

2657A High Power System SourceMeter® SMU Instrument



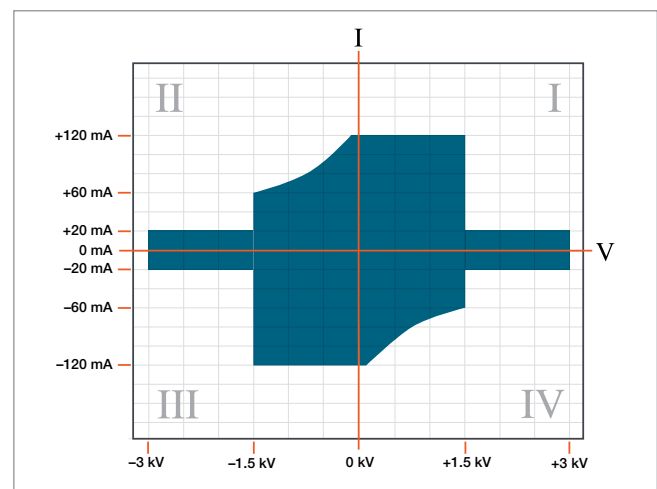
The 2657A is a high voltage, high power, low current source measure unit (SMU) instrument that delivers unprecedented power, precision, speed, flexibility, and ease of use to improve productivity in R&D, production test, and reliability environments. The 2657A is designed specifically for characterizing and testing high voltage electronics and power semiconductors, such as diodes, FETs, and IGBTs, as well as other components and materials in which high voltage, fast response, and precise measurements of voltage and current are required. The 2657A offers the highest power and best low current performance in the industry. It is supported by the industry's most powerful parametric characterization software platforms to grow with you as your applications evolve.

The 2657A offers highly flexible, four-quadrant voltage and current source/load coupled with precision voltage and current meters. It can be used as a:

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

Key Features

- Source or sink up to 180 W of DC or pulsed power (± 3000 V @ 20 mA, ± 1500 V @ 120 mA).
- 1 fA low current resolution.
- Dual 22-bit precision ADCs and dual 18-bit 1 μ s per point digitizers for high accuracy and high speed transient capture.
- Fully TSP® compliant for easy system integration with Series 2600B System SourceMeter models.
- Combines a precision power supply, current source, DMM, arbitrary waveform generator, V or I pulse generator, electronic 18-bit load, and trigger controller – all in one instrument.
- Includes TSP® Express characterization software, LabVIEW® driver, and Keithley's Test Script Builder software development environment.



The 2657A can source or sink up to 3000 V @ 20 mA or 1500 V @ 120 mA.

Typical Applications

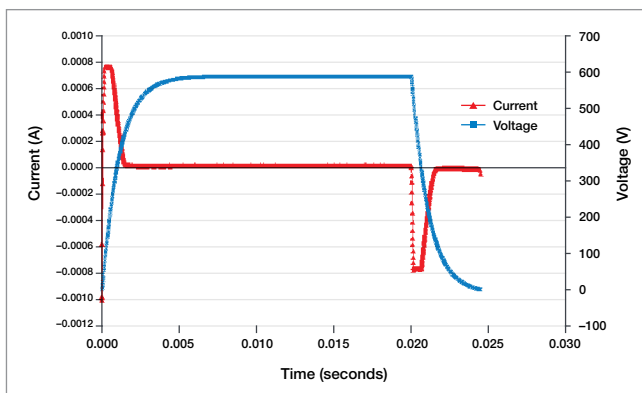
- Power semiconductor device characterization and testing
- Characterization of GaN, SiC, and other compound materials and devices
- Breakdown and leakage testing to 3 kV
- Characterization of sub-millisecond transients

Two Measurement Modes: Digitizing or Integrating

Precisely characterize transient and steady-state behavior, including rapidly changing thermal effects, with the two measurement modes in the 2657A. Each mode is defined by its independent analog-to-digital (A/D) converters.

