Agilent has a new name

Keysight Technologies.

Keysight Technologies Inc. is the world's leading electronic measurement company, transforming today's measurement experience through innovations in wireless, modular, and software solutions. With its HP and Agilent legacy, Keysight delivers solutions in wireless communications, aerospace and defense and semiconductor markets with world-class platforms, software and consistent measurement science.

Agilent B1500A
Semiconductor Device Analyzer

Technical Overview

Introduction

The Agilent B1500A Semiconductor Device Analyzer with EasyEXPERT software is a complete parametric test solution. It supports all aspects of parametric test, from basic manual measurement to test automation across a wafer in conjunction with a semiautomatic wafer prober. Because the B1500A utilizes the Microsoft® Windows® XP Professional operating system, it integrates easily into your PC-based work environment. Best of all, the familiar Windows graphical user interface (GUI) and convenient online help menus minimize the need for instrument training.

Basic Features

- PC-based instrument with touch screen interface; optional USB keyboard and mouse available
- EasyEXPERT software with over 200 categorized application tests supplied with the instrument
- Performs current versus voltage (IV) measurements
- Performs capacitance versus voltage (CV), capacitance versus time (Ct) and capacitance versus frequency (Cf) measurements
- Performs quasi-static CV (QSCV) measurements
- High voltage pulse forcing up to 40 V with ALWG and voltage monitor capabilities.
- Performs fast IV measurement synchronized with the applied waveforms for accurate transient IV or time-domain measurements
- Front-panel Classic Test measurement modes supported: single-channel sweep, multi-channel sweep, time sampling, list sweep, CV sweep and direct control (GPIB FLEX)
- GUI-based control of the Agilent B2200A, and B2201A switching matrices
- Modular mainframe with ten module slots and one 4.2 A ground unit
- Multiple source/monitor unit (SMU) types available: medium power (MPSMU), high-power (HPSMU), and high-resolution (HRSMU)
- Multi-frequency capacitance measurement unit (MFCMU) available
- High-voltage semiconductor pulse generator unit (HV-SPGU) available
- Waveform generator/fast measurement unit (WGFMU) available
- High-resolution, analog-to-digital converter (ADC) available to all installed SMUs
- High-speed ADC present on each installed SMU
- SMU/AUX path switching supported on the atto-sense and switch unit (ASU)
- SMU/MFCMU switching supported using SMU CMU unify unit (SCUU) and guard switch unit (GSWU)
- MFCMU automatically identifies capacitance measurement accessories
- WGFMU/SMU path switching supported on the remote-sense and switch unit (RSU)
- GPIB port for instrument control
- Self-test, self-calibration, diagnostics

Specification conditions

This document lists specifications and supplemental information for the B1500A and its associated modules. The specifications are the standards against which the B1500A and its associated modules are tested. When the B1500A and any of its associated modules are shipped from the factory, they meet the specifications. The "supplemental" information and "typical" entries in the following specifications are not warranted, but provide useful information about the functions and performance of the instrument.

The measurement and output accuracy are specified at the rear panel connector terminals when referenced to the Zero Check terminal. The B1530A WGFMU measurement and output accuracy are specified at the output terminal of the RSU. Accuracy is specified under the following conditions:

1. Temperature: 23 °C ±5 °C
2. Humidity: 20 % to 60 %
3. After 40 minute warm-up followed by self-calibration
4. Ambient temperature change less than ±1 °C after self-calibration execution, not applicable for MFCMU and WGFMU
5. Measurement made within one hour after self-calibration execution, not applicable for MFCMU and WGFMU
6. Calibration period: 1 year
7. SMU integration time setting:
1 PLC (1 nA to 1A range, voltage range)
20 PLC (100 pA range)
50 PLC (1 pA to 10 pA range)
Averaging of high-speed ADC:
128 samples per 1 PLC
8. SMU filter: ON (for SMUs)
9. SMU measurement terminal connection: Kelvin connection
10. WGFMU load capacitance: 25 pF or less

Note: Agilent Technologies is responsible for removing, installing, and replacing the B1500A modules. Contact your nearest Agilent Technologies to install and calibrate the B1500A modules

B1500A specification

Supported plug-in modules

The B1500A supports ten slots for plug-in modules.

Part number	Description	Slots occupied	Range of operation	Measure resolution
B1510A	High power source/monitor unit (HPSMU)	2	-200 V to 200 V, -1 A to 1 A	2 μV, 10 fA
B1511A	Medium power source/monitor unit (MPSMU)	1	-100 V to 100 V, -100 mA to 100 mA	0.5 μV, 10 fA
B1517A	High resolution source/monitor unit (HRSMU)	1	-100 V to 100 V, -100 mA to 100 mA	0.5 μV, 1 fA
E5288A[1]	Atto-sense and switch unit (ASU)	—	-100 V to 100 V, -100 mA to 100 mA	0.5 μV, 100 aA
B1520A	Multi frequency capacitance measurement unit (MFCMU)	1	1 kHz to 5 MHz	0.035 fFrms[2]
B1525A	High voltage semiconductor pulse generator unit (HV-SPGU)	1	±40 V (80 Vp-p)	50 μV
B1530A	Waveform generator/fast measurement unit (WGFMU)	1	PG Mode: -3 V to 3 V, -5 V to 5 V Fast IV Mode: -3 V to 3 V, -5 V to 5 V, 0 V to 10 V, -10 V to 0 V	0.014 % of the range [3]

1. This is connected with the B1517A high resolution SMU.
2. Dispersion of measurement values when connecting a DUT 10 pF to the measurement terminals under the measurement condition of frequency 1 MHz, signal level 250 mVac, and measurement time 1 PLC. The display resolution is 0.000001 fF at 1 fF order by 6 digits display.
3. Display resolution

Maximum module configuration

The B1500A can contain up to 4 dual-slot SMUs (HPSMUs) and 2 single-slot SMUs (MPSMUs and/or HRSMUs); it can contain up to 10 single-slot SMUs (MPSMUs and/or HRSMUs); and it can contain any combination of dual-slot and single-slot SMUs between these two extremes.
Only one single-slot MFCMU can be installed per B1500A mainframe. Up to five single-slot HV-SPGUs can be installed per mainframe. Up to five single-slot WGFMUs can be installed per mainframe.

When one or more WGFMU modules are installed in the B1500A mainframe, the following table applies. Multiply the values given below by the number of installed modules of that type and add the products together. The sum of the products must be less than or equal to 59 for the configuration to be permissible.

MPSMU	2
HRSMU	2
HPSMU	14
MFCMU	7
HV-SPGU	12
WGFMU	10

Maximum voltage between common and ground

≤ ±42 V

Ground unit (GNDU) specification

The GNDU is furnished standard with the B1500A mainframe.

Output voltage: 0 V ±100 μV

Maximum sink current: ±4.2 A

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

GNDU supplemental information

Load capacitance: 1 μF

Cable resistance:

For I_S ≤ 1.6 A: force line R < 1 Ω

For 1.6 A < I_S ≤ 2.0 A: force line R < 0.7 Ω

For 2.0 A < I_S ≤ 4.2 A: force line R < 0.35 Ω

For all cases: sense line R ≤ 10 Ω

Where I_S is the current being sunk by the GNDU.

MPSMU and HRSMU module specifications

Voltage range, resolution, and accuracy (high resolution ADC)

Voltage range	Force resolution	Measure resolution	Force accuracy [1]	Measure accuracy [1]	Maximum current
±0.5 V	25 μV	0.5 μV	±(0.018 % + 150 μV)	±(0.01 % + 120 μV)	100 mA
±2 V	100 μV	2 μV	±(0.018 % + 400 μV)	±(0.01 % + 140 μV)	100 mA
±5 V	250 μV	5 μV	±(0.018 % + 750 μV)	±(0.009 % + 250 μV)	100 mA
±20 V	1 mV	20 μV	±(0.018 % + 3 mV)	±(0.009 % + 900 μV)	100 mA
±40 V	2 mV	40 μV	±(0.018 % + 6 mV)	±(0.01 % + 1 mV)	[2]
±100 V	5 mV	100 μV	±(0.018 % + 15 mV)	±(0.012 % + 2.5 mV)	[2]

1. ± (% of read value + offset voltage V)
2. 100 mA (Vo ≤ 20 V), 50 mA (20 V < Vo ≤ 40 V), 20 mA (40 V < Vo ≤ 100 V), Vo is the output voltage in Volts.

