HP 4155B
Semiconductor Parameter Analyzer
HP 4156B
Precision Semiconductor Parameter Analyzer

Technical Data

Specifications - July 1997

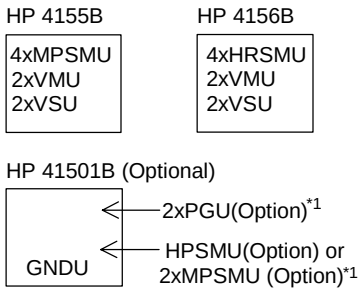
Introduction

Basic Functions

The HP 4155B and HP 4156B functions:

- Set measurement and/or stress conditions
- Control measurement and/or stress execution
- Perform arithmetic calculations
- Display measured and calculated results on the LCD display
- Perform graphical analysis
- Store and recall measurement setups, and measurement and graphical display data
- Dump to printers or plotters for hard-copy output
- Perform measurement and analysis with the built-in HP Instrument BASIC
- Self test, Auto calibration

Configuration



SMU: Source Monitor Unit
HRSMU: High Resolution SMU
(1fA/2µV to 100mA/100V)
MPSMU: Medium Power SMU
(10fA/2µV to 100mA/100V)
HPSMU: High Power SMU
(10fA/2µV to 1A/200V)
VMU: Voltage Monitor Unit
VSU: Voltage Source Unit
PGU: Pulse Generator Unit (1 channel)
GNDU: Ground Unit

*1: Minimum number of installable MPSMU or PGU is two.

Hardware

Specification Condition

The "supplemental" information and "typical" entries in the following specifications are not warranted, but provide useful information about the functions and performance of the instruments.

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

1. 23°C ± 5°C (double between 5°C to 18°C, and 28°C to 40°C if not noted otherwise)
2. After 40 minutes warm-up
3. Ambient temperature change less than ± 1°C after auto calibration execution.
4. Integration time: medium or long
5. Filter: ON (for SMUs)
6. Kelvin connection (for HRSMU, HPSMU, and GNDU)
7. Calibration period: 1 year

HP 4156B Precision Semiconductor Parameter Analyzer

HRSMU (High Resolution SMU) Specifications

Voltage Range, Resolution, and Accuracy (HRSMU)

Voltage Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
± 2V	100µV	±(0.02%+400µV)	2µV	±(0.01%+200µV)	100mA
± 20V	1mV	±(0.02%+3mV)	20µV	±(0.01%+1mV)	100mA
± 40V	2mV	±(0.025%+6mV)	40µV	±(0.015%+2mV)	*1
± 100V	5mV	±(0.03%+15mV)	100µV	±(0.02%+5mV)	*2

*1: 100mA (Vout≤20V), 50mA (20V<Vout≤40V)

*2: 100mA (Vout≤20V), 50mA (20V<Vout≤40V), 20mA (40V<Vout≤100V)

Current Range, Resolution, and Accuracy (HRSMU)

Current Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. V
±10pA	10fA	±(4%+400fA)*1*2	1fA	±(4%+20fA+1fA×Vout/100)*1*2	100V
±100pA	10fA	±(4%+400fA)*1*2	1fA	±(4%+40fA+10fA×Vout/100)*1*2	100V
±1nA	100fA	±(0.5%+0.7pA+1fA×Vout)*2	10fA	±(0.5%+0.4pA+1fA×Vout)*2	100V
±10nA	1pA	±(0.5%+4pA+10fA×Vout)	10fA	±(0.5%+2pA+10fA×Vout)	100V
±100nA	10pA	±(0.12%+40pA+100fA×Vout)	100fA	±(0.1%+20pA+100fA×Vout)	100V
±1µA	100pA	±(0.12%+400pA+1pA×Vout)	1pA	±(0.1%+200pA+1pA×Vout)	100V
±10µA	1nA	±(0.07%+4nA+10pA×Vout)	10pA	±(0.05%+2nA+10pA×Vout)	100V
±100µA	10nA	±(0.07%+40nA+100pA×Vout)	100pA	±(0.05%+20nA+100pA×Vout)	100V
±1mA	100nA	±(0.06%+400nA+1nA×Vout)	1nA	±(0.04%+200nA+1nA×Vout)	100V
±10mA	1µA	±(0.06%+4µA+10nA×Vout)	10nA	±(0.04%+2µA+10nA×Vout)	100V
±100mA	10µA	±(0.12%+40µA+100nA×Vout)	100nA	±(0.1%+20µA+100nA×Vout)	*3

*1: The accuracy is applicable when offset cancellation has been performed.

