

# Agilent E5270B

## 8 Slot Precision Measurement Mainframe

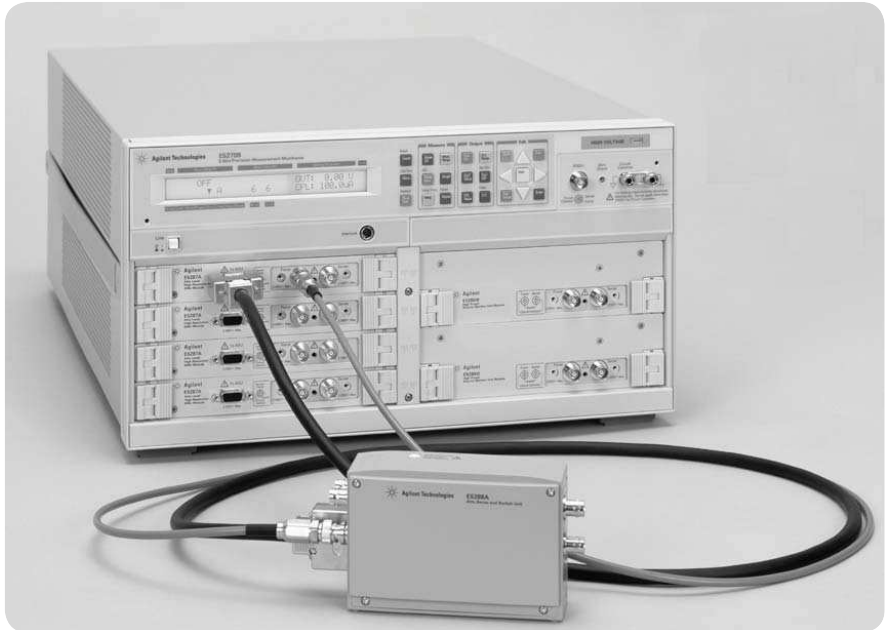
### Technical Overview

### Introduction

The Agilent E5270B 8 Slot Precision Measurement Mainframe is completely user-configurable. You can install up to eight single-slot modules (such as the Atto Level HRSMU or MPSMU), up to four dual-slot modules (such as the HPSMU), or any physically allowable combination thereof.

#### Basic features

- Performs high-speed, dc parametric measurements
- Eight slots for plug-in modules
- User interface allows spot measurements to be made from the front panel
- High-resolution, analog-to-digital converter (ADC) available to all installed modules
- High-speed ADC present on each installed SMU
- Ground unit up to 4 A
- SMU/AUX path switching on the Atto Sense and Switch Unit(ASU)
- BNC trigger-in and trigger-out connectors
- 16 general-purpose digital I/Os
- Program memory
- GPIB port for instrument control
- Self-test, self-calibration, diagnostics



*Agilent E5270B 8 Slot Precision Measurement Mainframe with E5288A ASU*

#### Measurement modes

The Agilent E5270B supports the following measurement modes:

- Spot
- Pulsed spot
- Quasi-pulsed spot
- Staircase sweep
- Multi-channel sweep
- Pulsed sweep
- Staircase sweep with pulsed bias
- Linear search
- Binary search



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## Hardware

### Specification conditions

The measurement and output accuracy are specified at the module connector terminals when referenced to the Zero Check terminal under the following conditions:

1. Temperature: 23°C ± 5°C  
(double for 5°C to 18°C, and 28°C to 40°C if not noted otherwise)
2. Humidity: 15 % to 60 %  
(double for 60 % to 70 %)
3. After 40 minutes warm-up
4. Ambient temperature change less than ± 1°C after auto calibration execution
5. Measurement made within one hour after auto calibration execution
6. Averaging (high-speed per-SMU ADC): 128 samples in 1 PLC;  
Integration time (high-resolution central ADC):  
1 PLC (1 nA to 1A range)  
20 PLC (100 pA range)  
50 PLC (1 pA to 10 pA range)
7. Filter: ON (for SMUs)
8. Kelvin connection
9. Calibration period: 1 year

Note: This document lists specifications and supplemental information for the E5270B and its associated modules. The specifications are the standards against which the E5270B and its associated modules are tested. When the E5270B or any of its associated modules are shipped from the factory, they meet the specifications. The “supplemental” information and “typical” entries in the following specifications are not warranted, but provide useful information about the functions and performance of the instrument.

## E5270B Mainframe Specification

### Supported plug-in modules

The E5270B supports eight slots for plug-in modules.

Part number	Description	Slots occupied	Range of operation	Measure resolution
E5280B	HPSMU	2	-200 V to 200 V, -1 A to 1 A	2 μV, 10 fA
E5281B	MPSMU	1	-100 V to 100 V, -100 mA to 100 mA	0.5 μV, 10 fA
E5287A	Atto Level HRSMU	1	-100 V to 100 V, -100 mA to 100 mA	0.5 μV, 1 fA
E5288A <sup>1</sup>	Atto Sense and Switch Unit (ASU)	–	-100 V to 100 V, -100 mA to 100 mA	0.5 μV, 0.1 fA

1. This is connected with the E5287A Atto Level HRSMU

### Maximum output power

The total module power consumption cannot exceed 80 W.

Note: Using the HPSMU, MPSMU, and Atto Level HRSMU units, it is impossible to create a combination that exceeds the 80 watt limit.

**Maximum voltage between common and ground**  
≤ ± 42 V

### Pulse measurement

Pulse width: 500 μsec to 2 s  
Pulse period: 5 ms to 5 s  
Period ≥ width + 2 ms  
(when width ≤ 100 ms)  
Period ≥ width + 10 ms  
(when width > 100 ms)  
Pulse resolution: 100 μs

### Ground unit (GNDU) specification

The GNDU is furnished with the E5270B mainframe.

Output voltage: 0 V ± 100 μV  
Maximum sink current: 4 A  
Output terminal/connection:  
Triaxial connector, Kelvin (remote sensing)

### GNDU supplemental information

Load capacitance: 1 μF  
Cable resistance:  
For  $I_s \leq 1.6$  A:  
Force line R < 1 Ω  
For 1.6 A <  $I_s \leq 2.0$  A:  
Force line R < 0.7 Ω  
For 2.0 A <  $I_s \leq 4.0$  A:  
Force line R < 0.35 Ω  
For all cases:  
Sense line R ≤ 10 Ω

Where  $I_s$  is the current being sunk by the GNDU.

