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## Specifications

### SPECIFICATION CONDITIONS

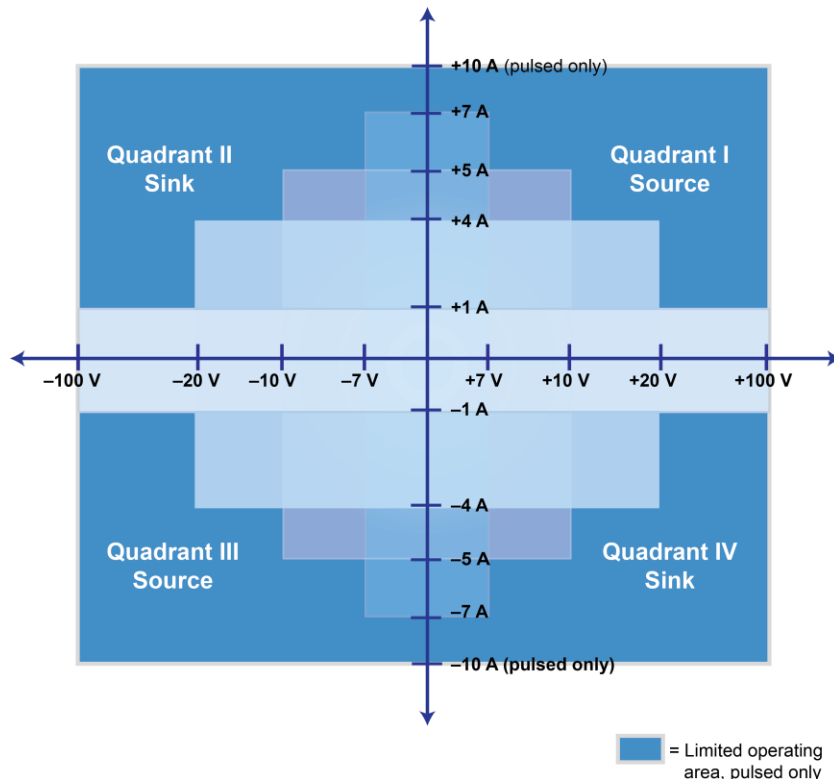
This document contains specifications and supplemental information for the Model 2461 High Current SourceMeter® SMU Instrument. Specifications are the standards against which the 2461 is tested. Upon leaving the factory, the 2461 meets these specifications. Supplemental and typical values are nonwarranted, apply at 23 °C, and are provided solely as useful information.

Source and measurement accuracies are specified at the 2461 terminals with A/D autozero enabled.

Calibration period: One year.

### DC POWER SPECIFICATIONS

	Voltage	Current
<b>Maximum output power and source limits</b>	105 W maximum DC; 1050 W pulse <ul style="list-style-type: none"> <li>▪ ± 105 V (<math>\leq</math> 1 A range; <math>\leq</math> 10 A pulsed)</li> <li>▪ Four-quadrant source or sink operation</li> </ul>	105 W maximum; 1050 W pulse <ul style="list-style-type: none"> <li>▪ ± 1.05 A; ± 10.5 A pulsed (<math>\leq</math> 100 V range)</li> <li>▪ Four-quadrant source or sink operation</li> </ul>
<b>Maximum DC voltage and current ratings</b>	105 V	1.05 A
	21 V	4.2 A
	10.5 V	5.25 A
	7.35 V	7.35 A



**VOLTAGE SPECIFICATIONS<sup>1,2</sup>**

Source					Measure <sup>3</sup>		
Range	Maximum DC current	Resolution	Accuracy 23 °C ± 5 °C 1 year ± (% setting + volts)	Noise (RMS) <10Hz	Resolution <sup>4</sup>	Accuracy 23 °C ± 5 °C 1 year ± (% reading + volts)	Digitizer accuracy <sup>5</sup> 23 °C ± 5 °C 1 week ± (% reading + 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	4.2 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	200 µV	100 µV	0.015% + 5 mV	0.05% + 40 mV