The digitizing measurement mode provides speeds up to 1 μ s per sample. The dual 18-bit digitizers allow you to capture voltage and current transients simultaneously. In the integrating measurement mode, the dual 22-bit integrating analog to digital converters allow more precise measurement of voltage and current. Two A/D converters are used with each measurement mode, one for current and the other for voltage, that run simultaneously for accurate source readback that does not sacrifice test throughput.

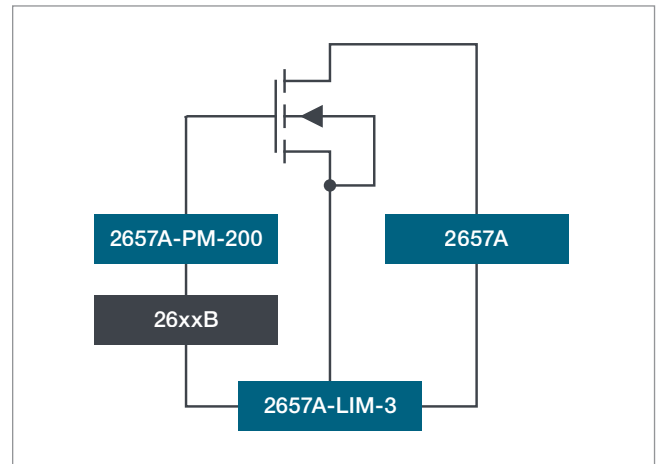
The dual high speed A/D converters sample as fast as 1 μ s per point, enabling full simultaneous characterization of both voltage and current.



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Expansion Capabilities

Through TSP-Link Technology technology, the 2657A can be linked with Series 2600B SMU instruments to form a larger integrated system with up to 32 nodes. Precision timing and tight channel synchronization are guaranteed with built-in 500 ns trigger controllers. The fully isolated, independent channels of the SourceMeter SMU instruments make true SMU-per-pin testing possible.



The 2657A can be combined with Series 2600B and 4200-SCS SMU instruments to support multi-terminal test capability. The 2657A-PM-200 Protection Module and 2657A-LIM-3 Low Interconnect Module make it easier to connect multiple instruments to a probe station safely (not required for connecting to the 8010 High Power Device Test Fixture).

High Power Device Test Fixture

The 8010 High Power Device Test Fixture provides safe and easy connections for testing packaged high power devices at up to 3000 V or 100 A. The 8010 provides connections for a high voltage SourceMeter SMU instrument (2657A), one or two high current SourceMeter SMU instruments (2651A), and three low power SourceMeter SMU instruments (Series 2600B or 4200-SCS SMU instruments). This allows devices with two terminals (diodes) or three terminals (transistors) or even four or five terminals to be characterized safely and accurately. The 8010 has full interlock capability for up to six SourceMeter SMU instruments. The 8010 has integrated protection circuits that protect the low voltage SourceMeter SMU instruments from high voltages the 2657A can output should a device fault occur. The 8010 includes both a high current (100 A) and a high voltage (3000 V) test socket. Various replacement test socket

modules are available, including TO-247, TO-220, axial lead, and a blank socket module that allows building a custom socket. In addition to standard banana jumpers, the 8010 has rear-panel scope and thermal probe ports to simplify system integration.



8010 High Power Device Test Fixture.

Standard Capabilities of Series 2600B SMU instruments

Each 2657A includes all the features and capabilities provided in Series 2600B SourceMeter SMU instruments:

- Flexibility for use as either a bench-top I-V characterization tool or as a building block component of multiple channel I-V test systems.
- TSP Express software to perform common I-V tests quickly and easily without programming or installing software.
- ACS Basic Edition software for semiconductor component characterization (optional). ACS Basic Edition now features a “Trace” mode for generating a suite of characteristic curves.
- Keithley’s Test Script Processor (TSP) technology supports creating and running custom user test scripts for high speed test automation, as well as creating programming sequences that allow the instrument to operate asynchronously without direct PC control.
- Parallel test execution and precision timing when multiple Series 2600B SMU instruments are connected together in a system.
- LXI Class C compliance.
- 14 digital I/O lines for direct connection to a probe station, component handler, or other automation tools.
- USB port for extra data and test program storage via USB memory device.