*2: The offset current specification is multiplied by one of the following factors depending upon the ambient temperature and humidity (RH = Relative Humidity):

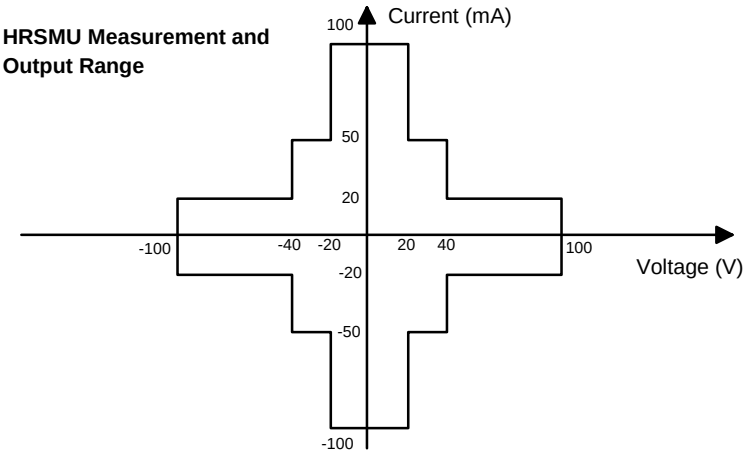
Temperature	Humidity % RH 5 - 60	60 - 80
5°C to 18°C	×2	×2
18°C to 28°C	×1	×2
28°C to 40°C	×2	×5

*3: 100V (Iout≤20mA)
40V (20mA<Iout≤50mA)
20V (50mA<Iout≤100mA)

Vout is the output voltage in volts.
Iout is the output current in amps.
For example, accuracy specifications are given as ±% of set/measured value (0.04%) plus offset value (200nA+1nA×Vout) for the 1mA range. The offset value consists of a fixed part determined by the set/measuremet range and a proportional part that is multiplied by Vout or Vout/100.

Output terminal/connection:
Dual triaxial connectors, Kelvin (remote sensing)

HRSMU Measurement and Output Range



Voltage/Current Compliance (Limiting):
The SMU can limit output voltage or current to prevent damaging the device under test.
Voltage: 0V to ±100V
Current: ±100fA to ±100mA
Compliance Accuracy: Same as the current (voltage) settling accuracy.

HRSMU Supplemental Information:
Maximum allowable cable resistance when using Kelvin connection (Force, Sense): 10Ω
Typical voltage source output resistance (Force line/non-Kelvin connection): 0.2Ω
Voltage measurement input resistance/ current source output resistance: $\geq 10^{15}\Omega$ (10pA range)
Current compliance setting accuracy for opposite polarity:
10pA to 10nA range: V/I setting accuracy ± 12% of range
100nA to 100mA range: V/I setting accuracy ± 2.5% of range

VSU (Voltage Source Unit) Specifications

VSU Output Range:

Voltage Range	Meas. Reso.	Meas. Accuracy
±20V	1mV	±(0.05% of setting+10mV)*1

*1: Specification is applicable under no load current.
Max. Output Current: 100mA

VSU Supplemental Information:

Output resistance: 0.2Ω
Maximum load capacitance: 10μF
Maximum slew rate: 0.2V/μs
Current limit: 120mA (typical)
Output Noise: 1mV rms (typical)

VMU (Voltage Monitor Unit) Specifications

VMU Measurement Range, Resolution, and Accuracy:

Voltage Range	Meas. Reso.	Meas. Accuracy
±2V	2μV	±(0.02%+200μV)
±20V	20μV	±(0.02%+1mV)

VMU Differential Mode Range Resolution, and Accuracy:

Diff V Range	Meas. Reso.	Meas. Accuracy
±0.2V	1μV	±(0.03%+100μV+1.3μV×Vi)
±2V	2μV	±(0.02%+1mV+13μV×Vi)

Max. Common Mode Voltage: ± 20V
Note: Vi is the input voltage of VMU2 in volts.

For example, accuracy specifications are given as ±% of set/measured value (0.02%) plus offset value (1mV+13μV×Vi) for the 2V range. The differential mode offset value consists of a fixed part determined by the measurement range and a proportional part that is multiplied by Vi.

VMU Supplemental Information:

Input Impedance: ≥1GΩ
Input leakage current (@0V): ≤ 500pA (Typical)
Measurement noise: 0.01% of range (p-p) (Typical)
Differential mode measurement noise: 0.005% of range (p-p) (Typical)

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MPSMU (Medium Power SMU) Specifications

Voltage Range, Resolution, and Accuracy (MPSMU)

Voltage Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
± 2V	100μV	±(0.03%+900μV+0.3×Iout)	2μV	±(0.02%+700μV+0.3×Iout)	100mA
± 20V	1mV	±(0.03%+4mV+0.3×Iout)	20μV	±(0.02%+2mV+0.3×Iout)	100mA
± 40V	2mV	±(0.03%+7mV)+0.3×Iout)	40μV	±(0.02%+3mV+0.3×Iout)	*1
± 100V	5mV	±(0.04%+15mV)+0.3×Iout)	100μV	±(0.03%+5mV+0.3×Iout)	*2

*1: 100mA (Vout≤20V), 50mA (20V<Vout≤40V)
*2: 100mA (Vout≤20V), 50mA (20V<Vout≤40V), 20mA (40V<Vout≤100V)

Current Range, Resolution, and Accuracy (MPSMU)