## MPSMU (Medium Power SMU) Module Specifications

### Voltage range, resolution, and accuracy (MPSMU)

Voltage range	Force resolution	Measure resolution		Force accuracy <sup>1</sup>	Measure accuracy <sup>1</sup>		Maximum current
		High speed ADC	High resolution ADC		High speed ADC	High resolution ADC	
±0.5 V	25 µV	25 µV	0.5 µV	±(0.03 % + 350 µV)	±(0.03 % + 250 µV)	±(0.02 % + 250 µV)	100 mA
±2 V	100 µV	100 µV	2 µV	±(0.03 % + 900 µV)	±(0.03 % + 700 µV)	±(0.02 % + 700 µV)	100 mA
±5 V	250 µV	250 µV	5 µV	±(0.03 % + 2 mV)	±(0.03 % + 2 mV)	±(0.02 % + 1 mV)	100 mA
±20 V	1 mV	1 mV	20 µV	±(0.03 % + 4 mV)	±(0.03 % + 4 mV)	±(0.02 % + 2 mV)	100 mA
±40 V	2 mV	2 mV	40 µV	±(0.03 % + 7 mV)	±(0.03 % + 8 mV)	±(0.02 % + 3 mV)	<sup>2</sup>
±100 V	5 mV	5 mV	100 µV	±(0.04 % + 15 mV)	±(0.03 % + 20 mV)	±(0.03 % + 5 mV)	<sup>3</sup>

1. ± (% of output/measured value + offset voltage V)

2. 100 mA ( $V_o \leq 20$  V), 50 mA ( $20$  V <  $V_o \leq 40$  V),  $V_o$  is the output voltage in volts.

3. 100 mA ( $V_o \leq 20$  V), 50 mA ( $20$  V <  $V_o \leq 40$  V), 20 mA ( $40$  V <  $V_o \leq 100$  V),  $V_o$  is the output voltage in volts.

### Current range, resolution, and accuracy (MPSMU)

Current range	Force resolution	Measure resolution <sup>4</sup>		Force accuracy <sup>1</sup>	Measure accuracy <sup>1,2</sup>	Maximum voltage
		High speed ADC	High resolution ADC			
±1 nA	50 fA	50 fA	10 fA	±(0.5 % + 3 pA + 2 fA x $V_o$ )	±(0.5 % + 3 pA + 2 fA x $V_o$ )	100 V
±10 nA	500 fA	500 fA	10 fA	±(0.5 % + 7 pA + 20 fA x $V_o$ )	±(0.5 % + 5 pA + 20 fA x $V_o$ )	100 V
±100 nA	5 pA	5 pA	100 fA	±(0.12 % + 50 pA + 200 fA x $V_o$ )	±(0.1 % + 30 pA + 200 fA x $V_o$ )	100 V
±1 µA	50 pA	50 pA	1 pA	±(0.12 % + 400 pA + 2 pA x $V_o$ )	±(0.1 % + 200 pA + 2 pA x $V_o$ )	100 V
±10 µA	500 pA	500 pA	10 pA	±(0.12 % + 5 nA + 20 pA x $V_o$ )	±(0.1 % + 3 nA + 20 pA x $V_o$ )	100 V
±100 µA	5 nA	5 nA	100 pA	±(0.12 % + 40 nA + 200 pA x $V_o$ )	±(0.1 % + 20 nA + 200 pA x $V_o$ )	100 V
±1 mA	50 nA	50 nA	1 nA	±(0.12 % + 500 nA + 2 nA x $V_o$ )	±(0.1 % + 300 nA + 2 nA x $V_o$ )	100 V
±10 mA	500 nA	500 nA	10 nA	±(0.12 % + 4 µA + 20 nA x $V_o$ )	±(0.1 % + 2 µA + 20 nA x $V_o$ )	100 V
±100 mA	5 µA	5 µA	100 nA	±(0.12 % + 50 µA + 200 nA x $V_o$ )	±(0.1 % + 30 µA + 200 nA x $V_o$ )	<sup>3</sup>

1. ± (% of output/measured value + offset current A (fixed part determined by the output/measurement range + proportional part that is multiplied by  $V_o$ ))

2. Measurement accuracy when using either the high-speed ADC or the high-resolution ADC

3. 100 V ( $I_o \leq 20$  mA), 40 V ( $20$  mA <  $I_o \leq 50$  mA), 20 V ( $50$  mA <  $I_o \leq 100$  mA),  $I_o$  is the output current in amps.

4. Specified measurement resolution is limited by fundamental noise limits.

### Power consumption (MPSMU)

Voltage source mode:

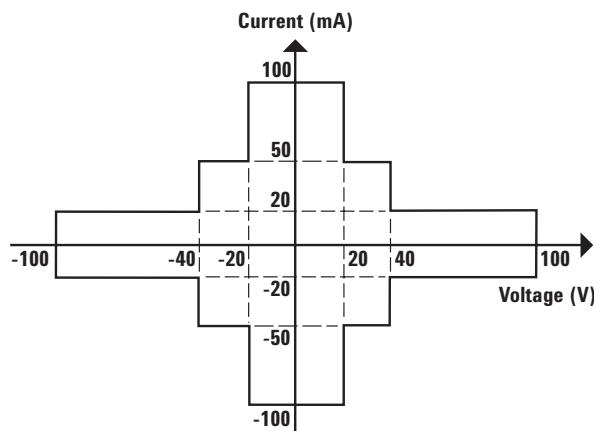
Voltage range	Power
0.5	V 20 x $I_c$ (W)
2 V	20 x $I_c$ (W)
5 V	20 x $I_c$ (W)
20 V	20 x $I_c$ (W)
40 V	40 x $I_c$ (W)
100 V	100 x $I_c$ (W)

Where  $I_c$  is the current compliance setting.

Current source mode:

Voltage compliance	Power
$V_c \leq 20$	20 x $I_o$ (W)
$20 < V_c \leq 40$	40 x $I_o$ (W)
$40 < V_c \leq 100$	100 x $I_o$ (W)

Where  $V_c$  is the voltage compliance setting and  $I_o$  is output current.