2657A rear panel.

2657A Condensed Specifications

Voltage Accuracy Specifications¹

Range	Source		Measure		
	Programming Resolution	Accuracy \pm (% rdg + volts)	Display Resolution	Integrating ADC Accuracy ² \pm (% rdg + volts)	High Speed ADC Accuracy ³ \pm (% rdg + volts)
200 V	5 mV	0.03% + 50 mV	100 μ V	0.025% + 50 mV	0.05% + 100 mV
500 V	10 mV	0.03% + 125 mV	100 μ V	0.025% + 100 mV	0.05% + 200 mV
1500 V	40 mV	0.03% + 375 mV	1 mV	0.025% + 300 mV	0.05% + 600 mV
3000 V	80 mV	0.03% + 750 mV	1 mV	0.025% + 600 mV	0.05% + 1.2 V

Current Accuracy Specifications⁴

Range	Source		Measure		
	Programming Resolution	Accuracy \pm (% reading + amperes + proportional offset in amperes). V_o is the output voltage.	Display Resolution	Integrating ADC Accuracy ² \pm (% reading + amperes ⁵ + proportional offset in amperes). V_o is the output voltage.	High Speed ADC Accuracy ³ \pm (% reading + amperes ⁵ + proportional offset in amperes). V_o is the output voltage.
1 nA	30 fA	0.1% + 2 pA + $V_o \times E^{-15}$	1 fA	0.1% + 1.2 pA + $V_o \times E^{-15}$	0.2% + 1.2 pA + $V_o \times E^{-15}$
10 nA	300 fA	0.1% + 5 pA + $V_o \times E^{-14}$	10 fA	0.1% + 5 pA + $V_o \times E^{-15}$	0.2% + 5 pA + $V_o \times E^{-15}$
100 nA	3 pA	0.1% + 60 pA + $V_o \times E^{-13}$	100 fA	0.1% + 60 pA + $V_o \times E^{-13}$	0.2% + 60 pA + $V_o \times E^{-13}$
1 μ A	30 pA	0.03% + 700 pA	1 pA	0.025% + 400 pA	0.08% + 800 nA
10 μ A	300 pA	0.03% + 5 nA	10 pA	0.025% + 1.5 nA	0.08% + 3 nA
100 μ A	3 nA	0.03% + 60 nA	100 pA	0.02% + 25 nA	0.05% + 50 nA
1 mA	30 nA	0.03% + 300 nA	1 nA	0.02% + 200 nA	0.05% + 400 nA
2 mA	60 nA	0.03% + 1.2 μ A	1 nA	0.02% + 500 nA	0.05% + 1 μ A
20 mA	600 nA	0.03% + 12 μ A	10 nA	0.02% + 5 μ A	0.05% + 10 μ A
120 mA	3 μ A	0.03% + 36 μ A	100 nA	0.02% + 24 μ A	0.05% + 50 μ A

1. For temperatures 0° to 18°C and 28° to 50°C, accuracy is degraded by $\pm(0.15 \times \text{accuracy specification})/^{\circ}\text{C}$.

2. Derate accuracy specification for NPLC setting <1 by increasing error term. Add appropriate typical percent of range term for resistive loads using the table below.

NPLC Setting	200 V and 500 V Ranges	1500 V and 3000 V Ranges	100 nA Range	1 μ A to 120 mA Ranges
0.1	0.01%	0.01%	0.01%	0.02%
0.01	0.08%	0.07%	0.1%	0.08%
0.001	0.8%	0.6%	1%	0.7%

3. 18-bit ADC. Average of 1000 samples taken at 100 μ s intervals.

4. For temperatures 0° to 18 °C and 28 ° to 50 °C, accuracy is degraded by $\pm(0.15 \times \text{accuracy specification})/^{\circ}\text{C}$. 1 nA to 10 μ A accuracy is degraded by $\pm (0.35 \times \text{accuracy specification})/^{\circ}\text{C}$.