Current Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. V
±1nA	100fA	±(0.5%+3pA+2fA×Vout)	10fA	±(0.5%+3pA+2fA×Vout)	100V
±10nA	1pA	±(0.5%+7pA+20fA×Vout)	10fA	±(0.5%+5pA+20fA×Vout)	100V
±100nA	10pA	±(0.12%+50pA+200fA×Vout)	100fA	±(0.1%+30pA+200fA×Vout)	100V
±1μA	100pA	±(0.12%+400pA+2pA×Vout)	1pA	±(0.1%+200pA+2pA×Vout)	100V
±10μA	1nA	±(0.12%+5nA+20pA×Vout)	10pA	±(0.1%+3nA+20pA×Vout)	100V
±100μA	10nA	±(0.12%+40nA+200pA×Vout)	100pA	±(0.1%+20nA+200pA×Vout)	100V
±1mA	100nA	±(0.12%+500nA+2nA×Vout)	1nA	±(0.1%+300nA+2nA×Vout)	100V
±10mA	1μA	±(0.12%+4μA+20nA×Vout)	10nA	±(0.1%+2μA+20nA×Vout)	100V
±100mA	10μA	±(0.12%+50μA+200nA×Vout)	100nA	±(0.1%+30μA+200nA×Vout)	*1

*1: 100V (Iout≤20mA), 40V (20mA<Iout≤50mA), 20V (50mA<Iout≤100mA)

Vout is the output voltage in volts.
Iout is the output current in amps.
For example, accuracy specifications are given as ±% of set/measured value (0.1%) plus offset value (30pA+200fA×Vout) for the 100nA range. The offset value consists of a fixed part determined by the set/measuremet range and a proportional part that is multiplied by Vout.

Output terminal/connection:

Single triaxial connector, non-Kelvin (no remote sensing)

Voltage/Current Compliance (Limiting):

The SMU can limit output voltage or current to prevent damaging the device under test.
Voltage: 0V to ±100V
Current: ±1pA to ±100mA
Compliance Accuracy: Same as the current (voltage) settling accuracy.

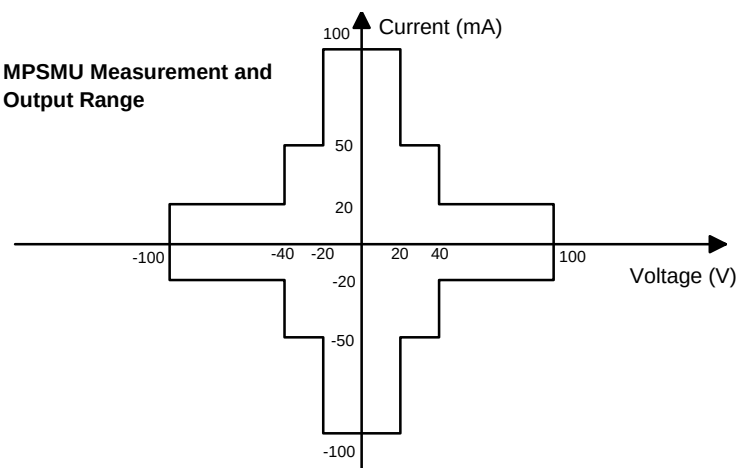
MPSMU Supplemental Information:

Typical voltage source output resistance: 0.3Ω
Voltage measurement input resistance/ current source output resistance: $\geq 10^{13}\Omega$ (1nA range)
Current compliance setting accuracy for opposite polarity:

1nA to 10nA range: V/I setting accuracy ± 12% of range

100nA to 100mA range: V/I setting accuracy ± 2.5% of range

MPSMU Measurement and Output Range



VSU Specifications

Same as HP 4156B VSU.

VMU Specifications

Same as HP 4156B VMU.

HP 41501B SMU and Pulse Generator Expander

HPSMU (High Power SMU) Specifications

Voltage Range, Resolution, and Accuracy (HPSMU)

Voltage Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
± 2V	100µV	±(0.03%+900µV)	2µV	±(0.02%+700µV)	1A
± 20V	1mV	±(0.03%+4mV)	20µV	±(0.02%+2mV)	1A
± 40V	2mV	±(0.03%+7mV)	40µV	±(0.02%+3mV)	500mA
± 100V	5mV	±(0.04%+15mV)	100µV	±(0.03%+5mV)	125mA
± 200V	10mV	±(0.04%+30mV)	200µV	±(0.035%+10mV)	50mA

Current Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. V
±1nA	100fA	±(0.5%+3pA+2fA×Vout)	10fA	±(0.5%+3pA+2fA×Vout)	200V
±10nA	1pA	±(0.5%+7pA+20fA×Vout)	10fA	±(0.5%+5pA+20fA×Vout)	200V
±100nA	10pA	±(0.12%+50pA+200fA×Vout)	100fA	±(0.1%+30pA+200fA×Vout)	200V
±1µA	100pA	±(0.12%+400pA+2pA×Vout)	1pA	±(0.1%+200pA+2pA×Vout)	200V
±10µA	1nA	±(0.12%+5nA+20pA×Vout)	10pA	±(0.1%+3nA+20pA×Vout)	200V
±100µA	10nA	±(0.12%+40nA+200pA×Vout)	100pA	±(0.1%+20nA+200pA×Vout)	200V
±1mA	100nA	±(0.12%+500nA+2nA×Vout)	1nA	±(0.1%+300nA+2nA×Vout)	200V
±10mA	1µA	±(0.12%+4µA+20nA×Vout)	10nA	±(0.1%+2µA+20nA×Vout)	200V
±100mA	10µA	±(0.12%+50µA+200nA×Vout)	100nA	±(0.1%+30µA+200nA×Vout)	*1
±1A	100µA	±(0.5%+500µA+2µA×Vout)	1µA	±(0.5%+300µA+2µA×Vout)	*2

*1: 200V (Iout≤50mA), 100V (50mA<Iout≤100mA)

*2: 200V (Iout≤50mA), 100V (50mA<Iout≤125mA), 40V (125mA<Iout≤500mA), 20V (500mA<Iout≤1mA)

Vout is the output voltage in volts.
Iout is the output current in amps.

