Agilent 4155C Semiconductor Parameter Analyzer

Agilent 4156C Precision Semiconductor Parameter Analyzer

Data Sheet

Introduction

Agilent 4155C and 4156C Basic 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 hardcopy output
- Perform measurement and analysis with built-in instrument BASIC
- Self test, Auto calibration

Configuration

The 4155C and 4156C both come standard with I/CV 2.1 Lite automation software. A PC-based instrument controller with I/CV Lite preinstalled and an Agilent 82357A USB/GPIB interface are also included with the standard configuration. You have the option of deleting the controller and cable from your order, but I/CV Lite is always included with both instruments. If you want the full version of I/CV 2.1, you can request the E5240BU upgrade kit when you order a 4155C or 4156C. For more information about the differences between I/CV 2.1 Lite and I/CV 2.1, please refer to the Agilent I/CV 2.1 Technical Overview, publication number 5988-8474EN.

4155C	4156C
4xMPSMU	4xHRSMU
2xVMU 2xVSU I/CV 2.1 Lite	2xVMU 2xVSU I/CV 2.1 Lite
Standard PC-based controller and USB/GPIB interface	

41501B (Optional)

GNDU

2xPGU (Option)[1]

HPSMU (Option) or 2xMPSMU (Option)[1]

SMU: Source Monitor Unit
Display resolution: 6 digits at each current range (0.01fA display resolution at 10pA range)[2]
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 (0.2µV resolution in differential mode)
VSU: Voltage Source Unit
PGU: Pulse Generator Unit (1 channel)
GNDU: Ground Unit

[1] Minimum number of installable MPSMU or PGU is two.

[2] Accuracy not guaranteed. Minimum guaranteedresolution is 1fA at 10pA range.

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 con-ditions:

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

Agilent 4156C 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):

	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)

Voltage/Current Compliance (Limiting):

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

Voltage: 0 V to ±100 V

Current: ±100 fA to ±100 mA

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

HRSMU Supplemental Information:

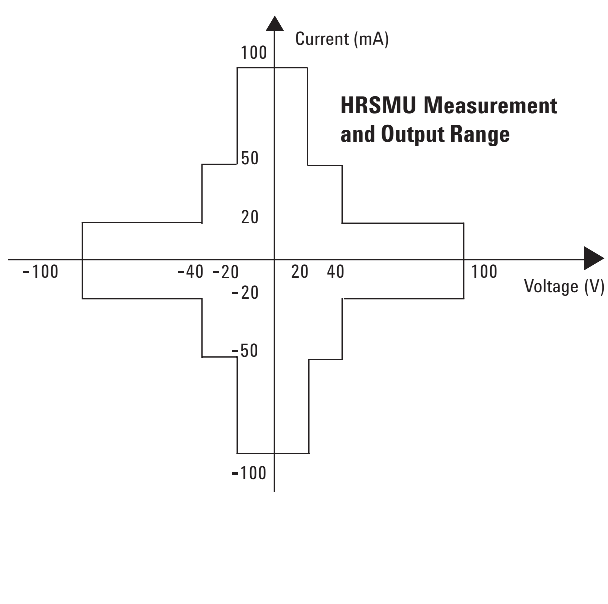
Maximum allowable cable resistance when using Kelvin connection (Force, Sense): 10 Ω

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

Voltage measurement input resistance/current source output resistance: ≥10^{15} Ω (10 pA range)

Current compliance setting accuracy for opposite polarity:

- 10 pA to 10 nA range: V/I setting accuracy ±12% of range
- 100 nA to 100 mA range: V/I setting accuracy ±2.5% of range



Agilent 4155C 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
±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]