**Measure Input Resistance:** > 10 GΩ all ranges  
**Temperature coefficient:** ± (0.10 × accuracy specification)/°C, 0 °C to 18 °C and 28 °C to 50 °C

**CURRENT SPECIFICATIONS<sup>1,2,6</sup>**

Source					Measure <sup>3</sup>		
Range	Maximum DC voltage	Resolution	Accuracy 23 °C ± 5 °C 1 year ± (% setting + amps)	Noise (RMS) <10Hz	Resolution <sup>4</sup>	Accuracy 23 °C ± 5 °C 1 year ± (% reading + amps)	Digitizer accuracy <sup>7</sup> 23 °C ± 5 °C 1 week ± (% reading + 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
10.00000 A <sup>8</sup>	7.35 V	500 µA	0.150% + 6 mA	125 µA	10 µA	0.150% + 5 mA	0.15% + 10 mA

**Voltage burden:**<sup>9</sup> < 100 µV all ranges  
**Temperature coefficient:** ± (0.10 × accuracy specification)/°C, 0 °C to 18 °C and 28 °C to 50 °C

<sup>1</sup> Speed = 1 PLC.

<sup>2</sup> All specifications guaranteed with output ON.

<sup>3</sup> Accuracies apply to 2-wire and 4-wire modes when properly zeroed.

<sup>4</sup> Measure resolution 6.5 digits. Digitizer resolution limited by noise.

<sup>5</sup> 18-bit ADC. Average of 1000 samples taken at 1 µs intervals. Internal temperature within ± 5 °C and 1 week of automatic calibration (ACAL).

<sup>6</sup> Accuracy specifications guaranteed when using Model 2460-KIT screw terminal accessory.

<sup>7</sup> 18-bit ADC. Average of 1000 samples taken at 1 µs intervals. Internal temperature within ± 5 °C and 1 week of automatic calibration (ACAL).

<sup>8</sup> 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.

<sup>9</sup> Four-wire mode.

**RESISTANCE MEASUREMENT ACCURACY (LOCAL OR REMOTE SENSE)<sup>10,11,12</sup>**

Range	Resolution <sup>13</sup>	Default test current	Normal accuracy 23 °C ± 5 °C 1 year ± (% reading + ohms)	Enhanced accuracy <sup>14</sup> 23 °C ± 5 °C 1 year ± (% reading + ohms)
< 2.000000 Ω <sup>15</sup>	1 μΩ	User-defined	Source I <sub>ACC</sub> + Meas V <sub>ACC</sub>	Meas I <sub>ACC</sub> + Meas V <sub>ACC</sub>
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% + 1000 Ω	0.12% + 500 Ω
200.0000 MΩ	100 Ω	100 nA	1.04% + 10000 Ω	0.74% + 5000 Ω
> 200.00000 MΩ <sup>15</sup>	-----	User-defined	Source I <sub>ACC</sub> + Meas V <sub>ACC</sub>	Meas I <sub>ACC</sub> + Meas V <sub>ACC</sub>
<b>Temperature coefficient:</b> ± (0.10 × accuracy specification)/°C 0 °C to 18 °C and 28 °C to 50 °C				
<b>Source current, measure resistance mode</b>		Total uncertainty = I source accuracy + V measure accuracy (4-wire remote sense)		
<b>Source voltage, measure resistance mode</b>		Total uncertainty = V source accuracy + I measure accuracy (4-wire remote sense)		

**CONTACT CHECK**

<b>Contact check speed</b>	< 100 μs for verification and notification, script (TSP®) programmed		
<b>Resistance settings:</b>	<b>2 Ω</b>	<b>15 Ω</b>	<b>50 Ω</b>
<b>No contact check failure</b>	< 1.0 Ω	< 10.0 Ω	< 40.0 Ω
<b>Always contact check failure</b>	> 6.0 Ω	> 20.0 Ω	> 60.0 Ω

<sup>10</sup> Speed = 1 PLC.<sup>11</sup> All specifications guaranteed with output ON.<sup>12</sup> Accuracies apply to 2-wire and 4-wire modes when properly zeroed.<sup>13</sup> Measure resolution 6.5 digits.<sup>14</sup> Source readback enabled; offset compensation on.<sup>15</sup> Source current, measure resistance or source voltage, measure resistance only.