For example, accuracy specifications are given as ±% of set/measured value (0.1%) plus offset value (30pA+200fA×Vout) for the 100nA range. The offset value consists of a fixed part determined by the set/measuremet range and a proportional part that is multiplied by Vout.

Output terminal/connection:

Dual triaxial connectors, Kelvin (remote sensing)

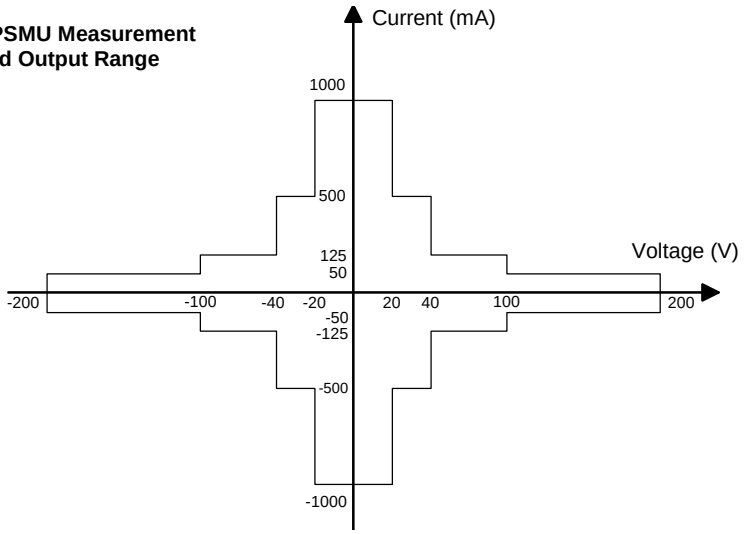
Voltage/Current Compliance (Limiting):

Voltage: 0V to ±200V
Current: ±1pA to ±1A
Compliance Accuracy: Same as the current (voltage) settling accuracy.

HPSMU Supplemental Information:

Maximum allowable cable resistance when using Kelvin connection:
Force: 0.7Ω (100mA to 1A)
Force: 10Ω (≤100mA)
Sense: 10Ω
Typical voltage source output resistance (Force line/non-Kelvin connection): 0.2Ω
Voltage measurement input resistance/ current source output resistance: $\geq 10^{13}\Omega$ (1nA range)
Current compliance setting accuracy for opposite polarity:
1nA to 10nA range: V/I setting accuracy ± 12% of range
100nA to 1A range: V/I setting accuracy ± 2.5% of range

HPSMU Measurement and Output Range



PGU (Pulse Generator Unit) Specifications

Modes: Pulse or constant
Amplitude: 0Vpp to 40Vpp
Window: -40.0V to +40.0V
Maximum current:
±200mA (pulse width: ≤1ms, average current≤100mA)
±100mA
Pulse width: 1.0µs to 9.99s
Minimum resolution: 100ns
Pulse period: 2.0µs to 10.0s
Minimum resolution: 100ns
Delay: 0s to 10s
Minimum resolution: 100ns
Transition time: 100ns to 10ms
Minimum resolution: 1ns
Output impedance: 50Ω or low impedance (≤1Ω)
Burst count range: 1 - 65535

Pulse/DC Output Voltage and Accuracy (PGU)

Set Parameter	Voltage Range	Resolution	Accuracy*1
Base	±20V	4mV	±(1% of Base + 50mV +1% of Pulse)
	±40V	8mV	±(1% of Base + 50mV +1% of Pulse)
Pulse	±20V	4mV	±(3% of Base + 50mV)
	±40V	8mV	±(3% of Base + 50mV)

Note: DC output is performed by the Base parameter.

*1: Accuracy is specified at leading edge - trailing edge = 1µs

Pulse parameter accuracy
Period: ±(2% +2ns)
Width: ±(3% +2ns)
Delay: ±(2% +40ns)
Transition time: ±(5% +10ns)
Trigger output
Level: TTL
Timing: Same timing and width as PGU1 pulse output

PGU Supplemental Information:
Overshoot: ≤ ±5% of amplitude ±10mV (50Ω output impedance to 50Ω load)
Pulse width jitter: 0.2% + 100ps
Pulse period jitter: 0.2% + 100ps
Maximum slew rate: 100V/µs (50Ω output impedance to 50Ω load)
Noise: 0.2% of range (@ DC output)

MPSMU Specifications
Same as HP 4155B MPSMU.

GNDU (Ground Unit) Specifications:
Output Voltage: 0V±100µV
Maximum sink current: 1.6A
Output terminal/connection:
Single triaxial connector, Kelvin (remote sensing)

Pulse Range and Pulse Parameter (PGU)

Range	Period	Width	Delay	Set resolution
1	2µs - 100µs	1µs - 100µs	0 - 100µs	0.1µs
2	100µs - 1000µs	1µs - 999µs	0 - 1000µs	1µs
3	1ms - 10ms	0.01ms -9.99ms	0 - 10ms	10µs
4	10ms -100ms	0.1ms - 99.9ms	0 - 100ms	100µs
5	100ms - 1000ms	1ms - 999ms	0 - 1000ms	1ms
6	1s - 10s	0.01s - 9.99s	0 - 10s	10ms

Note: Pulse width is defined when leading time is equal to trailing time. PGU2 must be set in the same range as PGU1.