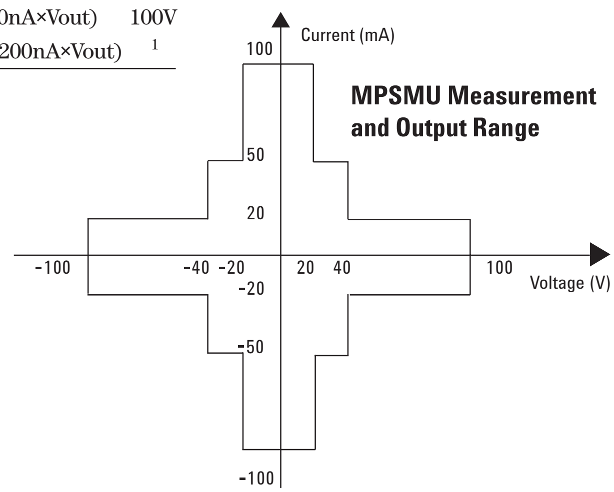
[1] 100V (Iout ≤20V), 40V (20mA<Iout≤50mA), 20V (50mA<Iout≤100mA)

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/measurement 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: 0 V to ±100 V
Current: ±1 pA to ±100 mA
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: ≥10^{13} Ω (1 nA range)
Current compliance setting accuracy foropposite polarity:
1nA to 10 nA range: V/I setting accuracy ±12% of range
100 nA to 100 mA range: V/I setting accuracy ±2.5% of range



MPSMU Measurement and Output Range

VSU and VMU specifications are common to both the 4155C and 4156C

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

VMU (Voltage Monitor Unit) Specifications

VMU Differential Mode Range, Resolution, and Accuracy:

Diff V Range	Meas. Reso.	Meas. Accuracy
±0.2V	0.2µV	±(0.03%+10µV+0.3µV×Vi)
±2V	2µV	±(0.02%+100µV+3µV×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 (100µV+3µV×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 Measurement Range, Resolution, and Accuracy:

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

VMU Supplemental Information:
Input Impedance: ≥1G Ω
Input leakage current (@0 V): ≤500 pA
Measurement noise: 0.01% of range (p-p) (typical) when integration time is 10 PLC
Differential mode measurement noise: 0.005% of range (p-p) (typical) when integration time is short.

Agilent 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	±(0.045%+30mV)	200µV	±(0.035%+10mV)	50mA

Current Range, Resolution, and Accuracy (HPSMU)

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/measurement range and a proportional part that is multiplied by Vout.

Output terminal/connection:

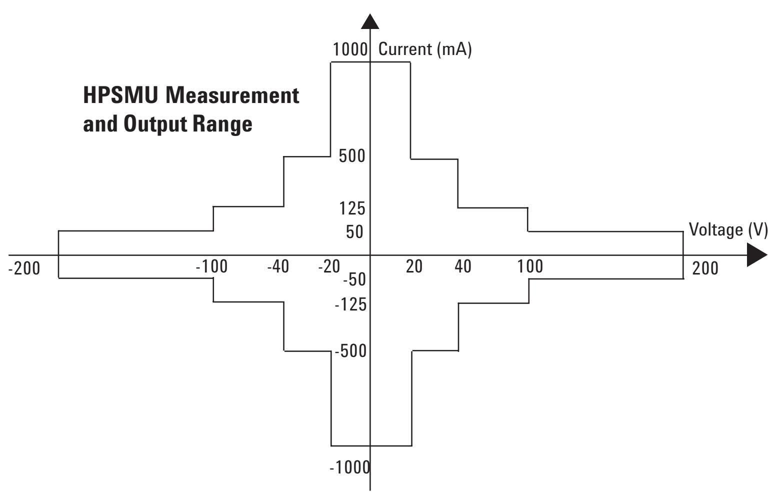
Dual triaxial connectors, Kelvin (remote sensing)

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:
$\geq 10^{13}$ Ω (1nA range)
Current compliance setting accuracy foropposite polarity:
1nA to 10nA range: V/I setting accuracy ±12% of range
100nA to 1A range: V/I setting accuracy ±2.5% of range



PGU (Pulse Generator Unit) Specifications

Modes: Pulse or constant
Amplitude: 0Vp-p to 40Vp-p
Window: -40.0V to +40.0V
Maximum current:
±100mA
±200mA (pulse width: ≤1ms, average current 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 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 4155C MPSMU.

