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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:

- 1 Set measurement and/or stress conditions
- 1 Control measurement and/or stress execution
- 1 Perform arithmetic calculations
- 1 Display measured and calculated results on the LCD display
- 1 Perform graphical analysis
- 1 Store and recall measurement setups, and measurement and graphical display data
- 1 Dump to printers or plotters for hard-copy output

- 1 Perform measurement and analysis with the built-in **HP Instrument BASIC**
- 1 Self test, Auto calibration

Configuration

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

HP 41501B (Optional)	
	2xPGU(Optional) *1
GNDU	HPSMU(Optional) 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 \pm 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 \pm 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
\pm 2V	100 ∞ V	\pm (0.02%+400 ∞ V)	2 ∞ V	\pm (0.01%+200 ∞ V)	100mA
\pm 20V	1mV	\pm (0.02%+3mV)	20 ∞ V	\pm (0.01%+1mV)	100mA
\pm 100V			100 ∞ V	\pm (0.01%+100 ∞ V)	100mA

Voltage/Current Compliance (Limiting):

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

Voltage: 0V to \pm 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):

	Humidity %	RH
Temperature	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/measurement 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

100

Current (mA)

50

20

-100

-40

-20

20 40

100

Voltage (V)

-20

-50

-100

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 Ω

Maximum load capacitance: 10 μ F

Maximum slew rate: 0.2V/ μ s

Current limit: 120mA (typical)

Output Noise: 1mV rms (typical)

Resolution, and Accuracy:

Diff V	Meas.	Meas.
Range	Reso.	Accuracy
$\pm 0.2V$	1 μ V	$\pm(0.03\%+100\mu V+1.3\mu V \cdot V_i)$
$\pm 2V$	2 μ V	$\pm(0.02\%+1mV+13\mu V \cdot V_i)$

Max. Common Mode Voltage: $\pm 20V$

Note: V_i 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)

HP 4155B Semiconductor Parameter Analyzer

MPSMU (Medium Power SMU) Specifications

Voltage Range, Resolution, and Accuracy (MPSMU)

Voltage Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. Current
$\pm 2V$	100 μ V	$\pm(0.03\%+900\mu V+0.3 \cdot I_{out})$	2 μ V	$\pm(0.02\%+700\mu V+0.3 \cdot I_{out})$	100mA
$\pm 20V$	1mV	$\pm(0.03\%+4mV+0.3 \cdot I_{out})$	20 μ V	$\pm(0.02\%+2mV+0.3 \cdot I_{out})$	100mA
$\pm 40V$	2mV	$\pm(0.03\%+7mV)+0.3 \cdot I_{out}$	40 μ V	$\pm(0.02\%+3mV+0.3 \cdot I_{out})$	*1
$\pm 100V$	5mV	$\pm(0.04\%+15mV)+0.3 \cdot I_{out}$	100 μ V	$\pm(0.03\%+5mV+0.3 \cdot I_{out})$	*2

*1: 100mA ($V_{out} \geq 20V$), 50mA ($20V < V_{out} = 40V$)

*2: 100mA ($V_{out} \geq 20V$), 50mA ($20V < V_{out} = 40V$), 20mA ($40V < V_{out} = 100V$)

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 $\pm 100V$

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

Compliance Accuracy: Same as the current (voltage) settling accuracy.

MPSMU Supplemental Information:

Typical voltage source output

resistance: 0.3 Ω

Voltage measurement input resistance/ current source output resistance: $\approx 10^{11} \Omega$ (1nA range)

Current compliance setting accuracy for opposite polarity:

1nA to 10nA range: V/I setting accuracy $\pm 12\%$ of range

100nA to 100mA range: V/I setting accuracy $\pm 2.5\%$ of range

Current Range, Resolution, and Accuracy (MPSMU)