Leading/Trailing Edge Times (PGU)

Range	Set Restrictions	Accuracy
100ns - 1000ns	1ns	±(5% + 10ns)
0.5µs - 10µs	10ns	±(5% + 10ns)
5.0µs - 100.0µs	100ns	±(5% + 10ns)
50µs - 1000µs	1µs	±(5% + 10ns)
0.5ms - 10.0ms	10µs	±(5% + 10ns)

Restrictions:
Pulse width < Pulse Period
Delay time < Pulse period
Leading time < Pulse width × 0.8
Trailing time < (Pulse period - Pulse width) × 0.8
Period, width, and delay of PGU1 and PGU2 must be in the same range. Leading time and trailing time for a PGU must be in the same range.

GNDU Supplemental Information:
Load Capacitance: ≤1µF
Cable resistance:
Force: ≤1Ω
Sense: ≤10Ω

HRSMU, MPSMU, and HPSMU Supplemental Information:

Maximum capacitive load: 1000pF
Maximum guard capacitance: 900pF
Maximum shield capacitance: 5000pF
Maximum guard offset voltage: ±1mV

Noise characteristics (typical, Filter: ON):
Voltage source noise: 0.01% of V range (rms)
Current source noise: 0.1% of I range (rms)
Voltage monitor noise: 0.02% of V range (p-p)
Current monitor noise: 0.2% of I range (p-p)

Output 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: 250mV
Current ranging: 10mV
Maximum slew rate: 0.2V/µs

Functions

Measurement Set-up
Setting
- Fill-in-the-blanks using front-panel or full-size external keyboard
- Load settings from floppy disk or via the LAN port
- Program using internal HP Instrument BASIC or via HP-IB
- HELP Function
- Library: Default measure setup, Vce-Ic, Vds-Id, Vgs-Id, and Vf-If are pre-defined softkeys
- User-defined measurement setup library
- Auto file load function on power-up

Measurement
The HP 4155B and HP 4156B can perform dc or pulsed force/measure, and stress force. For dc, voltage/current sweep and sampling (time domain) measurements are available.

Voltage/Current Sweep Measurement Characteristics
Each SMU and VSU can sweep using VAR1 (primary sweep), VAR2 (subordinate sweep), or VAR1′ (synchronous sweep).

VAR1
Primary sweep controls the staircase (dc or pulsed) voltage or current sweep.
Maximum number of steps: 1001 for one VAR1 sweep.
Sweep type: linear or logarithmic
Sweep direction: Single or double sweep
Hold time:
Initial wait time or wait time after VAR2 is set: 0 to 655.35s with 10ms resolution
Delay time:
Wait time from VAR1 step to the start of the measurement: 0 to 65.535s with 100 µs resolution

VAR2
Subordinate linear staircase or linear pulsed sweep. After primary sweep is completed, the VAR2 unit output is incremented.
Maximum number of steps: 128

VAR1'
Staircase or pulse sweep synchronized with the VAR1 sweep. Sweep is made with a user specified ratio and offset value. VAR1' output is calculated as VAR1' = a × VAR1 + b, where "a" is the user specified ratio and "b" is the user specified offset value.

CONSTANT
A source unit can be set as a constant voltage or current source depending on the unit.

PULSE
One of the SMUs can be set as a pulse source.
Pulse width: 0.5ms to 100ms, 100µs resolution.
Pulse period:
(5ms to 1s (≥ pulse width + 4ms), 100µs resolution.
SMU pulse setting accuracy (supplemental information, at fixed range measurement except multi- channel measurement):
Width: 0.5% + 50µs
Period: 0.5% + 100µs
Trigger output delay for pulsed measurement: 0 - 32.7ms with 100µs resolution (< pulse width).

Sampling (Time Domain) Measurement Characteristics
Displays the time sampled voltage/ current data versus time.
Maximum sampling points: 10,001 (linear)
Sampling mode: linear, log, and thinned-out
Note: The thinned-out mode is similar to reverse-log sampling. Sampling measurement continues by thinning out older data until the sampling completion condition is satisfied.
Sampling interval range and resolution:
Linear scale (auto mode):
60µs to 480µs range: 20µs resolution
480µs to 1s range: 80µs resolution
1s to 65.535s range: 2ms resolution
Linear scale (no limit mode), log scale, and thinned-out modes:
560µs (720µs at thinned-out mode) to 1s range: 80µs resolution
1s to 65.535s range: 2ms resolution
Note: The following conditions must be set when initial interval is less than 2ms.
- Number of measurement channels: 1
- Measurement ranging: fixed range
- Stop condition: disable

Hold time:
Initial wait rime: 0.03s to 655.35s, 100µs resolution
Sampling measurement stop condition:
A condition to stop the sampling can be defined.
Sampling interval setting accuracy (supplemental data):
0.5% + 10µs (sampling interval ≤ 480µs)
0.5% + 10µs (480µs ≤ sampling interval <2ms)
0.5% + 100µs (2ms ≤ sampling interval)

Stress Force Characteristics
SMU, VSU, and PGU output can be forced for the user specified period.
Stress time set range:
5000µs to 31,536,000s (365 days)
Resolution:
100µs (500µs≤stress time≤10s)
10ms (10s<stress time≤31,536,000s)
Burst pulse count:
1 - 65,535 (PGU only)
Trigger:
HP 4155B/4156B outputs a gate trigger while stress channels are forcing stress.

