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

HP 4155B	**HP** 4156B
4xMPSMU	4xHRSMU
2xVMU	2xVMU
2xVSU	2xVSU

HP 41501B (Optional)

2xPGU(Option) *1

GNDU — HPSMU(Option) or 2xMPSMU (Option) *1

SMU: Source Monitor Unit
HRSMU: High Resolution SMU
(1fA/2∝V to 100mA/100V)
MPSMU: Medium Power SMU
(10fA/2∝V to 100mA/100V)
HPSMU: High Power SMU
(10fA/2∝V 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	100∝V	±(0.02%+400∝V)	2∝V	±(0.01%+200∝V)	100mA
± 20V	1mV	±(0.02%+3mV)	20∝V	±(0.01%+1mV)	100mA

Voltage/Current Compliance (Limiting):

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

Voltage: 0V to ±100V

± 40V	2mV	±(0.025%+6mV)	40∝V	±(0.015%+2mV)	*1
± 100V	5mV	±(0.03%+15mV)	100∝V	±(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
±1∝A	100pA	±(0.12%+400pA+1pA·Vout)		1pA	±(0.1%+200pA+1pA·Vout)		100V
±10∝A	1nA	±(0.07%+4nA+10pA·Vout)		10pA	±(0.05%+2nA+10pA·Vout)		100V
±100∝A	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	1∝A	±(0.06%+4∝A+10nA·Vout)		10nA	±(0.04%+2∝A+10nA·Vout)		100V
±100m?	10∝A	±(0.12%+40∝A+100nA·Vout)		100nA	±(0.1%+20∝A+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):

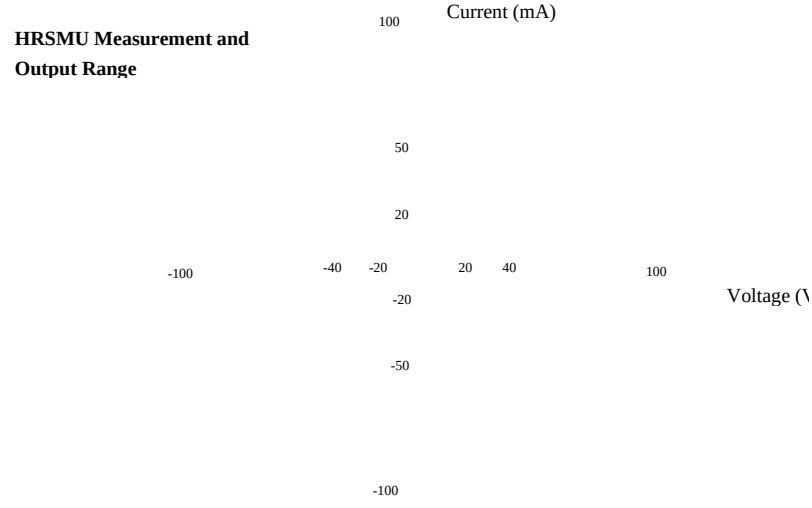
Temperature	Humidity % 5 - 60	RH 60 - 80
5°C to 18°C	·2	·2
18°C to 28°C	·1	·2
28°C to 40°C	·2	·5

*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



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): 10?
Typical voltage source output resistance (Force line/non-Kelvin connection): 0.2?
Voltage measurement input resistance/ current source output resistance: =10 [15] ? (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

VMU (Voltage Monitor Unit) Specifications

VMU Measurement Range, Resolution, and Accuracy:

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

VMU Differential Mode Range

For example, accuracy specifications are given as ±% of set/measured value (0.02%) plus offset value (1mV+13∝V·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: =1G?

VSU Supplemental Information:

Output resistance: 0.2?

Maximum load capacitance: 10∝F

Maximum slew rate: 0.2V/∝s

Current limit: 120mA (typical)

Output Noise: 1mV rms (typical)

Resolution, and Accuracy:

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

Max. Common Mode Voltage: ± 20V

Note: Vi is the input voltage of VMU2 in volts.

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	100∝V	±(0.03%+900∝V+0.3·Iout)	2∝V	±(0.02%+700∝V+0.3·Iout)	100mA
± 20V	1mV	±(0.03%+4mV+0.3·Iout)	20∝V	±(0.02%+2mV+0.3·Iout)	100mA
± 40V	2mV	±(0.03%+7mV)+0.3·Iout)	40∝V	±(0.02%+3mV+0.3·Iout)	*1
± 100V	5mV	±(0.04%+15mV)+0.3·Iout)	100∝V	±(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
±1∝A	100pA	±(0.12%+400pA+2pA·Vout)	1pA	±(0.1%+200pA+2pA·Vout)	100V
±10∝A	1nA	±(0.12%+5nA+20pA·Vout)	10pA	±(0.1%+3nA+20pA·Vout)	100V
±100∝A	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	1∝A	±(0.12%+4∝A+20nA·Vout)	10nA	±(0.1%+2∝A+20nA·Vout)	100V
±100m?	10∝A	±(0.12%+50∝A+200nA·Vout)	100nA	±(0.1%+30∝A+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: 0.3?