## PULSE SPECIFICATIONS

<b>Minimum programmable pulse width</b>	150 $\mu$ s; note that time for settling or measuring may be longer than 150 $\mu$ s
<b>Maximum extended range pulse width</b>	2.5 ms for the 7 A and lower ranges, 1 ms for the 10 A range
<b>Maximum DC pulse width</b>	10,000 seconds
<b>Pulse width programming resolution</b>	Variable; limited by pulse width and pulse-width jitter
<b>Pulse width jitter</b>	< (50 $\mu$ s + 10% of pulse width), typical, acquire readings = OFF
<b>Maximum pulse duty cycle</b>	10% for 20 V and lower ranges, 5% for 100 V range

## TYPICAL PULSE PERFORMANCE (BEST FIXED RANGE, 4-WIRE SENSE)

Source value	Limit range and value	Load	Rise time (10% to 90%)	Settling time (1% of range)
100 V	10.5 A	10 $\Omega$	300 $\mu$ s	520 $\mu$ s
100 V	1.05 A	200 $\Omega$	180 $\mu$ s	320 $\mu$ s
20 V	10 A	2 $\Omega$	150 $\mu$ s	340 $\mu$ s
10 A	105 V	10 $\Omega$	300 $\mu$ s	700 $\mu$ s
7 A	7.35 V	1 $\Omega$	120 $\mu$ s	360 $\mu$ s
5 A	10.5 V	2 $\Omega$	110 $\mu$ s	280 $\mu$ s

## DIGITIZER CHARACTERISTICS

<b>Maximum resolution</b>	18 bits
<b>Available measurement functions</b>	Voltage, current, simultaneous voltage and current, resistance, power
<b>Sampling rate<sup>16</sup></b>	Programmable 1,000 through 1,000,000 samples per second
<b>Volatile sample memory with timestamp</b>	27,500,000
<b>Minimum record time</b>	1 $\mu$ s
<b>Timestamp resolution</b>	1 ns with standard or full buffer style 1 $\mu$ s with compact buffer style
<b>Maximum record length</b>	5,000,000
<b>Range selection</b>	Fixed-range required for digitizer measurements
<b>Measurement settling time</b>	Range and load dependent; accuracy limited by settling time for 10 mA and lower current ranges

<sup>16</sup> Sample rate is not continuously adjustable. For valid discrete settings, see the Model 2461 Reference Manual.