Current Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. V
$\pm 1nA$	100fA	$\pm(0.5\%+3pA+2fA \cdot V_{out})$	10fA	$\pm(0.5\%+3pA+2fA \cdot V_{out})$	100V
$\pm 10nA$	1pA	$\pm(0.5\%+7pA+20fA \cdot V_{out})$	10fA	$\pm(0.5\%+5pA+20fA \cdot V_{out})$	100V
$\pm 100nA$	10pA	$\pm(0.12\%+50pA+200fA \cdot V_{out})$	100fA	$\pm(0.1\%+30pA+200fA \cdot V_{out})$	100V
$\pm 1\mu A$	100pA	$\pm(0.12\%+400pA+2pA \cdot V_{out})$	1pA	$\pm(0.1\%+200pA+2pA \cdot V_{out})$	100V
$\pm 10\mu A$	1nA	$\pm(0.12\%+5nA+20pA \cdot V_{out})$	10pA	$\pm(0.1\%+3nA+20pA \cdot V_{out})$	100V
$\pm 100\mu A$	10nA	$\pm(0.12\%+40nA+200pA \cdot V_{out})$	100pA	$\pm(0.1\%+20nA+200pA \cdot V_{out})$	100V
$\pm 1mA$	100nA	$\pm(0.12\%+500nA+2nA \cdot V_{out})$	1nA	$\pm(0.1\%+300nA+2nA \cdot V_{out})$	100V
$\pm 10mA$	1 μ A	$\pm(0.12\%+4\mu A+20nA \cdot V_{out})$	10nA	$\pm(0.1\%+2\mu A+20nA \cdot V_{out})$	100V
$\pm 100mA$	10 μ A	$\pm(0.12\%+50\mu A+200nA \cdot V_{out})$	100nA	$\pm(0.1\%+30\mu A+200nA \cdot V_{out})$	*1

*1: 100V ($I_{out} \geq 20mA$), 40V ($20mA < I_{out} = 50mA$), 20V ($50mA < I_{out} = 100mA$)

V_{out} is the output voltage in volts.

I_{out} is the output current in amps.

For example, accuracy specifications are given as $\pm\%$ of set/measured value (0.1%) plus offset value ($30pA+200fA \cdot V_{out}$) for the 100nA range. The offset value consists of a fixed part determined by the set/measurement range and a proportional part that is multiplied by V_{out} .

MPSMU Measurement and Output Range

VSU Specifications

Same as HP 4156B VSU.

VMU Specifications

Same as HP 4156B VMU.

100

50

20

-100

-40

-20

20 40

100

Voltage (V)

-20

-50

-100

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 \times V	$\pm(0.03\%+900\text{\timesV})$	2 \times V	$\pm(0.02\%+700\text{\timesV})$	1A
± 20V	1mV	$\pm(0.03\%+4\text{mV})$	20 \times V	$\pm(0.02\%+2\text{mV})$	1A
± 40V	2mV	$\pm(0.03\%+7\text{mV})$	40 \times V	$\pm(0.02\%+3\text{mV})$	500mA
± 100V	5mV	$\pm(0.04\%+15\text{mV})$	100 \times V	$\pm(0.03\%+5\text{mV})$	125mA
± 200V	10mV	$\pm(0.04\%+30\text{mV})$	200 \times V	$\pm(0.035\%+10\text{mV})$	50mA

Current Range	Set. Reso.	Set. Accuracy	Meas. Reso.	Meas. Accuracy	Max. V
±1nA	100fA	$\pm(0.5\%+3\text{pA}+2\text{fA}\cdot\text{Vout})$	10fA	$\pm(0.5\%+3\text{pA}+2\text{fA}\cdot\text{Vout})$	200V
±10nA	1pA	$\pm(0.5\%+7\text{pA}+20\text{fA}\cdot\text{Vout})$	10fA	$\pm(0.5\%+5\text{pA}+20\text{fA}\cdot\text{Vout})$	200V
±100nA	10pA	$\pm(0.12\%+50\text{pA}+200\text{fA}\cdot\text{Vout})$	100fA	$\pm(0.1\%+30\text{pA}+200\text{fA}\cdot\text{Vout})$	200V
±1 \times A	100pA	$\pm(0.12\%+400\text{pA}+2\text{pA}\cdot\text{Vout})$	1pA	$\pm(0.1\%+200\text{pA}+2\text{pA}\cdot\text{Vout})$	200V
±10 \times A	1nA	$\pm(0.12\%+5\text{nA}+20\text{pA}\cdot\text{Vout})$	10pA	$\pm(0.1\%+3\text{nA}+20\text{pA}\cdot\text{Vout})$	200V
±100 \times A	10nA	$\pm(0.12\%+40\text{nA}+200\text{pA}\cdot\text{Vout})$	100pA	$\pm(0.1\%+20\text{nA}+200\text{pA}\cdot\text{Vout})$	200V
±1mA	100nA	$\pm(0.12\%+500\text{nA}+2\text{nA}\cdot\text{Vout})$	1nA	$\pm(0.1\%+300\text{nA}+2\text{nA}\cdot\text{Vout})$	200V
±10mA	1 \times A	$\pm(0.12\%+4\text{\timesA}+20\text{nA}\cdot\text{Vout})$	10nA	$\pm(0.1\%+2\text{\timesA}+20\text{nA}\cdot\text{Vout})$	200V
±100m?	10 \times A	$\pm(0.12\%+50\text{\timesA}+200\text{nA}\cdot\text{Vout})$	100nA	$\pm(0.1\%+30\text{\timesA}+200\text{nA}\cdot\text{Vout})$	*1
±1?	100 \times A	$\pm(0.5\%+500\text{\timesA}+2\text{\timesA}\cdot\text{Vout})$	1 \times A	$\pm(0.5\%+300\text{\timesA}+2\text{\timesA}\cdot\text{Vout})$	*2