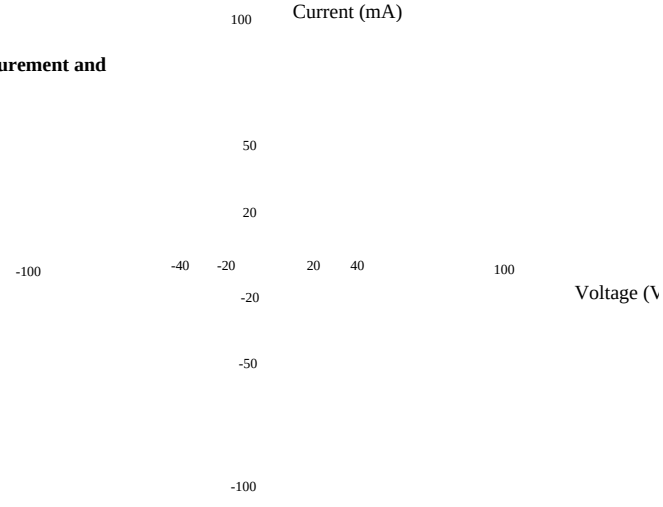
Voltage measurement input resistance/ current source output resistance: =10 [13] ? (1nA range)

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	100∝V	±(0.03%+900∝V)	2∝V	±(0.02%+700∝V)	1A
± 20V	1mV	±(0.03%+4mV)	20∝V	±(0.02%+2mV)	1A
± 40V	2mV	±(0.03%+7mV)	40∝V	±(0.02%+3mV)	500mA
± 100V	5mV	±(0.04%+15mV)	100∝V	±(0.03%+5mV)	125mA
± 200V	10mV	±(0.04%+30mV)	200∝V	±(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
±1∝A	100pA	±(0.12%+400pA+2pA·Vout)	1pA	±(0.1%+200pA+2pA·Vout)	200V
±10∝A	1nA	±(0.12%+5nA+20pA·Vout)	10pA	±(0.1%+3nA+20pA·Vout)	200V
±100∝A	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	1∝A	±(0.12%+4∝A+20nA·Vout)	10nA	±(0.1%+2∝A+20nA·Vout)	200V
±100m?	10∝A	±(0.12%+50∝A+200nA·Vout)	100nA	±(0.1%+30∝A+200nA·Vout)	*1
±1?	100∝A	±(0.5%+500∝A+2∝A·Vout)	1∝A	±(0.5%+300∝A+2∝A·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.

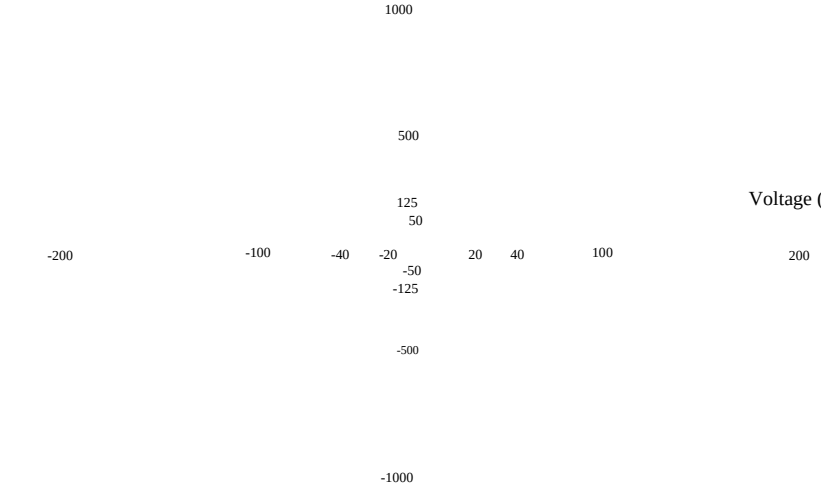
Output terminal/connection:
Dual triaxial connectors, Kelvin (remote sensing)

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: 0.7? (100mA to 1A)
Force: 10? (=100mA)
Sense: 10?
Typical voltage source output resistance (Force line/non-Kelvin connection): 0.2?
Voltage measurement input resistance/ current source output resistance: =10 ^{13} ? (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: 1.0∝s to 9.99s
Minimum resolution: 100ns
Pulse period: 2.0∝s to 10.0s
Minimum resolution: 100ns
Delay: 0s to 10s
Minimum resolution: 100ns
Transition time: 100ns to 10ms
Minimum resolution: 1ns
Output impedance: 50? or low impedance (=1?)
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 = 1∝s

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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 (50? output impedance to 50? load)
Pulse width jitter: 0.2% + 100ps
Pulse period jitter: 0.2% + 100ps
Maximum slew rate: 100V/∝s (50? output impedance to 50? load)
Noise: 0.2% of range (@ DC output)

MPSMU Specifications

Same as **HP** 4155B MPSMU.