MPSMU measurement and output range

**Output terminal/connection:**  
Triaxial connector, Kelvin (remote sensing)

**Voltage/current compliance (limiting)**

The SMU can limit output voltage or current to prevent damaging the device under test.

Voltage: 0 V to  $\pm 100$  V

Current:  $\pm 1$  pA to  $\pm 100$  mA

Compliance accuracy: Same as the current (or voltage) set accuracy.

**MPSMU supplemental information**

Maximum allowable cable resistance (Kelvin connection):

Force line: 10  $\Omega$

Sense line: 10  $\Omega$

Voltage source output resistance:

0.3  $\Omega$  typical (Force line, non-Kelvin connection)

Voltage measurement input resistance:  
 $\geq 10^{13}$   $\Omega$

Current source output resistance:  
 $\geq 10^{13}$   $\Omega$  (1 nA range)

Current compliance setting accuracy (for opposite polarity):

For 1 nA to 10 nA ranges:

I setting accuracy  $\pm 12$  % of range

For 100 nA to 100 mA ranges:

I setting accuracy  $\pm 2.5$  % of range

Maximum capacitive load:

For 1 nA to 10 nA ranges: 1000 pF

For 100 nA to 10 mA ranges: 10 nF

For 100 mA ranges: 100  $\mu$ F

Maximum guard capacitance: 900 pF

Maximum shield capacitance: 5000 pF

Maximum guard offset voltage:  $\pm 3$  mV

Noise characteristics (typical, filter ON):

Voltage source:

0.01 % of V range (rms)

Current source: 0.1 % of I range (rms)

Overshoot (typical, filter ON):

Voltage source: 0.03 % of V range

Current source: 1 % of I range

Range switching transient noise (typical, filter ON):

Voltage ranging: 250 mV

Current ranging: 10 mV

Slew rate: 0.2 V/ $\mu$ s

SMU pulse setting accuracy (fixed measurement range):

Width: 0.5 % + 50  $\mu$ s

Period: 0.5 % + 100  $\mu$ s

Trigger out delay (pulsed measurements):

0 to 32.7 ms with 100  $\mu$ s resolution (< pulse width)

**HPSMU (High Power SMU) Module Specifications**

**Voltage range, resolution, and accuracy (HPSMU)**

Voltage range	Force resolution	Measure resolution		Force accuracy <sup>1</sup>	Measure accuracy <sup>1</sup>		Maximum current
		High speed ADC	High resolution ADC		High speed ADC	High resolution ADC	
$\pm 2$ V	100 $\mu$ V	100 $\mu$ V	2 $\mu$ V	$\pm(0.03$ % + 900 $\mu$ V)	$\pm(0.03$ % + 700 $\mu$ V)	$\pm(0.02$ % + 700 $\mu$ V)	1 A
$\pm 20$ V	1 mV	1 mV	20 $\mu$ V	$\pm(0.03$ % + 4 mV)	$\pm(0.03$ % + 4 mV)	$\pm(0.02$ % + 2 mV)	1 A
$\pm 40$ V	2 mV	2 mV	40 $\mu$ V	$\pm(0.03$ % + 7 mV)	$\pm(0.03$ % + 8 mV)	$\pm(0.02$ % + 3 mV)	<sup>2</sup>
$\pm 100$ V	5 mV	5 mV	100 $\mu$ V	$\pm(0.04$ % + 15 mV)	$\pm(0.03$ % + 20 mV)	$\pm(0.03$ % + 5 mV)	<sup>3</sup>
$\pm 200$ V	10 mV	10 mV	200 $\mu$ V	$\pm(0.045$ % + 30 mV)	$\pm(0.035$ % + 40 mV)	$\pm(0.035$ % + 10 mV)	<sup>4</sup>

1.  $\pm$  (% of output/measured value + offset voltage V)

2. 1 A ( $V_o \leq 20$  V), 500 mA ( $20$  V  $< V_o \leq 40$  V),  $V_o$  is the output voltage in volts.

3. 1 A ( $V_o \leq 20$  V), 500 mA ( $20$  V  $< V_o \leq 40$  V), 125 mA ( $40$  V  $< V_o \leq 100$  V),  $V_o$  is the output voltage in volts.

4. 1 A ( $V_o \leq 20$  V), 500 mA ( $20$  V  $< V_o \leq 40$  V), 125 mA ( $40$  V  $< V_o \leq 100$  V), 50 mA ( $100$  V  $< V_o \leq 200$  V),  $V_o$  is the output voltage in volts.

**Current range, resolution, and accuracy (HPSMU)**

Current range	Force resolution	Measure resolution <sup>5</sup>		Force accuracy <sup>1</sup>	Measure accuracy <sup>1,2</sup>	Maximum voltage
		High speed ADC	High resolution ADC			
$\pm 1$ nA	50 fA	50 fA	10 fA	$\pm(0.5$ %+3 pA+2 fA x $V_o$ )	$\pm(0.5$ %+3 pA+2 fA x $V_o$ )	200 V
$\pm 10$ nA	500 fA	500 fA	10 fA	$\pm(0.5$ %+7 pA+20 fA x $V_o$ )	$\pm(0.5$ %+5 pA+20 fA x $V_o$ )	200 V
$\pm 100$ nA	5 pA	5 pA	100 fA	$\pm(0.12$ %+50 pA+200 fA x $V_o$ )	$\pm(0.1$ %+30 pA+200 fA x $V_o$ )	200 V
$\pm 1$ $\mu$ A	50 pA	50 pA	1 pA	$\pm(0.12$ %+400 pA+2 pA x $V_o$ )	$\pm(0.1$ %+200 pA+2 pA x $V_o$ )	200 V
$\pm 10$ $\mu$ A	500 pA	500 pA	10 pA	$\pm(0.12$ %+5 nA+20 pA x $V_o$ )	$\pm(0.1$ %+3 nA+20 pA x $V_o$ )	200 V
$\pm 100$ $\mu$ A	5 nA	5 nA	100 pA	$\pm(0.12$ %+40 nA+200 pA x $V_o$ )	$\pm(0.1$ %+20 nA+200 pA x $V_o$ )	200 V
$\pm 1$ mA	50 nA	50 nA	1 nA	$\pm(0.12$ %+500 nA+2 nA x $V_o$ )	$\pm(0.1$ %+300 nA+2 nA x $V_o$ )	200 V
$\pm 10$ mA	500 nA	500 nA	10 nA	$\pm(0.12$ %+4 $\mu$ A+20 nA x $V_o$ )	$\pm(0.1$ %+2 $\mu$ A+20 nA x $V_o$ )	200 V
$\pm 100$ mA	5 $\mu$ A	5 $\mu$ A	100 nA	$\pm(0.12$ %+50 $\mu$ A+200 nA x $V_o$ )	$\pm(0.1$ %+30 $\mu$ A+200 nA x $V_o$ )	<sup>3</sup>
$\pm 1$ A	50 $\mu$ A	50 $\mu$ A	1 $\mu$ A	$\pm(0.5$ %+500 $\mu$ A+2 $\mu$ A x $V_o$ )	$\pm(0.5$ %+300 $\mu$ A+2 $\mu$ A x $V_o$ )	<sup>4</sup>