## SUPPLEMENTAL SPECIFICATIONS

<b>Overrange</b>	105% of range, source and measure		
<b>Regulation</b>	<b>Voltage</b> <ul style="list-style-type: none"> <li>▪ Line: 0.01% of range</li> <li>▪ Load: 0.01% of range + 100 <math>\mu</math>V</li> </ul> <b>Current</b> <ul style="list-style-type: none"> <li>▪ Line: 0.01% of range</li> <li>▪ Load: 0.01% of range + 100 pA</li> </ul>		
<b>Source limits</b>	<b>Voltage source current limit:</b> <ul style="list-style-type: none"> <li>▪ Bipolar current limit set with a single value</li> <li>▪ Minimum value is 10% of range</li> </ul> <b>Current source voltage limit:</b> <ul style="list-style-type: none"> <li>▪ Bipolar voltage limit set with a single value</li> <li>▪ Minimum value is 10% of range</li> </ul>		
<b>V-limit and I-limit accuracy</b>	Add 0.3% of range and $\pm 0.02\%$ of reading to base specification		
<b>Overshoot</b>	<b>Voltage source:</b> <ul style="list-style-type: none"> <li>▪ &lt; 0.1% typical</li> <li>▪ Step size = Full scale, resistive load, 20 V range, 10 mA I-limit</li> </ul> <b>Current source:</b> <ul style="list-style-type: none"> <li>▪ &lt; 0.1% typical</li> <li>▪ Step size = 1 mA, <math>R_{Load} = 10</math> k<math>\Omega</math>, 20 V range</li> </ul>		
<b>Range change overshoot</b>	Overshoot into a fully resistive 100 k $\Omega$ load, 10 Hz to 20 MHz bandwidth, adjacent ranges: < 250 mV typical		
<b>Output settling time</b>	Time required to reach 0.1% of final value after command is processed and output slew: 20 V range, 100 mA I-limit: < 200 $\mu$ s typical		
<b>Maximum slew rate</b>	1 V per $\mu$ s, 100 V range, 100 mA limit into a 20 k $\Omega$ load (typical) 0.6 V per $\mu$ s, 20 V range, 100 mA limit into a 20 k $\Omega$ load (typical)		
<b>Overvoltage protection</b>	User-selectable values, 5% $\pm 0.5$ V tolerance; factory default = none		
<b>Voltage source noise</b>	10 Hz to 20 MHz (RMS): < 4.5 mV typical into a resistive load		
<b>Common mode voltage</b>	250 V DC		
<b>Common mode isolation</b>	> 1 G $\Omega$ , < 1000 pF		
<b>Noise rejection (typical)</b>	<b>NPLC</b>	<b>NMRR</b>	<b>CMRR</b>
	0.01	—	60 dB
	0.1	—	60 dB
	1	60 dB	100 dB

<b>Load impedance</b>	<b>Normal mode</b> <ul style="list-style-type: none"> <li>▪ 20 nF typical</li> </ul>	<b>High-capacitance mode</b> <ul style="list-style-type: none"> <li>▪ Stable into 50 <math>\mu</math>F typical</li> <li>▪ High-capacitance mode valid for <math>\geq 100 \mu</math>A ranges</li> </ul>
<b>Maximum voltage drop between force and sense terminals</b>	5 V	
<b>Maximum force lead voltage drop</b>	1 V	
<b>Maximum sense lead resistance</b>	1 M $\Omega$ for rated accuracy	
<b>Sense input impedance</b>	$> 10 \text{ G}\Omega$	
<b>Guard offset voltage</b>	$< 300 \mu$ V typical	

**SYSTEM MEASUREMENT SPEEDS<sup>17</sup>**

**Reading rates (readings per second) typical for 60 Hz (50 Hz), script (TSP<sup>®</sup>) programmed**

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

**Reading rates (readings per 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 NPLC	Internal	3000 (2800)	3000 (2790)	1700 (1600)	1550 (1500)
0.01 NPLC	External	2330 (2150)	2330 (2150)	1650 (1550)	1500 (1450)
0.1 NPLC	Internal	540 (460)	540 (460)	470 (410)	460 (400)
0.1 NPLC	External	510 (430)	510 (430)	470 (400)	460 (390)
1 NPLC	Internal	59 (49)	59 (49)	58 (48)	58 (48)
1 NPLC	External	58 (49)	58 (49)	58 (48)	58 (48)

<sup>17</sup> 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	5 ½	18	Up to 10 kS/s
20 kS/s	4 ½	16	Up to 20 kS/s
50 kS/s	4 ½	16	Up to 50 kS/s
100 kS/s	4 ½	15	Up to 100 kS/s
1 MS/s	3 ½	12	At least 100 kS/s
SCPI programmed; buffer style is compact.			

