (4-wire remote sense).Source Voltage,
Measure Resistance ModeTotal uncertainty = V_{source} accuracy + I_{measure} accuracy (4-wire remote sense).

Guard Output Impedance

0.5 Ω (DC) in ohms mode.

Notes

1. All specifications are guaranteed with output ON.
2. Accuracies apply to 2- and 4-wire mode when properly zeroed.
3. 6.5 digit measure resolution
4. Source readback enabled. Offset compensation ON.
5. Source Current, Measure Resistance or Source Voltage, Measure Resistance only. For best measurements, use rear panel triax connectors.

Operating Characteristics

Max. Output Power	20 W, four-quadrant source or sink operation.
Source Limits	Vsource: $\pm 21 \text{ V}$ ($\leq 1 \text{ A}$ range), $\pm 210 \text{ V}$ ($\leq 100 \text{ mA}$ range). Isource: $\pm 1.05 \text{ A}$ ($\leq 20 \text{ V}$ range), $\pm 105 \text{ mA}$ ($\leq 200 \text{ V}$ range).
Overrange	105% of range, source and measure.
Regulation	Voltage: Line: 0.01% of range. Load: 0.01% of range + 100 μV . Current: Line: 0.01% of range. Load: 0.01% of range + 100 pA.
Source Limits	Voltage Source Current Limit: Bipolar current limit set with single value. Min. 10% of range. Current Source Voltage Limit: Bipolar voltage limit set with single value. Min. 10% of range.
V-Limit / I-Limit Accuracy	Add 0.3% of setting and $\pm 0.02\%$ of reading to base specification.
Overshoot	Voltage Source: <0.1% typical (full scale step, resistive load, 20 V range, 10 mA I-Limit). Current Source: <0.1% typical (1 mA step, $R_{\text{Load}} = 10 \text{ k}\Omega$, 20 V range).
Range Change Overshoot	Overshoot into a fully resistive 100 k Ω load, 10 Hz to 20 MHz BW, adjacent ranges: 250 mV typical.
Output Settling Time	Time required to reach 0.1% of final value after command is processed and output slew, 20 V range, 100 mA I-Limit: <200 μs typical.
Maximum Slew Rate	0.2 V/ μs , 200 V range, 100 mA limit into a 2 k Ω load (typical).
Over Voltage Protection	User selectable values, 5% tolerance. Factory default = none.
Voltage Source Noise	Typical 10 Hz–1 MHz (RMS): 2 mV typical into a resistive load.

Common Mode Voltage 250 V DC.

Common Mode Isolation >1 GΩ, <1000 pF.

Noise Rejection (typical)

NPLC	NMRR	CMRR
0.01	—	60 dB
0.1	—	60 dB
1	60 dB	100 dB*

* Except lowest two current ranges ~90 dB.

Load Impedance 20 nF typical (standard). Stable into 50 μF typical (High-C mode).
High-C mode valid for ≥100 μA range s, ≥200 mV ranges.

Max. Voltage Drop Between Force and Sense Terminals 5 V.

Max. Sense Lead Resistance 1 MΩ for rated accuracy.

Sense Input Impedance >10 GΩ.

Guard Offset Voltage <300 μV, typical

System Measurement Speeds¹

Reading Rates (readings/second) typical for 60 Hz (50 Hz):

Script (TSP) Programmed

NPLC/Trigger Origin	Measure				Source-Measure Sweep			
	To Mem.	To GPIB	To USB	To LAN	To Mem.	To GPIB	To USB	To LAN
0.01 / Internal	3130 (2800)	2830 (2570)	2825 (2600)	2790 (2530)	1710 (1620)	1620 (1540)	1630 (1540)	1620 (1540)
0.01 / External	2170 (2050)	2150 (2030)	2170 (2040)	2160 (1990)	1670 (1590)	1580 (1500)	1590 (1510)	1580 (1510)
0.1 / Internal	540 (460)	530 (450)	530 (450)	530 (450)	470 (410)	460 (400)	470 (400)	470 (400)
0.1 / External	500 (430)	490 (420)	500 (430)	500 (420)	470 (400)	460 (390)	460 (400)	460 (400)
1.00 / Internal	59 (49)	58 (49)	59 (49)	59 (49)	58 (48)	58 (48)	58 (48)	58 (48)
1.00 / External	58 (48)	57 (48)	58 (48)	58 (48)	57 (48)	57 (47)	57 (48)	57 (48)

SCPI Programmed²

NPLC/Trigger Origin	Measure				Source-Measure Sweep			
	To Mem.	To GPIB	To USB	To LAN	To Mem.	To GPIB	To USB	To LAN
0.01 / Internal	3130 (2800)	3060 (2760)	3000 (2790)	3010 (2710)	1710 (1630)	1610 (1600)	1440 (1380)	1690 (1590)
0.01 / External	2350 (2200)	2320 (2170)	2340 (2190)	2320 (2130)	1680 (1590)	1560 (1570)	1410 (1360)	1660 (1560)
0.1 / Internal	540 (460)	540 (450)	540 (460)	540 (450)	470 (410)	470 (410)	450 (390)	470 (410)
0.1 / External	510 (440)	510 (430)	510 (440)	510 (430)	470 (400)	470 (400)	450 (390)	470 (400)
1.00 / Internal	59 (49)	59 (49)	59 (49)	59 (49)	58 (48)	58 (48)	57 (48)	58 (48)
1.00 / External	58 (49)	58 (49)	58 (49)	58 (49)	58 (48)	58 (48)	57 (47)	58 (48)

Notes

1. Reading rates applicable for voltage or current measurements, autozero off, autorange off, filter off, binary reading format, and source readback off.
2. SCPI programming mode. Speeds do not apply to SCPI 2400 mode.

General Characteristics (default mode unless specified)

Factory Default Standard Power-Up	SCPI Mode.
Source Output Modes	Fixed DC Level, Memory/Configuration List (mixed function), Stair (linear and log).
Source Memory List	100 points max. (SCPI 2400 Mode only).
Memory Buffer	>250,000 readings. Includes selected measured value(s) and time stamp.
Real-Time Clock	Lithium battery backup (3 yr. + battery life).
Remote Interfaces	
GPIO	IEEE-488.1 compliant. Supports IEEE-488.2 common commands and status model topology.
USB Device (rear panel, type B)	2.0 Full Speed USBTMC.
USB Host (front panel, type A)	USB 2.0, support for flash drives, FAT32.
Ethernet	RJ-45 (10/100BT).
Digital I/O Interface:	
Lines	6 Input/Output user defined for digital I/O or triggering.
Connector	9-pin female D.
Input Signal Levels	0.7 V (maximum logic low), 3.7 V (minimum logic high).
Input Voltage Limits	-0.25 V (Abs. minimum), +5.25 V (Abs. maximum).
Maximum Source Current	+2.0 mA @ >2.7 V (per pin).
Maximum Sink Current	-50 mA @ 0.7 V (per pin, solid-state fuse protected).
5V Power Supply Pin	Limited to 500 mA @ >4 V (solid-state fuse protected).
Handler	User definable Start of Test, End of Test, 4 category bits.
Programmability	SCPI or TSP command sets.
TSP Mode	Embedded Test Script Processor (TSP) accessible from any host interface.
IP Configuration	Static or DHCP.
Expansion Interface	The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.
LXI Compliance	1.5 LXI Device Specification 2016.
Display	5 inch capacitive touch, color TFT WVGA (800×480) with LED backlight.
Input Signal Connections	Front: Banana. Rear: Triaxial (3-lug).
Interlock	Active High Input.
Cooling	Forced air, variable speed.
Over Temperature Protection	Internally sensed temperature overload puts unit in standby mode.
Power Supply	100 V to 240 V RMS, 50–60 Hz (automatically detected at power up).
VA Rating	190 volt-amps max.
Altitude	Maximum 2000 meters above sea level.
EMC	Conforms to European Union EMC Directive.
Safety	NRTL listed to UL61010-1 and UL61010-2-30. Conforms with European Union Low Voltage Directive.
Vibration	MIL-PRF-28800F Class 3 Random.
Warm-Up	1 hour to rated accuracies.

Dimensions	With bumpers and handle: 106 mm high × 255 mm wide × 425 mm deep (4.18 in × 10.05 in × 16.75 in). Without bumpers and handle: 88 mm high × 213 mm wide × 403 mm deep (3.46 in × 8.39 in × 15.87 in).
Weight	With bumpers and handle: 4.04 kg (8.9 lbs.). Without bumpers and handle: 3.58 kg (7.9 lbs.).
Environment	For indoor, non-residential use only Operating: 0° to 50 °C, 70% relative humidity up to 35 °C. Derate 3% relative humidity/°C, 35° to 50 °C. Storage: -25 °C to 65 °C.
Accessories Supplied	Test Leads, USB Cable, Ethernet/TSP Cable, Interlock Adapter, Power Cord, Quick Start Guide.

Ordering Information

2450	200 V, 1 A, 20 W SourceMeter Instrument
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Supplied Accessories

CS-1616-3	Safety Interlock Mating Connector
17469460X	TSP-Link/Ethernet Cable
CA-432A	USB 2.0 Type A Male to Type B Male Cable
012173001	Safety Clip On Test Lead Set
	Documentation available at tek.com
	2450 Quick Start Guide
	TSP Toolkit Software (available at tek.com)
	LabVIEW and IVI Drivers (available at tek.com)

Available Accessories

Test Leads and Probes

5804	Kelvin (4-Wire) Universal 10-Piece Test Lead Kit
5805	Kelvin (4-Wire) Spring-Loaded Probes
5806	Kelvin Clip Lead Set
5808	Low Cost Single-pin Kelvin Probe Set

Cables, Connectors, Adapters

237-ALG-2	3-slot Male Triax Connector to 3 Alligator Clips
2450-TRX-BAN	Triax to Banana Adapter. Converts the 4 Triax adapters on the rear panel to 5 banana jacks
7078-TRX-*	3-slot, Low Noise Triax Cable
7078-TRX-GND	3-slot Male Triax To BNC Adapter (guard removed)
CA-18-1	Shielded Dual Banana Cable, 1.2 m (4 ft)
CAP-31	Protective Shield/Cap for 3-lug Triax Connectors
CS-1546	Triax 3-lug Special Shorting Plug. Shorts center pin to outer shield
CS-1616-3	Safety Interlock Mating Connector

Communication Interfaces and Cables

7007-1	Shielded GPIB Cable, 1 m (3.3 ft)
KPCI-488LPA	IEEE-488 Interface for PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

Rack Mount Kits

4299-8	Single Fixed Rack Mount Kit
4299-9	Dual Fixed Rack Mount Kit

Test Fixtures

8101-PIV	DC Test Fixture
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Software Options

I-V Tracer	Graphical SMU Curve Tracer Software
KickStart	Instrument Control Software
ACS Basic Edition	Semiconductor Parametric Test Software for Component and Discrete Devices

Available Services

2450-3Y-EW	1 Year Factory Warranty extended to 3 years from date of shipment
2450-5Y-EW	1 Year Factory Warranty extended to 5 years from date of shipment
C/2450-3Y-17025	KeithleyCare® 3 Year ISO 17025 Calibration Plan
C/2450-3Y-DATA	KeithleyCare 3 Year Calibration w/Data Plan
C/2450-3Y-STD	KeithleyCare 3 Year Std. Calibration Plan
C/2450-5Y-17025	KeithleyCare 5 Year ISO 17025 Calibration Plan
C/2450-5Y-DATA	KeithleyCare 5 Year Calibration w/Data Plan
C/2450-5Y-STD	KeithleyCare 5 Year Std. Calibration Plan

Warranty Information

Warranty Summary	This section summarizes the warranties of the 2450. For complete warranty information, refer to the Tektronix warranty page at www.tek.com/service/warranties/warranty-2 . Any portion of the product that is not manufactured by Keithley is not covered by this warranty and Keithley will have no duty to enforce any other manufacturer's warranties.
Hardware Warranty	Keithley Instruments, Inc. warrants the Keithley manufactured portion of the hardware for a period of one year from defects in materials or workmanship; provided that such defect has not been caused by use of the Keithley hardware which is not in accordance with the hardware instructions. The warranty does not apply upon any modification of Keithley hardware made by the customer or operation of the hardware outside the environmental specifications.
Software Warranty	Keithley warrants for the Keithley produced portion of the software or firmware will conform in all material respects with the published specifications for a period of ninety (90) days; provided the software is used on the product for which it is intended in accordance with the software instructions. Keithley does not warrant that operation of the software will be uninterrupted or error-free, or that the software will be adequate for the customer's intended application. The warranty does not apply upon any modification of the software made by the customer.

Contact Information:

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Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
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Switzerland* 00800 2255 4835
Taiwan 886 (2) 2656 6688
Thailand 1 800 011 931
United Kingdom / Ireland* 00800 2255 4835
USA 1 800 833 9200
Vietnam 12060128

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05182026 KEI 1KW-60904-3



2460 SourceMeter SMU Instrument

DATASHEET



The 2460 High Current SourceMeter® Source Measure Unit (SMU) Instrument brings advanced Touch, Test, Invent® technology right to your fingertips. It combines an innovative graphical user interface (GUI) with capacitive touchscreen technology to make testing intuitive and minimize the learning curve to help engineers and scientists learn faster, work smarter, and invent easier. With its 7 A DC and pulse current capability, the 2460 is optimized for characterizing and testing high power materials, devices, and modules such as silicon carbide (SiC), gallium nitride (GaN), DC-DC converters, power MOSFETs, solar cells and panels, LEDs and lighting systems, electrochemical cells and batteries, and much more. These new capabilities, combined with Keithley's decades of expertise in developing high precision, high accuracy SMU instruments, will make the 2460 a "go-to instrument" for high current applications in the lab and in the rack for years to come.

Key Features

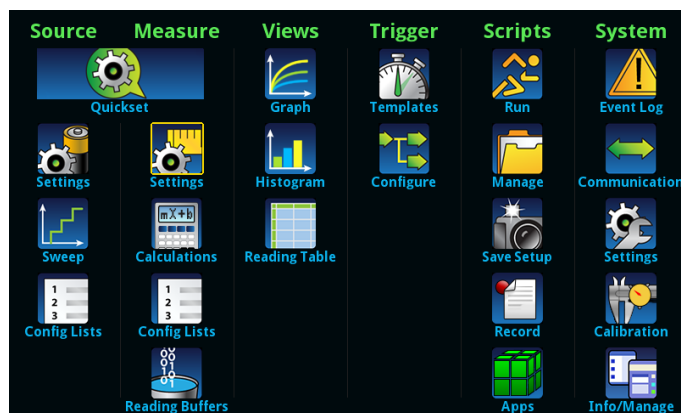
- One tightly coupled instrument that combines capabilities from analyzers, curve tracers, and I-V systems at a fraction of their cost
- Wide coverage up to 105 V, 7 A DC/7 A pulse, 100 W max.
- Five-inch, high-resolution capacitive touchscreen GUI
- 0.012% basic measure accuracy with 6½-digit resolution
- Source and sink (4-quadrant) operation
- Four "Quickset" modes for fast setup and measurements
- Context-sensitive help function
- Front panel input banana jacks; rear panel input mass termination screw connections
- 2460 SCPI and TSP® scripting programming modes
- Front-panel USB 2.0 memory I/O port for transferring data, test scripts, or test configurations



2460 main home screen.

Learn Faster, Work Smarter, Invent Easier

The 2460 features a five-inch, full-color, high-resolution touchscreen that supports intuitive operation, helps operators become familiar with the instrument quickly, and optimizes overall speed and productivity. A simple icon-based menu structure reduces the number of steps required to configure a test by as much as 50 percent and eliminates the cumbersome multi-layer menu structures typically used on soft-key instruments. Built-in, context-sensitive help supports intuitive operation and minimizes the need to review a separate manual. These capabilities, combined with the 2460's high versatility, simplify its operation in both basic and advanced measurement applications, regardless of the user's previous experience in working with SMU instruments.

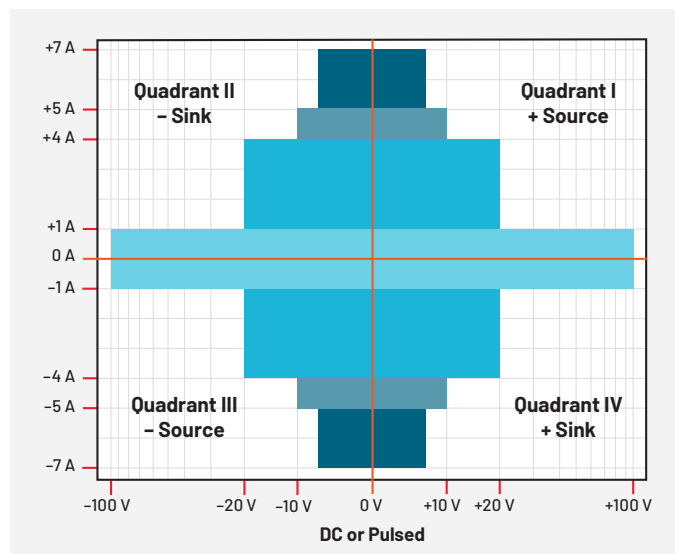


2460 icon-based menu.

All-in-One SMU Instrument

The 2460, built on the fourth generation of the award-winning SourceMeter SMU platform, leverages the proven capabilities of previously introduced high current SMU instruments from Keithley, including the 2420, 2425, and 2440. It offers a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current measurements. This all-in-one instrument gives you the capabilities of a:

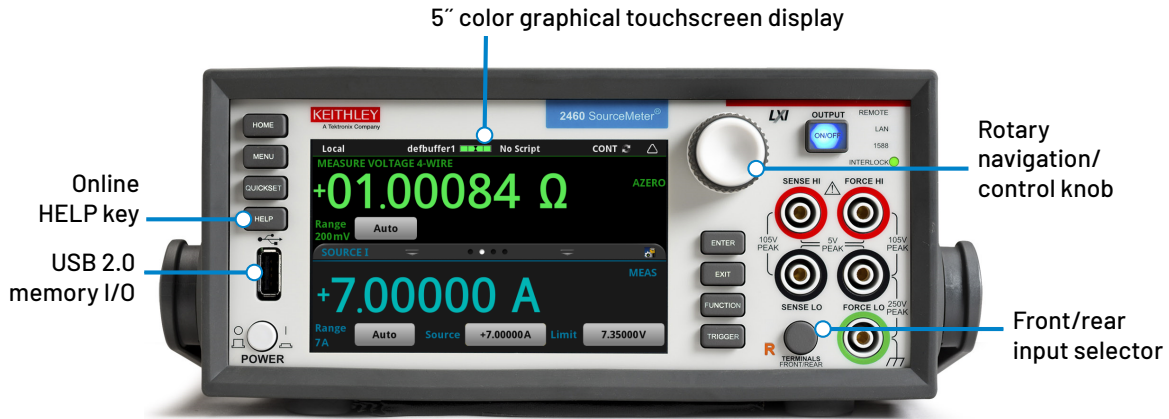
- Precision power supply with V and I readback
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load
- Trigger controller



2460 power envelope.