1.  $\pm$  (% of output/measured value + offset current A (fixed part determined by the output/measurement range + proportional part that is multiplied by  $V_o$ ))

2. Measurement accuracy when using either the high-speed ADC or the high-resolution ADC

3. 200 V ( $I_o \leq 50$  mA), 100 V ( $50$  mA  $< I_o \leq 100$  mA)

4. 200 V ( $I_o \leq 50$  mA), 100 V ( $50$  mA  $< I_o \leq 125$  mA), 40 V ( $125$  mA  $< I_o \leq 500$  mA), 20 V ( $500$  mA  $< I_o \leq 1$  A),  $I_o$  is the output current in amps.

5. Specified measurement resolution is limited by fundamental noise limits

### Power consumption (HPSMU)

Voltage source mode:

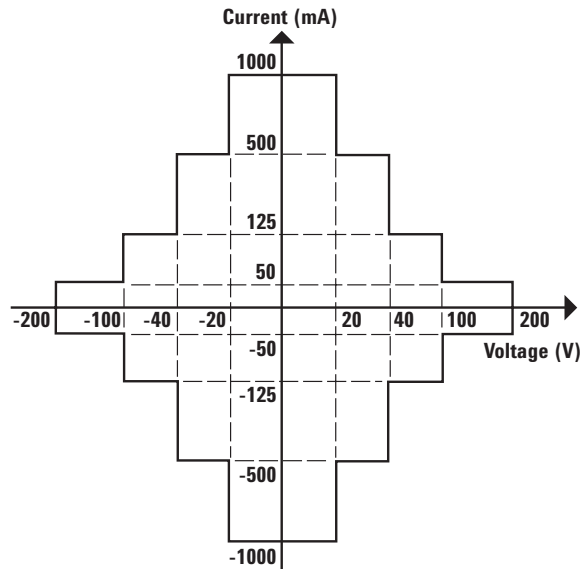
Voltage range	Power
2 V	20 x I <sub>c</sub> (W)
20 V	20 x I <sub>c</sub> (W)
40 V	40 x I <sub>c</sub> (W)
100 V	100 x I <sub>c</sub> (W)
200 V	200 x I <sub>c</sub> (W)

Where I<sub>c</sub> is the current compliance setting.

Current source mode:

Voltage compliance	Power
V <sub>c</sub> ≤ 20	20 x I <sub>o</sub> (W)
20 < V <sub>c</sub> ≤ 40	40 x I <sub>o</sub> (W)
40 < V <sub>c</sub> ≤ 100	100 x I <sub>o</sub> (W)
100 < V <sub>c</sub> ≤ 200	200 x I <sub>o</sub> (W)

Where V<sub>c</sub> is the voltage compliance setting and I<sub>o</sub> is output current.



HPSMU measurement and output range

### Output terminal/connection:

Triaxial connector, Kelvin (remote sensing)

### Voltage/current compliance (limiting)

The SMU can limit output voltage or current to prevent damaging the device under test.

Voltage: 0 V to ± 200 V

Current: ± 1 pA to ± 1 A

Compliance accuracy: Same as the current (or voltage) set accuracy.

### HPSMU supplemental information

Maximum allowable cable resistance (Kelvin connection):

Force line: 10 Ω (I ≤ 100 mA)

Force line: 1.5 Ω (100 mA < I ≤ 1 A)

Sense line: 10 Ω (All cases)

Voltage source output resistance:

0.2 Ω typical (Force line, non-Kelvin connection)

Voltage measurement input resistance: ≥ 10<sup>13</sup> Ω

Current source output resistance: ≥ 10<sup>13</sup> Ω (1 nA range)

Current compliance setting accuracy (for opposite polarity):

For 1 nA to 10 nA ranges:

I setting accuracy ± 12 % of range

For 100 nA to 1 A ranges:

I setting accuracy ± 2.5 % of range

Maximum capacitive load:

For 1 nA to 10 nA ranges: 1000 pF

For 100 nA to 10 mA ranges: 10 nF

For 100 mA to 1 A ranges: 100 μF

Maximum guard capacitance: 900 pF

Maximum shield capacitance: 5000 pF

Maximum guard offset voltage: ± 1 mV

Noise characteristics (typical, filter ON):

Voltage source: 0.01 % of V range (rms)

Current source: 0.1 % of I range (rms)

Overshoot (typical, filter ON):

Voltage source: 0.03 % of V range

Current source: 1 % of I range

Range switching transient noise (typical, filter ON):

Voltage ranging: 250 mV

Current ranging: 10 mV

Slew rate: 0.2 V/μs

SMU pulse setting accuracy (fixed measurement range):

Width: 0.5 % + 50 μs

Period: 0.5 % + 100 μs

Trigger out delay (pulsed measurements):

0 to 32.7 ms with 100 μs resolution (< pulse width)