Knob Sweep
In the knob sweep mode, sweep range is controlled instantaneously with the front-panel rotary knob.
Only the Channel Definition page needs to be defined.

Standby Mode
SMUs in "Standby" remain programmed to their specified output value even as other units are reset for the next measurement.

Other Characteristics
Limited auto-ranging, voltage/current compliance, power compliance, automatic sweep abort functions, self-test, and self-calibration.

Arithmetic and Analysis Functions

Arithmetic Functions

User Functions
Up to six USER FUNCTIONS can be defined using arithmetic expressions. Measured data and analyzed variables from graphics analysis (marker, cursor, and line data) can be used in the computation. The results can be displayed on the LCD.

Arithmetic Operators
+, -, *, /, ^, LGT (logarithm, base 10), LOG (logarithm, base e), EXP (exponent), DELTA, DIFF (differential), INTEG (integration), MAVG (moving average), SQRT, ABS (absolute value), MAX, MIN, AVG (averaging), COND (conditional evaluation).

Physical Constants
Keyboard constants are stored in memory as follows:
q: Electron Charge, 1.602177 E-19 C
k: Boltzman's Constant, 1.380658 E-23
ε: Dielectric Constant of Vacuum, 8.854188 E-12

Engineering Units
The following unit symbols are also available on the keyboard: f (10^{-15}), p (10^{-12}), n (10^{-9}), u or µ (10^{-6}), m (10^{-3}), K (10^{3}), M (10^{6}), G (10^{9})

Analysis Capabilities

Overlay Graph Comparison
A graphics plot can be stored and later recalled as an overlay plane. Four overlay planes can be stored. One plane can be overlaid onto the current data.

Marker
Marker to min/max, interpolation, direct marker, and marker slip

Cursor
Long and short, direct cursor.

Line
Two lines, normal mode, grad mode, tangent mode, and regression mode.

Scaling
Auto scale and zoom.

Data Variable Display
Up to two user defined parameters can be displayed on the graphics screen.

Read Out Function
The read out functions are built-in functions for reading various values related to the marker, cursor, or line.

Automatic Analysis Function
On a graphics plot, the markers and lines can be automatically located using the auto analysis setup. Parameters can be automatically determined using automatic analysis, user function, and read out functions.

User Variable
Display the data on the LCD via HP-IB or HP Instrument BASIC.

Output

Display

Display Modes
Graphics and list.

Graphics Display
X-Y or X-Y1/Y2 plot of source current/voltage, measured current/voltage, time, or calculated USER FUNCTION data.

List Display
Measurement data and calculated USER FUNCTION data are listed in conjunction with VAR1 step number or time domain sampling step number. Up to eight data sets can be displayed.

Display
8.4 inch diagonal color active matrix LCD, 640 dot (H) × 480 dot (V)

Hard Copy Functions

Graphics Hard Copy
Measured data and all data appearing on the LCD can be output via HP-IB, parallel printer port, or network interface to supported HP plotters or printers. PCL, HR PCL (high-resolution PCL), and HP GL formats are supported (selectable).

Text Hard Copy
Print out setup information or measured data list as ASCII text via HP-IB, parallel printer port, or network interface to supported HP plotters or printers. PCL, HR PCL, and HP GL formats are supported (selectable).

Hard Copy File
Hard copy output can be stored to an internal or external mass storage device instead of sending it to a printer or plotter. The data can be stored in PCL, HR PCL, TIFF, HR TIFF (high-resolution TIFF), or HP GL formats.

Hard Copy via Network Interface
The network interface has lpr client capability.

High-Resolution (HR) Mode
This file mode is available for cases where an extremely clean print-out or plot is desired.
Note: High resolution mode takes significantly greater CPU time to generate, so its use is recommended for final reports only.

Data Storage

Mass storage device:
Built-in 3.5 inch flexible disk drive
Media: 3.5 inch 2HD or 2DD diskette
Format type: HP LIF and DOS
User area:
1.44Mbyte (2HD) or 720Kbyte (2DD)
File types:
Auto start program file, initial setup file, measurement setup file, measurement setup/result file, stress setup file, customize file, hard copy data file, and HP Instrument BASIC program and data file.
Format of data made by HP BASIC program:
Data made by HP BASIC program and data made by HP Instrument BASIC program are compatible.
Network mass storage device:
An NFS mountable mass storage device
File types:
Auto start program file, initial setup file, measurement setup file, measurement setup/result file, stress setup file, customize file, and hard copy data file.
Maximum number of files allowed per directory on network mass storage device: 199
Data storage (supplemental data):
2HD DOS format:
Available bytes: 1457K (byte)
File size:
Measurement setup: 3843 (byte)
Stress setup: 601 (byte)
Measurement setup/result
(Typical data): 15387 (byte)
(VAR1: 101, VAR2: 5)
Customized system setup: 1661 (byte)
Hardcopy data: 30317 (byte)
(Monochrome PCL 75DPI file)
Hardcopy data: 38702 (byte)
(monochrome TIFF file)
Note: For LIF format, the total number of files is limited to 199.