Current range, resolution, and accuracy (high resolution ADC)

SMU type	Current range	Force resolution	Measure resolution [1,2]	Force accuracy [3]	Measure accuracy [3]	Maximum voltage
HRSMU w/ ASU	±1 pA	1 fA	100 aA	±(0.9 %+15 fA)	±(0.9 %+12 fA)	100 V
HRSMU	±10 pA	5 fA	400 aA (with ASU) 1 fA (HRSMU)	±(0.46 %+30 fA+10 aA x Vo)	±(0.46 %+15 fA+10 aA x Vo)	100 V
	±100 pA	5 fA	500 aA (with ASU) 2 fA (HRSMU)	±(0.3 %+100 fA+100 aA x Vo)	±(0.3 %+30 fA+100 aA x Vo)	100 V
MPSMU	±1 nA	50 fA	10 fA	±(0.1 %+300 fA+1 fA x Vo)	±(0.1 %+200 fA+1 fA x Vo)	100 V
	±10 nA	500 fA	10 fA	±(0.1 %+3 pA+10 fA x Vo)	±(0.1 %+1 pA+10 fA x Vo)	100 V
	±100 nA	5 pA	100 fA	±(0.05 %+30 pA+100 fA x Vo)	±(0.05 %+20 pA+100 fA x Vo)	100 V
	±1 μA	50 pA	1 pA	±(0.05 %+300 pA+1 pA x Vo)	±(0.05 %+100 pA+1 pA x Vo)	100 V
	±10 μA	500 pA	10 pA	±(0.05 %+3 nA+10 pA x Vo)	±(0.04 %+2 nA+10 pA x Vo)	100 V
	±100 μA	5 nA	100 pA	±(0.035 %+15 nA+100 pA x Vo)	±(0.03 %+3 nA+100 pA x Vo)	100 V
	±1 mA	50 nA	1 nA	±(0.04 %+150 nA+1 nA x Vo)	±(0.03 %+60 nA+1 nA x Vo)	100 V
	±10 mA	500 nA	10 nA	±(0.04 %+1.5 μA+10 nA x Vo)	±(0.03 %+200 nA+10 nA x Vo)	100 V
	±100 mA	5 μA	100 nA	±(0.045 %+15 μA+100 nA x Vo)	±(0.04 %+6 μA+100 nA x Vo)	[4]

1. Specified measurement resolution is limited by fundamental noise limits. Minimum displayed resolution is 1 aA at 1 pA range by 6 digits.
2. Measurements made in the lower ranges can be greatly impacted by vibrations and shocks. These specifications assume an environment free of these factors.
3. ± (% of read value + offset current (fixed part determined by the output/measurement range + proportional part that is multiplied by Vo))
4. 100 V (Io ≤ 20 mA), 40 V (20 mA < Io ≤ 50 mA), 20 V (50 mA < Io ≤ 100 mA), Io is the output current in Amps.

Voltage range, resolution, and accuracy (high speed ADC)

Voltage range	Force resolution	Measure resolution	Force accuracy[1]	Measure accuracy[1]	Maximum current
±0.5 V	25 μV	0.5 μV	±(0.018 % + 150 μV)	±(0.01 % + 250 μV)	100 mA
±2 V	100 μV	2 μV	±(0.018 % + 400 μV)	±(0.01 % + 700 μV)	100 mA
±5 V	250 μV	5 μV	±(0.018 % + 750 μV)	±(0.01 % + 2 mV)	100 mA
±20 V	1 mV	20 μV	±(0.018 % + 3 mV)	±(0.01 % + 4 mV)	100 mA
±40 V	2 mV	40 μV	±(0.018 % + 6 mV)	±(0.015 % + 8 mV)	[2]
±100 V	5 mV	100 μV	±(0.018 % + 15 mV)	±(0.02 % + 20 mV)	[2]

1. ± (% of read value + offset voltage V)
2. 100 mA (Vo ≤ 20 V), 50 mA (20 V < Vo ≤ 40 V), 20 mA (40 V < Vo ≤ 100 V), Vo is the output voltage in Volts.

Current range, resolution, and accuracy (high speed ADC)

SMU type	Current range	Force resolution	Measure resolution[1,2]	Force accuracy[3]	Measure accuracy[3]	Maximum voltage
HRSMU w/ ASU	±1 pA	1 fA	100 aA	±(0.9 %+15 fA)	±(1.8 %+12 fA)	100 V
HRSMU	±10 pA	5 fA	400 aA (with ASU) 1 fA (HRSMU)	±(0.46 %+30 fA+10 aA x Vo)	±(0.5 %+15 fA+10 aA x Vo)	100 V
	±100 pA	5 fA	500 aA (with ASU) 2 fA (HRSMU)	±(0.3 %+100 fA+100 aA x Vo)	±(0.5 %+40 fA+100 aA x Vo)	100 V
MPSMU	±1 nA	50 fA	10 fA	±(0.1 %+300 fA+1 fA x Vo)	±(0.25 %+300 fA+1 fA x Vo)	100 V
	±10 nA	500 fA	10 fA	±(0.1 %+3 pA+10 fA x Vo)	±(0.25 %+2 pA+10 fA x Vo)	100 V
	±100 nA	5 pA	100 fA	±(0.05 %+30 pA+100 fA x Vo)	±(0.1 %+20 pA+100 fA x Vo)	100 V
	±1 μA	50 pA	1 pA	±(0.05 %+300 pA+1 pA x Vo)	±(0.1 %+200 pA+1 pA x Vo)	100 V
	±10 μA	500 pA	10 pA	±(0.05 %+3 nA+10 pA x Vo)	±(0.05 %+2 nA+10 pA x Vo)	100 V
	±100 μA	5 nA	100 pA	±(0.035 %+15 nA+100 pA x Vo)	±(0.05 %+20 nA+100 pA x Vo)	100 V
	±1 mA	50 nA	1 nA	±(0.04 %+150 nA+1 nA x Vo)	±(0.04 %+200 nA+1 nA x Vo)	100 V
	±10 mA	500 nA	10 nA	±(0.04 %+1.5 μA+10 nA x Vo)	±(0.04 %+2 μA+10 nA x Vo)	100 V
	±100 mA	5 μA	100 nA	±(0.045 %+15 μA+100 nA x Vo)	±(0.1 %+20 μA+100 nA x Vo)	[4]

1. Specified measurement resolution is limited by fundamental noise limits. Minimum displayed resolution is 1 aA at 1 pA range by 6 digits.
2. Measurements made in the lower ranges can be greatly impacted by vibrations and shocks. These specifications assume an environment free of these factors.
3. ± (% of read value + offset current (fixed part determined by the output/measurement range + proportional part that is multiplied by Vo))
4. 100 V (Io ≤ 20 mA), 40 V (20 mA < Io ≤ 50 mA), 20 V (50 mA < Io ≤ 100 mA), Io is the output current in Amps.

Power consumption

Voltage source mode

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

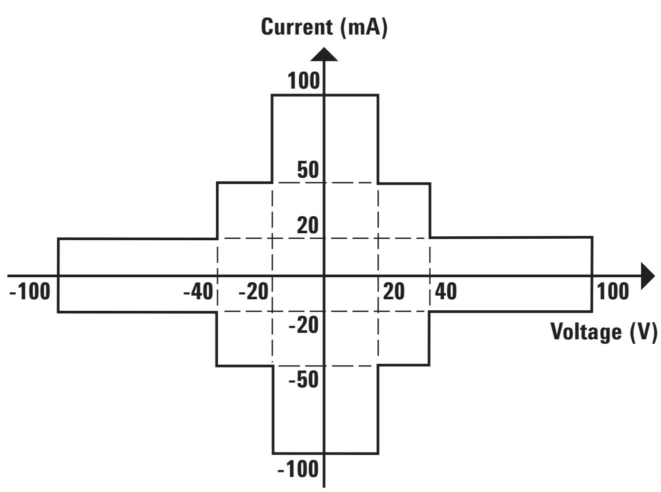
Where Ic is the current compliance setting.

Current source mode

Voltage compliance	Power
Vc ≤ 20	20 x Io (W)
20 < Vc ≤ 40	40 x Io (W)
40 < Vc ≤ 100	100 x Io (W)

Where Vc is the voltage compliance setting and Io is output current.

MPSMU and HRSMU measurement and output range



HPSMU module specifications

Voltage range, resolution, and accuracy (high resolution ADC)

Voltage range	Force resolution	Measure resolution	Force accuracy[1]	Measure accuracy[1]	Maximum current
±2 V	100 μV	2 μV	±(0.018 % + 400 μV)	±(0.01 % + 140 μV)	1 A
±20 V	1 mV	20 μV	±(0.018 % + 3 mV)	±(0.01 % + 140 μV)	1 A
±40 V	2 mV	40 μV	±(0.018 % + 6 mV)	±(0.01 % + 1 mV)	500 mA
±100 V	5 mV	100 μV	±(0.018 % + 15 mV)	±(0.012 % + 2.5 mV)	125 mA
±200 V	10 mV	200 μV	±(0.018 % + 30 mV)	±(0.014 % + 2.8 mV)	50 mA

1. ± (% of read value + offset voltage V)

Current range, resolution, and accuracy (high resolution ADC)

Current range	Force resolution	Measure resolution[1]	Force accuracy[2]	Measure accuracy[2]	Maximum voltage
±1 nA	50 fA	10 fA	±(0.1 %+300 fA+1 fA x Vo)	±(0.1 %+300 fA+1 fA x Vo)	200 V
±10 nA	500 fA	10 fA	±(0.1 %+3 pA+10 fA x Vo)	±(0.1 %+2.5 pA+10 fA x Vo)	200 V
±100 nA	5 pA	100 fA	±(0.05 %+30 pA+100 fA x Vo)	±(0.05 %+25 pA+100 fA x Vo)	200 V
±1 μA	50 pA	1 pA	±(0.05 %+300 pA+1 pA x Vo)	±(0.05 %+100 pA+1 pA x Vo)	200 V
±10 μA	500 pA	10 pA	±(0.05 %+3 nA+10 pA x Vo)	±(0.04 %+2 nA+10 pA x Vo)	200 V
±100 μA	5 nA	100 pA	±(0.035 %+15 nA+100 pA x Vo)	±(0.03 %+3 nA+100 pA x Vo)	200 V
±1 mA	50 nA	1 nA	±(0.04 %+150 nA+1 nA x Vo)	±(0.03 %+60 nA+1 nA x Vo)	200 V
±10 mA	500 nA	10 nA	±(0.04 %+1.5 nA+10 nA x Vo)	±(0.03 %+200 nA+10 nA x Vo)	200 V
±100 mA	5 μA	100 nA	±(0.045 %+15 μA+100 nA x Vo)	±(0.04 %+6 μA+100 nA x Vo)	[3]
±1 A	50 μA	1 μA	±(0.4 %+300 μA+1 μA x Vo)	±(0.4 %+150 μA+1 μA x Vo)	[3]

1. Specified measurement resolution is limited by fundamental noise limits.
2. ± (% of read value + offset current (fixed part determined by the output/measurement range + proportional part that is multiplied by Vo))
3. 200 V (Io ≤ 50 mA), 100 V (50 mA < Io ≤ 125 mA), 40 V (125 mA < Io ≤ 500 mA), 20 V (500 mA < Io ≤ 1 A), Io is the output current in Amps.