*1: 200V (Iout \leq 50mA), 100V (50mA<Iout=100mA)

*2: 200V (Iout \leq 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 $\pm\%$ of set/measured value (0.1%) plus offset value (30pA+200fA \cdot Vout) for the 100nA range. The offset value consists of a fixed part determined by the set/measurement range and a proportional part that is multiplied by Vout.

PGU (Pulse Generator Unit)

Specifications

Modes: Pulse or constant

Amplitude: 0Vpp to 40Vpp

Window: -40.0V to +40.0V

Maximum current:

$\pm 200\text{mA}$ (pulse width: =1ms, average

current=100mA)

$\pm 100\text{mA}$

Pulse width: 1.0 \times s to 9.99s

Minimum resolution: 100ns

Pulse period: 2.0 \times 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 Ω or low

impedance (=1 Ω)

Burst count range: 1 - 65535

Output terminal/connection:

Dual triaxial connectors, Kelvin (remote sensing)

Voltage/Current Compliance

(Limiting):

Voltage: 0V to $\pm 200\text{V}$

Current: $\pm 1\text{pA}$ to $\pm 1\text{A}$

Compliance Accuracy: Same as the current (voltage) settling accuracy.

HPSMU Supplemental Information:

Maximum allowable cable resistance when using Kelvin connection:

Force: 0.7 Ω (100mA to 1A)

Force: 10 Ω (=100mA)

Sense: 10 Ω

Typical voltage source output resistance (Force line/non-Kelvin connection): 0.2 Ω

Voltage measurement input resistance/
current source output resistance:
=10¹³ Ω (1nA range)

Current compliance setting accuracy for opposite polarity:

1nA to 10nA range: V/I setting

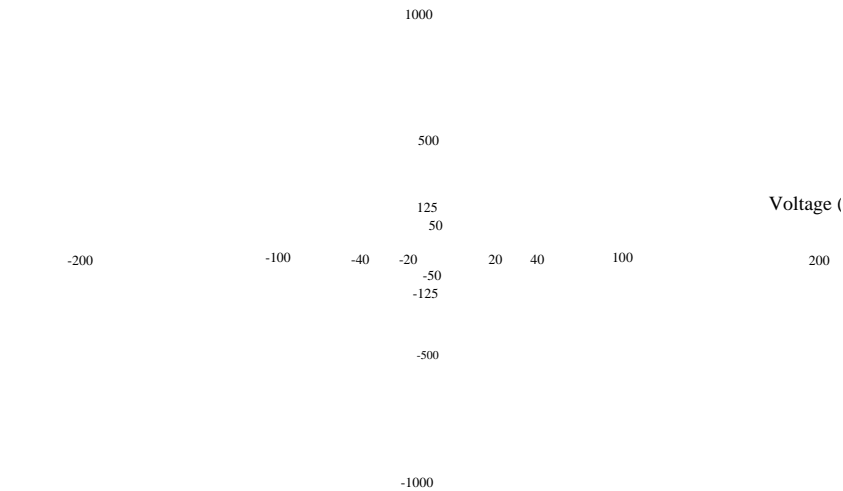
accuracy $\pm 12\%$ of range

100nA to 1A range: V/I setting

accuracy $\pm 2.5\%$ of range

Current (mA)

HPSMU Measurement and Output Range



Pulse/DC Output Voltage and Accuracy (PGU)

Set Parameter	Voltage Range	Resolution	Accuracy *1
Base	$\pm 20\text{V}$	4mV	$\pm(1\% \text{ of Base} + 50\text{mV} + 1\% \text{ of Pulse})$
	$\pm 40\text{V}$	8mV	$\pm(1\% \text{ of Base} + 50\text{mV} + 1\% \text{ of Pulse})$
Pulse	$\pm 20\text{V}$	4mV	$\pm(3\% \text{ of Base} + 50\text{mV})$
	$\pm 40\text{V}$	8mV	$\pm(3\% \text{ of Base} + 50\text{mV})$

Note: DC output is performed by the Base parameter.

