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Model 2657A

High Power System SourceMeter® Instrument Specifications

SPECIFICATION CONDITIONS

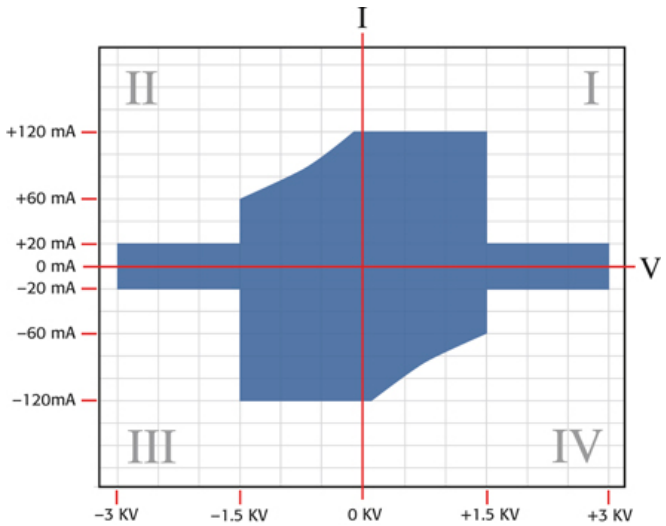
This document contains specifications and supplemental information for the Model 2657A High Power System SourceMeter® instrument. Specifications are the standards against which the Model 2657A is tested. Upon leaving the factory, the Model 2657A meets these specifications. Supplemental and typical values are nonwarranted, apply at 23 °C, and are provided solely as useful information.

Source and measurement accuracies are specified at the Model 2657A terminals under these conditions:

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

DC POWER SPECIFICATIONS

	Voltage	Current
Maximum output power and source/sink limits[1]	182 W maximum ▪ ± (3030 V at 20.0 mA, -20.0 mA) ▪ ± (1515 V at 120.0 mA, -60.0 mA) ▪ ± (505 V at 120.0 mA, -100.0 mA) ▪ ± (202 V at 120.0 mA, -115.0 mA) ▪ Four-quadrant source or sink operation	182 W maximum ▪ ± (20.2 mA at 3000.0 V, -3000.0 V) ▪ ± (60.6 mA at 1500.0 V, -1500.0 V) ▪ ± (121.2 mA at 1500.0 V, -100.0 V) ▪ Four-quadrant source or sink operation



[1] Full power source operation regardless of load to 30 °C ambient temperature. Above 30 °C or power sink operation, refer to “Operating Boundaries” in the Model 2657A Reference Manual for additional power derating information.

VOLTAGE ACCURACY SPECIFICATIONS[2]

Range	Source		Measure		
	Programming resolution	Accuracy ± (% reading + volts)	Display resolution	Integrating ADC accuracy[3] ± (% reading + volts)	High-speed ADC accuracy[4] ± (% reading + volts)
200 V	5 mV	0.03 % + 50 mV	100 µV	0.025 % + 50 mV	0.05 % + 100 mV
500 V	10 mV	0.03 % + 125 mV	100 µV	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 SPECIFICATIONS[2,5]

Range	Source		Measure		
	Programming resolution	Accuracy ± (% reading + amperes)	Display resolution	Integrating ADC accuracy[3] ± (% reading + amperes)	High-speed ADC accuracy[4] ± (% reading + amperes)
1 nA	30 fA	$0.1\% + 2E^{-12} + Vo \times E^{-15}$	1 fA	$0.1\% + 6E^{-13} + Vo \times E^{-15}$	$0.2\% + 6E^{-13} + Vo \times E^{-15}$
10 nA	300 fA	$0.1\% + 5E^{-12} + Vo \times E^{-14}$	10 fA	$0.1\% + 5E^{-12} + Vo \times E^{-15}$	$0.2\% + 5E^{-12} + Vo \times E^{-15}$
100 nA	3 pA	$0.1\% + 6E^{-11} + Vo \times E^{-13}$	100 fA	$0.1\% + 6E^{-11} + Vo \times E^{-13}$	$0.2\% + 6E^{-11} + Vo \times E^{-13}$
1 µA	30 pA	0.03 % + 700 pA	1 pA	0.025 % + 400 pA	0.08 % + 800 nA
10 µA	300 pA	0.03 % + 5 nA	10 pA	0.025 % + 1.5 nA	0.08 % + 3 nA
100 µA	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 µA	1 nA	0.02 % + 500 nA	0.05 % + 1 µA
20 mA	600 nA	0.03 % + 12 µA	10 nA	0.02 % + 5 µA	0.05 % + 10 µA
120 mA	3 µA	0.03 % + 36 µA	100 nA	0.02 % + 24 µA	0.05 % + 50 µA

[2] For temperatures 0 °C to 18 °C and 28 °C to 50 °C, accuracy is degraded by ± (0.15 × accuracy specification)/°C.

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

NPLC setting	200 V and 500V ranges	1500 V and 3000 V ranges	100 nA range and below	1 µA 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 %

[4] 18-bit ADC. Average of 1000 samples taken at 100 µs intervals.