Voltage range, resolution, and accuracy (high speed ADC)

Voltage range	Force resolution	Measure resolution	Force accuracy[1]	Measure accuracy[1]	Maximum current
±2 V	100 μV	2 μV	±(0.018 % + 400 μV)	±(0.01 % + 700 μV)	1 A
±20 V	1 mV	20 μV	±(0.018 % + 3 mV)	±(0.01 % + 4 mV)	1 A
±40 V	2 mV	40 μV	±(0.018 % + 6 mV)	±(0.015 % + 8 mV)	500 mA
±100 V	5 mV	100 μV	±(0.018 % + 15 mV)	±(0.02 % + 20 mV)	125 mA
±200 V	10 mV	200 μV	±(0.018 % + 30 mV)	±(0.035 % + 40 mV)	50 mA

1. ± (% of read value + offset voltage V)

Current range, resolution, and accuracy (high speed ADC)

Current range	Force resolution	Measure resolution[1]	Force accuracy[2]	Measure accuracy[2]	Maximum voltage
±1 nA	50 fA	10 fA	±(0.1 %+300 fA+1 fA x Vo)	±(0.25 %+300 fA+1 fA x Vo)	200 V
±10 nA	500 fA	10 fA	±(0.1 %+3 pA+10 fA x Vo)	±(0.25 %+2 pA+10 fA x Vo)	200 V
±100 nA	5 pA	100 fA	±(0.05 %+30 pA+100 fA x Vo)	±(0.1 %+20 pA+100 fA x Vo)	200 V
±1 µA	50 pA	1 pA	±(0.05 %+300 pA+1 pA x Vo)	±(0.1 %+200 pA+1 pA x Vo)	200 V
±10 µA	500 pA	10 pA	±(0.05 %+3 nA+10 pA x Vo)	±(0.05 %+2 nA+10 pA x Vo)	200 V
±100 µA	5 nA	100 pA	±(0.035 %+15 nA+100 pA x Vo)	±(0.05 %+20 nA+100 pA x Vo)	200 V
±1 mA	50 nA	1 nA	±(0.04 %+150 nA+1 nA x Vo)	±(0.04 %+200 nA+1 nA x Vo)	200 V
±10 mA	500 nA	10 nA	±(0.04 %+1.5 µA+10 nA x Vo)	±(0.04 %+2 µA+10 nA x Vo)	200 V
±100 mA	5 µA	100 nA	±(0.045 %+15 µA+100 nA x Vo)	±(0.1 %+20 µA+100 nA x Vo)	[3]
±1 A	50 µA	1 µA	±(0.4 %+300 µA+1 µA x Vo)	±(0.5 %+300 µA+1 µA x Vo)	[3]

1. Specified measurement resolution is limited by fundamental noise limits.
2. ± (% of read value + offset current (fixed part determined by the output/measurement range + proportional part that is multiplied by Vo))
3. 200 V (Io ≤ 50 mA), 100 V (50 mA < Io ≤ 125 mA), 40 V (125 mA < Io ≤ 500 mA), 20 V (500 mA < Io ≤ 1 A), Io is the output current in Amps.

Power consumption

Voltage source mode

Voltage range	Power
2 V	20 x Ic (W)
20 V	20 x Ic (W)
40 V	40 x Ic (W)
100 V	100 x Ic (W)
200 V	200 x Ic (W)

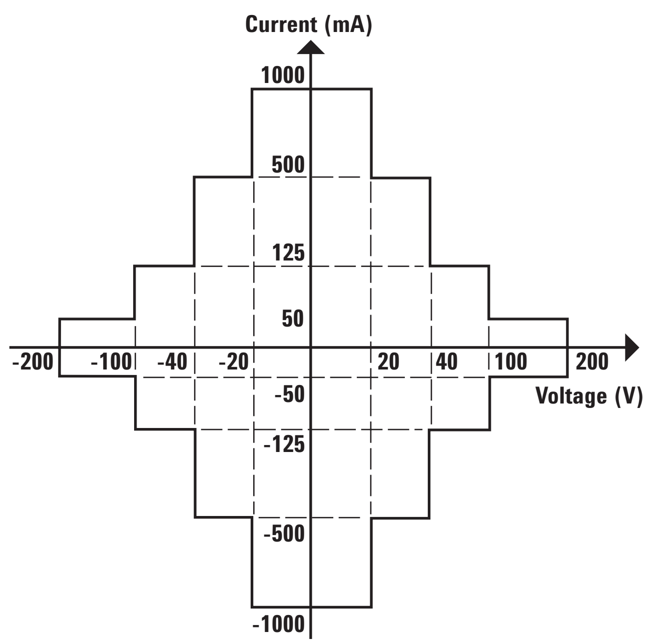
Where Ic is the current compliance setting.

Current source mode

Voltage compliance	Power
Vc ≤ 20	20 x Io (W)
20 < Vc ≤ 40	40 x Io (W)
40 < Vc ≤ 100	100 x Io (W)
100 < Vc ≤ 200	200 x Io (W)

Where Vc is the voltage compliance setting and Io is output current.

HPSMU measurement and output range



Output terminal/connection

Dual triaxial connector, Kelvin (remote sensing)

Voltage/current compliance (limiting)

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

Voltage:
0 V to ±100 V (MPSMU, HRSMU)
0 V to ±200 V (HPSMU)

Current:
±10 fA to ±100 mA (HRSMU with ASU)
±100 fA to ±100 mA (HRSMU)
±1 pA to ±100 mA (MPSMU)
±1 pA to ±1 A (HPSMU)

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

About measurement accuracy

RF electromagnetic field and SMU measurement accuracy:

SMU voltage and current measurement accuracy can be affected by RF electromagnetic field strengths greater than 3 V/m in the frequency range of 80 MHz to 1 GHz. The extent of this effect depends upon how the instrument is positioned and shielded.

Induced RF field noise and SMU measurement accuracy:

SMU voltage and current measurement accuracy can be affected by induced RF field noise strengths greater than 3 V_{rms} in the frequency range of 150 kHz to 80 MHz. The extent of this effect depends upon how the instrument is positioned and shielded.

Pulse measurement

Pulse width: 500 µsec to 2 s

Pulse period: 5 ms to 5 s

Period ≥ width + 2 ms
(when width ≤ 100 ms)

Period ≥ width + 10 ms
(when width > 100 ms)

Pulse resolution: 100 µs

SMU pulse setting accuracy
(fixed measurement range, supplemental information):
Width: 0.5 % + 50 µs
Period: 0.5 % + 100 µs

Supplemental information

Maximum allowable cable resistance (Kelvin connection):

Sense: 10 Ω

Force: 10 Ω (≤ 100 mA), 1.5 Ω (>100 mA)

Voltage source output resistance:
(Force line, Non-Kelvin connection)
0.2 Ω (HPSMU)
0.3 Ω (MPSMU, HRSMU)

Voltage measurement input resistance:
≥ 10^{13} Ω

Current source output resistance:
≥ 10^{13} Ω (1 nA range)

Current compliance setting accuracy
(for opposite polarity):
For 1 pA to 10 nA ranges:
I setting accuracy ±12 % of range

For 100 nA to 1 A ranges:
I setting accuracy ±2.5 % of range

Maximum capacitive load:
1 pA to 10 nA ranges: 1000 pF
100 nA to 10 mA ranges: 10 nF
100 mA and 1 A ranges: 100 µF

Maximum guard capacitance:
900 pF (HPSMU, MPSMU, HRSMU)
660 pF (HRSMU with ASU)

Maximum shield capacitance:
5000 pF (HPSMU, MPSMU, HRSMU)
3500 pF (HRSMU with ASU)

Maximum guard offset voltage:
±1 mV (HPSMU)
±3 mV (MPSMU, HRSMU)
±4.2 mV (HRSMU with ASU, Iout≤100 µA)

Noise characteristics (filter ON):
Voltage source: 0.01 % of V range (rms.)
Current source: 0.1 % of I range (rms.)