Comparison Table: 2420, 2425, and 2440 with 2460

2420/2425/2440	2460
Maximum Voltage: 60 V/100 V/40 V	Maximum Voltage: 100 V
Maximum Current: 3 A/3 A/5 A	Maximum Current: 7 A
DC Power: 60 W/100 W/50 W	DC Power: 100 W
Wideband Noise: 10 mV rms typ.	Wideband Noise: 2 mV rms typ.
Sweep Types: Linear, Log, Custom, Source-Memory	Sweep Types: Linear, Log, Dual Linear, Dual Log, Custom
5000 Point Reading Buffer	>250,000 Point Reading Buffer
>2000 Readings/second	>3000 Readings/second
SCPI Programming	SCPI Programming + TSP Scripting
GPIO, RS-232	GPIO, USB, Ethernet (LXI)
Front/Rear Banana Jacks	Front: Banana Jacks. Rear: Mass Termination Screw Connection

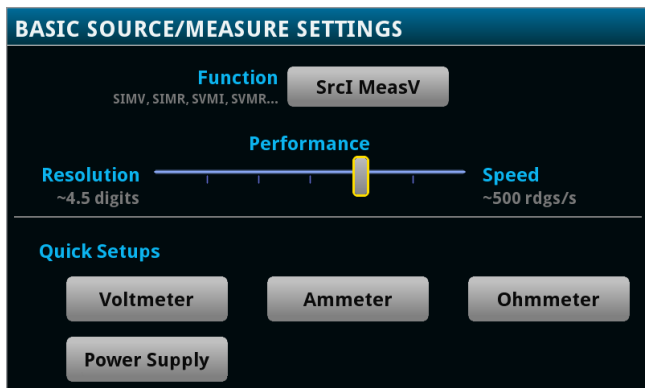


2460 front panel with high-resolution, capacitive touchscreen.

Ease of Use Beyond the Touchscreen

In addition to its advanced touchscreen, the 2460's front panel offers a variety of features that enhance its speed, user-friendliness, and learnability, including a USB 2.0 memory I/O port, a HELP key, a rotary navigation/control knob, a front/rear input selector button, and banana jacks for basic bench applications. The USB 2.0 memory port simplifies storing test results and instrument configurations, uploading test scripts into the instrument, and installing system upgrades. All front-panel buttons are backlit to enhance visibility in low-light environments.

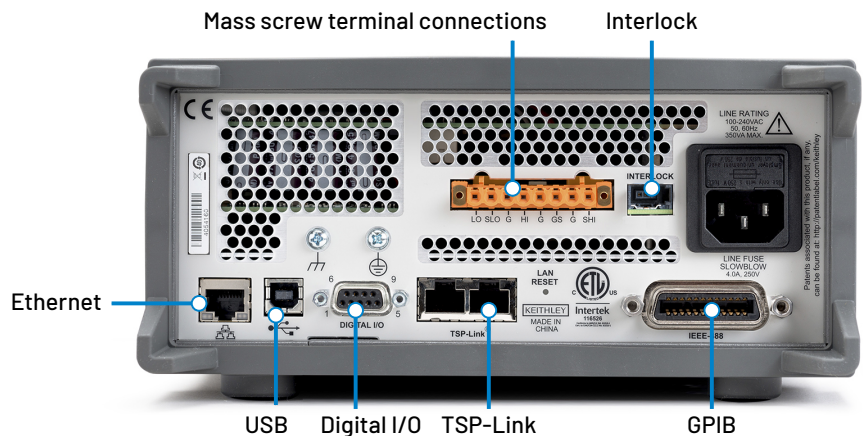
Four "Quickset" modes simplify instrument setup. With one touch, the instrument can be quickly configured for various operating modes without the need to configure the instrument indirectly for this operation.



One-touch Quickset modes speed measurement setups and minimize the time to measurements.

Comprehensive Built-in Connectivity

Rear panel access to rear-input mass termination screw connections, remote control interfaces (GPIB, USB 2.0, and LXI/Ethernet), D-sub 9-pin digital I/O port (for internal/ external trigger signals and handler control), instrument interlock control, and TSP-Link® jacks make it simple to configure multiple instrument test solutions and eliminate the need to invest in additional adapter accessories.



Rear panel connections are optimized for signal integrity and speed system setup.

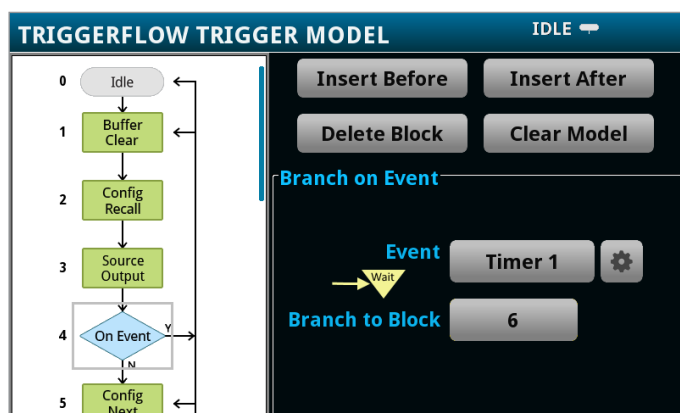
Convert Raw Data to Information

A full graphical plotting window converts raw data and displays it immediately as useful information, such as semiconductor I-V curves and voltammograms. Using the 2460's Sheet view, test data can also be displayed in tabular form. The instrument supports exporting data to a spreadsheet for further analysis, dramatically improving productivity for research, benchtop testing, device qualification, and debugging.

TriggerFlow® Building Blocks for Instrument Control and Execution

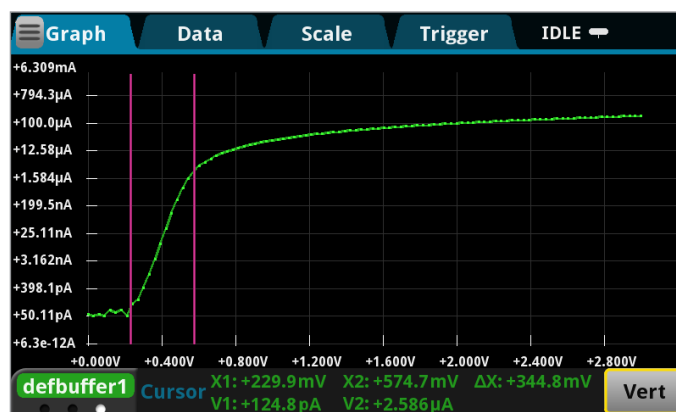
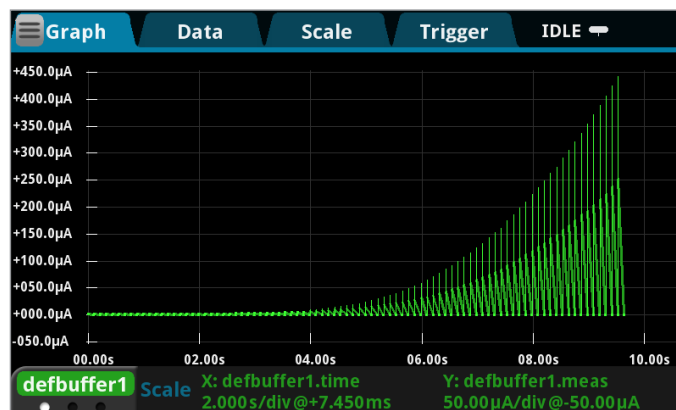
The 2460 incorporates Keithley's TriggerFlow triggering system, which provides user control over instrument execution. TriggerFlow diagrams are created in much the same way that flow charts are developed, using four fundamental building block types:

- Wait – Waits for an event to occur before the flow continues
- Branch – Branches when a condition has been satisfied
- Action – Initiates an action in the instrument, for example, measure, source, delay, set digital I/O, etc.
- Notify – Notifies other equipment that an event has occurred



TriggerFlow building blocks allow creating triggering models that range from very simple to highly complex.

A TriggerFlow model using a combination of these building blocks can be created from the front panel or by sending remote commands. With the TriggerFlow system, users can build triggering models from very simple to complex with up to 63 block levels. The 2460 also includes basic triggering functions, including immediate, timer, and manual triggering.



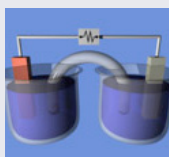
Index	Time	Reading	Source
62	11/14 11:30:49.891111	+0.08693 mA	+1.84858 V
63	11/14 11:30:49.962316	+0.08913 mA	+1.87886 V
64	11/14 11:30:50.033464	+0.09134 mA	+1.90919 V
65	11/14 11:30:50.104618	+0.09355 mA	+1.93952 V
66	11/14 11:30:50.175782	+0.09576 mA	+1.96982 V
67	11/14 11:30:50.246938	+0.09797 mA	+2.00013 V
68	11/14 11:30:50.318112	+0.10018 mA	+2.03042 V
69	11/14 11:30:50.389283	+0.10239 mA	+2.06071 V
70	11/14 11:30:50.460450	+0.10460 mA	+2.09100 V
71	11/14 11:30:50.531604	+0.10682 mA	+2.12133 V

Built-in data display, charting, and spreadsheet export functions simplify converting test results into useful information.

Typical Applications

Ideal for current/voltage characterization and functional test of a wide range of modern electronic devices:

- Power semiconductors and materials
 - SiC, GaN
 - Insulated Gate Bipolar Transistors (IGBTs)
 - Power MOSFETs
 - Thyristors
- Power devices
 - Telecom power management chipsets
 - DC-DC converters
- Electrochemistry
 - Battery charge/discharge cycling
 - Cyclic voltammetry
 - Electro-deposition
- Energy generation
 - Solar cells
 - Batteries
- Efficient energy consumption
 - LEDs/AMOLEDs
 - Automotive modules
 - Power management modules

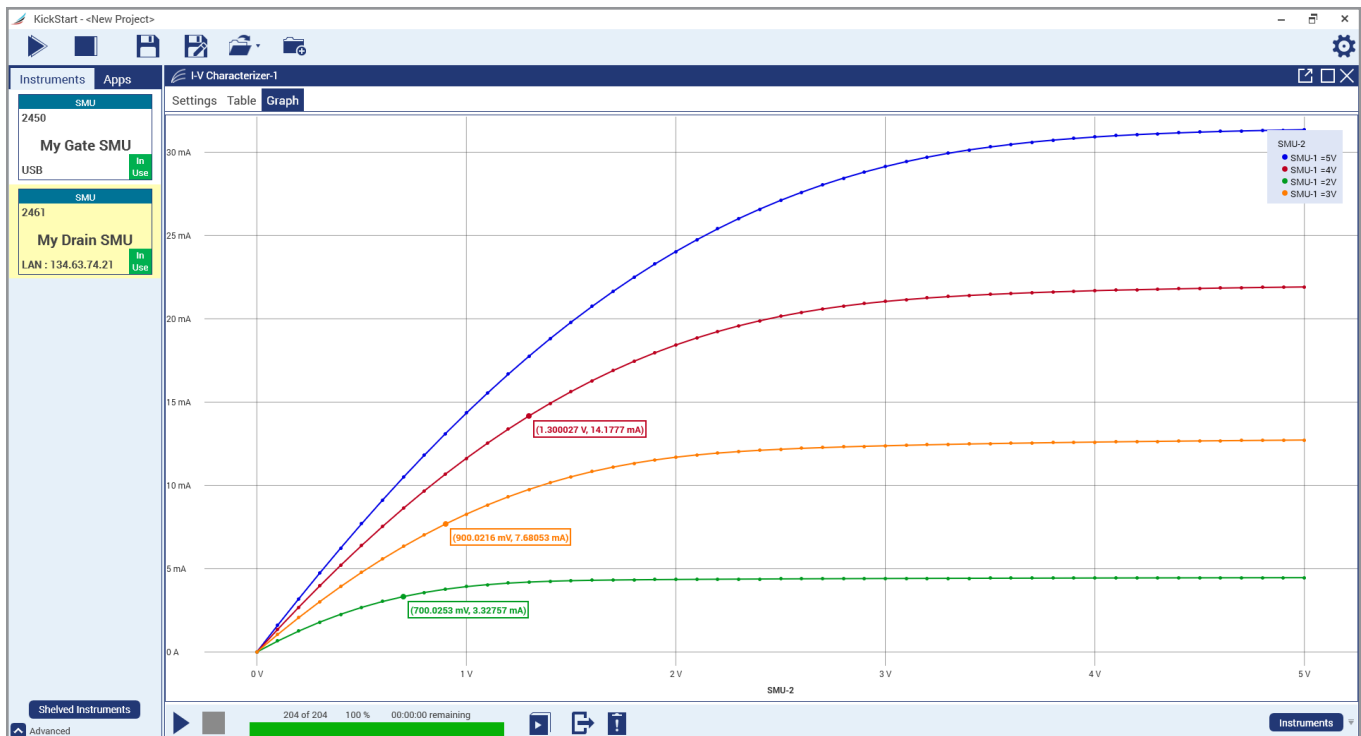


Unmatched System Integration and Programming Flexibility

When a 2460 is configured into a multi-channel I-V test system, its embedded Test Script Processor (TSP) allows it to run test scripts, so users can create powerful measurement applications with significantly reduced development times. TSP technology also offers channel expansion without a mainframe. Keithley's TSP-Link channel expansion bus, which uses a 100 Base T Ethernet cable, can connect multiple 2460s and other TSP instruments such as Keithley's 2450 SourceMeter SMU Instruments, Series 2600B System SourceMeter SMU instruments, and Series 3700A Switch/Multimeter systems in a master-subordinate configuration that operates as one integrated system. The TSP-Link expansion bus supports up to 32 units per GPIB or IP address, making it easy to scale a system to fit an application's particular requirements. The 2460 also includes a SCPI programming mode that takes advantage of all of the instrument's capabilities.

Parallel Test Capability

The TSP technology in the 2460 supports testing multiple devices in parallel to meet the needs of device research, advanced semiconductor lab applications, and even high throughput production test. This parallel testing capability allows each instrument in the system to run its own complete test sequence, creating a fully multi-threaded test environment. The number of tests that can be run in parallel on a 2460 can be as high as the number of instruments in the system.



KickStart start-up software lets users be ready to make measurements in minutes.

Instrument Control Start-up Software

KickStart instrument control/start-up software enables users to start making measurements in minutes without programming. In most cases, users merely need to make some quick measurements, graph the data, and store the data to disk for later analysis in software environments such as Microsoft Excel. KickStart offers:

- Configure and control up to four SMU instruments for DC or Pulsed I-V test in either the same app, same project, or a combination of the two.
- Create tests by mixing any of these SMU instruments: 2400 Graphical Series, 2400 Standard Series (DC only), 2600B Series, 2651A, 2657A, and 6430 SourceMeter SMU (DC only) instruments.
- Differentiate SMU instrument channels and their measurement data using labels that are relevant to your device or module.
- Native X-Y graphing, panning, and zooming; screenshot capturing of graphs.
- Spreadsheet/tabular viewing of data; export data for further analysis.
- Annotating of tests; save test setups.
- GPIB, USB 2.0, Ethernet compliance.

Optional Apps Tailored for your Characterization Needs

The 2460 is an excellent tool to define nearly any DC test you choose for characterizing materials, electronic devices and modules. For more specific needs, Keithley offers on-instrument software apps that alter the 2460's behavior, fitting your instrument to your needs. These apps can be installed directly to your 2460 by connecting to Keithley's KickStart instrument control software and opening the relevant app in KickStart.

I-V Tracer App

Curve tracing analysis is a critical task for many users in the semiconductor development supply chain. Engineers and technicians both hold the traditional curve tracer as the simplest, fastest method for generating characteristic I-V curves on a device. They are heavily used by engineers in failure analysis and incoming inspection to qualify parts, identify counterfeit devices, and to quickly identify the location of a failure on damaged devices. SMUs have typically been limited to predefined sweeps with longer set up times than curve tracers – until I-V Tracer.

Keithley's I-V Tracer app leverages the touchscreen and front-panel knob of the 2460 to allow precise, live control over the SMU output while viewing I-V results of 2 terminal devices. At each individual output level current and voltage are measured and plotted. The small footprint of the SMU enables portable benchtop use, reserving high power (kW) traditional curve tracers for special cases. The power envelope of the 2460 allows it to comfortably operate in the low power range of traditional curve tracers like the Tektronix 576 and Tektronix 370A, while offering enhanced low current measurements.



I-V Tracer home screen

Once installed, I-V Tracer exists on the SMU itself, meaning I-V tracer can be used wherever your SMU can go, without a continuous remote connection. It can also integrate with KickStart to enable simple data collection and comparison on the PC, simplifying the preparation of reports used in failure analysis or teaching labs at colleges and universities.

I-V Tracer capabilities with the 2460:

- Use the full power envelope of the 2460 (max 100 V or 7 A)
- Trace by sourcing voltage or current, positive or negative
- 2 or 4-wire sense
- Compare mode for verifying against a reference device
- Reading table view to see exact measurements
- Easily copy curves and settings to your PC with KickStart

Simplified Programming with Ready-to-Use Instrument Drivers

For those who prefer to create their own customized application software, native National Instruments LabVIEW® drivers and IVI-C and IVI-COM drivers are available at tek.com.