**GENERAL CHARACTERISTICS**

(Default mode unless specified)

<b>Factory default standard power-up setting</b>	<b>SCPI mode</b>
<b>Source output modes</b>	<ul style="list-style-type: none"> <li>▪ Fixed DC level</li> <li>▪ Memory/configuration list (mixed function)</li> <li>▪ Sweep (linear and logarithmic)</li> <li>▪ Sweep (dual linear and dual logarithmic)</li> </ul>
<b>Memory buffer</b>	> 250,000 readings with selected measured values and timestamp
<b>Real-time clock</b>	Lithium battery backup (more than 3 years of battery life)
<b>Remote interfaces</b>	<p><b> GPIB:</b> IEEE Std 488.1 compliant; supports IEEE Std 488.2 common commands and status model topology</p> <p><b> USB device (rear panel, type B):</b> 2.0 full-speed USBTMC</p> <p><b> USB host (front panel, type A):</b> USB 2.0, support for flash drives, FAT32</p> <p><b> Ethernet:</b> RJ-45 connector, 10/100 BT</p>
<b>IP configuration</b>	Static or DHCP
<b>Expansion interface</b>	The TSP-Link® expansion interface allows TSP-enabled instruments to trigger and communicate with each other
<b>LXI compliance</b>	1.5 LXI Device Specification 2016
<b>TSP mode</b>	Embedded Test Script Processor (TSP®) accessible from any host interface
<b>Display</b>	Five-inch capacitive touch, color TFT WVGA (800 × 480) with LED backlight
<b>Input signal connections</b>	<p><b> Front:</b> Banana</p> <p><b> Rear:</b> Mass termination screw terminal</p>
<b>Programmability</b>	SCPI or TSP command sets
<b>Interlock</b>	Active high-input

<b>Digital I/O</b>	<b>Lines</b>	Six input/output, user-defined, for digital I/O or triggering
	<b>Connector</b>	9-pin female D
	<b>Input signal levels</b>	0.7 V (maximum logic low) 3.7 V (minimum logic high)
	<b>Input voltage limits</b>	-0.25 V (absolute minimum) +5.25 V (absolute maximum)
	<b>Maximum source current</b>	+2.0 mA at > 2.7 V (per pin)
	<b>Maximum sink current</b>	-50 mA at 0.7 V (per pin, solid-state fuse protected)
	<b>5 V power supply pin</b>	Limited to 500 mA at > 4 V (solid-state fuse protected)
	<b>Handler</b>	User-definable start of test, end of test, four category bits
<b>Cooling</b>	Forced air, variable speed	
<b>Overtemperature protection</b>	Internally sensed temperature overload puts instrument in standby mode	
<b>Power supply</b>	100 V to 240 V <sub>RMS</sub> , 50 Hz to 60 Hz (automatically detected at power up)	
<b>VA rating</b>	350 V A maximum	
<b>Altitude</b>	Maximum 2000 meters (6562 feet) above sea level	
<b>EMC</b>	Conforms to European Union EMC Directive	
<b>Safety</b>	Compliance with CE and NRTL listed to UL61010-1 and UL61010-2-30 Conforms with European Union Low Voltage Directive	
<b>Vibration</b>	MIL-PRF-28800F Class 3 Random	
<b>Warm up</b>	One hour to rated accuracies	
<b>Dimensions</b>	<b>With handle and bumpers:</b> 106 mm x 255 mm x 425 mm deep (4.18 in. high x 10.05 in. wide x 16.75 in.) <b>Without handle and bumpers:</b> 88 mm x 213 mm x 397 mm deep (3.46 in. high x 8.39 in. wide x 15.63 in.)	
<b>Weight</b>	<b>With handle and bumpers:</b> 4.75 kg (10.5 lb) <b>Without handle and bumpers:</b> 4.55 kg (10.0 lb)	
<b>Environment</b>	<b>Operating:</b> 0 °C to 50 °C, 70% relative humidity up to 35 °C; derate 3% relative humidity per °C, 35 °C to 50 °C, noncondensing <b>Storage:</b> -25 °C to 65 °C	

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