5. Offset (amperes) is typical for 1 nA range.

SUPPLEMENTAL CHARACTERISTICS

The following specifications are supplemental characteristics that provide additional information about instrument functions and performance. These characteristics are nonwarranted specifications; they describe the typical performance of the 2657A.

PULSE⁶ CHARACTERISTICS

Pulse Width Programming Resolution

1 μ s.

Pulse Width Programming Accuracy

$\pm 10 \mu$ s.

Pulse Width Jitter

7 μ s.

Voltage Source Output Settling Time

Time required to reach within 1% of final value after source level command is processed on a fixed range⁷
 $R_L = 10\text{ M}\Omega$.

Range	Settling time
200 V	< 5 ms
500 V	< 5 ms
1500 V	< 5 ms
3000 V	< 7 ms

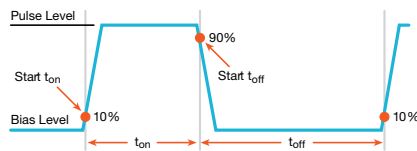
Current Source Output Settling Time

Time required to reach within 1% of final value after source level command is processed on a fixed range.

• Values below for $V = I_{OUT} \times R_{LOAD}$.

Current Range	R_{LOAD}	Settling Time
120 mA	12.5 k Ω	< 5 ms
20 mA	50 k Ω	< 5 ms
2 mA	500 k Ω	< 10 ms
1 mA	1 M Ω	< 5 ms
100 μ A	10 M Ω	< 15 ms
10 μ A	100 M Ω	< 20 ms
1 μ A	1 G Ω	< 200 ms
100 nA	10 G Ω	< 2 s
10 nA	10 G Ω	< 2 s
1 nA	10 G Ω	< 2 s

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



7. With measure and compliance set to the maximum current for the specified voltage range.

ADDITIONAL SOURCE CHARACTERISTICS

Noise 10 Hz to 20 MHz < 1.2 V peak to peak, < 400 mVRMS. 3000 V range with a 20 mA limit.

Noise (peak to peak) 0.1 Hz to 10 Hz

Voltage 0.005% of range.

Current 0.08% of range.

Overshoot

Voltage < $\pm 1\%$ for 1500 V and 3000 V ranges. Step size = 10% to 90% of range, resistive load, maximum current limit/compliance.

Current < $\pm 1\%$. Step size = 10% to 90% of range, resistive load. See Current source output settling time for additional test conditions.

Range Change Overshoot

Voltage < 1% of larger range. Overshoot into a 100 k Ω load, 20 MHz bandwidth.

Current < 5% of larger range. $I_{OUT} \times R_{LOAD} = 100\text{ V}$.

Guard Offset Voltage < 4 mV (100 k Ω guard impedance). Current < 700 μ A.

Remote Sense Operating Range⁸ Maximum voltage between HI and SENSE HI = 3 V.
 Maximum voltage between LO and SENSE LO = 3 V.

Voltage Output Headroom

3000 V Range Maximum output voltage = 3030 V – (total voltage drop across source leads).

1500 V range Maximum output voltage = 1515 V – (total voltage drop across source leads).

Overtemperature Protection	Internally sensed temperature overload puts the instrument in standby mode.
Limit (compliance)	Bipolar limit (compliance) set with a single value.
Voltage⁹	Minimum value is 20 V; accuracy is the same as voltage source.
Current¹⁰	Minimum value is 100 pA; accuracy is the same as current source.

8. Add 50 μ V to source accuracy specifications per volt of HI lead drop.

9. For sink operation (quadrants II and IV) without sink mode enabled, add 0.6 percent of limit range to the corresponding voltage source accuracy specifications. Specifications apply with sink mode enabled.

10. For sink operation (quadrants II and IV) without sink mode enabled, add 0.6 percent of limit range to the corresponding current limit accuracy specifications. Specifications apply with sink mode enabled.