Specifications

Voltage Specifications^{1, 2}

Range	Max. Current	Source			Measure ³		
		Resolution	Accuracy (23° ± 5°C) 1 Year ±(% setting + volts)	Noise (RMS) (<10 Hz)	Resolution	Input Resistance	Accuracy (23° ± 5°C) 1 Year ±(% rdg. + volts)
200.0000 mV	7.35 A	5 µV	0.015% + 200 µV	1 µV	100 nV	>10 GΩ	0.012% + 200 µV
2.000000 V	7.35 A	50 µV	0.015% + 300 µV	10 µV	1 µV	>10 GΩ	0.012% + 300 µV
7.000000 V	7.35 A	250 µV	0.015% + 2.4 mV	100 µV	1 µV	>10 GΩ	0.015% + 1 mV
10.00000 V	5.25 A	250 µV	0.015% + 2.4 mV	100 µV	10 µV	>10 GΩ	0.015% + 1 mV
20.00000 V	4.20 A	500 µV	0.015% + 2.4 mV	100 µV	10 µV	>10 GΩ	0.015% + 1 mV
100.0000 V	1.05 A	2.5 mV	0.015% + 15 mV	1 mV	100 µV	>10 GΩ	0.015% + 5 mV

Current Specifications^{1, 2, 5}

Range	Max. Voltage	Source			Measure ³		
		Resolution	Accuracy (23° ± 5°C) ⁴ 1 Year ±(% setting + amps)	Noise (RMS) (<10 Hz)	Resolution ⁴	Voltage Burden ⁶	Accuracy (23° ± 5°C) 1 Year ±(% rdg. + amps)
1.000000 µA	105 V	50 pA	0.025% + 1 nA	40 pA	1 pA	<100 µV	0.025% + 700 pA
10.00000 µA	105 V	500 pA	0.025% + 1.5 nA	40 pA	10 pA	<100 µV	0.025% + 1 nA
100.0000 µA	105 V	5 nA	0.020% + 15 nA	100 pA	100 pA	<100 µV	0.020% + 10 nA
1.000000 mA	105 V	50 nA	0.020% + 150 nA	1 nA	1 nA	<100 µV	0.020% + 100 nA
10.00000 mA	105 V	500 nA	0.020% + 1.5 µA	10 nA	10 nA	<100 µV	0.020% + 1 µA
100.0000 mA	105 V	5 µA	0.020% + 15 µA	100 nA	100 nA	<100 µV	0.020% + 10 µA
1.000000 A	105 V	50 µA	0.050% + 750 µA	5 µA	1 µA	<100 µV	0.050% + 500 µA
4.000000 A	21 V	250 µA	0.100% + 3 mA	25 µA	1 µA	<100 µV	0.100% + 2.5 mA
5.000000 A	10.5 V	250 µA	0.100% + 3 mA	25 µA	1 µA	<100 µV	0.100% + 2.5 mA
7.000000 A	7.35 V	500 µA	0.150% + 6 mA	125 µA	1 µA	<100 µV	0.150% + 5 mA

Temperature Coefficient (0°–18°C and 28°–50°C)

±(0.10 × accuracy specification)/°C.

Notes

1. Speed = 1 PLC.
2. All specifications are guaranteed with output ON.
3. Accuracies apply to 2- and 4-wire mode when properly zeroed.
4. 6.5-digit measure resolution.
5. Accuracy specifications guaranteed when using 2460-KIT screw terminal accessory.
6. Four-wire mode.

Resistance Measurement Accuracy (Local or Remote Sense)^{1, 2, 3}

Range	Default Resolution ⁴	Default Test Current	Normal Accuracy (23°C ±5°C) 1 Year, ±(% rdg. + ohms)	Enhanced Accuracy ⁵ (23°C ±5°C) 1 Year, ±(% rdg. + ohms)
<2.000000 Ω ⁶	1 μΩ	User defined	Source I _{ACC} + Meas. V _{ACC}	Meas. I _{ACC} + Meas. V _{ACC}
20.00000 Ω	10 μΩ	100 mA	0.05% + 0.003 Ω	0.04% + 0.001 Ω
200.0000 Ω	100 μΩ	10 mA	0.05% + 0.03 Ω	0.04% + 0.01 Ω
2.000000 kΩ	1 mΩ	1 mA	0.05% + 0.3 Ω	0.04% + 0.1 Ω
20.00000 kΩ	10 mΩ	100 μA	0.05% + 3 Ω	0.04% + 1 Ω
200.0000 kΩ	100 mΩ	10 μA	0.05% + 30 Ω	0.05% + 10 Ω
2.000000 MΩ	1 Ω	10 μA	0.06% + 100 Ω	0.06% + 50 Ω
20.00000 MΩ	10 Ω	1 μA	0.14% + 1000 Ω	0.12% + 500 Ω
>20.0000 MΩ ⁶	—	User defined	Source I _{ACC} + Meas. V _{ACC}	Meas. I _{ACC} + Meas. V _{ACC}

**Temperature Coefficient
(0°–18°C and 28°–50°C)**

±(0.10 × accuracy specification)/°C.

**Source Current,
Measure Resistance Mode**Total uncertainty = I_{source} accuracy + V_{measure} accuracy (4-wire remote sense).**Source Voltage,
Measure Resistance Mode**Total uncertainty = V_{source} accuracy + I_{measure} accuracy (4-wire remote sense).**Guard Output Impedance**

0.5 Ω (DC) in ohms mode.

Notes

1. Speed = 1 PLC.
2. All specifications are guaranteed with output ON.
3. Accuracies apply to 2- and 4-wire mode when properly zeroed.
4. 6.5-digit measure resolution.
5. Source readback enabled. Offset compensation ON.
6. Source current, measure resistance or source voltage, measure resistance only.

Supplemental Characteristics

Max. Output Power	100 W, four-quadrant source or sink operation.
Source Limits	V_{source}: ±7.35 V (≤7 A range), ±10.5 V (≤5 A range), ±21 V (≤4 A range), ±105 V (≤1 A range). I_{source}: ±7.35 A (≤7 V range), ±5.25 A (≤10 V range), ±4.2 A (≤20 V range), ±1.05 mA (≤100 V range).
Overrange	105% of range, source and measure.
Regulation	Voltage: Line: 0.01% of range. Load: 0.01% of range + 100 μV. Current: Line: 0.01% of range. Load: 0.01% of range + 100 pA.
Source Limits	Voltage Source Current Limit: Bipolar current limit set with single value. Min. 10% of range. Current Source Voltage Limit: Bipolar voltage limit set with single value. Min. 10% of range.
V-Limit / I-Limit Accuracy	Add 0.3% of setting and ±0.02% of reading to base specification.
Overshoot	Voltage Source: <0.1% typical (full scale step, resistive load, 20 V range, 10 mA I-Limit). Current Source: <0.1% typical (1 mA step, R _{Load} = 10 kΩ, 20 V range).
Range Change Overshoot	Overshoot into a fully resistive 100 kΩ load, 10 Hz to 20 MHz BW, adjacent ranges: <250 mV typical.
Output Settling Time	Time required to reach 0.1% of final value after command is processed and output slew, 20 V range, 100 mA I-Limit: <200 μs typical.
Maximum Slew Rate	1 V per μs, 100 V range, 100 mA limit into a 20 kΩ load (typical). 0.6 V per μs, 20 V range, 100 mA limit into a 20 kΩ load (typical).
Over Voltage Protection	User selectable values, 5% ±0.5 V tolerance. Factory default = none.
Voltage Source Noise	10 Hz–20 MHz (RMS): <4.5 mV typical into a resistive load.

Common Mode Voltage 250 V DC.

Common Mode Isolation >1G Ω , <1000 pF.

Noise Rejection (typical)

NPLC	NMRR	CMRR
0.01	—	60 dB
0.1	—	60 dB
1	60 dB	100 dB

Load Impedance **Normal Mode:** 20 nF typical.
High Capacitance Mode: Stable into 50 μ F typical. High-C mode valid for ≥ 100 μ A ranges.

Max. Voltage Drop Between Force and Sense Terminals 5 V.

Max. Sense Lead Resistance 1 M Ω for rated accuracy.

Sense Input Impedance >10 G Ω .

Guard Offset Voltage <300 μ V, typical

System Measurement Speeds¹

Reading Rates (readings/second) typical for 60 Hz (50 Hz), script (TSP®) programmed

NPLC	Trigger Origin	Measure to Memory	Measure to GPIB/USB/LAN	Source-Measure to Memory	Source-Measure to GPIB/USB/LAN
0.01	Internal	3050 (2800)	2800 (2500)	1700 (1600)	1650 (1550)
0.01	External	2300 (2100)	2150 (2000)	1650 (1550)	1600 (1450)
0.1	Internal	540 (460)	530 (450)	470 (410)	470 (400)
0.1	External	500 (420)	500 (420)	460 (390)	450 (350)
1.00	Internal	59 (49)	59 (49)	58 (48)	58 (48)
1.00	External	58 (48)	58 (48)	57 (48)	57 (46)

Reading Rates (readings/second) typical for 60 Hz (50 Hz), SCPI programmed

NPLC	Trigger Origin	Measure to Memory	Measure to GPIB/USB/LAN	Source-Measure to Memory	Source-Measure to GPIB/USB/LAN
0.01	Internal	3000 (2800)	3000 (2790)	1700 (1600)	1550 (1500)
0.01	External	2330 (2150)	2330 (2150)	1650 (1550)	1500 (1450)
0.1	Internal	540 (460)	540 (460)	470 (410)	460 (400)
0.1	External	510 (430)	510 (430)	470 (400)	460 (390)
1.00	Internal	59 (49)	59 (49)	58 (48)	58 (48)
1.00	External	58 (49)	58 (49)	58 (48)	58 (48)

Notes

1. Reading rates applicable for voltage or current measurements, autozero off, autorange off, filter off, binary reading format, and source readback off.

General Characteristics (default mode unless specified)

Factory Default Standard Power-Up	SCPI Mode.
Source Output Modes	Fixed DC Level, Memory/Configuration List (mixed function), Sweep (linear and logarithmic), Sweep (dual linear and dual logarithmic).
Memory Buffer	>250,000 readings. Includes selected measured values and timestamp.
Real-Time Clock	Lithium battery backup (3 yr. + battery life).
Remote Interfaces	
 GPIB	IEEE-488.1 compliant. Supports IEEE-488.2 common commands and status model topology.
 USB Device (rear panel, type B)	2.0 Full Speed USBTMC.
 USB Host (front panel, type A)	USB 2.0, support for flash drives, FAT32.
 Ethernet: RJ-45 (10/100BT)	
Digital I/O Interface	
 Lines	6 Input/Output user defined for digital I/O or triggering.
 Connector	9-pin female D.
 Input Signal Levels	0.7 V (maximum logic low), 3.7 V (minimum logic high).
 Input Voltage Limits	-0.25 V (absolute minimum), +5.25 V (absolute maximum).
 Maximum Source Current	+2.0 mA @ >2.7 V (per pin).
 Maximum Sink Current	-50 mA @ 0.7 V (per pin, solid-state fuse protected).
 5 V Power Supply Pin	Limited to 500 mA @ >4 V (solid-state fuse protected).
 Handler	User definable Start of Test, End of Test, 4 category bits.
Programmability	SCPI or TSP command sets.
TSP Mode	Embedded Test Script Processor (TSP) accessible from any host interface.
IP Configuration	Static or DHCP.
Expansion Interface	The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.
LXI Compliance	1.5 LXI Device Specification 2016.
Display	5 inch capacitive touch, color TFT WVGA (800×480) with LED backlight.
Input Signal Connections	Front: Banana. Rear: Mass termination screw terminal.
Interlock	Active High Input.
Cooling	Forced air, variable speed.
Over Temperature Protection	Internally sensed temperature overload puts unit in standby mode.
Power Supply	100 V to 240 V RMS, 50-60 Hz (automatically detected at power up).
VA Rating	350 volt-amps maximum.
Altitude	Maximum 2000 meters above sea level.
EMC	Conforms to European Union EMC Directive.
Safety	Compliance with CE and NRTL listed to UL61010-1 and UL61010-2-30. Conforms with European Union Low Voltage Directive.
Vibration	MIL-PRF-28800F Class 3 Random.
Warm-Up	1 hour to rated accuracies.

Dimensions	With bumpers and handle: 106 mm high × 255 mm wide × 425 mm deep (4.18 in × 10.05 in × 16.75 in). Without bumpers and handle: 88 mm high × 213 mm wide × 403 mm deep (3.46 in × 8.39 in × 15.87 in).
Weight	With bumpers and handle: 4.75 kg (10.5 lbs.). Without bumpers and handle: 4.35 kg (9.6 lbs.).
Environment	For indoor, non-residential use only. Operating: 0° to 50°C, 70% relative humidity up to 35°C. Derate 3% relative humidity/°C, 35° to 50°C. Storage: -25°C to 65°C.
Accessories Supplied	Test Leads, Mating Mass Termination Screw Connector, USB Cable, Ethernet/TSP Cable, Interlock Adapter, Power Cord, Quick Start Guide.

Ordering Information

2460	100 V, 7 A, 100 W SourceMeter Instrument
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Supplied Accessories

2460-KIT	Rear Panel Mating Mass Termination Screw Connector
CS-1616-3	Safety Interlock Mating Connector
17469460X	TSP-Link/Ethernet Cable
CA-432A	USB 2.0 Type A Male to Type B Male Cable
012173001	Safety Clip On Test Lead Set
	Documentation available at tek.com
	2460 QuickStart Guide
	TSP Toolkit Software (available at tek.com)
	LabVIEW and IVI Drivers (available at tek.com)

Available Accessories

Test Leads and Probes

5805	Kelvin (4-Wire) Spring-Loaded Probes
5808	Low Cost Single-pin Kelvin Probe Set

Cables, Connectors, Adapters

2460-BAN	Screw Terminal Connector to Banana Cable
2460-KIT	Mating Mass Termination Screw Connector
CS-1616-3	Safety Interlock Mating Connector

Communication Interfaces & Cables

7007-1	Shielded GPIB Cable, 1 m (3.3 ft)
KPCI-488LPA	IEEE-488 Interface for PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

Rack Mount Kits

4299-8	Single Fixed Rack Mount Kit
4299-9	Dual Fixed Rack Mount Kit

Software Options

I-V Tracer	Graphical SMU Curve Tracer Software
KickStart	Instrument Control Software
ACS Basic Edition	Semiconductor Parametric Test Software for Component and Discrete Devices

Available Services

2460-3Y-EW	1 Year Factory Warranty extended to 3 years from date of shipment
2460-5Y-EW	1 Year Factory Warranty extended to 5 years from date of shipment
C/2460-3Y-17025	KeithleyCare® 3 Year ISO 17025 Calibration Plan
C/2460-3Y-DATA	KeithleyCare 3 Year Calibration w/Data Plan
C/2460-3Y-STD	KeithleyCare 3 Year Std. Calibration Plan
C/2460-5Y-17025	KeithleyCare 5 Year ISO 17025 Calibration Plan
C/2460-5Y-DATA	KeithleyCare 5 Year Calibration w/Data Plan
C/2460-5Y-STD	KeithleyCare 5 Year Std. Calibration Plan
C/NEW DATA	Calibration Data for New Units
C/NEW DATA ISO	ISO-17025 Calibration Data for New Units

Warranty Information

Warranty Summary	This section summarizes the warranties of the 2460. For complete warranty information, refer to the Tektronix warranty page at www.tek.com/service/warranties/warranty-2 . Any portion of the product that is not manufactured by Keithley is not covered by this warranty and Keithley will have no duty to enforce any other manufacturer's warranties.
Hardware Warranty	Keithley Instruments, Inc. warrants the Keithley manufactured portion of the hardware for a period of one year from defects in materials or workmanship; provided that such defect has not been caused by use of the Keithley hardware which is not in accordance with the hardware instructions. The warranty does not apply upon any modification of Keithley hardware made by the customer or operation of the hardware outside the environmental specifications.
Software Warranty	Keithley warrants for the Keithley produced portion of the software or firmware will conform in all material respects with the published specifications for a period of ninety (90) days; provided the software is used on the product for which it is intended in accordance with the software instructions. Keithley does not warrant that operation of the software will be uninterrupted or error-free, or that the software will be adequate for the customer's intended application. The warranty does not apply upon any modification of the software made by the customer.

Contact Information:

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Belgium* 00800 2255 4835
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Central Europe / Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
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Germany* 00800 2255 4835
Hong Kong 400 820 5835
India 000 800 650 1835
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Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2656 6688
Thailand 1 800 011 931
United Kingdom / Ireland* 00800 2255 4835
USA 1 800 833 9200
Vietnam 12060128

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

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2461 SourceMeter SMU Instrument

DATASHEET

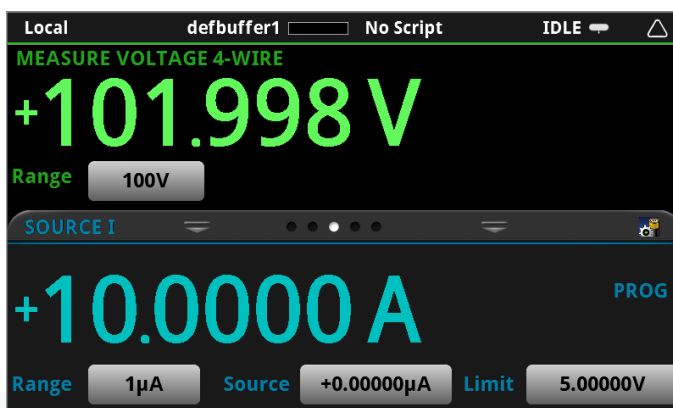


The 2461 High Current SourceMeter® Source Measure Unit (SMU) Instrument brings advanced Touch, Test, Invent® technology right to your fingertips. It combines an innovative graphical user interface (GUI) with capacitive touchscreen technology to make testing intuitive and minimize the learning curve to help engineers and scientists learn faster, work smarter, and invent easier. With its 10 A/1000 W pulse current and 7 A/100 W DC current capability combined with dual 18-bit 1 MS/s digitizers, the 2461 is optimized for characterizing and testing high power materials, devices, and modules, such as silicon carbide (SiC), gallium nitride (GaN), DC-DC converters, circuit protection devices, solar cells and panels, high brightness LEDs and lighting systems, electrochemical cells and batteries, and much more. These new capabilities, combined with Keithley's expertise in high precision, high accuracy SMU instruments, will make the 2461 a "go-to instrument" for high current sourcing and high speed measurement applications in the lab and in the rack for years to come.