Repeating and Automating Test

Instrument Control

HP 4155B and 4156B function control:
Internal or external computer controls the HP 4155B and HP 4156B functions via HP-IB interface.
Command sets:
SCPI command set
HP FLEX command set
HP 4145B command set
Program Memory:
Using the HP 4155B/4156B HP FLEX command set, the user can store program code in the HP 4155B or the HP 4156B. Maximum number of subprograms is 256 (8 bit).
External instrument remote control:
Control external equipment via HP-IB interface.

HP Instrument BASIC

HP Instrument BASIC is a subset of HP BASIC.

Functions:

Arithmetic operation, binary operation, string manipulation, logical operation, array operation, program flow control, event-initiated branching, program editing and debugging support, mass storage operation, instrument control, real-time clock, softkey operation, and graphics.

HP 4145B automatic sequence program (ASP) typing aid:

HP 4145B ASP-like syntax softkeys are available in HP Instrument BASIC. An HP 4145B ASP file cannot be read by the HP 4155B and 4156B.

Remote control:

HP Instrument BASIC is remote controllable from an external computer via the HP-IB interface.

HP Instrument BASIC memory area (supplemental data):

Program (text) area: 16K (byte)
Variable/stack area: 500K (byte)
Common variable area: 600K (byte)

Note: The memory size for common variable is decreased when hard copy or disk operation is performed.

Trigger

Input:

External trigger input starts a sweep or sampling measurement or can be used as a trigger input for continuing an HP Instrument BASIC program.

Input Level:

TTL level, negative or positive edge trigger

Output:

External trigger can be generated by the following events: start of each sweep measurement step, start of each pulse (SMU) output, while the stress source is forcing, and Instrument BASIC trigger out command execution.

Output Level:

TTL level, negative or positive logic

HP 4145B Data Compatibility and HP 4145B Syntax Commands

Setup and data file

Measurement setup and data from the HP 4145B can be loaded.

HP-IB program

HP-IB programs for the HP 4145B can be used when the HP 4145B command set is selected.

Note: There is a possibility that HP-IB programs for the HP 4145B will need to be modified.

Interfaces

HP-IB interface:

SH1, AH1, T6, L4, SR1, RL1, PP0, DC1, DT1, C1, C2, C3, C4, C11, E2

Parallel interface: Centronics

RJ45:

Ethernet IEEE 802.3 10BASE-T for a 10Mbps CSMA/CD local area network

External keyboard:

Compatible PC-style 101-key keyboard (mini DIN connector)

Interlock and LED connector

R-BOX control connector

Trigger in/out

SMU/PGU selector control connector (HP 41501B)

Sample Application Programs

Flash EEPROM test
TDDB
Constant I (Electromigration test)
V-Ramp Test
J-Ramp Test
SWEAT
GO/NO-GO Test
HCI degradation test

Sample VEE Program

Vth measurement using the HP 4155B or HP 4156B, the E5250A, and a wafer prober.

VXI*plug&play* Drivers

VXI*plug&play* drivers for the HP 4155B and HP 4156B

Supported VXI*plug&play* operating systems:

Windows NT
Windows 95

Format

Tree-structured function panel.
Panel mode for hardware configuration and manual parameter setting.
Parameter mode for variable definition and I/O configuration.

General Specifications

Temperature range

Operating:
+10°C to +40°C (if using floppy disk drive)
+5°C to +40°C (if not using floppy disk drive)
Storage: -22°C to +60°C

Humidity range

Operating:
20% to 80% RH, non-condensing and wet bulb temperature ≤ 29°C (if using floppy disk drive)
15% to 80% RH, non-condensing and wet bulb temperature ≤ 29°C (if not using floppy disk drive)
Storage: 5% to 90% RH , non-condensing and wet bulb temperature ≤ 39°C

Altitude

Operating: 0 to 2,000 m (6,561 ft)
Storage: 0 to 4,600 m (15,091 ft)

Power requirement

90V to 264V, 47 to 63 Hz

Maximum VA

HP 4155B or 4156B: 450VA
HP 41501B: 350 VA

Regulatory Compliance

EMC:
EN55011 (1991) Group 1, Class A, EN50082-1 (1992)
Safety:
CSA C22.2 NO. 1010.1 (1992)
IEC 1010-1 (1990) + A2/EN61010-1 (1993)

Dimensions:

HP 4155B and 4156B:
235mm H × 426mm W × 600mm D
HP 41501B:
190mm H × 426mm W × 600mm D

Weight (approx.):

HP 4155B and 4156B: 21kg
HP 41501B: 16kg
(option 412, HPSMU + 2×PGU)

HP 4155B and HP 4156B Furnished Accessories

Triaxial cable, 4 ea. (HP 4155B)
Kelvin triaxial cable, 4 ea. (HP 4156B)
Coaxial cable, 4 ea.
Interlock cable, 1 ea.
Keyboard, 1 ea.
User manual, 1 set
Sample application program disk, 1 ea.
Sample VEE program disk, 1 ea
VXI*plug&play* drivers disk for the HP 4155B & HP 4156B, 1 ea.
VXI*plug&play* drivers disk for the HP E5250A, 1 ea

Accessory Specifications

Specification Condition
The "supplemental information" and "typical" entries in the following specifications are not warranted, but provide useful information about the functions and performance of the instruments. 23°C ± 5°C, 50% RH.