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 Range and Pulse Parameter (PGU)

Range	Period	Width	Delay	Set resolution
1	2µs -100µs	1µs - 99.9µs	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 Resolution`	Accuracy
100ns - 1000ns	1ns	±(5% + 10ns)
0.5µs - 10µs	10ns	±(5% + 10ns)
5.0µs - 100µs	100ns	±(5% + 10ns)
50µs - 1000µs	1µs	±(5% + 10ns)
0.5ms - 10ms	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 timefor a PGU must be in the same range.

GNDU (Ground Unit) Specifications:

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

GNDU Supplemental Information

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

HRSMU, MPSMU, 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
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

Capacitance Calculation Accuracy (Supplemental Data)

Accuracy is derived from the current range, voltage range, capacitance measurement and leakage current measurement integration times, and the guard capacitance of cabling and step voltage. The information in the chart below is based on the following conditions: Voltage Range ±20V; Voltage Step: 100mV; Guard Capacitance : 100pF; Equivalent parallel resistance of DUT: $1 \times 10^{15}\Omega$. The ratio of integration times for capacitance measurement and leakage current measurement is 1:1.

HRSMU

Current Range	Integration Time	Max. Meas. Value	Resolution	Accuracy Reading %	Offset
10pA/100pA	0.5sec	100pF/1pF	5fF	4.2	70fF
	1sec	2pF/20pF	10fF	4.3	90fF
	2sec	76pF/760pF	20fF	4.3	130fF
1nA	0.1sec	700pF	10fF	0.84	160fF
	0.5sec	4.5nF	40fF	0.85	280fF
	2sec	18nF	200fF	0.93	740fF
10nA	0.1sec	7nF	10fF	0.84	200fF
	0.5sec	45nF	40fF	0.85	440fF
	2sec	180nF	200fF	0.93	1.4pF
	10sec	940nF	1pF	1.3	6.2pF

MPSMU

Current	Integration Time	Max. Meas. Value	Resolution	Accuracy Reading %	Offset
1nA	0.1sec	700pF	10fF	0.91	170fF
	0.5sec	4.5nF	40fF	0.94	340fF
	2sec	18nF	200fF	1.0	1pF
10nA	0.1sec	7nF	10fF	0.91	180fF
	0.5sec	45nF	40fF	0.94	480fF
	2sec	180nF	200fF	1.0	1.6pF
	10sec	940nF	1pF	1.6	7.6pF

Current complicance must be smaller than the current range. The capacitance of the DUT and measurement path must be smaller than the maximum measurement value.

Functions

Measurement Setup

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 Instrument BASIC or via GPIB
- 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 4155C and 4156C 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 100µs 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 (^{3}pulse width + 4ms), 100µs resolution.
SMU pulse setting accuracy (supplemental information, at fixed range measurement except multichannel 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.
Max. 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 time: 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)

C-V Measurement Characteristics

Capacitance is a calculated value derived from the following equation:

$$C = \frac{\Delta Q}{\Delta V}$$

ΔQ is the change in charge when ΔV, the step voltage, is applied by the SMU; ΔQ is derived from the measurement current (amps) and the integration time (seconds).

Maximum Measurable Value

Maximum measurable value depends on thecurrent range, integration time, and step voltage (refer to the chart in supplemental data).

Capacitance Calculation Accuracy

Accuracy is dependent on accuracy of the current measurement and voltage measurement and the stray capacitance and leakage current of measurement path, etc. (Refer to the chart in supplemental data).

Zero Offset

Cancels stray capacitance of the fixtures and test leads.

Leakage Current Compensation

Cancels the influence of the leakage current to the capacitance measurement.

Stress Force Characteristics

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

Stress time set range: 500µs 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: The 4155C and 4156C output a gate trigger while stress channels are forcing stress.

Knob Sweep

In knob sweep mode, sweep range is controlled instantaneously with the front-panel rotary knob. Only the Channel Definition page need 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

Measurement Control: Single, append, repeat, and stop

Stress Control: Stress force and stop

SMU Setting Capabilities: 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 (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}), u or m (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 GPIB or 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). More than 99.99% of the pixels on an LCD are active.