Overshoot (typical, filter ON):
Voltage source: 0.03 % of V range
Current source: 1 % of I range

Range switching transient noise (filter ON):
Voltage ranging: 250 mV
Current ranging: 70 mV

Slew rate: 0.2 V/µs (maximum)

Voltage range, resolution, and accuracy (high speed ADC)

Voltage range	Measure resolution	Measure accuracy[1, 2]
±0.5 V[3]	25 µV	±(0.01 % + 250 µV)
±2 V	100 µV	±(0.01 % + 700 µV)
±5 V[3]	250 µV	±(0.01 % + 2 mV)
±20 V	1 mV	±(0.01 % + 4 mV)
±40 V	2 mV	±(0.015 % + 8 mV)
±100 V	5 mV	±(0.02 % + 20 mV)
±200 V[4]	10 mV	±(0.035 % + 40 mV)

1. ± (% of read value + offset voltage V)
2. Averaging is 128 samples in 1 PLC.
3. Only for MPSMU and HRSMU.
4. Only for HPSMU.

Current range, resolution, and accuracy (high speed ADC)

Current range	Measure resolution[1, 2]	Measure accuracy[3]
±1 pA[4]	100 aA	±(1.8 %+12 fA)
±10 pA[5]	1 fA	±(0.5 %+15 fA+10 aA x Vo)
±100 pA[5]	5 fA	±(0.3 %+30 fA+100 aA x Vo)
±1 nA	50 fA	±(0.1 %+300 fA+1 fA x Vo)
±10 nA	500 fA	±(0.1 %+2 pA+10 fA x Vo)
±100 nA	5 pA	±(0.05 %+20 pA+100 fA x Vo)
±1 µA	50 pA	±(0.05 %+200 pA+1 pA x Vo)
±10 µA	500 pA	±(0.04 %+2 nA+10 pA x Vo)
±100 µA	5 nA	±(0.03 %+20 nA+100 pA x Vo)
±1 mA	50 nA	±(0.03 %+200 nA+1 nA x Vo)
±10 mA	500 nA	±(0.03 %+2 µA+10 nA x Vo)
±100 mA	5 µA	±(0.04 %+20 µA+100 nA x Vo)
±1 A[6]	50 µA	±(0.4 %+300 µA+1 µA x Vo)

1. Specified measurement resolution is limited by fundamental noise limits. Minimum displayed resolution is 1 aA at 1 pA range by 6 digits.
2. Measurements made in the lower ranges can be greatly impacted by vibrations and shocks. These specifications assume an environment free of these factors.
3. ± (% of read value + offset current (fixed part determined by the output/measurement range + proportional part that is multiplied by Vo)
4. 1 pA range is for HRSMU with ASU.
5. 10 pA range and 100 pA range is for HRSMU with or without ASU.
6. Only for HPSMU.

MFCMU (multi frequency capacitance measurement unit) module specifications

Measurement functions

Measurement parameters:
Cp-G, Cp-D, Cp-Q, Cp-Rp, Cs-Rs, Cs-D, Cs-Q, Lp-G, Lp-D, Lp-Q, Lp-Rp, Ls-Rs, Ls-D, Ls-Q, R-X, G-B, Z-θ, Y-θ

Ranging:
Auto and fixed

Measurement terminal:
Four-terminal pair configuration, four BNC (female) connectors

Cable length:
1.5 m or 3 m, automatic identification of accessories

Test signal

Frequency:
Range: 1 kHz to 5 MHz
Resolution: 1 mHz (minimum)
Accuracy: ±0.008 %

Output signal level:
Range: 10 mV_{rms} to 250 mV_{rms}

Resolution: 1 mV_{rms}

Accuracy:
±(10.0 % + 1 mV_{rms})
at the measurement port of the MFCMU

±(15.0 % + 1 mV_{rms})
at the measurement port of the MFCMU cable (1.5 m or 3.0 m)

Output impedance: 50 Ω, typical

Signal level monitor:
Range: 10 mV_{rms} to 250 mV_{rms}

Accuracy (open load):
±(10.0 % of reading + 1 mV_{rms})
at the measurement port of the MFCMU

±(15.0 % of reading + 1 mV_{rms})
at the measurement port of the MFCMU cable (1.5 m or 3 m)

DC bias function

DC bias:
Range: 0 to ±25 V
Resolution: 1 mV
Accuracy: ±(0.5 % + 5.0 mV) at the measurement port of the MFCMU or the MFCMU cable (1.5 m or 3.0 m)

Maximum DC bias current (supplemental information)

Impedance range	Maximum DC bias current
50 Ω	10 mA
100 Ω	10 mA
300 Ω	10 mA
1 kΩ	1 mA
3 kΩ	1 mA
10 kΩ	100 µA
30 kΩ	100 µA
100 kΩ	10 µA
300 kΩ	10 µA

Output impedance: 50 Ω, typical

DC bias monitor:
Range: 0 to ±25 V

Accuracy (open load):
±(0.2 % of reading + 10.0 mV) at the measurement port of the MFCMU or the MFCMU cable (1.5 m or 3.0 m)

Sweep characteristics

Available sweep parameters:
Oscillator level, DC bias voltage, frequency
Sweep type: linear, log
Sweep mode: single, double
Sweep direction: up, down
Number of measurement points:
Maximum 1001 points

Measurement accuracy

The following parameters are used to express the impedance measurement accuracy at the measurement port of the MFCMU or the MFCMU cable (1.5 m or 3.0 m).

Z_X: Impedance measurement value (Ω)

D_X: Measurement value of D

$E = E_P' + (Z_S'/|Z_X| + Y_O'|Z_X|) \times 100$ (%)

$E_P' = E_{PL} + E_{POSC} + E_P$ (%)

$Y_O' = Y_{OL} + Y_{OSC} + Y_O$ (S)

$Z_S' = Z_{SL} + Z_{OSC} + Z_S$ (Ω)

|Z| accuracy
±E (%)

θ accuracy
±E/100 (rad)

C accuracy
at $D_X \leq 0.1$
±E (%)

at $D_X > 0.1$
$\pm E \times \sqrt{(1 + D_X^2)}$ (%)

D accuracy
at $D_X \leq 0.1$
±E/100

at $D_X > 0.1$
$\pm E \times (1 + D_X)/100$

G accuracy
at $D_X \leq 0.1$
$\pm E/D_X$ (%)

at $D_X > 0.1$
$\pm E \times \sqrt{(1 + D_X^2)}\,/D_X$ (%)

Note: measurement accuracy is specified under the following conditions:
Temperature: 23 °C ±5 °C
Integration time: 1 PLC or 16 PLC

Parameters E_{POSC} Z_{OSC}

Oscillator level	E_{POSC} (%)	Z_{OSC} (mΩ)
125 mV < V_{OSC} ≤ 250 mV	0.03 x (250/ V_{OSC} - 1)	5 x (250/ V_{OSC} - 1)
64 mV < V_{OSC} ≤ 125 mV	0.03 x (125/ V_{OSC} - 1)	5 x (125/ V_{OSC} - 1)
32 mV < V_{OSC} ≤ 64 mV	0.03 x (64/ V_{OSC} - 1)	5 x (64/ V_{OSC} - 1)
V_{OSC} ≤ 32 mV	0.03 x (32/ V_{OSC} - 1)	5 x (64/ V_{OSC} - 1)

V_{OSC} is oscillator level in mV.

Parameters E_{PL} Y_{OL} Z_{SL}

Cable length	E_{PL} (%)	Y_{OL} (nS)	Z_{SL} (mΩ)
1.5 m	0.02 + 3 x f/100	750 x f/100	5.0
3 m	0.02 + 5 x f/100	1500 x f/100	5.0

f is frequency in MHz. If measurement cable is extended, open compensation, short compensation, and load compensation must be performed.

Parameters Y_{OSC} Y_O E_P Z_S

Frequency	Y_{OSC} (nS)	Y_O (nS)	E_P (%)	Z_S (mΩ)
1 kHz ≤ f ≤ 200 kHz	1 x (125/ V_{OSC} – 0.5)	1.5	0.095	5.0
200 kHz < f ≤ 1 MHz	2 x (125/ V_{OSC} – 0.5)	3.0	0.095	5.0
1 MHz < f ≤ 2 MHz	2 x (125/ V_{OSC} – 0.5)	3.0	0.28	5.0
2 MHz < f	20 x (125/ V_{OSC} – 0.5)	30.0	0.28	5.0

f is frequency in Hz.
V_{OSC} is oscillator level in mV.