ADDITIONAL CHARACTERISTICS

Contact Check Accuracy	50 Ω .
Maximum Load Capacitance	Normal mode 100 nF, High-capacitance mode 10 μ F.
Common Mode Voltage	250 V dc.
Common Mode Isolation	> 1 G Ω , < 4500 pF.
Sense High Input Impedance	> 100 T Ω .
Maximum Sense Lead Resistance	1 k Ω for rated accuracy.
Overrange	101% of source range, 101% of measure range.

HIGH-CAPACITANCE MODE CHARACTERISTICS^{11, 12}

Accuracy Characteristics Accuracy characteristics are applicable in both normal and high-capacitance modes.

Voltage Source Output Settling Time

Time required to reach within 1% of final value after source level command is processed on a fixed range for the maximum current limit of the given range¹³. Values below for $V_{OUT} = 100$ V.

Voltage Source Range	Settling Time with $C_{LOAD} = 4.7$ μ F
200 V to 500 V	< 5 ms
1500 V	< 7 ms
3000 V	< 30 ms

Current Measure Settling Time

Time required to reach within 1% of final value after voltage source is stabilized on a fixed range. Values below for $V_{OUT} = 1$ kV.

Current Measure Range	Settling Time
2 mA to 120 mA	< 100 μ s
100 μ A to 1 mA	< 3 ms
1 μ A to 10 μ A	< 230 ms

Mode Change Delay

Current ranges of 100 μ A and above: 11 ms delay for both in and out of high-capacitance mode.
Current ranges below 100 μ A: 250 ms delay into high-capacitance mode.
 11 ms delay out of high-capacitance mode.

Measure Input Impedance

> 30 G Ω in parallel with 150 pF.

Voltage Source Range Change Overshoot

< 400 mV + 0.1% of larger range. Overshoot into a 100 k Ω load, 20 MHz bandwidth.

11. High-capacitance mode specifications are for dc measurements only and use locked ranges. Autorange is disabled.

12. 100 nA range and below are not available in high-capacitance mode.

13. With measure and compliance set to the maximum current for the specified voltage range.

MEASUREMENT SPEED CHARACTERISTICS¹⁴

MAXIMUM SWEEP OPERATION RATES (OPERATIONS PER SECOND) FOR 60 HZ (50 HZ):

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

HIGH-SPEED ADC BURST MEASUREMENT RATES:¹⁵

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

14. Exclude current measurement ranges less than 1 mA.

15. `smua.measure.adc` must be enabled and the `smua.measure.count` set to the burst length.

MAXIMUM SINGLE MEASUREMENT RATES (OPERATIONS PER SECOND) FOR 60 HZ (50 HZ):

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

Maximum Measurement Range Change Rate

> 4000 per second for > 10 μ A.

Maximum Source Range Change Rate

> 250 per second > 10 μ A.

Maximum Source Function Change Rate

> 90 per second.

Command Processing Time

< 1 ms. Maximum time required for the output to begin to change after receiving the `smua.source.levelv` or `smua.source.leveli` command.

TRIGGERING AND SYNCHRONIZATION CHARACTERISTICS

TRIGGERING

Trigger In to Trigger Out 0.5 μ s.

Trigger In to Source Change¹⁶ 10 μ s.

Trigger Timer Accuracy ± 2 μ s.

Source Change¹⁶ after LXI Trigger 280 μ s.

SYNCHRONIZATION

Multi-node Synchronized Source Change¹⁶
 $< 0.5 \mu\text{s}$.

Single-node Synchronized Source Change¹⁶
 $< 0.5 \mu\text{s}$.

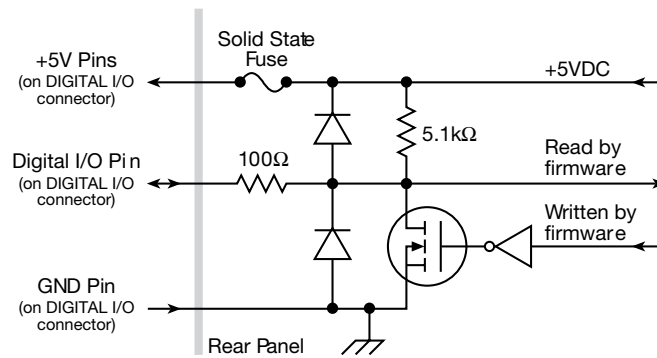
16. Fixed source range with no polarity change.