## Atto Level HRSMU Module Specifications (without ASU)

### Voltage range, resolution, and accuracy (Atto level HRSMU without ASU)

Voltage range	Force resolution	Measure resolution		Force accuracy <sup>1</sup>	Measure accuracy <sup>1</sup>		Maximum current
		High speed ADC	High resolution ADC		High speed ADC	High resolution ADC	
±0.5 V	25 µV	25 µV	0.5 µV	±(0.02 % + 150 µV)	±(0.01 % + 250 µV)	±(0.01 % + 150 µV)	100 mA
±2 V	100 µV	100 µV	2 µV	±(0.02 % + 400 µV)	±(0.01 % + 700 µV)	±(0.01 % + 200 µV)	100 mA
±5 V	250 µV	250 µV	5 µV	±(0.02 % + 750 µV)	±(0.01 % + 2 mV)	±(0.01 % + 250 µV)	100 mA
±20 V	1 mV	1 mV	20 µV	±(0.02 % + 3 mV)	±(0.01 % + 4 mV)	±(0.01 % + 1 mV)	100 mA
±40 V	2 mV	2 mV	40 µV	±(0.025 % + 6 mV)	±(0.015 % + 8 mV)	±(0.015 % + 2 mV)	<sup>2</sup>
±100 V	5 mV	5 mV	100 µV	±(0.03 % + 15 mV)	±(0.02 % + 20 mV)	±(0.02 % + 5 mV)	<sup>3</sup>

1. ± (% of output/measured value + offset voltage)

2. 100 mA ( $V_o \leq 20$  V), 50 mA ( $20$  V  $< V_o \leq 40$  V),  $V_o$  is the output voltage in volts.

3. 100 mA ( $V_o \leq 20$  V), 50 mA ( $20$  V  $< V_o \leq 40$  V), 20 mA ( $40$  V  $< V_o \leq 100$  V),  $V_o$  is the output voltage in volts.

### Current range, resolution, and accuracy (Atto level HRSMU without ASU)

Current range	Force resolution	Measure resolution <sup>4,5</sup>		Force accuracy <sup>1</sup>	Measure accuracy <sup>1,2</sup>	Maximum voltage
		High speed ADC	High resolution ADC			
±10 pA	5 fA	1 fA	1 fA	±(0.5 % + 40 fA + 10 aA x $V_o$ )	±(0.5 % + 15 fA + 10 aA x $V_o$ )	100 V
±100 pA	5 fA	5 fA	2 fA	±(0.5 % + 120 fA + 100 aA x $V_o$ )	±(0.5 % + 40 fA + 100 aA x $V_o$ )	100 V
±1 nA	50 fA	50 fA	10 fA	±(0.25 % + 400 fA + 1 fA x $V_o$ )	±(0.25 % + 300 fA + 1 fA x $V_o$ )	100 V
±10 nA	500 fA	500 fA	10 fA	±(0.25 % + 4 pA + 10 fA x $V_o$ )	±(0.25 % + 2 pA + 10 fA x $V_o$ )	100 V
±100 nA	5 pA	5 pA	100 fA	±(0.12 % + 40 pA + 100 fA x $V_o$ )	±(0.1 % + 20 pA + 100 fA x $V_o$ )	100 V
±1 µA	50 pA	50 pA	1 pA	±(0.12 % + 400 pA + 1 pA x $V_o$ )	±(0.1 % + 200 pA + 1 pA x $V_o$ )	100 V
±10 µA	500 pA	500 pA	10 pA	±(0.07 % + 4 nA + 10 pA x $V_o$ )	±(0.05 % + 2 nA + 10 pA x $V_o$ )	100 V
±100 µA	5 nA	5 nA	100 pA	±(0.07 % + 40 nA + 100 pA x $V_o$ )	±(0.05 % + 20 nA + 100 pA x $V_o$ )	100 V
±1 mA	50 nA	50 nA	1 nA	±(0.06 % + 400 nA + 1 nA x $V_o$ )	±(0.04 % + 200 nA + 1 nA x $V_o$ )	100 V
±10 mA	500 nA	500 nA	10 nA	±(0.06 % + 4 µA + 10 nA x $V_o$ )	±(0.04 % + 2 µA + 10 nA x $V_o$ )	100 V
±100 mA	5 µA	5 µA	100 nA	±(0.12 % + 40 µA + 100 nA x $V_o$ )	±(0.1 % + 20 µA + 100 nA x $V_o$ )	<sup>3</sup>

1. ± (% of output/measured value + offset current A (fixed part determined by the output/measurement range + proportional part that is multiplied by  $V_o$ ))

2. Measurement accuracy when using either the high-speed ADC or the high-resolution ADC.

3. 100 V ( $I_o \leq 20$  mA), 40 V ( $20$  mA  $< I_o \leq 50$  mA), 20 V ( $50$  mA  $< I_o \leq 100$  mA),  $I_o$  is the output current in amps.

4. Minimum 10 aA display resolution at 10 pA range by 6 digits.

5. Specified measurement resolution is limited by fundamental noise limits.

### Power consumption

#### (Atto level HRSMU without ASU)

Voltage source mode:

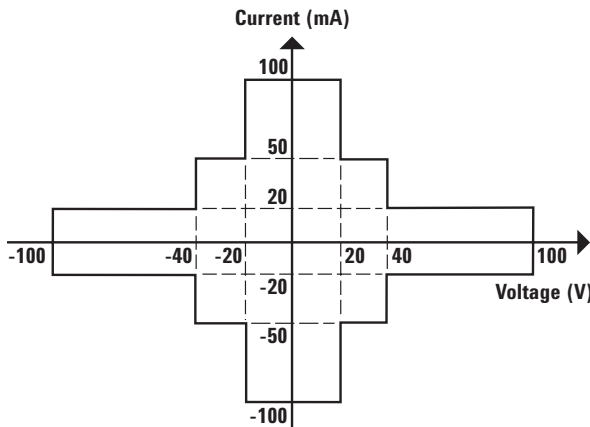
Voltage range	Power
0.5 V	20 x $I_c$ (W)
2 V	20 x $I_c$ (W)
5 V	20 x $I_c$ (W)
20 V	20 x $I_c$ (W)
40 V	40 x $I_c$ (W)
100 V	100 x $I_c$ (W)

Where  $I_c$  is the current compliance setting.