Example of calculated C/G measurement accuracy

Frequency	Measured capacitance	C accuracy[1]	Measured conductance	G accuracy[1]
5 MHz	1 pF	±0.61 %	≤ 3 μS	±192 nS
	10 pF	±0.32 %	≤ 31 μS	±990 nS
	100 pF	±0.29 %	≤ 314 μS	±9 μS
	1 nF	±0.32 %	≤ 3 mS	±99 μS
1 MHz	1 pF	±0.26 %	≤ 628 nS	±16 nS
	10 pF	±0.11 %	≤ 6 μS	±71 nS
	100 pF	±0.10 %	≤ 63 μS	±624 nS
	1 nF	±0.10 %	≤ 628 μS	±7 μS
100 kHz	10 pF	±0.18 %	≤ 628 nS	±11 nS
	100 pF	±0.11 %	≤ 6 μS	±66 nS
	1 nF	±0.10 %	≤ 63 μS	±619 nS
	10 nF	±0.10 %	≤ 628 μS	±7 μS
10 kHz	100 pF	±0.18 %	≤ 628 nS	±11 nS
	1 nF	±0.11 %	≤ 6 μS	±66 nS
	10 nF	±0.10 %	≤ 63 μS	±619 nS
	100 nF	±0.10 %	≤ 628 μS	±7 μS
1 kHz	100 pF	±0.92 %	≤ 63 nS	±6 nS
	1 nF	±0.18 %	≤ 628 nS	±11 nS
	10 nF	±0.11 %	≤ 6 μS	±66 nS
	100 nF	±0.10 %	≤ 63 μS	±619 nS

1. The capacitance and conductance measurement accuracy is specified under the following conditions:
   D_X = 0.1
   Integration time: 1 PLC
   Test signal level: 30 mVrms
   At four-terminal pair port of MFCMU

Atto-sense and switch unit (ASU) specifications

AUX path specification

Maximum voltage
- 100 V (AUX input to AUX common)
- 100 V (AUX input to circuit common)
- 42 V (AUX common to circuit common)

Maximum current
- 0.5 A (AUX input to force output)

ASU supplemental information

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

SMU CMU unify unit (SCUU) and guard switch unit (GSWU) specifications

The SCUU multiplexes the outputs from two SMUs (MPSMUs and/or HRSMUs) and the CMU. The SCUU outputs are two sets of Kelvin triaxial ports (Force and Sense). The SCUU also allows the SMUs to act as DC bias sources in conjunction with the CMU. Special cables are available to connect the SMUs and CMU with the SCUU, and an auto-detect feature automatically compensates for the cable length going to the SCUU.

The GSWU contains a relay that automatically opens for IV measurements and closes for CV measurements, forming a guard return path to improve CV measurement accuracy.

Supported SMU
- MPSMU and HRSMU

For SCUU

Inputs:
- Triaxial ports: Force1, Sense1, Force2, and Sense2
- BNC ports: for MFCMU
- Control port: for MFCMU

Outputs:
- Triaxial ports: Force1/CMUH, Sense1, Force2/CMUL, and Sense2
- Control port: for GSWU
- LEDs: SMU/CMU output status indicator

Docking mode:
- Direct and indirect mode

For GSWU

Input:
- Control port: for SCUU
- Mini pin plug ports: Guard1, Guard2

Output:
- LED: Connection status indicator

SCUU supplemental information

SMU path:

- Offset current: < 20 fA
- Offset voltage: < 100 μV at 300 sec
- Closed channel residual resistance: < 200 mΩ
- Channel isolation resistance: > 10^{15} Ω

CMU path:

Test signal

Signal output level additional errors (CMU bias, open load):
- ±2 % (direct docking)
- ±7 % (indirect docking)

Signal output level additional errors (SMU bias, open load):
- ±5 % (direct docking, ≥ 10 kHz)
- ±10 % (indirect docking, ≥ 10 kHz)

Output impedance: 50 Ω, typical

Signal level monitor additional errors (open load):
- ±2 % (CMU bias), direct docking
- ±5 % (SMU bias), direct docking
- ±7 % (CMU bias), indirect docking
- ±10 % (SMU bias), indirect docking

DC bias function

DC voltage bias (CMU bias):
- Range: 0 to ±25 V
- Resolution: 1 mV
- Additional errors (for CMU bias): ±100 μV (open load)

DC voltage bias (SMU bias):
- Range: 0 to ±100 V
- Resolution: 5 mV
- Additional errors (for SMU voltage output accuracy): ±100 μV (open load)

DC bias monitor additional errors (open load):
- ±20 mV, direct docking
- ±30 mV, indirect docking

Output impedance:
- 50 Ω, typical

DC output resistance: 50 Ω (CMU bias), 130 Ω (SMU bias)

Measurement accuracy

Impedance measurement error is given by adding the following additional error E_e to the MFCMU measurement error.

$E_e = \pm(A + Z_S/|Z_X| + Y_0|Z_X|) \times 100$ (%)

Z_X: Impedance measurement value (Ω)

A: 0.05 % (direct docking) or 0.1 % (indirect docking)

Z_S: 500 + 500 x f (mΩ)

Y_0: 1 + 1000 x f/100 (nS) (direct docking, x2 for indirect docking)
Note: f is frequency in MHz.

When the measurement terminals are extended by using the measurement cable, the measurement accuracy is applied to the data measured after performing the open/short/load correction at the DUT side cable end.

Note: The error is specified under the following conditions:
- Temperature: 23 °C ±5 °C
- Integration time: 1 PLC or 16 PLC

HV-SPGU (high voltage semiconductor pulse generator unit) module specification

Specifications

Number of output channels:
2 channels per module

Modes: pulse, constant, and freerun

Standard pulse mode:
- Two level pulse
- Three level pulse per one channel
- Pulse period: 30 ns to 10 s

Delay range: 0 s to 9.99 s

Delay resolution: 2.5 ns (minimum)

Output count: 1 to 1,000,000

Voltage monitor minimum sampling period: 5 µs

Trigger output:
Level: TTL
Timing: Synchronized with pulse period
Trigger width:
Pulse period x 1/2 (pulse period ≤ 10 µs)
Maximum 5 µs (pulse period > 10 µs)

SPGU supplemental information

Pulse width jitter: 0.001 % +150 ps

Pulse period jitter: 0.001 % +150 ps

Maximum slew rate: 1000 V/µs (50 Ω load)

Noise: 10 mV_{rms} (at DC output)

Advanced feature:
Voltage monitor: The HV-SPGU has a voltage monitor function to measure the voltage at the DUT terminal.

Measurement accuracy (open load): ±(0.1 % of reading + 25 mV)

Measurement resolution: 50 µV

Note: Specified at 1 PLC (20 ms = (5 µs sample + 5 µs interval) x 2000 samples.)

Voltage compensation: The HV-SPGU can measure the impedance of DUT and adjust the output voltage according to the DUT impedance.

ALWG (arbitrary linear waveform generator) function

Arbitrary linear waveform generator (ALWG) mode:
- Output complex waveform per one channel of HV-SPGU
- Define multi-level pulse and multi-pulse waveform including open state pulse with ALWG GUI editor
- Sequential pulse waveform from user-defined pulse waveform
- 1024 points per one channel
- Programmable timing range: 10 ns to 10 s, 10 ns resolution

Pulse/DC output voltage and accuracy

Output voltage (Vout)	50 Ω load	–20 V to +20 V
	Open load	–40 V to +40 V
Accuracy[1]	Open load	±(0.5 % + 50 mV)
Amplitude resolution	50 Ω load	0.2 mV (±10 V range) 0.8 mV (±40 V range)
	Open load	0.4 mV (±10 V range) 1.6 mV (±40 V range)
Output connectors		SMA
Source impedance		50 Ω[2]
Short circuit current		800 mA peak (400 mA average[3])
Overshoot/ pre-shoot/ringing[4]	50 Ω load	±(5 % + 20 mV)
Output limit		Monitoring over current limit

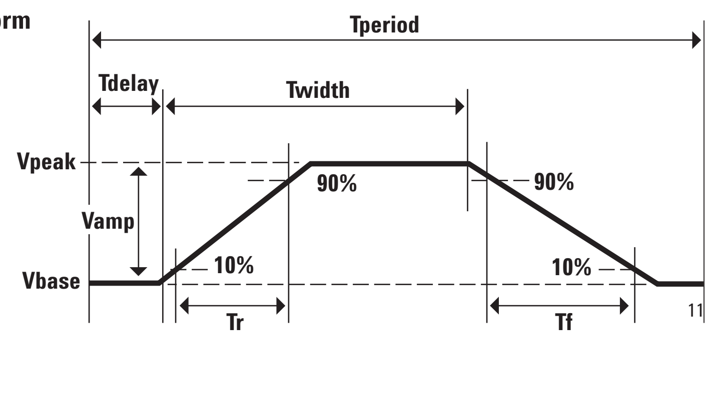
1. At 1 µs after completing transition.
2. Typical (±1 %)
3. This value is specified under the following condition: [(Number of installed HV-SPGUs) x 0.2 A] + [DC current output by all modules (including HV-SPGUs)] < 3.0 A
4. Following the specified condition with transition time.

Pulse range and pulse parameter[1]

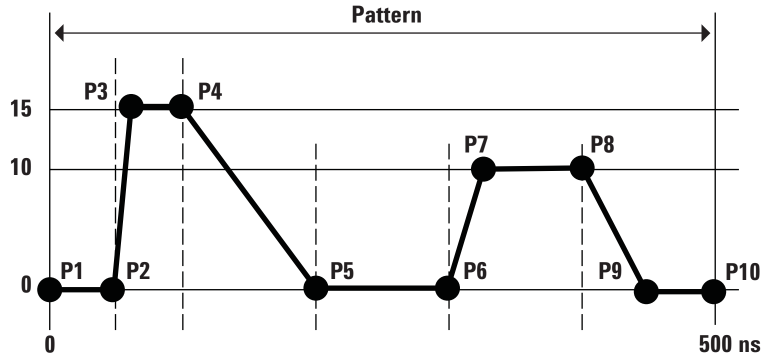
Frequency range		0.1 Hz to 33 MHz
Pulse period	Programmable range	30 ns to 10 s
	Resolution	10 ns
	Minimum	100 ns[3]
	Accuracy	±1 % (±0.01 % [2])
Width	Programmable range	10 ns to (period – 10 ns)
	Resolution	2.5 ns (Tr and Tf ≤ 8 µs) 10 ns (Tr or Tf > 8 µs)
	Minimum	50 ns (25 ns typical)[3]
	Accuracy	±(3 % + 2 ns)
Transition time[5] (Tr and Tf)	Programmable range	8 ns to 400 ms
	Resolution	2 ns (Tr and Tf ≤ 8 µs) 8 ns (Tr or Tf > 8 µs)
	Minimum (typical)	< 15 ns[3]
	Minimum	20 ns (Vamp ≤ 10 V) 30 ns (Vamp ≤ 20 V) 60 ns (Vamp > 20 V)
	Accuracy	–5 % to 5 % + 10 ns (Vamp ≤ 10 V) –5 % to 5 % + 20 ns (Vamp ≤ 20 V)
Output relay switching time[4]	Open/close	< 100 µs

1. Unless otherwise stated, all specifications assume a 50 Ω termination.
2. Typical minimum. This is supplemental information.
3. This is specified at Vamp ≤ 10 V.
4. The time it takes the open state relay to open or close.
5. The time from 10 % to 90 % of Vamp which is the amplitude of output pulse.