[5] At temperatures 0 °C to 18 °C and 28 °C to 50 °C; 1 nA to 10 µA accuracy is degraded by ± (0.35 × accuracy specification)/°C.

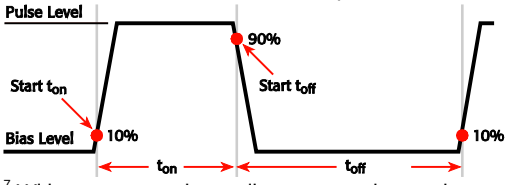
SUPPLEMENTAL CHARACTERISTICS

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 Model 2657A.

PULSE[6] CHARACTERISTICS

<table>
<tr><td>Pulse width programming resolution</td><td colspan="3">1 µs</td></tr>
<tr><td>Pulse width programming accuracy</td><td colspan="3">± 10 µs</td></tr>
<tr><td>Pulse width jitter</td><td colspan="3">7 µs</td></tr>
<tr><td rowspan="5">Voltage source output settling time</td><td colspan="3">Time required to reach within 1 % of final value after source level command is processed on a fixed range[7] R_L=10 MΩ</td></tr>
<tr><td>Range</td><td colspan="2">Settling time</td></tr>
<tr><td>200 V</td><td colspan="2">< 5 ms</td></tr>
<tr><td>500 V</td><td colspan="2">< 5 ms</td></tr>
<tr><td>1500 V</td><td colspan="2">< 5 ms</td></tr>
<tr><td>3000 V</td><td colspan="2">< 7 ms</td></tr>
<tr><td rowspan="14">Current source output settling time</td><td colspan="3">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} × R_{load}</td></tr>
<tr><td>Current range</td><td>R_{load}</td><td>Settling time</td></tr>
<tr><td>120 mA</td><td>12.5 kΩ</td><td>< 5 ms</td></tr>
<tr><td>20 mA</td><td>50 kΩ</td><td>< 5 ms</td></tr>
<tr><td>2 mA</td><td>500 kΩ</td><td>< 10 ms</td></tr>
<tr><td>1 mA</td><td>1 MΩ</td><td>< 5 ms</td></tr>
<tr><td>100 µA</td><td>10 MΩ</td><td>< 15 ms</td></tr>
<tr><td>10 µA</td><td>100 MΩ</td><td>< 20 ms</td></tr>
<tr><td>1 µA</td><td>1 GΩ</td><td>< 200 ms</td></tr>
<tr><td>100 nA</td><td>10 GΩ</td><td>< 2 s</td></tr>
<tr><td>10 nA</td><td>10 GΩ</td><td>< 2 s</td></tr>
<tr><td>1 nA</td><td>10 GΩ</td><td>< 2 s</td></tr>
</table>

[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-peak, < 400 mV RMS ▪ 3000 V range with a 20 mA limit
Noise **0.1 Hz to 10 Hz**	Voltage: ▪ 0.005 % of range Current: ▪ 0.08 % of range
Overshoot	Voltage: ▪ < ±1 % for 1500 V and 3000 V ranges ▪ Step size = 10 % to 90 % of range, resistive load, maximum current limit/compliance Current: ▪ < ±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 kΩ load, 20 MHz bandwidth Current: ▪ < 5 % of larger range ▪ I_{out} x R_{load} = 100 V
Guard offset voltage	< 4 mV (100 kΩ guard impedance) ▪ Current < 700 µA
Remote sense operating range[8]	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)
Over-temperature protection	Internally sensed temperature overload puts the instrument in standby mode
Limit/compliance	Bipolar limit (compliance) set with a single value **Voltage:**[9] ▪ Minimum value is 20 V; accuracy is the same as voltage source **Current:**[10] ▪ Minimum value is 100 pA; accuracy is the same as current source

[8] Add 50 µV 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 µF
Common mode voltage	250 V DC	
Common mode isolation	> 1 GΩ < 4500 pF	
Sense high input impedance	> 100 TΩ	
Maximum sense lead resistance	1 kΩ 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 range[13] ▪ Values below for Vout = 100 V	
	Voltage source range	**Settling time with C_{load} = 4.7 µF**
	200 V – 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 Vout = 1 kV	
	Current measure range	**Settling time**
	2 mA – 120 mA	< 100 µs
	100 µA – 1 mA	< 3 ms
	1 µA – 10 µA	< 230 ms
Mode change delay	Current ranges of 100 µA and above: ▪ 11 ms delay for both in and out of High Capacitance Mode Current ranges below 100 µA: ▪ 250 ms delay into High Capacitance Mode ▪ 11 ms delay out of High Capacitance Mode	
Measure input impedance	> 30 GΩ in parallel with 150 pF	
Voltage source range change overshoot	< 400 mV + 0.1 % of larger range ▪ Overshoot into a 100 kΩ 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 CHARACTERISTICS[14,15]

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:[16]

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] Tests performed with a Model 2657A using the following equipment: Computer hardware (Intel® Pentium® 4 2.4 GHz, 2 GB RAM, National Instruments™ PCI-GPIB); driver (NI-488.2 Version 2.2 PCI-GPIB); software (Microsoft® Windows® XP, Microsoft® Visual Studio® 2010, VISA™ version 4.1).