Hard Copy Functions

Graphics Hard Copy

Measured data and all data appearing on the LCD can be output via GPIB, 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 GPIB, 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 floppy 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, mea surement setup/result file, stress setup file, customize file, hard copy data file, and Instrument BASIC program and data file.
Format of data made by the HP BASIC program:
 Data made by the HP BASIC program and data made by the 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

Agilent 4155C and 4156C function control:
 Internal or external computer controls the 4155C and 4156C functions via the GPIB interface
Command sets:
 SCPI command set
 Agilent FLEX command set
 Agilent 4145B command set
Program Memory:
 Using the Agilent FLEX command set, the user can store program code in the 4155C or the 4156C. The maximum number of subprograms is 255 (8 bit).
External instrument remote control:
 Control external equipment via the GPIB interface.

Instrument BASIC

Instrument BASIC is a subset of HP BASIC.
Functions:
 Arithmetic operation, binary opera tion, string manipulation, logical operation, array operation, program flow control, event-initiated branch ing, program editing and debugging support, mass storage operation, instrument control, real-time clock, softkey operation, and graphics.
Agilent 4145B automatic sequence program (ASP) typing aid:
 4145B ASP-like syntax softkeys are available in instrument BASIC. A 4145B ASP file cannot be read by the 4155C or 4156C.
Remote control:
 Instrument BASIC is remote controllable from an external computer via the GPIB interface.
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 Instrument BASIC program.
Input Level:
 TTL level, negative or positive edge trigger
Output:
 External edge trigger outputs can be generated by the start of a sweep measurement, the start of each sweep step in a staircase sweep, the start of each pulse leading edge for an SMU in pulse mode, and the issuance of an an IBASIC trigger out command execution. In addition, you can set the trigger signal to be active during the Stress Force State. If you have a 41501A/B with PGU option, you can output a synchronized trigger output through the 41501A/B trigger output.
Output Level:
 TTL level, negative or positive logic

4145B Data Compatibility and Syntax Commands

Setup and data file

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

GPIB program

GPIB programs for the 4145B can be used when the 4145B command set is selected.

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

Interfaces

GPIB 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 (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
Charging pump test

Sample VEE Program

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

VXI *plug&play* Drivers

VXI *plug&play* drivers for the 4155C and 4156C

Supported VXI *plug&play* operating systems:

Microsoft Windows 95, 98, NT, 2000 Professional, and XP Professional

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

4155C and 4156C: 450VA
41501B: 350 VA

Regulatory Compliance

EMC: EN 61326-1:+A1, AS/NZS 2064.1
Safety:
CSA C22.2 NO.1010.1 (1992),
IEC 61010-1:+A2/EN 61010-1:+A2
UL3111-1:1994
Certification:
CE, CSA, NRTL/C, C-Tick

Dimensions

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

Weight (approx.)

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

4155C and 4156C Furnished Accessories

Triaxial cable, 4 ea. (4155C)
Kelvin triaxial cable, 4 ea. (4156C)
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.
VX*Iplug&play* drivers disk for the 4155C and 4156C, 1 ea.
VX*Iplug&play* drivers disk for the E5250A, 1 ea.
LAN Interface Test Adapter, 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°, 50% RH).

16440A SMU/Pulse Generator Selector

The 16440A switches either an SMU or PGU to the associated output port. You can expand to 4 channels by adding an additional 16440A. The channel 1 PGU port provides a "PGU OPEN" function, which can disconnect the PGU by opening a semiconductor relay. The 16440A cannot work without two pulse generator units of the 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 and Current Range

Input port	Max. V	Max. I
SMU	200V	1.0A
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:
50mm H × 250mm W × 275mm D
Approximate weight: 1.1kg

16441A R-BOX

The 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 automaticallycompensated for in the measurement result.