Pulse waveform

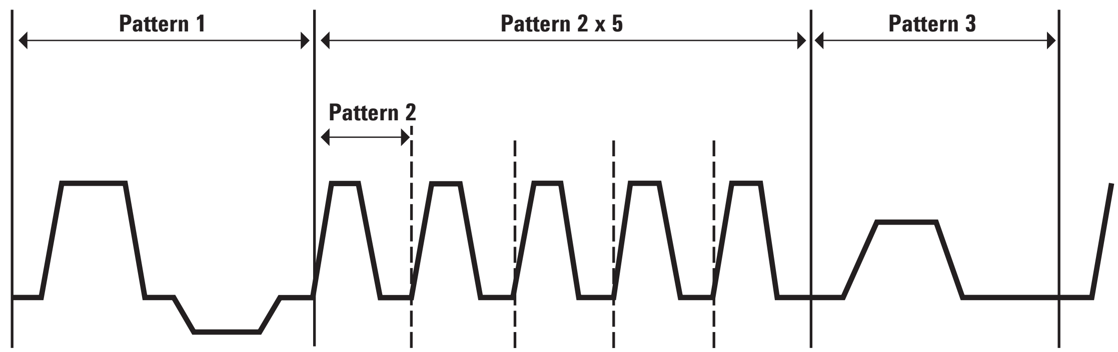


Example 1. ALWG setup table and pattern



Point	Time	Voltage
1	0	0.0 V
2	50 ns	0.0 V
3	70 ns	15.0 V
4	100 ns	15.0 V
5	200 ns	0.0 V
6	300 ns	0.0 V
7	320 ns	10.0 V
8	400 ns	10.0 V
9	450 ns	0.0 V
10	500 ns	0.0 V

Example 2. ALWG complex waveform



16440A SMU/pulse generator selector

The Agilent 16440A SMU/pulse generator selector switches either a SMU or PGU to the associated output port. You can expand to four channels by adding an additional 16440A. The PGU port on channel 1 provides a "PGU OPEN" function, which can disconnect the PGU by opening a semiconductor relay. The Agilent B1500A and 16445A are required to use the 16440A.

The following specifications data is specified at 23 °C ± 5 °C and 50% relative humidity.

- Channel configuration:
  2 channels (CH 1 and CH 2).
  Can add an additional 2 channels (CH 3 and CH 4) by adding another 16440A (selector expander).

	Input	Output
Channel 1 (CH 1)	2 (SMU and PGU [1])	1
Channel 2 (CH 2)	2 (SMU and PGU)	1
Channel 3 (CH 3) [2]	2 (SMU and PGU [1])	1
Channel 4 (CH 4) [2]	2 (SMU and PGU)	1

1. PGU channels 1 & 3 have a built-in series semiconductor relay.
2. Available when a second 16440A (selector expander) is installed.

- Voltage and current range

Input port	Maximum voltage	Maximum current
SMU	200 V	1.0 A
PGU	40 V	0.2 A [1]

1. This is peak-to-peak ac current.

16445A SMU/PGU selector connection adaptor

The Agilent 16445A selector adapter is required to control and to supply DC power to the Agilent 16440A SMU/pulse generator selector.

Power requirement: 100 to 240 V, 50/60 Hz

Maximum volt-amps (VA): 20 VA

WGFMU (waveform generator/fast measurement unit) module specification

Overview

The WGFMU is a self-contained module offering the combination of arbitrary linear waveform generation (ALWG) with synchronized fast current or voltage (IV) measurement. The ALWG function allows you to generate not only DC, but also various types of AC waveforms. In addition to this versatile sourcing capability, the WGFMU can also perform measurement in synchronization with the applied waveform, which enables accurate high-speed IV characterization.

Specifications

Number of output channels:
2 channels per module

Modes: Fast IV, PG (pulse generator), DC, and SMU pass-through

RSU:

Output Connector: SMA
Source Impedance: 50 Ω (nominal) at DC in PG mode

SMU path: Maximum voltage ±25 V, Maximum current ±100 mA

V monitor terminal:
Connector: BNC

Source Impedance: 50 Ω (nominal) at DC

The terminal outputs a buffered signal equal to 1/10 of Vout (into a 50 Ω load)

WGFMU to RSU cable length:
The WGFMU and RSU are connected by a special composite cable. The following configurations are available:

- 3 m
- 5 m
- 1.5 m
- 2.4 m + connector adapter + 0.6 m
- 4.4 m + connector adapter + 0.6 m

Note: The connector adapter is used when routing the cable through the prober's connector panel.

Measurement functions, voltage forcing, voltage measurement, and current measurement

Mode	Function	V force ranges	V measure ranges	I measure ranges
Fast IV	V force/I measure, V force/V measure	-3 V to +3 V -5 V to +5 V -10 V to 0 V 0 V to +10 V	-5 V to +5 V -10 V to +10 V	1 μA, 10 μA, 100 μA, 1 mA, 10 mA.
PG	V force/V measure	-3 V to +3 V -5 V to +5 V	-5 V to +5 V	—
DC	V force/I measure, V force/V measure	-3 V to +3 V -5 V to +5 V -10 V to 0 V 0 V to +10 V	-5 V to +5 V -10 V to 10 V	1 μA, 10 μA, 100 μA, 1 mA, 10 mA
SMU pass-through	Measurement using SMU	Max ±25 V	—	Max ±100 mA

Voltage force accuracy, resolution, and timing

V force (Fast IV mode)	-5 V to 5 V, -10 V to 0 V, 0 V to 10 V
V force (PG mode)	-5 V to 5 V (open load) -2.5 V to 2.5 V (50 Ω load)
Accuracy	±0.1% of setting ±0.1% of range [1]
Resolution [2]	96 μV (-3 to 3V) 160 μV (all ranges except for -3 V to 3 V)
Overshoot/undershoot	±(5%+20 mV) [3]
Noise	Maximum 0.1 mV_{rms} [4]
Rise time T_{rise} (10 to 90%)/ Fall time T_{fall} (90 to 10%)	Accuracy: -5% to (+5% +10 ns) of setting [5] Minimum: 24 ns, PG mode and 50 Ω load
Pulse period	Timing Accuracy: ±1% of setting [6] Minimum:100 ns, PG mode and 50 Ω load
Pulse width	Accuracy: ±(3%+2 ns) [7] Minimum: 50 ns, PG mode and 50 Ω load

Voltage measurement accuracy, resolution, and noise

Accuracy	±(0.1% of reading ±0.1% of range) [8]
Resolution [9]	680 μV (-5 V to +5 V range) 1.4 mV (-10 V to +10 V range)
Noise [10]	Maximum 4 mV_{rms} (-5 V to +5 V range)

1. Independent of the range or the mode. DC constant voltage output. Load impedance must be ≥ 1 MΩ (1 μA range) or ≥ 200 kΩ (all other current ranges) for Fast IV mode, or ≥ 1 MΩ for PG mode.
2. Can vary at most 5% based on the result of calibration.
3. PG mode, 50 Ω load, T_{rise} and T_{fall} >16 ns with the 1.5 m cable, >32 ns with 3 m cable, or >56 ns with 5 m cable
4. Theoretical value for observed time 100 ns to 1 ms, supplemental information
5. PG mode, 50 Ω load, T_{rise} and T_{fall} ≥ 24 ns
6. PG mode, 50 Ω load, pulse period ≥ 100 ns
7. PG mode, 50 Ω load, pulse width ≥ 50 ns
8. Independent of the range or the mode. DC constant voltage output. Applicable condition: 10,000 averaging samples for 10 μA range and above; 100,000 averaging samples for the 1 μA range.
9. Display resolution. Can vary at most 5% based on the result of calibration.
10. 0 V output, open load, no averaging. Maximum 1.5 mV_{rms} as supplemental information.

Current measurement accuracy and resolution

Accuracy	±(0.1% of reading ±0.2% of range) [1]
Resolution [2]	0.014% of range
Noise (Effective resolution)	Maximum 0.2% of range [3]

1. Independent of the range or the mode. DC constant voltage output. Applicable condition: 10,000 averaging samples for 10 µA range and above; 100,000 averaging samples for the 1 µA range.
2. Display resolution. Can vary at most 5% based on the result of calibration
3. Effective value at 0 V output, open load, and no averaging. Supplemental information

ALWG function

Maximum number of vectors	2048
Maximum number of sequences	512
Maximum number of loop counts	1 to 10^{12}
Length of a vector	10 ns to 10,000 s with 10 ns resolution
Sampling rate	5 ns, or 10 ns to 1 s with 10 ns resolution
Averaging time	10 ns to 20 ms with 10 ns resolution
Hardware memory	About 4 M data points/channel (typical)

Trigger output

Level: TTL

Trigger width: 10 ns

Generated synchronously with ALWG waveform.