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Pulse parameter accuracyPeriod: $\pm(2\% + 2\text{ns})$ Width: $\pm(3\% + 2\text{ns})$ Delay: $\pm(2\% + 40\text{ns})$ Transition time: $\pm(5\% + 10\text{ns})$ **Trigger output**

Level: TTL

Timing: Same timing and width as

PGU1 pulse output

PGU Supplemental Information:Overshoot: = $\pm 5\%$ of amplitude $\pm 10\text{mV}$ (50 Ω output impedance to 50 Ω load)

Pulse width jitter: 0.2% + 100ps

Pulse period jitter: 0.2% + 100ps

Maximum slew rate: 100V/ μ s(50 Ω output impedance to 50 Ω load)

Noise: 0.2% of range (@ DC output)

MPSMU Specifications

Same as HP 4155B MPSMU.

**GNDU (Ground Unit)
Specifications:**Output Voltage: 0V \pm 100 μ 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: $\pm 1\text{mV}$ **Functions****Measurement Set-up
Setting**

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

Pulse Range and Pulse Parameter (PGU)

Range	Period	Width	Delay	Set resolu
1	2 μ s - 100 μ s	1 μ s - 100 μ s	0 - 100 μ s	0.1 μ s
2	100 μ s - 1000 μ s	1 μ s - 999 μ s	0 - 1000 μ s	1 μ s
3	1ms - 10ms	0.01ms - 9.99ms	0 - 10ms	10 μ s
4	10ms - 100ms	0.1ms - 99.9ms	0 - 100ms	100 μ s
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	$\pm(5\% + 10\text{ns})$
0.5 μ s - 10 μ s	10ns	$\pm(5\% + 10\text{ns})$
5.0 μ s - 100.0 μ s	100ns	$\pm(5\% + 10\text{ns})$
50 μ s - 1000 μ s	1 μ s	$\pm(5\% + 10\text{ns})$
0.5ms - 10.0ms	10 μ s	$\pm(5\% + 10\text{ns})$

Restrictions:

Pulse width < Pulse Period

Delay time < Pulse period

Leading time < Pulse width $\cdot 0.8$ Trailing time < (Pulse period - Pulse width) $\cdot 0.8$

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 μ 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/ μ s**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 μ 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 $VAR1 = a \cdot VAR1 + b$, 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 μ s resolution.

Pulse period:

(5ms to 1s (= pulse width + 4ms),

100 μ s resolution.

SMU pulse setting accuracy

(supplemental information, at fixed range measurement except multi-channel measurement):

Width: $0.5\% + 50\mu s$

Period: $0.5\% + 100\mu s$

Trigger output delay for pulsed

measurement: 0 - 32.7ms with 100 μ s

Linear scale (no limit mode), log scale, and thinned-out modes:

560 μ s (720 μ s at thinned-out mode)

to 1s range: 80 μ 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 time: 0.03s to 655.35s,

100 μ s resolution

Sampling measurement stop condition:

A condition to stop the sampling can be defined.

Sampling interval setting accuracy (supplemental data):

$0.5\% + 10\mu s$ (sampling interval = 480 μ s)

$0.5\% + 10\mu s$ (480 μ s = sampling interval < 2ms)

$0.5\% + 100\mu s$ (2ms = sampling interval)

Stress Force Characteristics

SMU, VSU, and PGU output can be forced for the user specified period.

Stress time set range:

5000 μ s to 31,536,000s (365 days)

Resolution:

100 μ s (500 μ s = stress time = 10s)

10ms (10s < stress time = 31,536,000s)

Burst pulse count:

1 - 65,535 (PGU only)

Trigger:

HP 4156B/4156C outputs a gate

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

e: 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), μ or μ (10⁻⁶), m (10⁻³), K (10³), M (10⁶), G (10⁹)

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 μ s to 480 μ s range: 20 μ s resolution

480 μ s to 1s range: 80 μ 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 probe.

VXIplug&play Drivers

VXIplug&play drivers for the

HP 4155B and **HP 4156B**

Supported VXIplug&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

VXIplug&play drivers disk for the

HP 4155B & **HP 4156B**, 1 ea.

VXIplug&play drivers disk for the

HP E5250A, 1 ea

Accessory Specifications

Specification Condition

The supplemental information and typical

PGU port signal transfer characteristics

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:

ì 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.

ì 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,
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