Current source mode:

Voltage compliance	Power
$V_c \leq 20$	20 x $I_o$ (W)
$20 < V_c \leq 40$	40 x $I_o$ (W)
$40 < V_c \leq 100$	100 x $I_o$ (W)

Where  $V_c$  is the voltage compliance setting and  $I_o$  is output current.



Atto level HRSMU without ASU measurement and output range

**Output terminal/connection:**

Triaxial connector, Kelvin (remote sensing)

**Voltage/current compliance (limiting)**

The SMU can limit output voltage or current to prevent damaging the device under test.

Voltage: 0 V to  $\pm 100$  V

Current:  $\pm 100$  fA to  $\pm 100$  mA

Compliance accuracy: Same as the current (or voltage) set accuracy.

**Atto level HRSMU without ASU supplemental information**

Maximum allowable cable resistance (Kelvin connection):

Force line: 10  $\Omega$

Sense line: 10  $\Omega$

Voltage source output resistance:

0.3  $\Omega$  typical (Force line, non-Kelvin connection)

Voltage measurement input resistance:  $\geq 10^{13}$   $\Omega$

Current source output resistance:  $\geq 10^{13}$   $\Omega$  (1 nA range)

Current compliance setting accuracy (for opposite polarity):

For 10 pA to 10 nA ranges:

I setting accuracy  $\pm 12$  % of range

For 100 nA to 100 mA ranges:

I setting accuracy  $\pm 2.5$  % of range

Maximum capacitive load:

For 10 pA to 10 nA ranges: 1000 pF

For 100 nA to 10 mA ranges: 10 nF

For 100 mA ranges: 100  $\mu$ F

Maximum guard capacitance: 900 pF

Maximum shield capacitance: 5000 pF

Maximum guard offset voltage:  $\pm 3$  mV

Noise characteristics (typical, filter ON):

Voltage source: 0.01 % of V range (rms)

Current source: 0.1 % of I range (rms)  
Overshoot (typical, filter ON):

Voltage source: 0.03 % of V range

Current source: 1 % of I range

Range switching transient noise (typical, filter ON):

Voltage ranging: 250 mV

Current ranging: 10 mV

Slew rate: 0.2 V/ $\mu$ s

SMU pulse setting accuracy (fixed measurement range):

Width: 0.5 % + 50  $\mu$ s

Period: 0.5 % + 100  $\mu$ s

Trigger out delay (pulsed measurements):

0 to 32.7 ms with 100  $\mu$ s resolution (< pulse width)

**Atto Level HRSMU Module Specifications (with ASU)****Voltage range, resolution, and accuracy (Atto level HRSMU with ASU)**

Voltage range	Force resolution	Measure resolution		Force accuracy <sup>1</sup>	Measure accuracy <sup>1</sup>		Maximum current
		High speed ADC	High resolution ADC		High speed ADC	High resolution ADC	
$\pm 0.5$ V	25 $\mu$ V	25 $\mu$ V	0.5 $\mu$ V	$\pm(0.02$ % + 150 $\mu$ V)	$\pm(0.01$ % + 250 $\mu$ V)	$\pm(0.01$ % + 150 $\mu$ V)	100 mA
$\pm 2$ V	100 $\mu$ V	100 $\mu$ V	2 $\mu$ V	$\pm(0.02$ % + 400 $\mu$ V)	$\pm(0.01$ % + 700 $\mu$ V)	$\pm(0.01$ % + 200 $\mu$ V)	100 mA
$\pm 5$ V	250 $\mu$ V	250 $\mu$ V	5 $\mu$ V	$\pm(0.02$ % + 750 $\mu$ V)	$\pm(0.01$ % + 2 mV)	$\pm(0.01$ % + 250 $\mu$ V)	100 mA
$\pm 20$ V	1 mV	1 mV	20 $\mu$ V	$\pm(0.02$ % + 3 mV)	$\pm(0.01$ % + 4 mV)	$\pm(0.01$ % + 1 mV)	100 mA
$\pm 40$ V	2 mV	2 mV	40 $\mu$ V	$\pm(0.025$ % + 6 mV)	$\pm(0.015$ % + 8 mV)	$\pm(0.015$ % + 2 mV)	<sup>2</sup>
$\pm 100$ V	5 mV	5 mV	100 $\mu$ V	$\pm(0.03$ % + 15 mV)	$\pm(0.02$ % + 20 mV)	$\pm(0.02$ % + 5 mV)	<sup>3</sup>

1.  $\pm$  (% of output/measured value + offset voltage)

2. 100 mA ( $V_o \leq 20$  V), 50 mA ( $20$  V <  $V_o \leq 40$  V),  $V_o$  is the output voltage in volts.

3. 100 mA ( $V_o \leq 20$  V), 50 mA ( $20$  V <  $V_o \leq 40$  V), 20 mA ( $40$  V <  $V_o \leq 100$  V),  $V_o$  is the output voltage in volts.

### Current range, resolution, and accuracy (Atto level HRSMU with ASU)

Current range	Force resolution	Measure resolution <sup>4,5</sup>		Force accuracy <sup>1</sup>	Measure accuracy <sup>1,2</sup>	Maximum voltage
		High speed ADC	High resolution ADC			
±1 pA	1 fA	100 aA	100 aA	±(1.8 % + 15 fA)	±(1.8 % + 12 fA)	100 V
±10 pA	5 fA	1 fA	400 aA	±(0.5 % + 40 fA + 10 aA × Vo)	±(0.5 % + 15 fA + 10 aA × Vo)	100 V
±100 pA	5 fA	5 fA	500 aA	±(0.5 % + 120 fA + 100 aA × Vo)	±(0.5 % + 40 fA + 100 aA × Vo)	100 V
±1 nA	50 fA	50 fA	10 fA	±(0.25 % + 400 fA + 1 fA × Vo)	±(0.25 % + 300 fA + 1 fA × Vo)	100 V
±10 nA	500 fA	500 fA	10 fA	±(0.25 % + 4 pA + 10 fA × Vo)	±(0.25 % + 2 pA + 10 fA × Vo)	100 V
±100 nA	5 pA	5 pA	100 fA	±(0.12 % + 40 pA + 100 fA × Vo)	±(0.1 % + 20 pA + 100 fA × Vo)	100 V
±1 μA	50 pA	50 pA	1 pA	±(0.12 % + 400 pA + 1 pA × Vo)	±(0.1 % + 200 pA + 1 pA × Vo)	100 V
±10 μA	500 pA	500 pA	10 pA	±(0.07 % + 4 nA + 10 pA × Vo)	±(0.05 % + 2 nA + 10 pA × Vo)	100 V
±100 μA	5 nA	5 nA	100 pA	±(0.07 % + 40 nA + 100 pA × Vo)	±(0.05 % + 20 nA + 100 pA × Vo)	100 V
±1 mA	50 nA	50 nA	1 nA	±(0.06 % + 400 nA + 1 nA × Vo)	±(0.04 % + 200 nA + 1 nA × Vo)	100 V
±10 mA	500 nA	500 nA	10 nA	±(0.06 % + 4 μA + 10 nA × Vo)	±(0.04 % + 2 μA + 10 nA × Vo)	100 V
±100 mA	5 μA	5 μA	100 nA	±(0.12 % + 40 μA + 100 nA × Vo)	±(0.1 % + 20 μA + 100 nA × Vo)	100 V <sup>3</sup>