To help users who wish to transition to the 2461 from Keithley's legacy 2420, 2425, 2430, and 2440 SMUs, the 2461 now includes four SCPI emulation modes for each of the older models, minimizing SCPI code rewriting and maximizing your investment.

Key Features

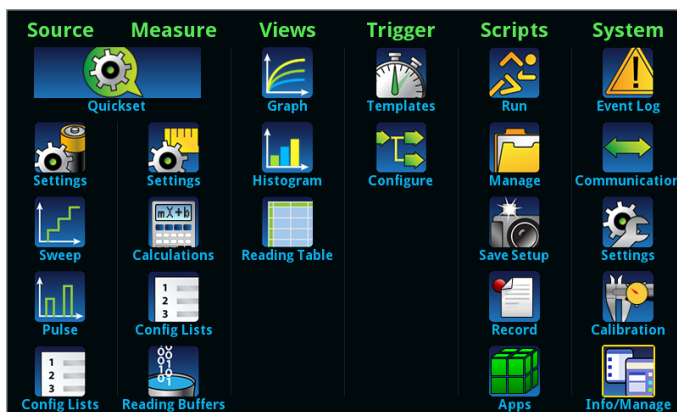
- One tightly coupled instrument that combines the capabilities of analyzers, curve tracers, and I-V systems at a fraction of their cost
- Wide coverage up to 105 V/7 A DC 100 W, 100 V/10 A Pulse 1000 W maximum.
- Dual 1 MS/s digitizers for fast sampling measurements
- Five-inch, high resolution capacitive touchscreen GUI
- 0.012% DCV accuracy with 6½-digit resolution
- Source and sink (4-quadrant) operation
- Four Quickset modes for fast setup and measurements
- Context-sensitive help function
- Front panel input banana jacks; rear panel mass termination screw connections
- SCPI and Test Script Processor (TSP®) programming modes
- Front-panel USB 2.0 memory I/O port for transferring data, test scripts, or test configurations



The 2461's home screen makes testing intuitive and helps minimize the learning curve for new users.

Learn Faster, Work Smarter, Invent Easier

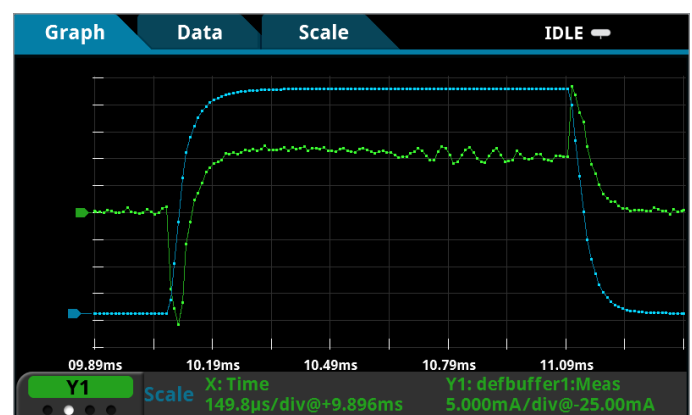
The 2461 features a five-inch, full-color, high resolution touchscreen that supports intuitive operation, helps operators become familiar with the instrument quickly, and optimizes overall speed and productivity. A simple icon-based menu structure reduces the number of steps required to configure a test by as much as 50 percent and eliminates the cumbersome multi-layer menu structures typically used on soft-key instruments. Built-in, context-sensitive help supports intuitive operation and minimizes the need to review a separate manual. These capabilities, combined with the 2461's high versatility, simplify its operation in both basic and advanced measurement applications, regardless of the user's previous experience in working with SMU instruments.



The graphical SMU's icon-based menu structure helps even novice users configure tests quickly and confidently.

Capture Real Device Operation with the Built-in Dual 1 MS/s Digitizers

Capturing and displaying real device operation, waveforms, and transient events just got easier with the 2461's digitizing function. The two built-in 1 MS/s, 18-bit digitizers make it possible to acquire both voltage and current waveforms simultaneously without the need to use a separate instrument. The digitizing functions employ the same DC voltage and current measure ranges that the standard A/D converter uses. In addition, the voltage digitizing function uses the same DC voltage 10 GΩ input impedance levels to reduce loading significantly on the device under test (DUT).



The high speed digitizing function allows capturing and displaying voltage and current measurements simultaneously.

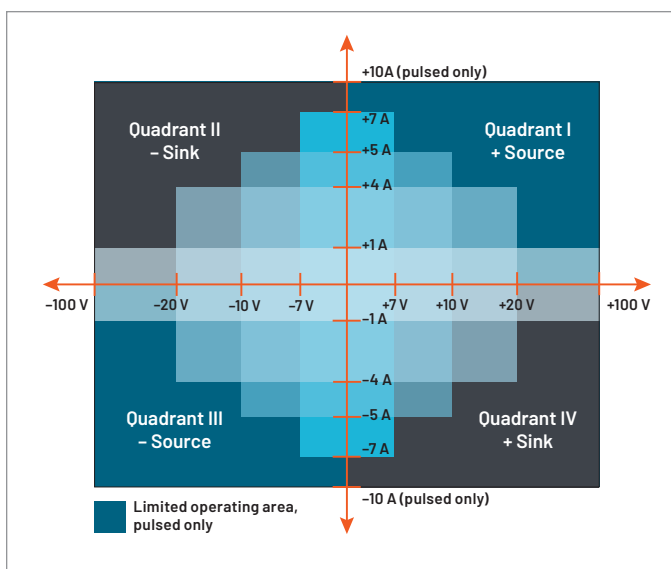
Comparison of 2461 vs. 2420, 2425, 2430, 2440

Feature	2461	2420/2425/2440	2430
Max Voltage	100 V	60 V/100 V/40 V	100 V
Max DC Current	7 A	3 A/3 A/5 A	3 A
Max Pulse Current	10 A	NA	10 A
DC/Pulse Power	100 W/1000 W	Up to 100 W/NA	100 W/1000 W
Digitizers	Dual 18-bit 1 MS/s	None	None
Wideband Noise	<4.5 mVrms typical	10 mVrms typical	10 mVrms typical
Sweep Types	Linear, Log, Dual Linear, Dual Log, Custom	Linear, Log, Custom, Source-Memory	Linear, Log, Custom, Source-Memory
Reading Buffer Size	>2 Million Point Reading Buffer	5000 Point Reading Buffer	5000 Point Reading Buffer
Programming Command Type	SCPI Programming + TSP Scripting	SCPI	SCPI
PC interface	GPIO, USB, Ethernet (LXI)	GPIO, RS-232	GPIO, RS-232
Signal Input Connections	Front: Banana Jacks Rear: Mass Screw Terminal Connection	Front/Rear Banana Jacks	Front/Rear Banana Jacks

All-in-One SMU Instrument

The 2461, built on the fourth generation of the award-winning SourceMeter SMU platform, leverages the proven capabilities of previously introduced high current SMU instruments from Keithley, including the 2420, 2425, and 2440. It offers a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current measurements. This all-in-one instrument gives you the capabilities of a:

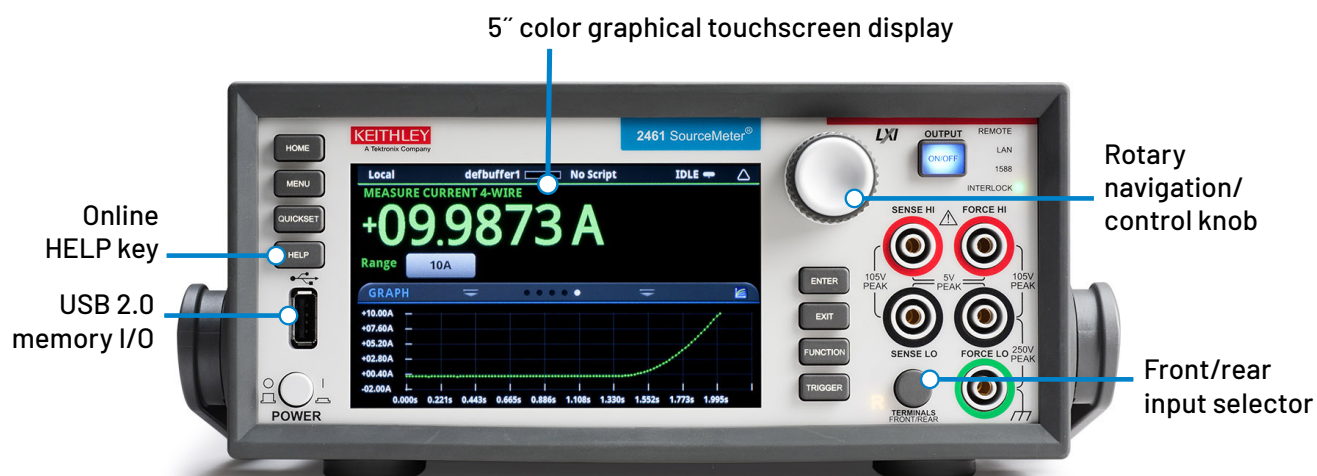
- Precision power supply with V and I readback
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load
- Pulse generator
- Trigger controller



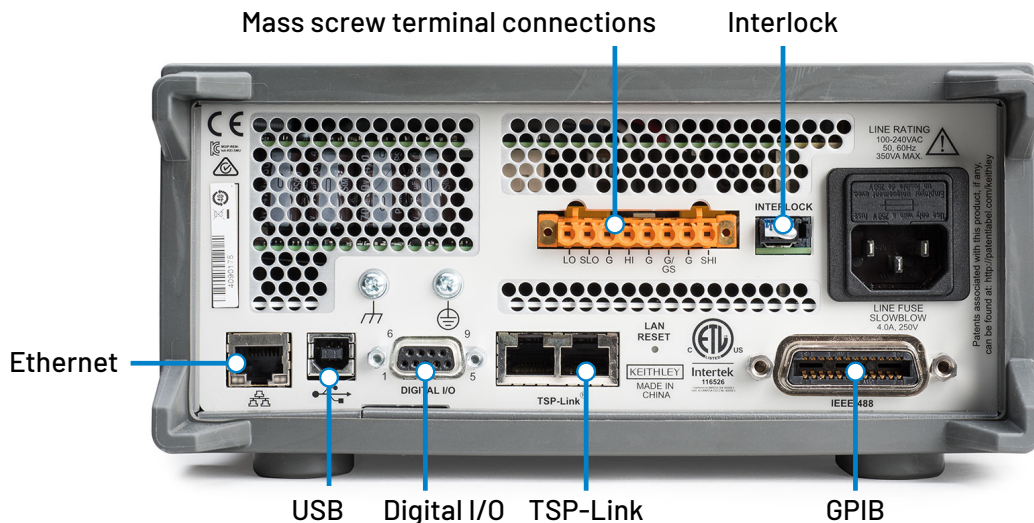
2461 Power Envelope

Ease of Use Beyond the Touchscreen

In addition to its five-inch color touchscreen, the 2461 Graphical SourceMeter front panel offers a variety of features that enhance its speed, user-friendliness, and learnability, including a USB 2.0 memory I/O port, a HELP key, a rotary navigation/control knob, a front/rear input selector button, and banana jacks for basic bench applications. The USB 2.0 memory port simplifies storing test results and instrument configurations, uploading test scripts into the instrument, and installing system upgrades. All front-panel buttons are backlit to enhance visibility in low-light environments.

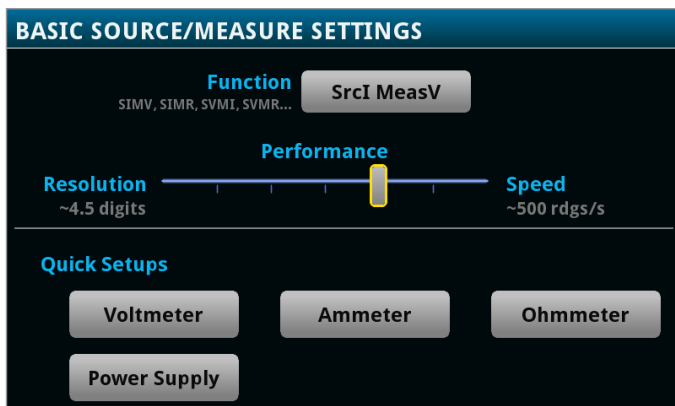


The 2461's high resolution, capacitive touchscreen and front panel controls allow for intuitive operation, even by novice users.



2461 rear panel connections are optimized to maintain signal integrity and speed system setup.

Four Quickset modes simplify instrument setup. With one touch, the instrument can be quickly configured for various operating modes without the need to configure the instrument indirectly for this operation.



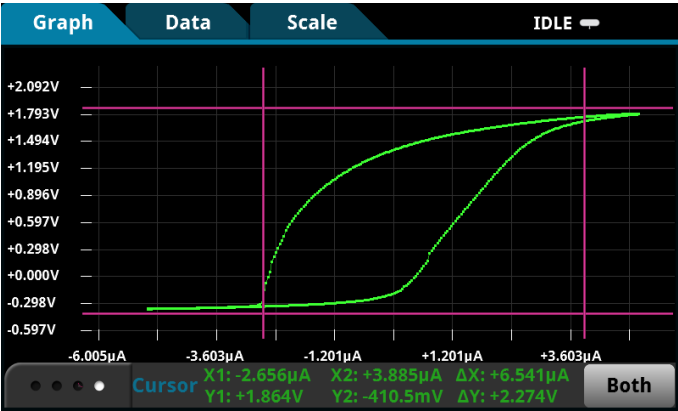
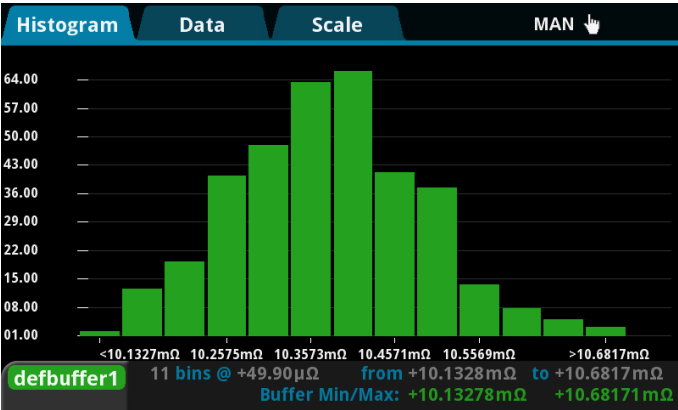
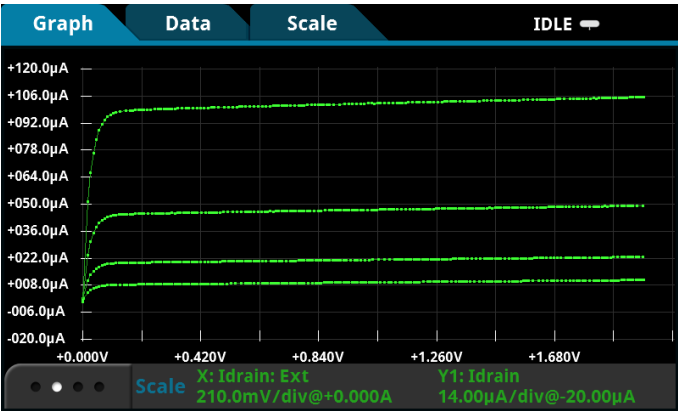
One-touch Quickset modes speed measurement setups and minimize the time to measurements.

Comprehensive Built-in Connectivity

Rear panel access to rear-input connectors, remote control interfaces (GPIB, USB 2.0, and LXI/Ethernet), D-sub 9-pin digital I/O port (for internal/external trigger signals and handler control), instrument interlock control, and TSP-Link® jacks make it simple to configure multiple instrument test solutions and eliminate the need to invest in additional adapter accessories.

Convert Raw Data to Information

A full graphical plotting window converts raw data and displays it immediately as useful information, such as semiconductor I-V curves and digitized waveforms. The touchscreen interface makes it easy to observe, interact with, and explore measurements with “pinch and zoom” simplicity. By using the built-in graphing cursors, you can immediately analyze your data without a PC. All graphic screens can be saved to a USB thumb drive for incorporation into reports and journals. Using the graphical SMU’s Sheet view, test data can also be displayed in tabular form. The instrument supports exporting data to a spreadsheet for further analysis, dramatically improving productivity for research, benchtop testing, device qualification, and debugging. This combination of high performance and high ease of use offers unparalleled insight into your test results.



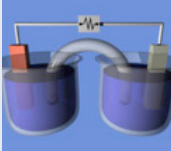
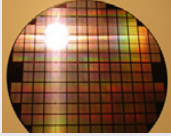
READING TABLE			
Buffer Active (defbuffer1)			
Buffer Index	Time	Source	Reading
1	04/14 12:56:46.766230	+6.000000 A	+5.98635 V
2	04/14 12:56:46.770194	+6.000000 A	+5.98594 V
3	04/14 12:56:46.774216	+6.000000 A	+5.98594 V
4	04/14 12:56:46.778194	+6.000000 A	+5.98594 V
5	04/14 12:56:46.782211	+6.000000 A	+5.98580 V
6	04/14 12:56:46.786198	+6.000000 A	+5.98649 V
7	04/14 12:56:46.790208	+6.000000 A	+5.98566 V
8	04/14 12:56:46.794203	+6.000000 A	+5.98484 V
9	04/14 12:56:46.798219	+6.000000 A	+5.98594 V
10	04/14 12:56:46.802194	+6.000000 A	+5.98566 V

Built-in functions like real-time graphing, charting, scope-like cursors, and data display spreadsheet for export simplify converting test results into useful information.