Supplemental Information

RSU SMU path:

Leak current: < 100 pA

Residual resistance: <300 mΩ

Jitter: <1 ns

Skew between channels: <3 ns, under no electrostatic discharge condition.

Trigger output skew: <3 ns

Current range change time: <150 µs*

* The time until the measured current settles within ± 0.3 % of the final result value after the range change.

Minimum rise/fall time*

Mode	Current measurement range	Minimum rise/fall time			Load condition
		0 to 1V	0 to 5 V	0 to 10V	
PG mode	NA	30 ns	30 ns	NA	25 pF, open
Fast IV mode	10 mA	80 ns	80 ns	80 ns	25 pF, 1 MΩ
	1 mA	250 ns	250 ns	250 ns	
	100 µA	600 ns	600 ns	1.5 µs	
	10 µA	2 µs	4.5 µs	7 µs	
	1 µA	6 µs	—	—	
		—	35 µs	75 µs	25 pF, open

* This is the minimum setting value effective for suppressing overshoot and distortion.

Settling time*

Mode	Current measurement range	Settling time		Load condition
		Voltage measurement	Current measurement	
PG mode	NA	150 ns	NA	25 pF, open
Fast IV mode	10 mA	150 ns	100 ns	25 pF, 1 kΩ
	1 mA	150 ns	250 ns	25 pF, 10 kΩ
	100 µA	400 ns	1µs	25 pF, 100 kΩ
	10 µA	1.2 µs	10 µs	25 pF, 1 MΩ
	1 µA	6 µs	80 µs	25 pF, 10 MΩ

* The time until the measured value settles within ± 0.3 % of the final result value after the output voltage is changed from the initial value (0 V). Applicable condition: Rise time = 10 ns

Minimum pulse width*

Mode	Current measurement range	Minimum pulse width	Load condition
PG mode	NA	170 ns	25 pF, open
Fast IV mode	10 mA	180 ns	25 pF, 1 kΩ
	1 mA	500 ns	25 pF, 10 kΩ
	100 µA	1.6 µs	25 pF, 100 kΩ
	10 µA	14.5 µs	25 pF, 1 MΩ
	1 µA	115 µs	25 pF, 10 MΩ

* The time until the pulse peak output value (0 to 5 V) settles within ±0.3% of the setup value after the output voltage is changed from the initial value (0 V). Applicable condition: Rise time is set to the minimum rise/fall time shown in the above table.

Software

Instrument library for WGFMU control

Operating system:
Microsoft Windows XP Professional SP2 and Windows Vista Business SP1

NBTI and general-purpose EasyEXPERT Application Tests

Sample programs (NBTI and general-purpose measurement using WGFMU and RTS data analysis)

WGFMU supported prober vendors

Cascade Microtech

Suss MicroTec

Vector Semicon

Note: The maximum number of installable RSUs for a given prober depends upon the available space. Please contact your local sales representative for details on connecting and mounting the WGFMU and RSU.

Agilent EasyEXPERT software

Functions

Operation mode:
Application test mode, Classic test mode, Quick test mode

Key features

- Categorized and predefined application test library
- GUI-based application test editor
- Save/Recall "My Favorite Setups"
- Define/customize application library
- Execute measurement (Single/Repeat/Append)
- Quick test execution
- Direct control (GPIB FLEX)
- Save/Recall measurement data and settings
- Test result data management
- Import/Export device definition, measurement settings, my favorite setup, measurement data, and application library
- Graph plot display/analysis/printing
- Switching matrix control
- Workspace management
- Self-test, self-calibration, diagnostics

Application library

Sample application tests are supplied for the following categories; they are subject to change without notice.
Structure, CMOS, Bipolar (BJT), Memory, Mixed Signal Device, TFT, Discrete, Reliability, Power Device, Nanotechnology, Utility

Measurement mode details

The Agilent B1500A supports the following measurement modes:

- Staircase sweep
- Multi-channel sweep[1]
- Pulsed sweep
- Staircase sweep with pulsed bias
- IV sampling
- High speed IV sampling
- CV sweep
- C-t sampling
- C-f sweep
- List sweep
- Linear search[2]
- Binary search[2]

1. EasyEXPERT does not support VAR1′ in multi-channel sweep mode.
2. They are supported by FLEX command only.

Each SMU can be set to VAR1 (primary sweep), VAR2 (secondary sweep), VAR1′ (synchronous sweep), or CONST (constant voltage/current source).

VAR1

Primary sweep controls the staircase (DC or pulsed) voltage or current sweep.
Maximum number of VAR1 steps:
N_1 = 1001

VAR2

Subordinate linear staircase or linear pulsed sweep. After primary sweep is completed, the VAR2 unit output voltage or current is changed.

Maximum number of VAR2 steps:
N_2 = 1001 ($1 \le N_1 \times N_2 \le 128128$)

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 x VAR1 + b, where "a" is the user specified ratio and "b" is the user specified offset value.

CONST

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

Staircase sweep measurement mode

Forces swept voltage or current, and measures DC voltage or current. One channel can sweep current or voltage while up to ten channels can measure current or voltage. A second channel can be synchronized with the primary sweep channel as an additional voltage or current sweep source.

Number of steps: 1 to 1001

Sweep mode: Linear or logarithmic (log)

Sweep direction: Single or double sweep

Hold time: 0 to 655.35 s, 10 ms resolution

Delay time: 0 to 65.5350 s, 100 μs resolution

Pulsed sweep measurement mode:

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

Staircase sweep with pulsed bias measurement mode

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

Sampling (time domain) measurement mode

Displays the time sampled voltage/current data (by SMU) versus time.

Sampling channels: Up to 10

Sampling mode: Linear, logarithmic (log)

Sampling points:
For linear sampling:
1 to 100,001/(number of channels)
For log sampling:
1 to 1+ (number of data for 11 decades)

Sampling interval range:
100 μs +20 μs x (num. of channels – 1) to 2 ms, 10 μs resolution
2 ms to 65.535 s, 1 ms resolution

Hold time, bias hold time:
-90 ms to -100 μs, 100 μs resolution
0 to 655.35 s, 10 ms resolution

Measurement time resolution: 100 μs

Standby mode

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

Current offset cancel

This function subtracts the offset current from the current measurement raw data, and returns the result as the measurement data. This function is used to compensate the error factor (offset current) caused by the measurement path such as the measurement cables, manipulators, or probe card.

Time stamp

The B1500A supports a time stamp function utilizing an internal quartz clock.
Resolution: 100 μs

Other measurement characteristics

Measurement control:
Single, repeat, append, 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

User functions
Up to 20 user-defined functions can be defined using arithmetic expressions.

Measured data and pre-defined variables can be used in the computation. The results can be displayed on the LCD.

Arithmetic operators
+, -, *, /, ^, abs (absolute value), at (arc tangent), avg (averaging), cond (conditional evaluation), delta, diff (differential), exp (exponent), integ (integration), lgt (logarithm, base 10), log (logarithm, base e), mavg (moving average), max, min, sqrt, trigonometric function, inverse trigonometric function, and so on.

Physical constants
Keyboard constants are stored in memory as follows:

q: Electron charge, 1.602177E-19 C

k: Boltzman's constant, 1.380658E-23

ϵ (e): Dielectric constant of vacuum, 8.854188E-12

Engineering units
The following unit symbols are also available on the keyboard:

a (10^{-18}), f (10^{-15}), p (10^{-12}), n (10^{-9}), u or μ (10^{-6}), m (10^{-3}), k (10^{3}), M (10^{6}), G (10^{9}), T (10^{12}) , P (10^{15})

Analysis capabilities

Overlay graph comparison
Graphical plots can be stored and overlaid.

Scale
Auto scale and zoom

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

Cursor
Direct cursor

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

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.

Data variable display
Up to 20 user-defined parameters can be displayed on the graphics screen.

Analysis functions
Up to 20 user-defined analysis functions can be defined using arithmetic expressions.

Measured data, pre-defined variables, and read out functions can be used in the computation. The results can be displayed on the LCD.

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

Graph plot

Display mode
Data display window can be printed. Only X-Y graph can be printed.

Graph plot file
Graph plot can be stored as image data to clip board or mass storage device.

File type: bmp, gif, png, emf

Output

Display mode
X-Y graph, list, and parameter

X-Y graph display
X-axis and up to eight Y-axes, linear and log scale, real time graph plotting

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 20 data sets can be displayed.

Other functions

Import/export files
File type:
Agilent EasyEXPERT format, XML-SS format, CSV format

Data storage
Hard disk drive, DVD-ROM/CD-R/CD-RW drive

Interfaces
GPIB, interlock, USB (USB 2.0, front 2, rear 2), LAN (100BASE-TX/10BASE-T), trigger in/out, digital I/O

Trigger I/O
Only available using GPIB FLEX commands.