[15] Exclude current measurement ranges less than 1 mA.

[16] `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 µA
Maximum source range change rate	> 250 per second > 10 µA
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 µs
Trigger in to source change[17]	10 µs
Trigger timer accuracy	±2 µs
Source change[17] after LXI trigger	280 µs

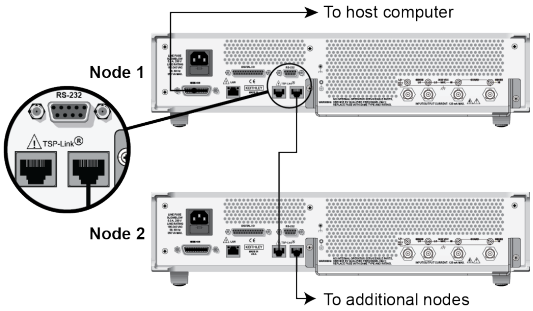
Synchronization

Multi-node synchronized source change[17]	< 0.5 µs
Single-node synchronized source change[17]	< 0.5 µs

[17] 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®) scripting engine is accessible from any host interface: ▪ Responds to individual instrument control commands ▪ Responds to high-speed test scripts comprised of remote commands and test script language (TSL) statements (for example, branching, looping, and math) ▪ Able to execute high-speed test scripts stored in memory without host intervention
Minimum user memory available	16 MB (approximately 250,000 lines of TSP code)
Test Script Builder	Integrated development environment for building, running, and managing TSP scripts; includes an instrument console for interactive communication with any TSP-enabled instrument Requires: ▪ VISA (NI-VISA included on the Product Information CD-ROM) ▪ Microsoft® .NET Framework (included on the Product Information CD-ROM) ▪ Keithley I/O Layer (included on the Product Information CD-ROM) ▪ Intel® Pentium III 800 MHz or faster personal computer ▪ Microsoft® Windows® 2000, XP, Vista®, or 7
TSP® Express (embedded)	Tool that allows you to quickly and easily perform common I-V tests without programming or installing software To run TSP Express, you need: ▪ Java™ Platform, Standard Edition 6 or 7 ▪ Microsoft® Internet Explorer®, Mozilla® Firefox®, or another Java-compatible web browser
Software interface	TSP™ Express (embedded), direct GPIB/VISA, read/write with Microsoft® Visual Basic®, Visual C/C++®, Visual C#®, LabVIEW™, CEC TestPoint™ Data Acquisition Software Package, NI LabWindows™/CVI, and so on.

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: ▪ 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
System expansion	The TSP-Link expansion interface allows TSP-enabled instruments to trigger and communicate with each other. See the figure below.  Each Model 2657A has two TSP-Link connectors to make it easier to connect instruments in a sequence. ▪ Once source-measure instruments are interconnected through the TSP-Link expansion interface, a computer can access all of the resources of each source-measure instrument through the host interface of any Model 2657A ▪ A maximum of 32 TSP-Link nodes can be interconnected. Each source-measure instrument uses one TSP-Link node

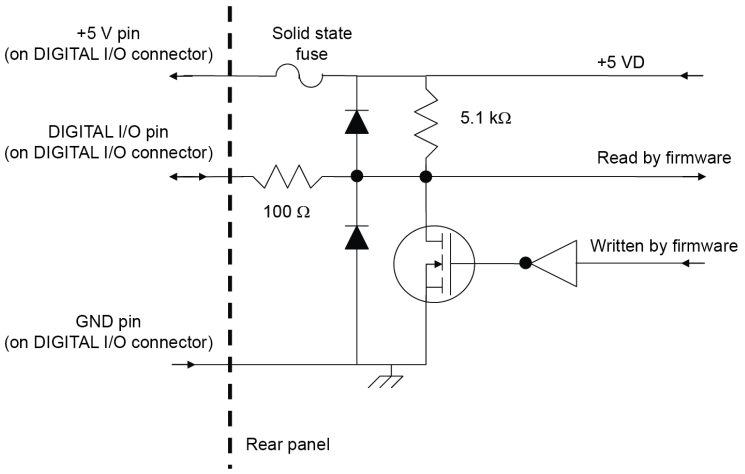
Timer

Timing	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 µs
Timestamp accuracy	±100 ppm

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 Model 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 ▪ 9.84 ft (3 m) maximum between each TSP-enabled instrument
USB File System	USB 2.0 Host: Mass storage class device
Power supply	100 V 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 UL61010-1:2004 Conforms to European Union Low Voltage Directive
Environment	For indoor use only **Altitude:** Maximum 6562 ft (2000 m) 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: 3.5 in. high × 17.1 in. wide × 24.8 in. deep (89 mm × 435 mm × 630 mm) Bench configuration (with handle and feet): 4.1 in. high × 19 in. wide × 24.8 in. deep (104 mm × 483 mm × 630 mm)
Weight	23.5 lb (10.7 kg)

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: 0.7V, +850 µA max

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 Model 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.