Typical Applications

Ideal for current/voltage (I-V) characterization and functional test of a wide range of today's modern electronics and devices, including:

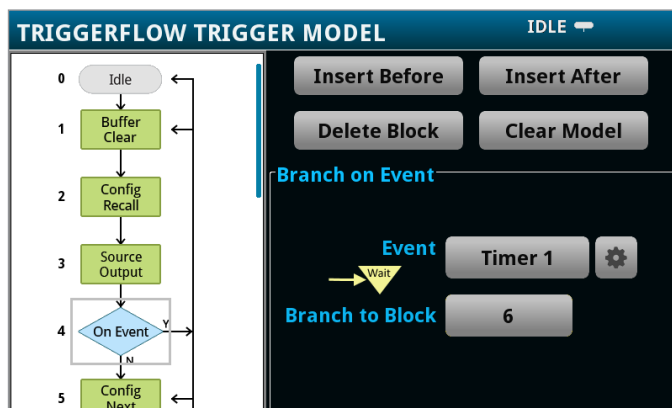
- Power semiconductors and materials
 - SiC, GaN
 - IGBTs, Power MOSFETs, HBLEDs
 - Thyristors
- Power management and protection devices
 - Telecom power management chipsets
 - DC-DC converters
 - Metal-oxide varistors (MOV), transient voltage suppressors (TVS)
- Electrochemistry
 - Galvanic cycling
 - Cyclic voltammetry
 - Electro-deposition



TriggerFlow® Building Blocks for Instrument Control and Execution

The 2461 incorporates Keithley's TriggerFlow triggering system, which provides user control over instrument execution. TriggerFlow diagrams are created in much the same way that flow charts are developed, using four fundamental building block types:

- **Wait** – Waits for an event to occur before the flow continues
- **Branch** – Branches when a condition has been satisfied
- **Action** – Initiates an action in the instrument, for example, measure, source, delay, set digital I/O, etc.
- **Notify** – Notifies other equipment that an event has occurred



TriggerFlow building blocks allow you to create triggering models that range from very simple to highly complex.

A TriggerFlow model using a combination of these building blocks can be created from the front panel or by sending remote commands. With the TriggerFlow system, users can build triggering models from very simple to complex with up to 63 block levels. The 2461 also includes basic triggering functions, including immediate, timer, and manual triggering.

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 failures associated with contact fatigue, breakage, contamination, loose or broken connection, relay failures, etc. Some capabilities of this function are:

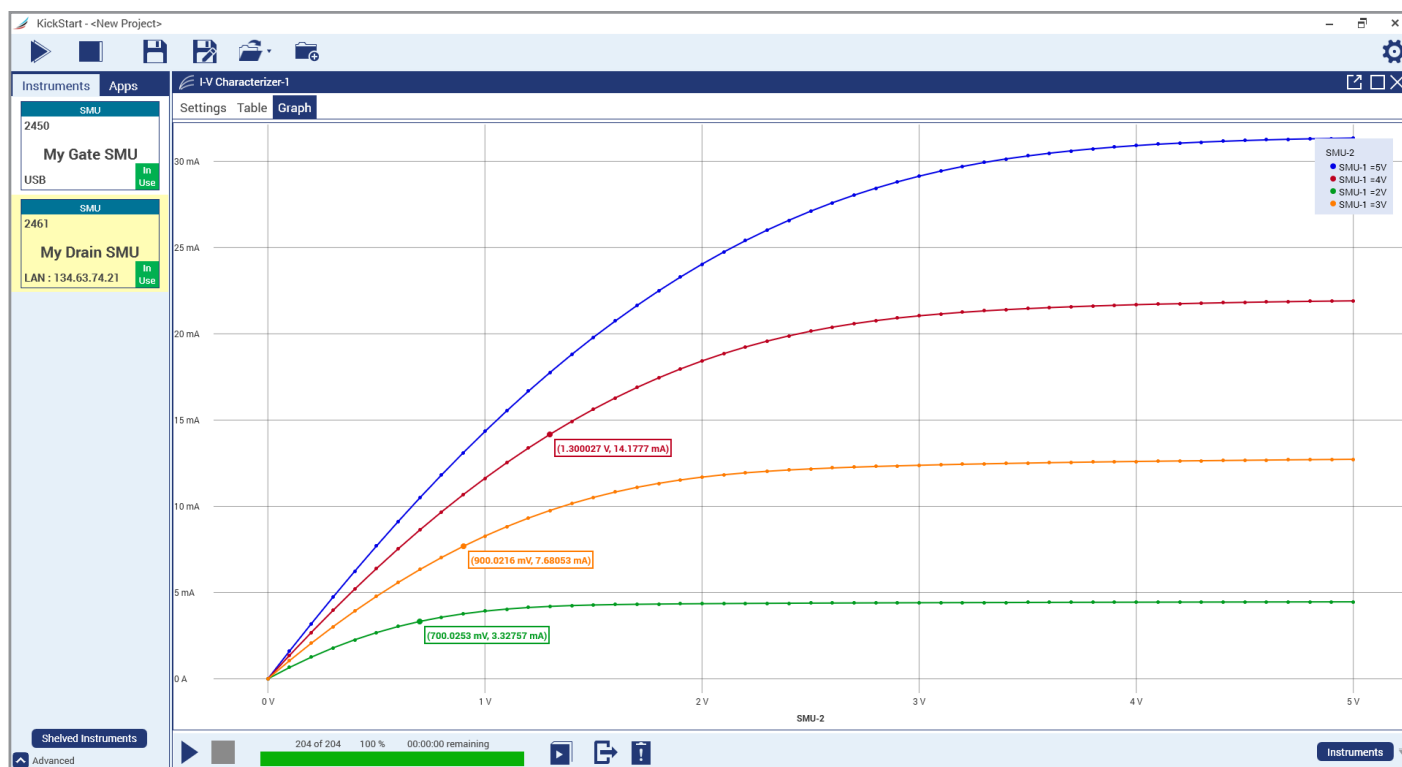
- <100 μ s verification and notification process time
- 3 pass/fail threshold values: 2 Ω , 15 Ω , and 50 Ω
- Enabled remotely over the GPIB, USB, or Ethernet (LXI) interfaces

Unmatched System Integration and Programming Flexibility

When a 2461 is configured into a multi-channel I-V test system, its embedded Test Script Processor (TSP®) allows it to run test scripts, so users can create powerful measurement applications with significantly reduced development times. TSP technology also offers channel expansion without a mainframe. Keithley's TSP-Link® channel expansion bus, which uses a 100 Base T Ethernet cable, can connect multiple graphical SourceMeter SMUs (2450, 2460, 2461), and other TSP instruments such as Keithley's DMM7510 7½-Digit Graphical Sampling Multimeter, Series 2600B System SourceMeter SMU instruments, and Series 3700A Switch/Multimeter systems in a master-subordinate configuration that operates as one integrated system. The TSP-Link expansion bus supports up to 32 units per GPIB or IP address, making it easy to scale a system to fit an application's particular requirements. The 2461 also includes a SCPI programming mode that takes advantage of all of the instrument's capabilities.

Parallel Test Capability

The TSP technology in the 2461 supports testing multiple devices in parallel to meet the needs of device research, advanced semiconductor lab applications, and even high throughput production test. This parallel testing capability allows each instrument in the system to run its own complete test sequence, creating a fully multi-threaded test environment. The number of tests that can be run in parallel on a graphical SourceMeter can be as high as the number of instruments in the system.



KickStart start-up software lets users be ready to make measurements in minutes.

Instrument Control Start-up Software

KickStart instrument control/start-up software enables users to start making measurements in minutes without programming. In most cases, users merely need to make some quick measurements, graph the data, and store the data to disk for later analysis in software environments such as Excel. KickStart offers:

- Configure and control up to four SMU instruments for DC or Pulsed I-V test in either the same app, same project, or a combination of the two.
- Create tests by mixing any of these SMU instruments: 2400 Graphical Series, 2400 Standard Series (DC only), 2600B Series, 2651A, 2657A, and 6430 SourceMeter® SMU (DC only) instruments.
- Differentiate SMU instrument channels and their measurement data using labels that are relevant to your device or module.

- Native X-Y graphing, panning, and zooming; screenshot capturing of graphs.
- Spreadsheet/tabular viewing of data; export data for further analysis.
- Annotating of tests; save test setups.
- GPIB, USB 2.0, Ethernet compliance.

Optional Apps Tailored for your Characterization Needs

The 2461 is an excellent tool to define nearly any DC test you choose for characterizing materials, electronic devices and modules. For more specific needs, Keithley offers on-instrument software apps that alter the 2461's behavior, fitting your instrument to your needs. These apps can be installed directly to your 2461 by connecting to Keithley's KickStart instrument control software and opening the relevant app in KickStart.

I-V Tracer App

Curve tracing analysis is a critical task for many users in the semiconductor development supply chain. Engineers and technicians both hold the traditional curve tracer as the simplest, fastest method for generating characteristic I-V curves on a device. They are heavily used by engineers in failure analysis and incoming inspection to qualify parts, identify counterfeit devices, and to quickly identify the location of a failure on damaged devices. SMUs have typically been limited to predefined sweeps with longer set up times than curve tracers — until I-V Tracer.

Keithley's I-V Tracer app leverages the touchscreen and front-panel knob of the 2461 to allow precise, live control over the SMU output while viewing I-V results of 2 terminal devices. At each individual output level current and voltage are measured and plotted. The small footprint of the SMU enables portable benchtop use, reserving high power (kW) traditional curve tracers for special cases. The power envelope of the 2461 allows it to comfortably operate in the low power range of traditional curve tracers like the Tektronix 576 and Tektronix 370A, while offering enhanced low current measurements.



AC mode with I-V Tracer, available on the 2461.

Once installed, I-V Tracer exists on the SMU itself, meaning I-V tracer can be used wherever your SMU can go, without a continuous remote connection. It can also integrate with KickStart to enable simple data collection and comparison on the PC, simplifying the preparation of reports used in failure analysis or teaching labs at colleges and universities.

I-V Tracer capabilities with the 2461:

- Use the full DC power envelope of the 2461 (max 100 V or 7 A)
- Trace by sourcing voltage or current, positive or negative
- Use AC polarity to continuously sweep positive and negative about 0 to see the full behavior of your device
- Pulse mode with adjustable pulse width to limit self-heating effects
- 2 or 4-wire sense
- Compare mode for verifying against a reference device
- Reading table view to see exact measurements
- Easily copy curves and settings to your PC with KickStart

Simplified Programming with Ready-to-Use Instrument Drivers

For those who prefer to create their own customized application software, native National Instruments LabVIEW® drivers, as well as IVI-C and IVI-COM drivers, are available at tek.com.

Specifications

Voltage Specifications^{1, 2}

Range	Max. DC Current	Source			Measure ³		
		Resolution	Accuracy (23° ± 5°C) 1 Year ±(% setting + volts)	Noise (RMS) (<10 Hz)	Resolution ⁴	Accuracy (23° ± 5°C) 1 Year ±(% rdg. + volts)	Digitizer Accuracy ⁵ (23° ± 5°C) 1 Year ±(% rdg. + volts)
200.0000 mV	7.35 A	5 µV	0.015% + 200 µV	1 µV	100 nV	0.012% + 200 µV	0.05% + 1.2 mV
2.000000 V	7.35 A	50 µV	0.015% + 300 µV	2 µV	1 µV	0.012% + 300 µV	0.05% + 1.2 mV
7.000000 V	7.35 A	250 µV	0.015% + 2.4 mV	20 µV	1 µV	0.015% + 1 mV	0.05% + 8 mV
10.00000 V	5.25 A	250 µV	0.015% + 2.4 mV	20 µV	10 µV	0.015% + 1 mV	0.05% + 8 mV
20.00000 V	4.20 A	500 µV	0.015% + 2.4 mV	20 µV	10 µV	0.015% + 1 mV	0.05% + 8 mV
100.0000 V	1.05 A	2.5 mV	0.015% + 15 mV	100 µV	100 µV	0.015% + 5 mV	0.05% + 40 mV

Current Specifications^{1, 2, 6}

Range	Max. DC Voltage	Source			Measure ³		
		Resolution	Accuracy (23° ± 5°C) 1 Year ±(% setting + amps)	Noise (RMS) (<10 Hz)	Resolution ⁴	Accuracy (23° ± 5°C) 1 Year ±(% rdg. + volts)	Digitizer Accuracy ⁵ (23° ± 5°C) 1 Year ±(% rdg. + amps)
1.000000 µA	105 V	50 pA	0.025% + 1 nA	40 pA	1 pA	0.025% + 700 pA	0.05% + 4 nA
10.00000 µA	105 V	500 pA	0.025% + 1.5 nA	40 pA	10 pA	0.025% + 1 nA	0.05% + 8 nA
100.0000 µA	105 V	5 nA	0.020% + 15 nA	100 pA	100 pA	0.020% + 10 nA	0.05% + 80 nA
1.000000 mA	105 V	50 nA	0.020% + 150 nA	1 nA	1 nA	0.020% + 100 nA	0.05% + 800 nA
10.00000 mA	105 V	500 nA	0.020% + 1.5 µA	10 nA	10 nA	0.020% + 1 µA	0.05% + 8 µA
100.0000 mA	105 V	5 µA	0.020% + 15 µA	100 nA	100 nA	0.020% + 10 µA	0.05% + 80 µA
1.000000 A	105 V	50 µA	0.050% + 750 µA	5 µA	1 µA	0.050% + 500 µA	0.05% + 1 mA
4.000000 A	21 V	250 µA	0.100% + 3 mA	25 µA	1 µA	0.100% + 2.5 mA	0.10% + 5 mA
5.000000 A	10.5 V	250 µA	0.100% + 3 mA	25 µA	1 µA	0.100% + 2.5 mA	0.10% + 5 mA
7.000000 A	7.35 V	500 µA	0.150% + 6 mA	125 µA	1 µA	0.150% + 5 mA	0.15% + 10 mA
10.000000 A ⁷	7.35 V	500 µA	0.150% + 6 mA	125 µA	10 µA	0.150% + 5 mA	0.15% + 10 mA

Voltage Burden⁸ <100 µV all ranges.

Temperature Coefficient ±(0.10 × accuracy specification)/°C, 0° to 18°C and 28° to 50°C.

Notes

- Speed = 1 PLC.
- All specifications guaranteed with output ON.
- Accuracies apply to 2-wire and 4-wire modes when properly zeroed.
- Measure resolution 6.5 digits. Digitizer resolution limited by noise.
- 18-bit ADC. Average of 1000 samples taken at 1 µs intervals. Internal temperature within ±5°C and 1 week of ACAL.
- Accuracy specifications guaranteed when using 2461-KIT screw terminal accessory for 2461.
- 10 A range DC specifications valid up to 7.35 A. Operation >7.35 A only in pulse mode. Pulse width and duty cycle limits apply. See Pulse Specifications and Typical Pulse Performance sections for more details on pulse operation.
- 4-wire mode.

Resistance Measurement Accuracy (Local or Remote Sense)^{9, 10, 11}

Range	Resolution ¹²	Default Test Current	Normal Accuracy (23°C ± 5°C), 1 Year ±(% rdg. + ohms)	Enhanced Accuracy ¹³ (23°C ± 5°C), 1 Year ±(% rdg. + ohms)
<2.000000 Ω ¹⁴	1 μΩ	User defined	Source I _{ACC} + Meas. V _{ACC}	Meas. I _{ACC} + Meas. V _{ACC}
2.000000 Ω	1 μΩ	100 mA	0.05 % + 0.003 Ω	0.04 % + 0.001 Ω
20.00000 Ω	10 μΩ	100 mA	0.05 % + 0.003 Ω	0.04 % + 0.001 Ω
200.0000 Ω	100 μΩ	10 mA	0.05 % + 0.03 Ω	0.04 % + 0.01 Ω
2.000000 kΩ	1 mΩ	1 mA	0.05 % + 0.3 Ω	0.04 % + 0.1 Ω
20.00000 kΩ	10 mΩ	100 μA	0.05 % + 3 Ω	0.04 % + 1 Ω
200.0000 kΩ	100 mΩ	10 μA	0.05 % + 30 Ω	0.05 % + 10 Ω
2.000000 MΩ	1 Ω	10 μA	0.06 % + 100 Ω	0.06 % + 50 Ω
20.00000 MΩ	10 Ω	1 μA	0.14 % + 1 kΩ	0.12 % + 500 Ω
200.0000 MΩ	100 Ω	100 nA	1.04 % + 10 kΩ	0.74 % + 5 kΩ
>200.0000 MΩ ¹⁴	—	User defined	Source I _{ACC} + Meas. V _{ACC}	Meas. I _{ACC} + Meas. V _{ACC}

**Temperature Coefficient
(0° to 18°C and 28° to 50°C)**

±(0.10 × accuracy specification)/°C.

**Source Current,
Measure Resistance Mode**Total uncertainty = I_{source} accuracy + V_{measure} accuracy (4-wire remote sense).**Source Voltage,
Measure Resistance Mode**Total uncertainty = V_{source} accuracy + I_{measure} accuracy (4-wire remote sense).**Notes**

9. Speed = 1 PLC.

10. All specifications are guaranteed with output ON.

11. Accuracies apply to 2- and 4-wire mode when properly zeroed.

12. 6.5-digit measure resolution.

13. Source readback enabled. Offset compensation ON.

14. Source current, measure resistance or source voltage, measure resistance only

Additional Pulse Mode Source Specifications**Minimum Programmable
Pulse Width**150 μs (Digitizing mode only with source readback disabled). **Note:** Time for settling and/or measuring may be longer than 150 μs.**Maximum Extended Range
Pulse Width**

2.5 ms for 7 A and lower ranges, 1 ms for 10 A range.

Maximum DC Pulse Width

10,000 seconds.

**Pulse Width Programming
Resolution**

Variable, limited by Pulse Width and Pulse Width Jitter.

Pulse Width Jitter<(50 μs + 10% of pulse width), typical, A_{CQIN} Readings = OFF.**Maximum Pulse Duty Cycle**

10% for 20 V and lower ranges, 5% for 100 V range.