SUPPLEMENTAL INFORMATION

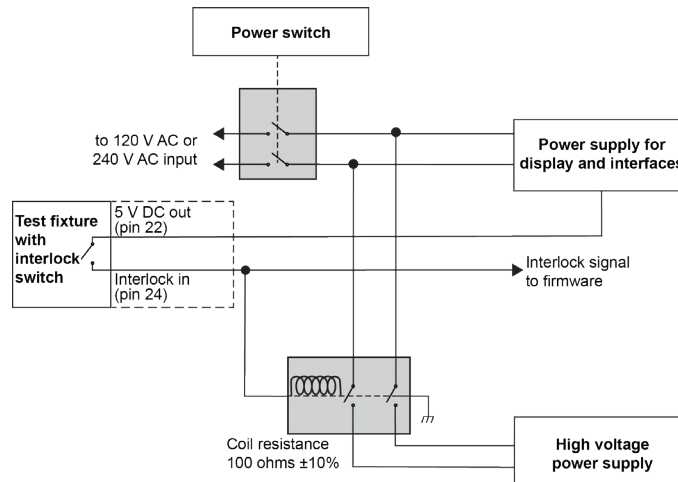
Front-panel Interface	Two-line vacuum fluorescent display (VFD) with keypad and navigation wheel
Display	Show error messages and user-defined messages. Display source and limit settings. Show current and voltage measurements. View measurements stored in dedicated reading buffers.
Keypad Operations	Change host interface settings. Save and restore instrument setups. Load and run factory and user-defined test scripts that prompt for input and send results to the display. Store measurements into dedicated reading buffers.
Programming	Embedded Test Script Processor (TSP™) accessible from any host interface; responds to high-speed test scripts comprised of remote commands and statements (for example, branching, looping, and math); able to execute test scripts stored in memory without host intervention.
Minimum User Memory Available	16 MB (approximately 250,000 lines of TSP code).
Reading Buffers	Nonvolatile memory uses dedicated storage areas reserved for measurement data. Reading buffers are arrays of measurement elements. Each element can store the following items: <ul style="list-style-type: none"> • Measurement • Source setting (at the time the measurement was taken) • Measurement status • Range information • Timestamp Reading buffers can be filled using the front-panel STORE key and retrieved using the RECALL key or host interface.
Buffer Size, with Timestamp and Source Setting	$> 60,000$ samples.
Buffer Size, without Timestamp and Source Setting	$> 140,000$ samples.

TIMER

Timer	Free-running 47-bit counter with 1 MHz clock input. Reset each time instrument power is turned on. If the instrument is not turned off, the timer is automatically reset to zero (0) every four years.
Timestamp	TIMER value is automatically saved when each measurement is triggered.
Resolution	$1 \mu\text{s}$.
Timestamp Accuracy	± 100 ppm.