HP 16440A SMU/Pulse Generator Selector

The HP 16440A switches either an SMU or PGU to the associated output port. You can expand to 4 channels by adding an additional HP 16440A. The channel 1 PGU port provides "PGU OPEN" function, which can disconnect the PGU by opening a semiconductor relay. The HP 16440A cannot work without two pulse generator units of the HP 41501A/B (SMU and Pulse Generator Expander).
Channel configurations:
Two channels (CH1, CH2)
CH1: INPUT ports: 2
(SMU and PGU, PGU port has additional series semiconductor relay)
OUTPUT port: 1
CH2: INPUT ports: 2 (SMU and PGU)
OUTPUT port: 1

Voltage & Current Range

Input port	Max. V	Max I
SMU	200 V	1.0 A
PGU	40V	0.2A (AC peak)

Supplemental Information (at 23°C ± 5°C, 50% RH)
SMU port leakage current:
< 100fA @100V
SMU port residual resistance (typical):
0.2Ω
SMU port stray capacitance (typical @1MHz):
Force ↔ Common: 0.3pF
Force ↔ Guard: 15pF
Guard ↔ Common: 130pF
PGU port residual resistance: 3.4Ω
PGU port OFF capacitance (typical):
5pF
PGU port OPEN capacitance (typical):
700pF (@ 1MHz, Vin - Vout = 0V)

PGU port signal transfer characteristics
Overshoot: < 5% of pulse amplitude (@20ns leading and trailing time, 50Ω pulse generator source impedance, 50pF and 1MΩ in parallel load).

General Specifications
Dimensions:
50 mm H × 250 mm W × 275 mm D
Weight (approx.): 1.1kg

HP 16441A R-BOX

HP 16441A R-BOX adds a selectable series resistor to the SMU output. You can select the resistor from the setup page, and the voltage drop due to the series resistor is automatically compensated for in the measurement result.
Measurement limitations with the HP 4155B/56B and R-BOX:

- If you measure device characteristics including negative resistance over 1MΩ with the HP 4155B/56B and R-BOX, there is a possibility that they cannot be measured.
- There is a possibility that the HP 4155B/56B cannot perform measurements because of DUT oscillations even with the R-BOX. Whether oscillation occurs or not depends upon the DUT and measurement conditions.

Number of SMU channels that can add resistor: 2
Resistor values:
1MΩ, 100kΩ, 10kΩ, 0Ω (each channel)
Resistance accuracy:
0.3% (at 23°C±5°C, between input-output terminal)
Maximum voltage: 200V
Maximum current: 1A (0Ω selected)
Kelvin connection: Kelvin connection is effective only when 0Ω is selected.

Supplemental Information (at 23°C ± 5°C, 50% RH)
Leakage current: <100fA @ 100V

General Specifications
Dimensions:
72 mm H × 250 mm W × 270 mm D
Weight (approx.): 1.6kg

HP 16442A Test Fixture

Channel Information
SMU:
6 channels (1 triaxial connector/channel)
3 channels (1 Kelvin triaxial connector/channel)
VSU:
2 channels (1 BNC connector/channel)
VMU:
2 channels (1 BNC connector/channel)
PGU:
2 channels (1 BNC connector/channel)
GNDU:
1 channel (1 triaxial connector)
INTLK: 6 pin connector

Supplemental Information (at 23°C ± 5°C, 50% RH)
SMU channel:
Leakage current: 10pA max @200V (Force or Sense ↔ Common)
Stray capacitance: 15pF max (Force or Sense ↔ Common)
Stray capacitance: 3pF typical (Force or Sense ↔ Other SMU)
Residual resistance: 60mΩ typical (Force, Sense)
Guard capacitance: 70pF max (Force or Sense ↔ Guard)
VSU channel residual resistance:
60mΩ typical
VMU channel residual resistance:
60mΩ typical
PGU channel characteristic impedance:
50Ω typical
GNDU channel residual resistance:
40mΩ typical (Force, Sense)

General Specifications
Temperature range
Operating: +5°C to +40°C
Storage: -40°C to +70°C
Humidity range
Operating: 5% to 80% RH (no condensation)
Storage: 5% to 90% RH at 65°C (no condensation)
Dimensions:
140 mm H × 260 mm W × 260 mm D
Weight (approx.): 2.5kg

For more information on Hewlett-Packard Test & Measurement products, applications, services, and current sales office listings, visit our web site at http://www.hp.com/go/tmdir. You can also contact one of the following centers and ask for a test and measurement sales representative.

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http://www.hp.com/go/semiconductor

United States:
Hewlett-Packard Company
Test and Measurement Call Center
P.O. Box 4026
Englewood, CO 80155-4026
1-800-452-4844

Canada:
Hewlett-Packard Canada Ltd.
5150 Spectrum Way
Mississauga, Ontario
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905-206-4725

Europe:
Hewlett-Packard
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P.O. Box 999
1180 AZ Amstelveen
The Netherlands
(31-20) 547-9900

Japan:
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