Typical Pulse Performance (Best fixed range, 4W sense)

Source Value	Limit Range and Value	Load	Rise Time (10% to 90%)	Settling Time (1% of range)
100 V	10.5 A	10 Ω	300 μ s	520 μ s
100 V	1.05 A	200 Ω	180 μ s	320 μ s
20 V	10 A	2 Ω	150 μ s	340 μ s
10 A	105 V	10 Ω	300 μ s	700 μ s
7 A	7.35 V	1 Ω	120 μ s	360 μ s
5 A	10.5 V	2 Ω	110 μ s	280 μ s

Contact Check

Contact Check Speed <100 μ s for verification and notification

Resistance Settings	2 Ω	15 Ω	50 Ω
No contact check failure	<1.0 Ω	<10.0 Ω	<40.0 Ω
Always contact check failure	>6.0 Ω	>20.0 Ω	>60.0 Ω

Digitizer Characteristics

Maximum Resolution	18 bits.
Available Measurement Functions	Voltage, Current, Simultaneous Voltage and Current, Resistance, Power.
Sampling Rate ¹⁵	Programmable 1 k through 1 million samples per second.
Volatile Sample Memory with Timestamp	27.5 million.
Minimum Record Time	1 μ s.
Timestamp Resolution	1 ns with standard or full buffer style. 1 μ s with compact buffer style.
Maximum Record Length	5 million.
Range Selection	Fixed-range required for digitizer measurements.
Measurement Settling Time	Range and load dependent. Accuracy limited by settling time for 10 mA and lower current ranges.

Notes

¹⁵. Sample rate is not continuously adjustable. For valid discrete settings, see the Model 2461 Reference Manual.

Supplemental Characteristics

Maximum Output Power	1050 W pulse, 105 W DC, four quadrant source or sink operation.
Overrange	105% of range, source and measure.
Regulation	Voltage: Line: 0.01% of range. Load: 0.01% of range + 100 μ V. Current: Line: 0.01% of range. Load: 0.01% of range + 100 pA.

Source Limits

Voltage Source Current Limit Bipolar current limit set with single value. Min. 10% of range.

Current Source Voltage Limit Bipolar voltage limit set with single value. Min. 10% of range.

V/I-Limit Accuracy Add 0.3% of setting and $\pm 0.02\%$ of reading to base specification.

Overshoot

Voltage Source <0.1% typical. Step size = Full scale, resistive load, 20 V range, 10 mA I-limit).

Current Source <0.1% typical. Step size = 1 mA step, R_{Load} = 10 k Ω , 20 V range)

Range Change Overshoot	Overshoot into a fully resistive 100 kΩ load, 10 Hz to 20 MHz bandwidth, adjacent ranges: <250 mV typical.														
Output Settling Time	Time required to reach 0.1% of final value after command is processed and output slew: 20 V range, 100 mA I-limit: <200 μs typical.														
Maximum Slew Rate	1 V per μs, 100 V range, 100 mA limit into a 20 kΩ load (typical). 0.6 V per μs, 20 V range, 100 mA limit into a 20 kΩ load (typical).														
Over Voltage Protection	User selectable values, 5% ±0.5 V tolerance. Factory default = none.														
Voltage Source Noise	10 Hz to 20 MHz (RMS): <4.5 mV typical into a resistive load.														
Common Mode Voltage	250 V DC.														
Common Mode Isolation	>1 GΩ, <1000 pF.														
Noise Rejection (typical)	<table><tr><th>NPLC</th><th>NMRR</th><th>CMRR</th></tr><tr><td>0.01</td><td>—</td><td>60 dB</td></tr><tr><td>0.1</td><td>—</td><td>60 dB</td></tr><tr><td>1</td><td>60 dB</td><td>100 dB</td></tr></table>			NPLC	NMRR	CMRR	0.01	—	60 dB	0.1	—	60 dB	1	60 dB	100 dB
NPLC	NMRR	CMRR													
0.01	—	60 dB													
0.1	—	60 dB													
1	60 dB	100 dB													
Load Impedance	Normal Mode: 20 nF typical. High Capacitance Mode: Stable into 50 μF typical. High-C mode valid for ≥100 μA ranges.														
Maximum Voltage Drop Between Force and Sense Terminals	5 V.														
Maximum Sense Lead Resistance	1 MΩ for rated accuracy.														
Sense Input Impedance	>10 GΩ.														
Guard Offset Voltage	<300 μV, typical.														

System Measurement Speeds¹⁶

Reading Rates (readings/second) typical for 60 Hz (50 Hz), script (TSP®) programmed

NPLC	Trigger Origin	Measure to Memory	Measure to GPIB/USB/LAN	Source-Measure to Memory	Source-Measure to GPIB/USB/LAN
0.01	Internal	3050 (2800)	2800 (2500)	1700 (1600)	1650 (1550)
0.01	External	2300 (2100)	2150 (2000)	1650 (1550)	1600 (1450)
0.1	Internal	540 (460)	530 (450)	470 (410)	470 (400)
0.1	External	500 (420)	500 (420)	460 (390)	450 (350)
1	Internal	59 (49)	59 (49)	58 (48)	58 (48)
1	External	58 (48)	58 (48)	57 (48)	57 (46)

Reading Rates (readings/second) typical for 60 Hz (50 Hz), SCPI programmed

NPLC	Trigger Origin	Measure to Memory	Measure to GPIB/USB/LAN	Source-Measure to Memory	Source-Measure to GPIB/USB/LAN
0.01	Internal	3000 (2800)	3000 (2790)	1700 (1600)	1550 (1500)
0.01	External	2330 (2150)	2330 (2150)	1650 (1550)	1500 (1450)
0.1	Internal	540 (460)	540 (460)	470 (410)	460 (400)
0.1	External	510 (430)	510 (430)	470 (400)	460 (390)
1	Internal	59 (49)	59 (49)	58 (48)	58 (48)
1	External	58 (49)	58 (49)	58 (48)	58 (48)

Notes

16. Reading rates applicable for voltage or current measurements, autozero off, autorange off, filter off, binary reading format, and source readback off.

Digitize, Typical

Sampling Rate	Digits	Resolution, Bits	Measure to USB
10 kS/s	5½	18	Up to 10 kS/s
20 kS/s	4½	16	Up to 20 kS/s
50 kS/s	4½	16	Up to 50 kS/s
100 kS/s	4½	15	Up to 100 kS/s
1 MS/s	3½	12	At least 100 kS/s

SCPI Programmed. Buffer style is compact.

General Characteristics (default mode unless specified)

Factory Default Standard Power-Up	SCPI Mode.
Source Output Modes	Fixed DC Level, Memory/Configuration List (mixed function), Sweep (linear and logarithmic), Sweep (dual linear and dual logarithmic).
Memory Buffer	>2 million readings, user adjustable. Includes selected measured values and timestamp.
Real-Time Clock	Lithium battery backup (3 yr.+ battery life).
Remote Interfaces	
GPIOB	IEEE-488.2.
USB Device (rear panel, type B)	2.0 Full Speed USBTMC.
USB Device (front panel, type A)	USB 2.0, support for thumb drives.
Ethernet	RJ-45 (10/100BT)
Digital I/O Interface	
Lines	6 Input/Output user defined for digital I/O or triggering.
Connector	9-pin female D.
Input Signal Levels	0.7 V (maximum logic low), 3.7 V (minimum logic high).
Input Voltage Limits	-0.25 V (absolute minimum), +5.25 V (absolute maximum).
Maximum Source Current	+2.0 mA @ >2.7 V (per pin).
Maximum Sink Current	-50 mA @ 0.7 V (per pin, solid-state fuse protected).
5 V Power Supply Pin	Limited to 500 mA @ >4 V (solid-state fuse protected).
Handler Interface	Start of test, end of test, 4 category bits.
Programmability	SCPI or TSP command sets.
TSP Mode	Embedded Test Script Processor (TSP) accessible from any host interface.
IP Configuration	Static or DHCP.
Expansion Interface	The TSP-Link expansion interface allows TSP enabled instruments to trigger and communicate with each other.
LXI Compliance	1.5 LXI Device Specification 2016.
Display	5 inch capacitive touch, color TFT WVGA (800×480) with LED backlight.
Input Signal Connections	Front: Banana. Rear: Mass termination screw terminal.
Interlock	Active High Input.
Cooling	Forced air, variable speed.
Over Temperature Protection	Internally sensed temperature overload puts unit in standby mode.
Power Supply	100 V to 240 V RMS, 50–60 Hz (automatically detected at power up).

VA Rating	350 volt-amps maximum.
Altitude	Maximum 2000 meters above sea level.
EMC	Conforms to European Union EMC Directive.
Safety	Compliance with CE and NRTL listed to UL61010-1 and UL61010-2-30. Conforms with European Union Low Voltage Directive.
Vibration	MIL-PRF-28800F Class 3 Random.
Warm-Up	1 hour to rated accuracies.
Dimensions	With bumpers and handle: 106 mm high × 255 mm wide × 425 mm deep (4.18 in × 10.05 in × 16.75 in). Without bumpers and handle: 88 mm high × 213 mm wide × 397 mm deep (3.46 in × 8.39 in × 15.63 in).
Weight	With bumpers and handle: 4.75 kg (10.5 lbs.). Without bumpers and handle: 4.55 kg (10.0 lbs.).
Environment	For indoor, non-residential use only Operating: 0° to 50 °C, 70% relative humidity up to 35 °C. Derate 3% relative humidity/°C, 35° to 50 °C. Storage: -25 °C to 65 °C.

Ordering Information

2461	100 V, 10 A, 1000 W SourceMeter Instrument
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Supplied Accessories

2460-KIT	Rear Panel Mating Mass Termination Screw Connector
CS-1616-3	Safety Interlock Mating Connector
17469460X	TSP-Link/Ethernet Cable
CA-432A	USB 2.0 Type A Male to Type B Male Cable
012173001	Safety Clip On Test Lead Set
	Documentation available at tek.com
	2461 QuickStart Guide
	TSP Toolkit Software (available at tek.com)
	LabVIEW and IVI Drivers (available at tek.com)

Available Accessories

Test Leads and Probes

5805	Kelvin (4-Wire) Spring-Loaded Probes
5808	Low Cost Single-pin Kelvin Probe Set

Cables, Connectors, Adapters

2460-BAN	Screw Terminal Connector to Banana Cable
2460-KIT	Mating Mass Termination Connector
CS-1616-3	Safety Interlock Mating Connector

Communication Interfaces & Cables

7007-1	Shielded GPIB Cable, 1 m (3.3 ft)
KPCI-488LPA	IEEE-488 Interface for PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

Rack Mount Kits

4299-8	Single Fixed Rack Mount Kit
4299-9	Dual Fixed Rack Mount Kit

Software Options

I-V Tracer	Graphical SMU Curve Tracer Software
Kickstart	Instrument Control Software

Available Services

2461-3Y-EW	1 Year Factory Warranty extended to 3 years from date of shipment
2461-5Y-EW	1 Year Factory Warranty extended to 5 years from date of shipment
C/2461-3Y-17025	KeithleyCare® 3 Year ISO 17025 Calibration Plan
C/2461-3Y-DATA	KeithleyCare 3 Year Calibration w/Data Plan
C/2461-3Y-STD	KeithleyCare 3 Year Std. Calibration Plan
C/2461-5Y-17025	KeithleyCare 5 Year ISO 17025 Calibration Plan
C/2461-5Y-DATA	KeithleyCare 5 Year Calibration w/Data Plan
C/2461-5Y-STD	KeithleyCare 5 Year Std. Calibration Plan
C/NEW DATA	Calibration Data for New Units
C/NEW DATA ISO	ISO-17025 Calibration Data for New Units

Warranty Information

Warranty Summary	This section summarizes the warranties of the 2461. For complete warranty information, refer to the Tektronix warranty page at www.tek.com/service/warranties/warranty-2 . Any portion of the product that is not manufactured by Keithley is not covered by this warranty and Keithley will have no duty to enforce any other manufacturer's warranties.
Hardware Warranty	Keithley Instruments, Inc. warrants the Keithley manufactured portion of the hardware for a period of one year from defects in materials or workmanship; provided that such defect has not been caused by use of the Keithley hardware which is not in accordance with the hardware instructions. The warranty does not apply upon any modification of Keithley hardware made by the customer or operation of the hardware outside the environmental specifications.
Software Warranty	Keithley warrants for the Keithley produced portion of the software or firmware will conform in all material respects with the published specifications for a period of ninety (90) days; provided the software is used on the product for which it is intended in accordance with the software instructions. Keithley does not warrant that operation of the software will be uninterrupted or error-free, or that the software will be adequate for the customer's intended application. The warranty does not apply upon any modification of the software made by the customer.

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05182026 KEI1KW-60288-3



2470 Graphical SourceMeter SMU Instrument

DATASHEET



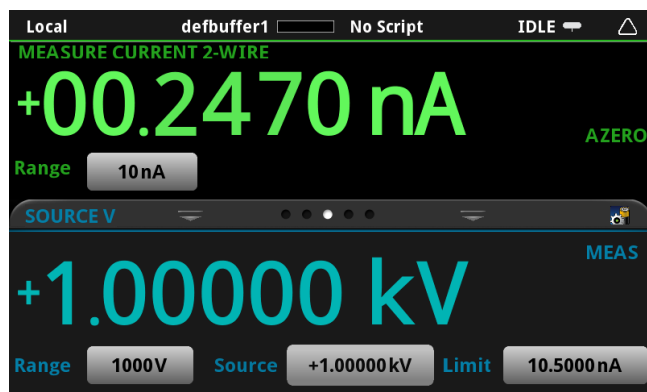
The 2470 High Voltage SourceMeter® Source Measure Unit (SMU) Instrument brings advanced Touch, Test, Invent® technology right to your fingertips. It combines an innovative graphical user interface (GUI) with capacitive touchscreen technology to make testing intuitive and minimize the learning curve to help engineers and scientists learn faster, work smarter, and invent easier. With its 1100 V and 10 fA capability, the 2470 is optimized for characterizing and testing high voltage, low leakage devices, materials, and modules, such as silicon carbide (SiC), gallium nitride (GaN), power MOSFETs, transient suppression devices, circuit protection devices, power modules, batteries, and much more. These new capabilities, combined with Keithley's decades of expertise in developing high precision, high-accuracy SMU instruments, make the 2470 a "go-to instrument" for high-voltage source and low-current measurement applications in the lab and in the test rack.

Key Features

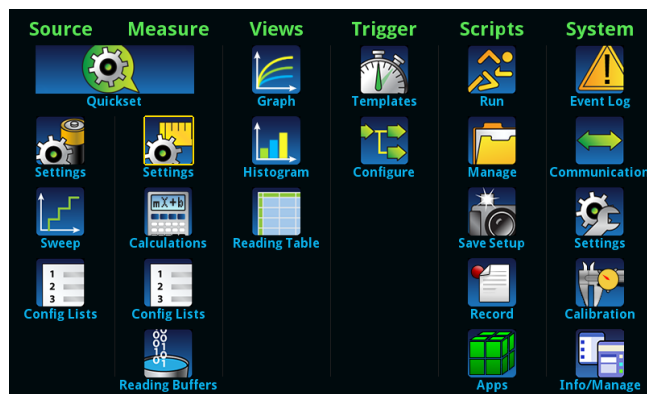
- Wide coverage up to 1100 V / 1 A DC, 20 W maximum
- 10 fA measure resolution
- 0.012% basic measure accuracy with 6½-digit resolution
- Five-inch, high resolution capacitive touch screen GUI
- Source and sink (4-quadrant) operation
- SCPI and TSP® scripting programming modes
- TSP-Link for multi-channel I-V testing
- Front panel input banana jacks; rear panel high-voltage input triaxial connections
- Built-in context-sensitive help
- Front-panel USB 2.0 memory I/O port for transferring data, test scripts, and test configurations

Learn Faster; Work Smarter; Invent Easier

The 2470 features a five-inch, full-color, high resolution touchscreen that supports intuitive operation, helps operators become familiar with the instrument quickly, and optimizes overall speed and productivity. A simple icon-based menu structure reduces the number of steps required to configure a test by as much as 50 percent and eliminates the cumbersome multi-layer menu structures typically used on soft-key instruments. Built-in, context-sensitive help supports intuitive operation and minimizes the need to review a separate manual. These capabilities, combined with the 2470's high versatility, simplify its operation in both basic and advanced measurement applications, regardless of the user's previous experience in working with SMU instruments.



2470 main home screen.

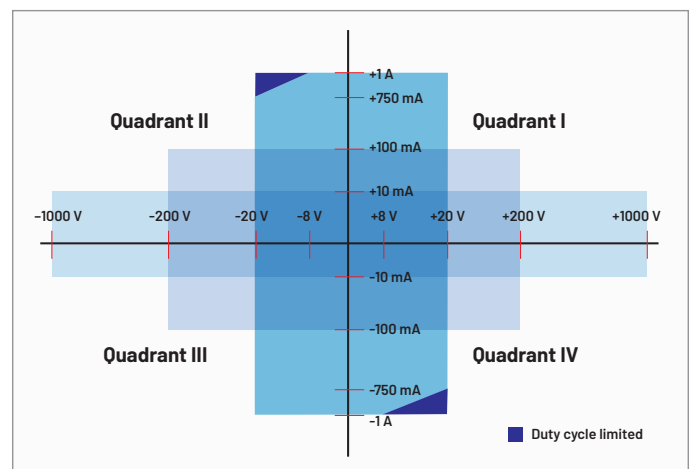


2470 icon-based menu.

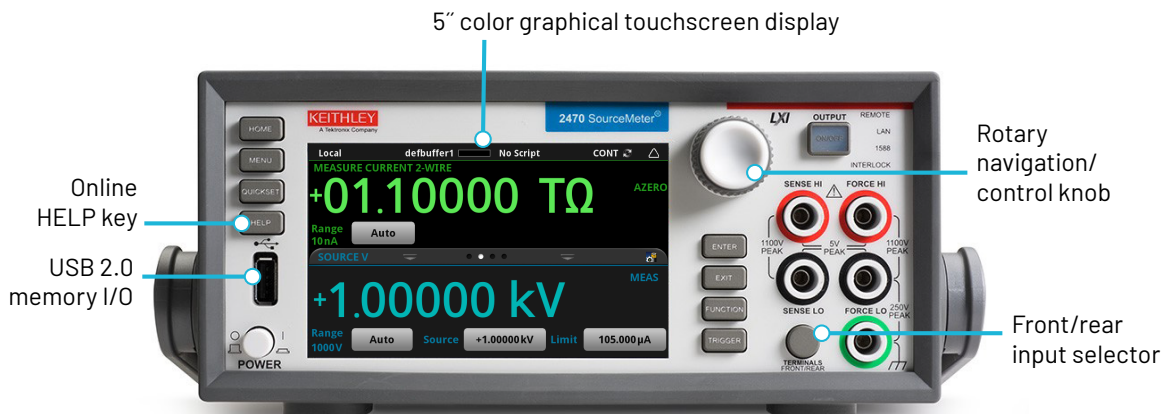
All-in-One SMU Instrument

The 2470, Keithley's fourth generation of SourceMeter SMUs, leverages the proven capabilities of the original 2410 High Voltage SourceMeter SMU Instrument. SMU instruments offer a highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current measurements. This all-in-one instrument has the capabilities of a:

- Precision power supply with V and I readback
- True current source
- Digital multimeter (DCV, DCI, ohms, and power with 6½-digit resolution)
- Precision electronic load
- Trigger controller



2470 power envelope.