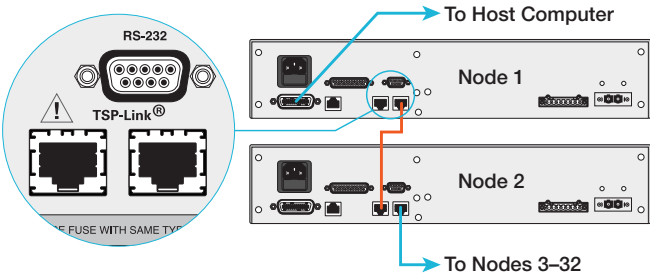
DIGITAL I/O INTERFACE

Connector	25-pin female D.
Input/Output Pins	14 open drain I/O bits.
Absolute Maximum Input Voltage	5.25 V.
Absolute Minimum Input Voltage	−0.25 V.
Maximum Logic Low Input Voltage	0.7 V, +850 μA.
Minimum Logic High Input Voltage	2.1 V, +570 μA.
Maximum Source Current (flowing out of digital I/O bit)	+960 μA.
Maximum Sink Current At Maximum Logic Low Voltage (0.7)	−5.0 mA.
Absolute Maximum Sink Current (flowing into digital I/O pin)	−11 mA.
5 V Power Supply Pin	Limited to 250 mA, solid-state fuse protected.
Safety Interlock Pin	Active high input > 4.0 V at 50 mA must be externally applied to this pin to allow the high-voltage output to operate. Connect the 5 V output and the interlock input of the 25-pin digital I/O connector on the back of the 2657A to the switch in your fixture. The output will be disabled when the interlock signal is < 4.0 V. Absolute maximum input is −0.4 V to +6.0 V.



General Specifications

IEEE-488	IEEE Std 488.1 compliant. Supports IEEE Std 488.2 common commands and status model topology.
RS-232	Baud rates from 300 bps to 115,200 bps. Programmable number of data bits, parity type, and flow control (RTS/CTS hardware or none). When not programmed as the active host interface, the 2657A can use the RS-232 interface to control other instruments.
Ethernet	RJ-45 connector, LXI version 1.4 Core 2011, 10/100Base-T, Auto-MDIX.
LXI compliance	LXI version 1.4 Core 2011.
Expansion interface	The TSP-Link™ expansion interface allows TSP-enabled instruments to trigger and communicate with each other. Cable type: Category 5e or higher LAN crossover cable. Three meter (9.84 ft) maximum between each TSP-enabled instrument. A maximum of 32 TSP-Link nodes can be interconnected. Each source-measure instrument uses one TSP-Link node.



USB File System	USB 2.0 Host: Mass storage class device.
Power supply	100 V ac to 240 V ac, 50 Hz or 60 Hz, 350 VA maximum.
Cooling	Forced air; side and top intake and rear exhaust.
Warranty	1 year.
EMC	Conforms to European Union EMC Directive.
Safety	NRTL listed to UL 61010-1:2012 Ed.3+R:16Nov2018 and UL 61010-2-030:2018 Ed.2. Conforms to European Union Low Voltage Directive.
Environment	For indoor use only.
Altitude	Maximum 2000 m (6562 ft) above sea level.
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.
Dimensions	Rack Mount: 89 mm high × 435 mm wide × 630 mm deep (3.5 in. × 17.1 in. × 24.8 in.). Bench Configuration (with handle and feet): 104 mm high × 483 mm wide × 630 mm deep (4.1 in. × 19 in. × 24.8 in.).
Weight	10.7 kg (23.5 lb).

Specifications are subject to change without notice.

Ordering Information

2657A	High Power System SourceMeter SMU Instrument
	Cables must be purchased separately. Please contact your local sales office for configuration assistance.
8010	High Power Device Test Fixture

Supplied Accessories

7709-308A	Digital I/O and Interlock Connector
17469460X	TSP-Link/Ethernet Cable
	Rack Mount Kit

Documentation

Software Available

KickStart	Instrument Control Software
LabVIEW and IVI Drivers	
Test Script Builder Software	

Available Accessories

2657A-LIM-3	Low Interconnect Module
2657A-PM-200	200V Protection Module
SHV-CA-553-x	High Voltage Triax to SHV Cable (1, 2, 3 m)
HV-CA-554-x	High Voltage Triax to Triax Cable (1, 2, 3 m)
HV-CA-571-3	High-Voltage Triaxial Panel-Mount Cable
HV-CS-1613	High Voltage Triax Feedthrough Connector

ACCESSORIES SUPPLIED WITH THE 8010

CA-558-2	25-pin D-sub Interlock Cable for 26xxA
CA-560-x	4 mm Black and Red Banana Cables, 8 in.
CA-562-x	6 mm Black and Red Banana Cables, 10 in.
CA-563	BNC to Banana Cable, 9.5 in.
CA-568-120	Safety Earth Ground Cable