Measurement limitations with the 4155C and 4156C and R-BOX:
If you measure device characteristics including negative resistance over 1MΩ with the 4155C/4156C and R-BOX, there is a possibility that they cannot be measured. There is a possibility that the 4155C and 4156C 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 a 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:
72mm H × 250mm W × 270mm D
Approximate weight: 1.6kg

16442A Test Fixture

Channel Information

SMU:
6 channels (1 triaxial connector per channel)
3 channels (1 Kelvin triaxial connector per channel)
VSU:
2 channels (1 BNC connector per channel)
VMU:
2 channels (1 BNC connector per channel)
PGU:
2 channels (1 BNC connector per 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:
50mΩ 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

Automation Software

I/CV 2.1 Lite

Overview

Agilent I/CV 2.1 Lite provides automated test solutions for semiconductor characterization. It supports the Agilent 4155C and 4156C, the Agilent E5270 Series, the Agilent E5250A Low Leakage Switch, the Keithley 707 Switching Matrix, the Agilent 4284A and 4294A LCR meters, and many popular semiautomatic wafer probers. I/CV 2.1 Lite also provides wizard-based test development, test execution, and sequencing along with data logging and post- analysis tools on Microsoft® Windows.®

Software Functions

Interactive Measurements

I/CV 2.1 Lite includes Agilent ICS as the default measurement tool. ICS provides point-and-click measurements, intuitive matrix control, and graphical analysis capabilities for semiconductor parametric measurements. Created setups can be used as measurement algorithms in the script editor.

Script Editor

The script editor provides a wizard-based interface for building test scripts used in the execution of automated tests. It allows access to libraries of built- in software components that support functions for creating test plans. Components include:

- Automated sub-die prober movement
- Switch connection execution
- Test algorithm execution
- Pass/Fail determination and processing
- Conditional branching: IF, ELSE
- Looping: FOR, WHILE
- User variable creation
- User prompts
- Message displays
- Test script commenting

Wafer Prober Navigation

I/CV 2.1 Lite provides support for popular semiautomatic probers as well as several automatic probers. Probe plans can be defined that include sub-die movement for performing automated test of multiple modules or individual devices across a wafer. Interactive prober control can also be implemented for analytical applications.

Test Execution

Test scripts can be executed for either manual or automated tests. Manual tests are used for single devices or single modules (which can include several devices) on a manual prober. Automated tests are used for wafer tests combing semiautomatic prober control with die or module test scripts. Test wizards provide step-by-step instructions for entering runtime information, selection of wafer navigation plans, selection of test plans, and starting a test.

Auto-Analysis and Test Reporting

Parametric quantities from test data can be extracted and standard reports and graphs can be generated. Supported graphs and reports include:

- Color wafer maps
- Histograms
- Parameter statistics
- Parametric values vs. die location
- Tables of I-V or C-V curve data

Software Measurement Tool Support

Test algorithms can be created using the following tools:

- Agilent ICS
- Microsoft VBScript (resident in the script editor)

Computer System Requirements

Operating System

Microsoft Windows 2000 Professional or XP Professional with Service Pack 1

CPU

300 MHz Pentium II-class (500 MHz Pentium III-class or faster recommended)

Hard Disk

5 GB available space (20 GB recommended)

Memory

128 MB for Windows 2000 Professional (256 MB recommended)

256 MB for Windows XP Professional

Disk Drive

CD-ROM

Software Security

Parallel or USB port required to attach security key

Control I/F

Supported GPIB card (see requirements below)

GPIB Card Support

Agilent

Card	Windows 2000 Professional	Windows XP Pro. (Service Pack 1)
82341C (ISA)	X	–
82357A (USB/GPIB)	X	X

Agilent I/O Library L.02.01 required

National Instruments

Card	Windows 2000 Professional	Windows XP Pro. (Service Pack 1)
PCI-GPIB	X	X
GPIB-USB-A	X	X

Prober Support

Cascade Microtech

S 300 with Nucleus version 2.1 or 2.5

Summit 12k with Nucleus version 2.1 or 2.5

Electroglas

2001 and 408X

SUSS MicroTec

All SUSS MicroTec probe stations using Prober Bench NT v4.2

Vector Semiconductor

AX-2000 / VX-3000, Version 3.2 or later

Supported Measurement Instruments

- E5270 Series of Parametric Measurement Solutions
- 4155A/B/C Semiconductor Parameter Analyzer
- 4156A/B/C Precision Semiconductor Parameter Analyzer
- 4284A Precision LCR Meter
- 4294A Impedance Analyzer*
- E5250A Low Leakage Switch Mainframe
- Keithley 707 Switch

* VBScript libraries are supplied.

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