2470 front panel with high-resolution, capacitive touchscreen.

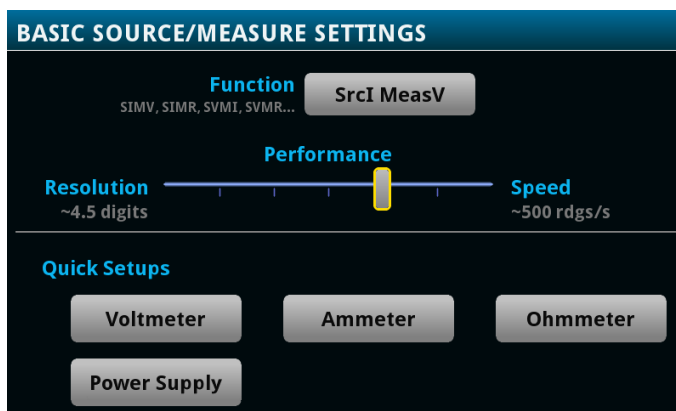
Ease of Use Beyond the Touchscreen

In addition to its five-inch color touchscreen, the 2470 front panel offers a variety of features that enhance its speed, user-friendliness, and learnability, including a USB 2.0 memory I/O port, a HELP key, a rotary navigation/control knob, a front/rear input terminal selector button, and banana jacks for basic bench applications. The USB 2.0 memory port simplifies storing test results and instrument configurations, uploading test scripts into the instrument, and installing system upgrades. All front-panel buttons are backlit to enhance visibility in low-light environments.

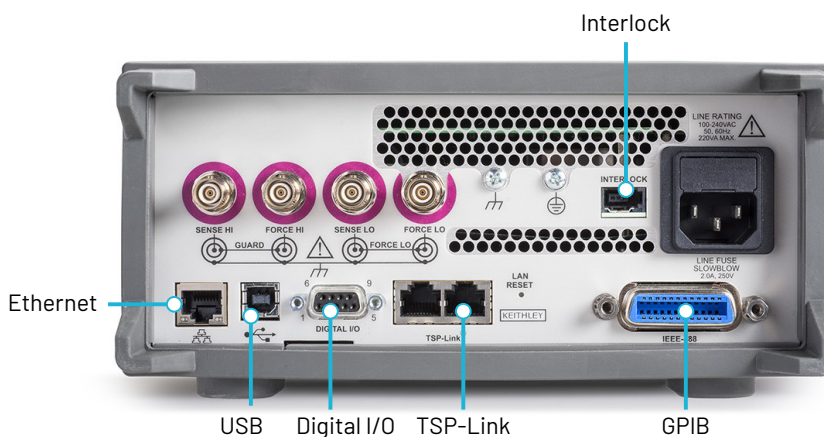
Four Quick Setup modes simplify instrument setup. With one touch, the instrument can be quickly configured for various operating modes without the need to configure the instrument indirectly for this operation.

Comprehensive Built-in Connectivity

Rear panel access to rear-input connectors, remote control interfaces (GPIB, USB 2.0, and LXI/Ethernet), a D-sub 9-pin digital I/O port (for internal/external trigger signals and handler control), instrument interlock connector, and TSP-Link® connectors make it simple to configure multiple instrument test solutions and eliminate the need to invest in additional adapter accessories.



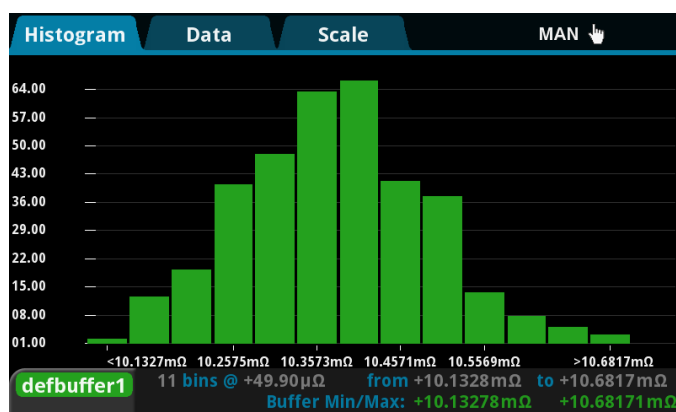
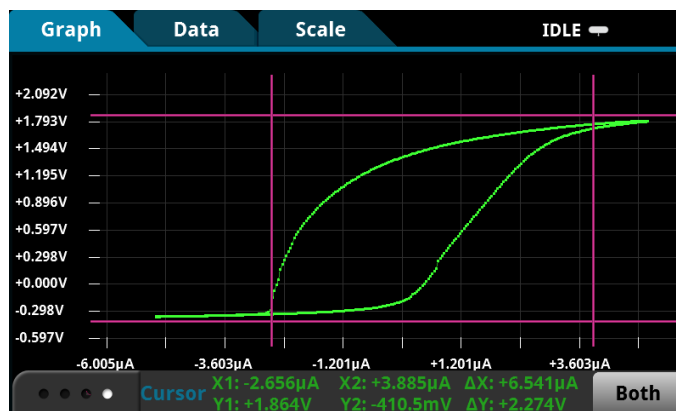
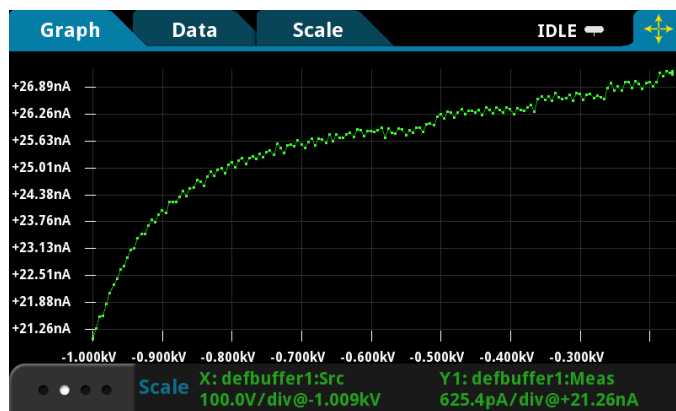
One-touch Quickset modes speed measurement setups and minimize the time to measurements.



Rear panel connections are optimized for signal integrity and speed system setup.

Convert Raw Data to Information

A full graphical plotting window converts raw data and displays it immediately as useful information, such as semiconductor I-V curves and waveforms. Using the 2470's Sheet view, test data can also be displayed in tabular form. The instrument supports exporting data to a spreadsheet for further analysis, dramatically improving productivity for research, benchtop testing, device qualification, and debugging.



READING TABLE

Buffer Active (defbuffer1)

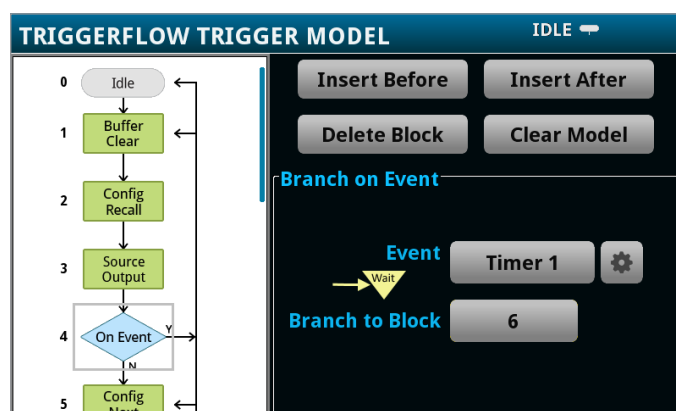
Buffer Index	Time	Reading	Source
182	05/17 02:03:01.706949	+0.02370 μA	-0.914992 kV
183	05/17 02:03:01.794075	+0.02366 μA	-0.919999 kV
184	05/17 02:03:01.881199	+0.02340 μA	-0.924986 kV
185	05/17 02:03:01.968317	+0.02335 μA	-0.929993 kV
186	05/17 02:03:02.055452	+0.02330 μA	-0.935001 kV
187	05/17 02:03:02.142584	+0.02309 μA	-0.939991 kV
188	05/17 02:03:02.229710	+0.02306 μA	-0.945001 kV
189	05/17 02:03:02.316844	+0.02283 μA	-0.950005 kV
190	05/17 02:03:02.403972	+0.02261 μA	-0.954990 kV
191	05/17 02:03:02.491093	+0.02261 μA	-0.959997 kV

Built-in data display, charting, and spreadsheet export functions simplify converting test results into useful information.

TriggerFlow® Building Blocks for Instrument Control and Execution

The 2470 incorporates Keithley's TriggerFlow triggering system, which provides user control of instrument execution. TriggerFlow diagrams are created in much the same way that flow charts are developed, using four building blocks:

- Wait – Waits for an event to occur before the flow continues
- Branch – Branches when a condition has been satisfied
- Action – Initiates an action in the instrument, for example, measure, source, delay, set digital I/O, etc.
- Notify – Notifies other equipment that an event has occurred



TriggerFlow building blocks allow you to create triggering models that range from very simple to highly complex.

A TriggerFlow model using a combination of these building blocks can be created from the front panel or by sending remote commands. With the TriggerFlow system, users

can build triggering models from very simple to complex with up to 63 block levels. The 2470 also includes basic triggering functions, including immediate, timer, and manual triggering.

Unmatched System Integration and Programming Flexibility

When a 2470 is configured into a multi-channel I-V test system, its embedded Test Script Processor (TSP) allows it to run test scripts, so users can create powerful measurement applications with significantly-reduced development times. TSP technology also offers channel expansion without a mainframe. Keithley's TSP-Link channel expansion bus can connect multiple 2470s and other TSP instruments, including Keithley's other graphical SourceMeter instruments (2450, 2460, 2461), Keithley's DMM7510, DMM6500, and DAQ6510 graphical multimeters, Series 2600B System SourceMeter SMU instruments, and Series 3700A Switch/Multimeter systems, in a master-subordinate configuration that operates as one integrated system. The TSP-Link expansion bus supports up to 32 units per GPIB or IP address, making it easy to scale a system to fit an application's particular requirements.

Parallel Test Capability

The TSP technology in the 2470 supports testing multiple devices in parallel to meet the needs of device research, advanced semiconductor lab applications, and even high throughput production test. This parallel testing capability

Typical Applications

Ideal for current/voltage characterization and functional test of a wide range of today's modern electronics and devices, including:

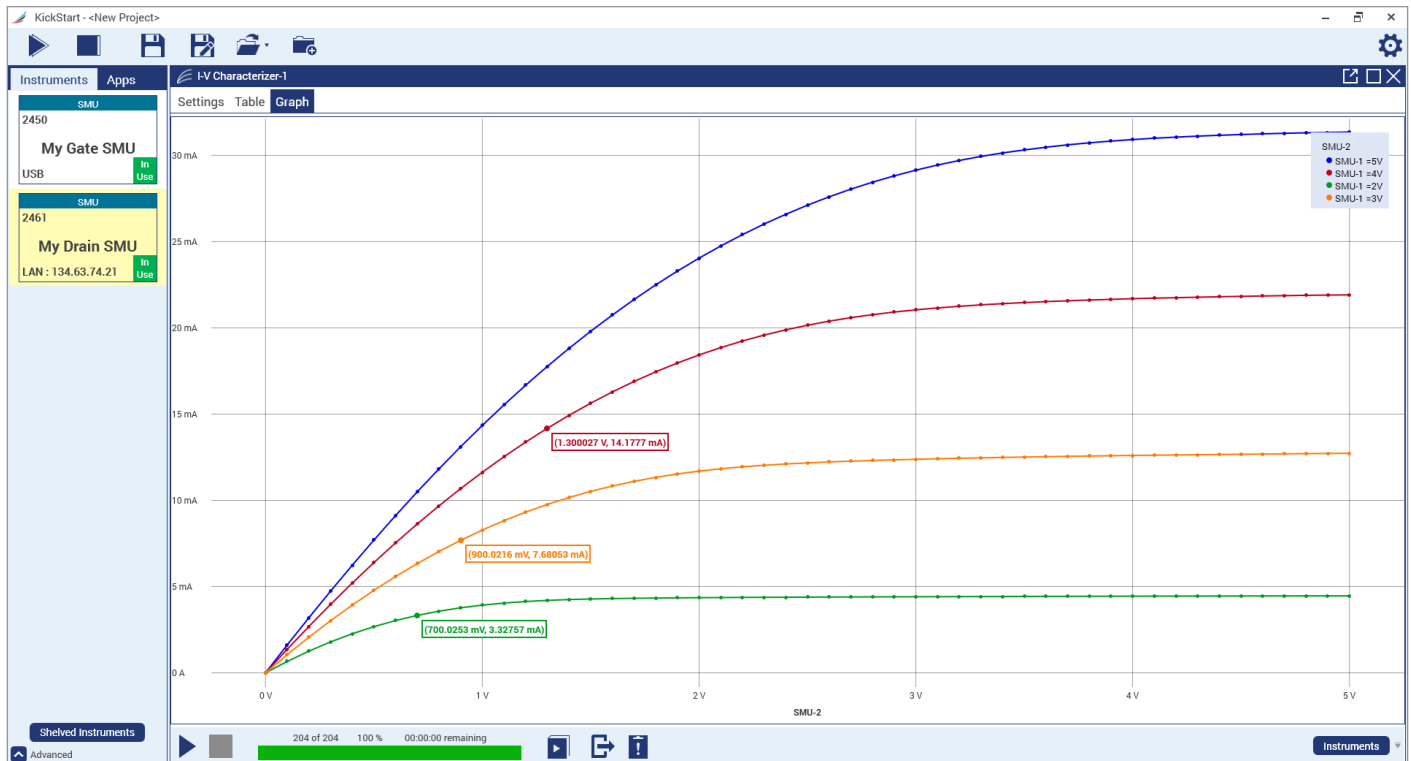
- Devices
 - Power semiconductors and materials: SiC, GaN, power MOSFETs, power diodes
 - IGBT
 - Thyristors, SCRs
 - Transient suppression devices
 - Circuit protection devices: TVS, MOVs, fuses, etc.
 - Connectors, switches, relays
 - Power management modules
 - Batteries
- Tests
 - I-V characterization
 - Forward voltage
 - Breakdown voltage
 - Leakage current
 - Isolation
 - Hi-Pot
 - Dielectric withstanding



Characterize transistors with multiple SMU instruments on wafer or packaged transistors



The 2470 is the ideal addition to your development bench for designing today's high power devices and components.



KickStart start-up software lets users be ready to make measurements in minutes.

allows each instrument in the system to run its own complete test sequence, creating a fully multi-threaded test environment. The number of tests that can be run in parallel on a graphical SourceMeter can be as high as the number of instruments in the system.

Instrument Control Start-up Software

KickStart instrument control/start-up software enables users to start making measurements in minutes without programming. In most cases, users merely need to make some quick measurements, graph the data, and store the data to disk for later analysis in software environments such as Excel. KickStart offers:

- Configure and control up to four SMU instruments for DC or Pulsed I-V test in either the same app, same project, or a combination of the two.
- Create tests by mixing any of these SMU instruments: 2400 Graphical Series, 2400 Standard Series (DC only), 2600B Series, 2651A, 2657A, and 6430 SourceMeter SMU (DC only) instruments.

- Differentiate SMU instrument channels and their measurement data using labels that are relevant to your device or module.
- Native X-Y graphing, panning, and zooming; screenshot capturing of graphs.
- Spreadsheet/tabular viewing of data; export data for further analysis.
- Annotating of tests; save test setups.
- GPIB, USB 2.0, Ethernet compliance.

Optional Apps Tailored for your Characterization Needs

The 2470 is an excellent tool to define nearly any DC test you choose for characterizing materials, electronic devices and modules. For more specific needs, Keithley offers on-instrument software apps that alter the 2470's behavior, fitting your instrument to your needs. These apps can be installed directly to your 2470 by connecting to Keithley's KickStart instrument control software and opening the relevant app in KickStart.

I-V Tracer App

Curve tracing analysis is a critical task for many users in the semiconductor development supply chain. Engineers and technicians both hold the traditional curve tracer as the simplest, fastest method for generating characteristic I-V curves on a device. They are heavily used by engineers in failure analysis and incoming inspection to qualify parts, identify counterfeit devices, and to quickly identify the location of a failure on damaged devices. SMUs have typically been limited to predefined sweeps with longer set up times than curve tracers – until I-V Tracer.

Keithley's I-V Tracer app leverages the touchscreen and front-panel knob of the 2470 to allow precise, live control over the SMU output while viewing I-V results of 2 terminal devices. At each individual output level current and voltage are measured and plotted. The small footprint of the SMU enables portable benchtop use, reserving high power (kW) traditional curve tracers for special cases. The power envelope of the 2470 allows it to comfortably operate in the low power range of traditional curve tracers like the Tektronix 576 and Tektronix 370A, while offering enhanced low current measurements.



I-V Tracer home screen

Once installed, I-V Tracer exists on the SMU itself, meaning I-V tracer can be used wherever your SMU can go, without a continuous remote connection. It can also integrate with KickStart to enable simple data collection and comparison on the PC, simplifying the preparation of reports used in failure analysis or teaching labs at colleges and universities.

I-V Tracer capabilities with the 2470:

- Use the full power envelope of the 2470 (max 1000 V or 1 A)
- 1000 V range allows careful tracing into reverse breakdown behavior
- Trace by sourcing voltage or current, positive or negative
- 2 or 4-wire sense
- Compare mode for verifying against a reference device
- Reading table view to see exact measurements
- Easily copy curves and settings to your PC with KickStart

Simplified Programming with Ready-to-Use Instrument Drivers

For those who prefer to create their own customized application software, native National Instruments LabVIEW® drivers, and IVI-C and IVI-COM drivers are available at tek.com.