- ± (% of output/measured value + offset current A (fixed part determined by the output/measurement range + proportional part that is multiplied by Vo)
- Measurement accuracy when using either the high-speed ADC or the high-resolution ADC.
- 100 V ( $I_o \leq 20$  mA), 40 V ( $20$  mA <  $I_o \leq 50$  mA), 20 V ( $50$  mA <  $I_o \leq 100$  mA),  $I_o$  is the output current in amps
- Minimum 1 aA display resolution at 1 pA range by 6 digits.
- Specified measurement resolution is limited by fundamental noise limits.
- Measurements at lower range are affected strongly by vibrations and shocks. Do not place the environment of vibrations and shocks during measurements.

### Power consumption (Atto level HRSMU with ASU)

Voltage source mode:

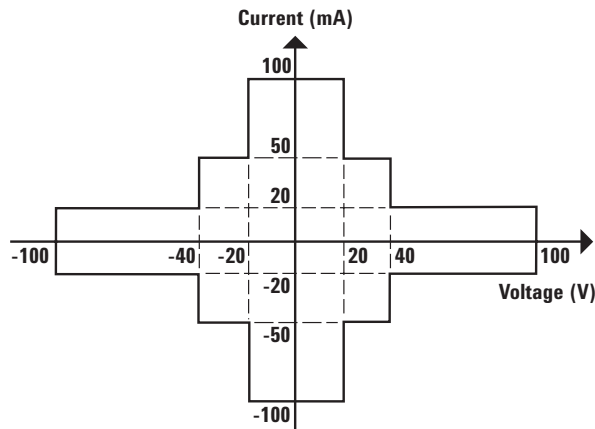
Voltage range	Power
0.5 V	20 × I <sub>c</sub> (W)
2 V	20 × I <sub>c</sub> (W)
5 V	20 × I <sub>c</sub> (W)
20 V	20 × I <sub>c</sub> (W)
40 V	40 × I <sub>c</sub> (W)
100 V	100 × I <sub>c</sub> (W)

Where I<sub>c</sub> is the current compliance setting.

Current source mode:

Voltage compliance	Power
V <sub>c</sub> ≤ 20	20 × I <sub>o</sub> (W)
20 < V <sub>c</sub> ≤ 40	40 × I <sub>o</sub> (W)
40 < V <sub>c</sub> ≤ 100	100 × I <sub>o</sub> (W)

Where V<sub>c</sub> is the voltage compliance setting and I<sub>o</sub> is output current.



Atto level HRSMU with ASU measurement and output range



**Output terminal/connection:**

Triaxial connector, Kelvin (remote sensing)

**Voltage/current compliance (limiting)**

The SMU can limit output voltage or current to prevent damaging the device under test.

Voltage: 0 V to  $\pm 100$  V

Current:  $\pm 10$  fA to  $\pm 100$  mA

Compliance accuracy: Same as the current (or voltage) set accuracy.

**Atto level HRSMU with ASU supplemental information**

Maximum allowable cable resistance (Kelvin connection):

Force line: 10  $\Omega$

Sense line: 10  $\Omega$

Voltage source output resistance:

0.3  $\Omega$  typical (Force line, non-Kelvin connection)

Voltage measurement input resistance:  
 $\geq 10^{13}$   $\Omega$

Current source output resistance:  
 $\geq 10^{13}$   $\Omega$  (1 nA range)

Current compliance setting accuracy (for opposite polarity):

For 1 pA to 10 nA ranges:

I setting accuracy  $\pm 12$  % of range

For 100 nA to 100 mA ranges:

I setting accuracy  $\pm 2.5$  % of range

Maximum capacitive load:

For 1 pA to 10 nA ranges: 1000 pF

For 100 nA to 10 mA ranges: 10 nF

For 100 mA ranges: 100  $\mu$ F

Maximum guard capacitance: 660 pF

Maximum shield capacitance: 3500 pF

Maximum guard offset voltage:

$\pm 4.2$  mV ( $I_{out} \leq 100$   $\mu$ A)

Noise characteristics (typical, filter ON):

Voltage source: 0.01 % of V range (rms)

Current source: 0.1 % of I range (rms)

Overshoot (typical, filter ON):

Voltage source: 0.03 % of V range

Current source: 1 % of I range

Range switching transient noise (typical, filter ON):

Voltage ranging: 250 mV

Current ranging: 10 mV

Slew rate: 0.2 V/ $\mu$ s

Maximum capacitive load:

SMU pulse setting accuracy (fixed measurement range):

Width: 0.5 % + 50  $\mu$ s

Period: 0.5 % + 100  $\mu$ s

Trigger out delay (pulsed measurements):

0 to 32.7 ms with 100  $\mu$ s resolution (< pulse width)

## Atto Sense and Switch Unit (ASU)

**AUX path specification**

Maximum voltage

100 V: between AUX input and AUX common

100 V: between AUX input and circuit common

42 V: between AUX common and circuit common

Maximum current

0.5 A: between AUX input and force output

**ASU supplemental information**

Band width (at  $-3$  dB): < 30 MHz (AUX port)

## Functions

### Front panel operations

#### Display

- Display error messages
- Display spot measurement set value
- Display spot measurement result

#### Keypad operations

- Set GPIB address
- Set local/remote mode
- Select measurement channel
- Set spot measurement set value
- Start calibration/diagnostics

## MPSMU, HPSMU, and Atto Level HRSMU Measurement Mode Details

#### Spot measurement mode

Outputs and measures voltage and current.