GNDU (Ground Unit) Specifications:

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

HRSMU, MPSMU, and HPSMU Supplemental Information:

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

Pulse Range and Pulse Parameter (PGU)

Range	Period	Width	Delay	Set resolu
1	2∝s - 100∝s	1∝s - 100∝s	0 - 100∝s	0.1∝
2	100∝s - 1000∝s	1∝s - 999∝s	0 - 1000∝s	1∝s
3	1ms - 10ms	0.01ms -9.99ms	0 - 10ms	10∝
4	10ms -100ms	0.1ms - 99.9ms	0 - 100ms	100∝
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)
0.5∝s - 10∝s	10ns	±(5% + 10ns)
5.0∝s - 100.0∝s	100ns	±(5% + 10ns)
50∝s - 1000∝s	1∝s	±(5% + 10ns)
0.5ms - 10.0ms	10∝s	±(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: =1∝F
Cable resistance:
Force: =1?
Sense: =10?

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/∝s

Functions

Measurement Set-up

Setting

ì Fill-in-the-blanks using front-panel or full-size external keyboard

Measurement

The **HP** 4155B and **HP** 4156B can perform dc or pulsed force/measure, and stress force. For dc,

VAR1

Primary sweep controls the staircase (dc or pulsed) voltage or current sweep.
Maximum number of steps: 1001 for one VAR1 sweep

- 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

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 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 ∝s 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, 100∝s resolution.
Pulse period:
(5ms to 1s (= pulse width + 4ms), 100∝s resolution.
SMU pulse setting accuracy (supplemental information, at fixed range measurement except multi- channel measurement):
Width: 0.5% + 50∝s
Period: 0.5% + 100∝s
Trigger output delay for pulsed measurement: 0 - 32.7ms with 100∝s

Linear scale (no limit mode), log scale, and thinned-out modes:
560∝s (720∝s at thinned-out mode) to 1s range: 80∝s 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, 100∝s resolution
Sampling measurement stop condition:
A condition to stop the sampling can be defined.
Sampling interval setting accuracy (supplemental data):
0.5% + 10∝s (sampling interval = 480∝s)
0.5% + 10∝s (480∝s = sampling interval <2ms)
0.5% + 100∝s (2ms = sampling interval)

Stress Force Characteristics

SMU, VSU, and PGU output can be forced for the user specified period.
Stress time set range:
5000∝s to 31,536,000s (365 days)
Resolution:
100∝s (500∝s=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

Arithmetic and Analys 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 ∝ (10^{-6}), m (
K (10^{3}), M (10^{6}), G (10^{9})

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):
60∝s to 480∝s range: 20∝s resolution
480∝s to 1s range: 80∝s resolution
1s to 65.535s range: 2ms resolution

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.

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.

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.

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

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).

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.

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-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

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

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.

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.

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

PGU port signal transfer characteristics

HP 16442A Test Fixtu

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):
0.2?
SMU port stray capacitance (typical @1MHz):
Force ? Common: 0.3pF
Force ? Guard: 15pF
Guard ? Common: 130pF
PGU port residual resistance: 3.4?
PGU port OFF capacitance (typical):
5pF
PGU port OPEN capacitance (typical):
700pF (@ 1MHz, Vin - Vout = 0V)
Overshoot: < 5% of pulse amplitude (@20ns leading and trailing time, 50? pulse generator source impedance, 50pF and 1M? 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 1M? 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:
1M?, 100k?, 10k?, 0? (each channel)
Resistance accuracy:
0.3% (at 23°C±5°C, between input-output terminal)
Maximum voltage: 200V
Maximum current: 1A (0? selected)
Kelvin connection: Kelvin connection is effective only when 0? 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

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: 60m? typical
(Force, Sense)
Guard capacitance: 70pF max
(Force or Sense ? Guard)
VSU channel residual resistance:
60m? typical
VMU channel residual resistance:
60m? typical
PGU channel characteristic impedance:
50? typical
GNDU channel residual resistance:
40m? 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.

Semiconductor Test Web Site:
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
L4W 5G1
905-206-4725

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

Japan:
Hewlett-Packard Japan Ltd.
Measurement Assistance Center
9-1, Takakura-Cho, Hachioji-Shi,
Tokyo 192, Japan
Tel: (81) 426-56-7832
Fax: (81) 426-56-7840

Latin America:
Hewlett-Packard
Latin American Region Headquarters
5200 Blue Lagoon Drive
9th Floor
Miami, Florida 33126 USA.
305-267-4245/4220

Australia/New Zealand:
Hewlett-Packard Australia Ltd.
31-41 Joseph Street
Blackburn, Victoria 3130
Australia
1-800-629-485

Asia Pacific:
Tel: (852) 2599-7777
Fax: (852) 2506-9285
Taiwan:
(886-2) 717-9524
Korea:
(822) 769-0800

Singapore:
(65) 1800-292-8100

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