Specifications

Voltage Specifications^{1, 2}

Range ⁴	Source			Measure ³		
	Resolution	Accuracy ⁵ 23 °C ± 5 °C, 1 Year ±(% setting + volts)	Noise (RMS) <10 Hz	Resolution	Input Resistance	Accuracy 23 °C ± 5 °C, 1 Year ±(% reading + volts)
200.0000 mV	5 µV	0.015% + 200 µV	2 µV	100 nV	> 10 GΩ	0.012% + 200 µV
2.000000 V	50 µV	0.020% + 300 µV	10 µV	1 µV	> 10 GΩ	0.012% + 300 µV
20.00000 V	500 µV	0.015% + 2.4 mV	100 µV	10 µV	> 10 GΩ	0.015% + 1 mV
200.0000 V	5 mV	0.015% + 24 mV	1 mV	100 µV	> 10 GΩ	0.015% + 10 mV
1000.000 V	50 mV	0.02% + 100 mV	20 mV	10 mV	> 10 GΩ	0.015% + 50 mV

Temperature Coefficient

20 V and 1000 V ranges: $\pm(0.15 \times \text{accuracy specification})/^{\circ}\text{C}$, 0 °C to 18 °C and 28 °C to 50 °C.
200 mV and 2 V ranges: $\pm(0.30 \times \text{accuracy specification})/^{\circ}\text{C}$, 0 °C to 18 °C and 28 °C to 50 °C.

Current Specifications^{1, 2}

Range ⁴	Source			Measure ³		
	Resolution	Accuracy ⁵ 23 °C ± 5 °C, 1 Year ±(% setting + amps)	Noise (RMS) <10 Hz	Resolution	Voltage Burden	Accuracy 23 °C ± 5 °C, 1 Year ±(% reading + amps)
10.00000 nA ⁶	500 fA	0.100% + 200 pA	500 fA	10 fA	< 100 µV	0.10% + 250 pA
100.0000 nA ⁶	5 pA	0.060% + 250 pA	500 fA	100 fA	< 100 µV	0.060% + 300 pA
1.000000 µA	50 pA	0.025% + 400 pA	5 pA	1 pA	< 100 µV	0.025% + 300 pA
10.00000 µA	500 pA	0.025% + 1.5 nA	40 pA	10 pA	< 100 µV	0.025% + 700 pA
100.0000 µA	5 nA	0.020% + 15 nA	400 pA	100 pA	< 100 µV	0.02% + 6 nA
1.000000 mA	50 nA	0.020% + 150 nA	5 nA	1 nA	< 100 µV	0.02% + 60 nA
10.00000 mA	500 nA	0.020% + 1.5 µA	40 nA	10 nA	< 100 µV	0.02% + 600 nA
100.0000 mA	5 µA	0.025% + 15 µA	100 nA	100 nA	< 100 µV	0.025% + 6 µA
1.000000 A	50 µA	0.067% + 900 µA	10 µA	1 µA	< 100 µV	0.03% + 500 µA

Temperature Coefficient

$\pm(0.15 \times \text{accuracy specification})/^{\circ}\text{C}$, 0 °C to 18 °C and 28 °C to 50 °C

Notes

- Speed = 1 PLC.
- All specifications are guaranteed with output ON.
- Accuracies apply to 2-wire and 4-wire modes when properly zeroed. For the 200 mV and 1 A ranges, the voltage burden may exceed the specification in 2-wire mode.
- Maximum display and programming ranges are 5% overrange for voltage, except for the 1000 V range, which is 10% overrange (1100 V), and 5% overrange for current (for example, 1.05 A on the 1 A range).
- For sink mode, 1 µA to 100 mA range, accuracy is $\pm(0.5\% + \text{offset} \times 3)$. For 1 A range, accuracy is $\pm(0.15 \times \text{accuracy specification})/^{\circ}\text{C}$ on 20 V and 1000 V ranges $\pm(1.5\% + \text{offset} \times 3)$.
- Rear-panel triaxial connections only.

Resistance Measurement Accuracy (Local Or Remote Sense)^{7, 8, 9}

Range	Default Resolution ¹⁰	Default Test Current	Normal Accuracy 23 °C ± 5 °C, 1 Year ± (% reading + ohms)	Enhanced Accuracy ¹¹ 23 °C ± 5 °C, 1 Year ± (% reading + ohms)
< 2.000000 Ω ¹²	1 μΩ	User-defined	Source I _{ACC} + Meas V _{ACC}	Meas I _{ACC} + Meas V _{ACC}
20.00000 Ω	10 μΩ	100 mA	0.098% + 0.003 Ω	0.073% + 0.001 Ω
200.0000 Ω	100 μΩ	10 mA	0.077% + 0.03 Ω	0.053% + 0.01 Ω
2.000000 kΩ	1 mΩ	1 mA	0.066% + 0.3 Ω	0.045% + 0.1 Ω
20.00000 kΩ	10 mΩ	100 μA	0.063% + 3 Ω	0.043% + 1 Ω
200.0000 kΩ	100 mΩ	10 μA	0.065% + 30 Ω	0.046% + 10 Ω
2.000000 MΩ	1 Ω	1 μA	0.11% + 300 Ω	0.049% + 100 Ω
20.00000 MΩ	10 Ω	1 μA	0.11% + 1 kΩ	0.052% + 500 Ω
200.0000 MΩ ¹³	100 Ω	100 nA	0.655% + 10 kΩ	0.349% + 5 kΩ
> 200.0000 MΩ ^{12, 13}	—	User-defined	Source I _{ACC} + Meas V _{ACC}	Meas I _{ACC} + Meas V _{ACC}

Temperature Coefficient ±(0.15 × accuracy specification)/°C 0 °C to 18 °C and 28 °C to 50 °C

Source Current, Measure Resistance Mode

Total uncertainty = I source accuracy + V measure accuracy (4-wire remote sense)

Source Voltage, Measure Resistance Mode

Total uncertainty = V source accuracy + I measure accuracy (4-wire remote sense)

Guard Output Impedance ≥ 300 Ω typical

Notes

7. Speed = 1 PLC.
 8. All specifications are guaranteed with output ON.
 9. Accuracies apply to 2-wire and 4-wire modes when properly zeroed.
 10. Measure resolution 6.5 digits.
 11. Source readback enabled; offset compensation on.
 12. Source current, measure resistance or source voltage, measure resistance only.
 13. Rear-panel triaxial connections only.

Supplemental Specifications

Overrange 105% of range for 200 mV to 200 V, source and measure ranges; 110% of range for 1000 V, source and measure ranges

Regulation

Voltage	Line: 0.01% of range Load: 0.01% of range + 100 μV
Current	Line: 0.01% of range Load: 0.01% of range + 100 pA

Source Limits

Voltage Source Current Limit	Bipolar current limit set with a single value Minimum value is 10% of range
Current Source Voltage Limit	Bipolar voltage limit set with a single value Minimum value is 10% of range

Voltage Limit/Current Limit Accuracy

Add 0.3% of range and ±0.02% of reading to base specification

Overshoot

Voltage Source	< 0.1% typical Step size = Full scale, resistive load, 20 V range, 10 mA current limit
Current Source	< 0.1% typical Step size = Full scale, resistive load of 10 kΩ, 1 mA range, 20 V voltage limit

Range Change Overshoot	Overshoot into a fully resistive 100 kΩ load, 10 Hz to 20 MHz bandwidth, adjacent ranges: 250 mV typical
Output Settling Time	Time required to reach 0.1% of final value after command is processed and output slew: 20 V range, 100 mA current limit: < 200 μs typical
Maximum Slew Rate¹⁴	0.2 V/μs, 200 V range, 100 mA limit into a 2 kΩ load (typical) 0.5 V/μs, 1000 V range, 10 mA limit into a 100 kΩ load (typical)
Overvoltage Protection	User-selectable values, 10% tolerance; factory default = none
Voltage Source Noise	10 Hz to 20 MHz (RMS): 4 mV typical into a resistive load
Common Mode Voltage	250 V DC
Common Mode Isolation	> 1 GΩ, < 1000 pF

Notes

14. High capacitance mode off.

Noise Rejection (typical)

NPLC	NMRR	CMRR
0.01	—	60 dB
0.1	—	60 dB
1	60 dB	100 dB*
* Except 10 nA and 100 nA current ranges ~90 dB		

Load Impedance**Normal Mode** 20 nF typical**High-Capacitance Mode** Stable into 1 μF typical (specification only valid for ranges ≥100 μA)**Maximum Voltage Drop Between Force and Sense Terminals**
5 V**Maximum Sense Lead Resistance** 1 MΩ for rated accuracy**Sense Input Impedance** > 10 GΩ**Guard Offset Voltage** < 300 μV typical**System Measurement Speeds¹⁵****Reading rates (readings per second) typical for 60 Hz (50 Hz), script (TSP) programmed**

NPLC	Trigger Origin	Measure to Memory	Measure to GPIB	Measure to USB	Measure to LAN	Source Measure Sweep to Memory	Source measure sweep to GPIB	Source Measure Sweep to USB	Source Measure Sweep to LAN
0.01	Internal	3150(2800)	2760(2570)	2825(2570)	2740(2530)	1710(1620)	1620(1540)	1630(1540)	1620(1540)
0.01	External	2170(2050)	2120(2003)	2170(2010)	2100(1990)	1670(1590)	1580(1500)	1590(1510)	1580(1510)
0.10	Internal	540(460)	530(450)	530(450)	530(450)	470(410)	460(400)	470(400)	470(400)
0.10	External	500(430)	490(420)	500(425)	480(420)	450(400)	460(390)	460(390)	410(350)
1.00	Internal	59(49)	58(49)	59(49)	59(49)	58(48)	58(48)	58(48)	57(48)
1.00	External	58(48)	57(48)	58(48)	58(48)	57(48)	57(48)	57(48)	55(48)

Reading rates (readings per second) typical for 60 Hz (50 Hz), SCPI programmed¹⁶

NPLC	Trigger Origin	Measure to Memory	Measure to GPIB	Measure to USB	Measure to LAN	Source Measure Sweep to memory	Source Measure Sweep to GPIB	Source Measure Sweep to USB	Source Measure Sweep to LAN
0.01	Internal	3040(2800)	3000(2760)	3000(2760)	3010(2710)	1710(1630)	1610(1544)	1440(1380)	1690(1590)
0.01	External	2320(2165)	2290(2140)	2340(2150)	2290(2130)	1680(1590)	1560(1525)	1410(1360)	1660(1560)
0.10	Internal	540(460)	540(450)	540(460)	540(450)	470(410)	470(410)	450(390)	470(410)
0.10	External	510(440)	510(430)	510(440)	510(430)	470(400)	470(400)	450(390)	470(400)
1.00	Internal	59(49)	59(49)	59(49)	59(49)	58(48)	58(48)	57(48)	58(48)
1.00	External	58(49)	58(49)	58(49)	58(49)	58(48)	58(48)	57(47)	58(48)

Notes

15. Reading rates applicable for voltage or current measurements, autozero off, autorange off, filter off, binary reading format, and source readback off.

16. SCPI programming mode.

General Characteristics

(Default mode unless specified)

Factory Default Standard Power-Up Setting

SCPI mode

Source Output Modes

Fixed DC level
Memory/configuration list (mixed function)
Stair (linear and logarithmic)

Memory Buffer

>5,000,000 readings with selected measured values and timestamp

Real-Time Clock

Lithium battery backup (more than 3 years of battery life)

Remote Interfaces

GPIB: IEEE Std 488.1 compliant; supports IEEE Std 488.2 common commands and status model topology

USB device (rear panel, type B): 2.0 full-speed USBTMC

USB host (front panel, type A): USB 2.0, support for flash drives, FAT32

Ethernet: RJ-45 connector, 10/100 BT

IP Configuration

Static or DHCP

Expansion Interface

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

LXI Compliance

1.5 LXI Device Specification 2016

TSP Mode

Embedded Test Script Processor (TSP) accessible from any host interface

Display

Five-inch capacitive touch, color TFT WVGA (800 × 480) with LED backlight

Input Signal Connections

Front: Banana. **Rear:** High-voltage triaxial

Programmability

SCPI or TSP command sets

Interlock

Active high-input

Digital I/O	Lines: Six input/output, user-defined, for digital I/O or triggering Connector: 9-pin female D Input Signal Levels: 0.7 V (maximum logic low), 3.7 V (minimum logic high) Input Voltage Limits: -0.25 V (absolute minimum), +5.25 V (absolute maximum) Maximum Source Current: +2.0 mA at > 2.7 V (per pin) Maximum Sink Current: -50 mA at 0.7 V (per pin, solid-state fuse protected) 5 V Power Supply Pin: Limited to 500 mA at > 4 V (solid-state fuse protected) Handler: User-definable start of test, end of test, four category bits
Cooling	Forced air, variable speed
Overtemperature Protection	Internally sensed temperature overload puts instrument in standby mode
Power Supply	100 VRMS to 240 VRMS, 50 Hz or 60 Hz (automatically detected at power up)
VA Rating	220 VA maximum
Altitude	Maximum 2000 meters (6562 feet) above sea level
EMC	Conforms to European Union EMC Directive
Safety	NRTL listed to UL61010-1 and UL61010-2-30; conforms to European Union Low Voltage Directive
RoHS	Conforms to European Union Restriction on Hazardous Substances Directive
Vibration	MIL-PRF-28800F Class 3 Random
Warm up	One hour to rated accuracies
Dimensions	With handle and bumpers: 106 mm × 255 mm × 425 mm (4.18 in. high × 10.05 in. wide × 16.75 in. deep) Without handle and bumpers: 88 mm × 213 mm × 403 mm (3.46 in. high × 8.39 in. wide × 15.87 in. deep)
Weight	With handle and bumpers: 4.54 kg (10 lb) Without handle and bumpers: 4.08 kg (9.0 lb)
Environment	For indoor, non-residential, use only. Operating: 0 °C to 50 °C, 70% relative humidity up to 35 °C; derate 3% relative humidity/°C, 35 °C to 50 °C Storage: -25 °C to 65 °C Pollution Category: 2

Ordering Information

2470	1000 V, 1 A, 20 W SourceMeter SMU Instrument
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Supplied Accessories

CS-1616-3	Safety Interlock Mating Connector
17469460X	TSP-Link/Ethernet Cable
CA-432A	USB 2.0 Type A Male to Type B Male Cable
012173001	Safety Clip On Test Lead Set
TRX-1100V-FFBARREL	3-Slot 1100 V Triax Female to Female Barrel Interconnect
TRX-1100V-FMFTEE	3-Slot 1100 V Triax Male to Dual Female Tee Adapter
TRX-1100V-FFFTEE	3-Slot 1100 V Triax Female to Dual Female Tee Adapter
TRX-1100V-TBC	3-Slot 1100 V Triax Female Bulkhead Connector
	2470 Quick Start Guide
	TSP Toolkit Software (available at tek.com)
	LabVIEW and IVI Drivers (available at tek.com)

Available Accessories

Cables, Connectors, Adapters

TRX-1100V-BAN	HV Triax to Banana Adapter. Converts the 4 triax connectors on the rear panel to 5 banana jacks
TRX-1100V-*	3-slot HV Low Noise Triax Cable (0.5 m, 1 m, 2 m, 3 m lengths available)
TRX-1100V-CONN	3-Slot HV Male Triax Cable Connector
TRX-1100V-PCBCONN	3-Slot HV Female Triax PC Board Mount Connector
TRX-1100V-FFBARREL	3-Slot 1100 V Triax Female to Female Barrel Interconnect
TRX-1100V-FMFTEE	3-Slot 1100 V Triax Male to Dual Female Tee Adapter
TRX-1100V-FFFTEE	3-Slot 1100 V Triax Female to Dual Female Tee Adapter
TRX-1100V-TBC	3-Slot 1100 V Triax Female Bulkhead Connector
CS-1616-3	Safety Interlock Mating Connector

Communication Interfaces & Cables

7007-1	Shielded GPIB Cable, 1 m (3.3 ft)
KPCI-488LPA	IEEE-488 Interface for PCI Bus
KUSB-488B	IEEE-488 USB-to-GPIB Interface Adapter

Rack Mount Kits

4299-8	Single Fixed Rack Mount Kit
4299-9	Dual Fixed Rack Mount Kit

Software Options

I-V Tracer	Graphical SMU Curve Tracer Software
KickStart	Instrument Control Software

Available Services

2470-3Y-EW	1-year factory warranty extended to 3 years from date of shipment
2470-5Y-EW	1-year factory warranty extended to 5 years from date of shipment
C/2470-3Y-17025	KeithleyCare® 3 Year ISO 17025 Calibration Plan
C/2470-3Y-DATA	KeithleyCare 3 Year Calibration w/Data Plan
C/2470-3Y-STD	KeithleyCare 3 Year STD Calibration Plan
C/2470-5Y-17025	KeithleyCare 5 Year ISO 17025 Calibration Plan
C/2470-5Y-DATA	KeithleyCare 5 Year Calibration w/Data Plan
C/2470-5Y-STD	KeithleyCare 5 Year STD Calibration Plan
C/NEW DATA	Calibration Data for New Units
C/NEW DATA ISO	ISO-17025 Calibration Data for New Units

Warranty Information

Warranty Summary	This section summarizes the warranties of the 2470. For complete warranty information, refer to the Tektronix warranty page at https://www.tek.com/service/warranties/warranty-2 . Any portion of the product that is not manufactured by Keithley is not covered by this warranty and Keithley will have no duty to enforce any other manufacturer's warranties.
Hardware Warranty	Keithley warrants the Keithley manufactured portion of the hardware for a period of one year from defects in materials or workmanship; provided that such defect has not been caused by use of the Keithley hardware which is not in accordance with the hardware instructions. The warranty does not apply upon any modification of Keithley hardware made by the customer or operation of the hardware outside the environmental specifications.
Software Warranty	Keithley warrants for the Keithley produced portion of the software or firmware will conform in all material respects with the published specifications for a period of ninety(90) days; provided the software is used on the product for which it is intended in accordance with the software instructions. Keithley does not warrant that operation of the software will be uninterrupted or error-free, or that the software will be adequate for the customer's intended application. The warranty does not apply upon any modification of the software made by the customer.

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