#### Staircase sweep measurement mode

Outputs swept voltage or current, and measures dc voltage or current. One channel can sweep current or voltage while up to eight channels can measure current or voltage. A second channel can be synchronized with the primary sweep channel as an additional voltage or current sweep source. Linear or log sweeps can be performed.

Number of steps: 1 – 1,001  
Hold time: 0 – 655.35 s,  
1 ms resolution  
Delay time: 0 – 65.5350 s,  
100  $\mu$ s resolution

#### Multi-channel sweep measurement mode

Outputs swept voltage or current, and measures dc voltage or current. Up to eight channels can sweep current or

voltage and up to eight channels can measure current or voltage. Linear or log sweeps can be performed.

Number of steps: 1– 1,001  
Hold time: 0 – 655.35 s,  
1 ms resolution  
Delay time: 0 – 65.5350 s,  
100  $\mu$ s resolution

#### Pulsed spot measurement mode

Outputs a voltage or current pulse and measures dc voltage or current.

Pulse width: 500  $\mu$ s to 100 ms,  
100  $\mu$ s resolution  
Pulse period: 5 ms to 1 s ( $\geq$  pulse width + 4 ms), 100  $\mu$ s resolution  
Maximum pulse duty: 50 %

#### Pulsed sweep measurement mode

Outputs pulsed swept voltage or current, and measures dc voltage or current. A second channel can be programmed to output a staircase sweep voltage or current synchronized with the pulsed sweep output.

#### Staircase sweep with pulsed bias measurement mode

Outputs swept voltage or current, and measures dc voltage or current. A second channel can be programmed to output a pulsed bias voltage or current. A third channel can be synchronized with the primary sweep channel as an additional voltage or current sweep source.

#### Quasi-pulsed spot measurement mode

Outputs quasi-pulsed voltage and measures dc voltage or current.

#### Linear search measurement mode

Outputs and measure voltage or current by using linear search method.

#### Binary search measurement mode

Outputs and measure voltage or current by using binary search method.

## Time Stamp

The E5270B supports a time stamp function utilizing an internal quartz clock.

Resolution: 100  $\mu$ s

## Program Memory

The E5270B mainframe contains (volatile) memory that can be used to increase test measurement throughput. Program memory allows the storage of program code in the E5270B, eliminating the need to communicate over the GPIB interface. In addition, input data can be passed to code sequences stored in program memory.

Maximum lines of storable code:  
40,000

Maximum number of program sequences: 2,000

## Output Data Buffer

The number of data points that can be stored in the data buffer varies with the choice of the output data format.

Minimum number of storable data Points: 34,034

## Trigger I/O

Trigger in/out synchronization pulses before and after setting and measuring dc voltage and current. Arbitrary trigger events can be masked or activated independently.

### Input

An external trigger input signal can be used to do any of the following:

1. Start a measurement
2. Start a measurement at each sweep step for a staircase sweep or multi channel sweep measurement
3. Start the source output at each sweep step for a staircase sweep, pulsed sweep, staircase sweep with pulsed bias, or multi-channel sweep measurement.
4. Start the pulsed output for a pulsed spot measurement.
5. Recover from a wait state.

Input level: TTL level, negative or positive edge trigger, or TTL level, negative or positive gate trigger.

### Output

An output trigger signal can be sent when one of the following events occurs:

1. The end of a measurement is reached.
2. The end of a measurement at each sweep step for a staircase sweep or multi channel sweep measurement is reached.
3. Completion of the source output setup at each sweep step for a staircase sweep, pulsed sweep, staircase sweep with pulsed bias, or multi-channel sweep measurement.
4. Completion of the pulsed output setup for a pulsed spot measurement.
5. A trigger command is issued.

Output level: TTL level, negative or positive edge trigger, or TTL level, negative or positive gate trigger.

## General Purpose Digital I/O

16 general-purpose digital I/O signals are available via a 25-pin DIN connector. These pins can be used as an alternative to the BNC trigger-in and trigger-out lines to synchronize the E5270B with other instruments. They can also be used as output and input ports for digital signals. The user can selectively assign pins to trigger mode or digital I/O mode.

## Attached Software

A VXI *plug&play* driver and E5270 TIS Library software are supplied.

### Supported operating systems for VXI *plug&play* driver:

Microsoft® Windows® XP Professional (SP3), Windows Vista Business (SP2, 32 bit), Windows 7 Professional (SP1, 32 bit or 64 bit)

### Supported operating system for E5270 TIS Library:

Microsoft Windows XP Professional (SP3), Windows 7 Professional (SP1, 32 bit or 64 bit)

## General Specifications

### Temperature range

Operating: +5°C to +40°C  
Storage: -20°C to +60°C

### Humidity range

Operating: 15 % to 70 % RH, non-condensing  
Storage: 5 % to 80 % RH, non-condensing

### Altitude

Operating: 0 m to 2,000 m (6,561 ft)  
Storage: 0 m to 4,600 m (15,092 ft)

### Power requirement

ac voltage: 90 V to 264 V  
Line frequency: 47 Hz to 63 Hz

### Maximum volt-amps (VA)

E5270B: 600 VA

### Regulatory compliance

EMC: IEC61326-1:+A1/  
EN61326-1:+A1  
AS/NZS 2064.1

Safety: CSA C22.2 No.1010.1-1992  
IEC61010-1:+A2/  
EN61010-1:+A2  
UL3111-1:1994

### Certification

CE, CSA, NRTL/C, C-Tick

### Dimensions

E5270B: 426 mm W x 235 mm H x 575 mm D

### Weight

E5270B (empty): 17 kg  
E5280A: 2.5 kg  
E5281A: 1.4 kg  
E5287A: 1.5 kg  
E5288A: 0.5 kg

### Furnished accessories

Software CD-ROM (including VXI *plug&play* driver and E5270 TIS Library)