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

Supported external instruments
EasyEXPERT Standard edition:
- Supported by switching matrix GUI: B2200A/B2201A
- Supported by application tests: E5250A (E5252A cards), 4284A/E4980A, 81110A, 3458A

EasyEXPERT Plus edition:
- All external instruments supported by EasyEXPERT Standard edition
- Also supported by switching matrix GUI: E5250A (E5252A cards)

Furnished software

- Prober control execution files
- Desktop EasyEXPERT software with license-to-use for Standard edition
- 4155/56 setup file converter tool (Supported operating systems: Microsoft Windows 2000 Professional, XP Home or Professional, and Vista Business)
- A VXI*plug&play* driver for the B1500A (Supported operating systems: Microsoft Windows 2000 Professional and XP Professional)

Agilent Desktop EasyEXPERT software

Desktop EasyEXPERT is the same software that is built-in to the PC-based Agilent B1500A Semiconductor Device Analyzer, except that it runs on a stand-alone PC. Just like standard EasyEXPERT, Desktop EasyEXPERT supports all aspects of parametric test, from basic manual measurements to test automation across a wafer in conjunction with a semi-automatic wafer prober.

Features and benefits

Large application test library
Desktop EasyEXPERT comes with over 200 application tests conveniently organized by device type, application, and technology. Many of these application tests will run on the 4155/4156 without modification, and you can easily edit and customize the furnished application tests to fit your specific needs.

Offline capability
Desktop EasyEXPERT can be run in either online or offline mode. In the offline mode you can perform tasks such as analyzing data and creating new application tests. This frees up your existing analyzer from being needed for development work and enables you to use it for its primary purpose: making measurements.

GUI-based classic test mode
Desktop EasyEXPERT offers a classic test mode that maintains the look, feel, and terminology of the 4155/4156 user interface. In addition, it improves the 4155/4156 user interface by taking full advantage of Microsoft Windows GUI features.

Easy test sequencing
A GUI-based Quick Test mode enables you to perform test sequencing without programming. You can select, copy, rear-range and cut-and-paste any application tests with a few simple mouse clicks. Once you have selected and arranged your tests, simply click on the measurement button to begin running an automated test sequence.

Prober control
All popular semiautomatic wafer probers are supported by Desktop EasyEXPERT. You can define wafer, die, and module information for probing across an entire wafer. You can also combine wafer prober control with either Quick Test mode or an application test based test sequence to perform multiple testing on various devices across the wafer.

Automatic data export
The Desktop EasyEXPERT has the ability to automatically export measurement data in real time, in a variety of formats. You can save data to any drive connected to the PC. If you wish, you can export data to a network drive and view test results on your desktop PC as your instruments are performing the testing in your lab.

System requirements

The following are the minimum require-ment for executing Desktop EasyEXPERT.

Operating system and service pack	Microsoft Windows XP Professional SP2	Microsoft Windows Vista Business SP1
Processer	Intel Celeron 2 GHz	Vista certified PC with 1GB memory
Memory	512 Megabytes DDR266	
Display	XGA 1024x768 (SXGA 1280x1024 recommended)	
HDD	1 GB free space on the C drive, 10 GB (30 GB recommended) free space on a drive for test setup/result data strage.	
.NET Framework	Microsoft .NET Framework Ver. 2.0 Redistributable Package Microsoft .NET Framework 2.0 SP1	Microsoft .NET Framework Ver. 3.0
IO Libraries (for online mode)	Agilent IO Libraries Suite 15.0	Agilent IO Libraries Suite 15.0

Supported GPIB I/F (for online mode)

	B1500A	4155B/C 4156B/C
Agilent 82350B	O	O
Agilent 82357A	X	O
Agilent 82357B	X	O

O = Supported
X = Not supported

Supported instruments
- B1500A
- 4155B, 4156B, 4155C, and 4156C
- Supported 4155/4156 firmware:
  HOSTC: 03.08 or later
  SMUC: 04.08 or later

Supported external instruments
Desktop EasyEXPERT Standard edition:
- Supported by switching matrix GUI: B2200A/B2201A
- Supported by application tests: E5250A (E5252A cards), 4284A/E4980A, 81110A, 3458A

Desktop EasyEXPERT Plus edition:
- All external instruments supported by Desktop EasyEXPERT Standard edition
- Also supported by switching matrix GUI: E5250A (E5252A cards)

Supported 4155/4156 functionality

Desktop EasyEXPERT Standard edition:

- I/V Sweep
- B2200A and B2201A switching matrix GUI control

Desktop EasyEXPERT Plus edition:

The following functions are additionally supported.

- I/V-t sampling (except thinned out mode)
- VSU/VMU (except differential voltage measurement using VMU)
- PGU (41501B)
- E5250A/E5252A switching matrix GUI control

Setup converter tool

In addition to Desktop EasyEXPERT, Agilent supplies a free setup converter tool that runs on any Windows-based PC. This tool can convert 4155 and 4156 measurement setup files (file extensions MES or DAT) into equivalent Desktop EasyEXPERT classic test mode setup files.

General specifications

Temperature range

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

Humidity range

Operating: 20 % to 70 % RH, non-condensing
Storage: 10 % to 90 % RH, non-condensing

Altitude

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

Power requirement

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

Maximum volt-amps (VA)

B1500A: 900 VA

Regulatory compliance

EMC:
IEC61326-1:+A1/EN61326-1:+A1
AS/NZS 2064.1
Safety:
CSA C22.2 No.1010.1-1992
IEC61010-1:+A2/EN61010-1:+A2
UL3111-1:1994

Certification

CE, CSA, NRTL/C, C-Tick

Dimensions

B1500A:
420 mm W x 330 mm H x 575 mm D
N1301A-100 SMU CMU unify unit:
148 mm W x 75 mm H x 70 mm D
N1301A-200 guard switch unit:
33.2 mm W x 41.5 mm H x 32.8 mm D
E5288A Atto-sense and switch unit:
132 mm W × 88.5 mm H × 50 mm D
B1531A RSU:
45.2 mm W x 70 mm H x 82 mm D
16440A SMU/PGU selector:
250 mm W × 50 mm H × 275 mm D
16445A Selector adaptor:
250 mm W × 50 mm H × 260 mm D

Weight

B1500A (empty): 20 kg
B1510A: 2.0 kg
B1511A: 1.0 kg
B1517A: 1.2 kg
B1520A: 1.5 kg
B1525A: 1.3 kg
B1530A: 1.3 kg
B1531A: 0.13 kg
E5288A: 0.5 kg
N1301A-100: 0.8 kg
N1301A-200: 0.1 kg
16440A: 1.1 kg
16445A: 1.0 kg

Furnished accessories

Power cable
Manual CD-ROM
Desktop EasyEXPERT CD-ROM
Software CD-ROM (including VXI*plug&play* driver and utility tools)
License-to-use for Desktop EasyEXPERT standard edition

Order information

Mainframe and modules

B1500A	Semiconductor device analyzer mainframe The following modules are available: High power SMU (HPSMU) Medium power SMU (MPSMU) High resolution SMU (HRSMU) Atto-sense switch unit (ASU) Multi frequency CMU (MFCMU) High voltage SPGU (HV-SPGU) Waveform generator/fast measurement unit (WGFMU)
B1500A-050	50 Hz line frequency
B1500A-060	60 Hz line frequency
B1500A-A6J	ANSI Z540 compliant calibration
B1500A-UK6	Commercial calibration certificate with test data
B1500A-ABA	English documentation
B1500A-ABJ	Japanese documentation
B1540A-001	Agilent EasyEXPERT with license-to-use for standard version
B1540A-002	License-to-use for Agilent EasyEXPERT Plus
B1541A	Agilent Desktop EasyEXPERT software and measurement libraries
B1541A-001	Agilent Desktop EasyEXPERT with license-to-use for standard version
B1541A-002	License-to-use for Agilent Desktop EasyEXPERT Plus
B1500 accessories	
16444A-001	Keyboard
16444A-002	Mouse
16444A-003	Stylus pen
N1253A-100	Digital I/O cable
N1253A-200	Digital I/O BNC box
N1254A-100	GNDU to Kelvin adapter
N1254A-108	ASU magnetic stand
SMU cables	
16494A-001	Triaxial cable (1.5 m)
16494A-002	Triaxial cable (3 m)
16493K-001	Kelvin triaxial cable (1.5 m)
16493K-002	Kelvin triaxial cable (3 m)
CMU accessories	
N1300A-001	CMU cable (1.5 m)
N1300A-002	CMU cable (3 m)
N1301A-100	SMU CMU unify unit (SCUU)
N1301A-102	SMU CMU unify unit cable (3 m)
N1301A-110	SMU CMU unify unit magnetic stand
N1301A-200	Guard switch unit (GSWU)
N1301A-201	Guard switch unit cable (1 m)
N1301A-202	Guard switch unit cable (3 m)

HV-SPGU accessories

16440A	SMU/PGU selector
16440A-003	Control cable (40 cm)
16445A	SMU/PGU selector connection adapter
16445A-001	Control cable for B1500A to 16440A (1.5 m)
16445A-002	Control cable for B1500A to 16440A (3 m)
16493P-001	SPGU cable (1.5 m)
16493P-002	SPGU cable (3 m)
16493Q-001	SPGU synchronization cable
WGFMU accessories	
16493R	WGFMU cables and accessories
16493R-001	0.6 m cable between WGFMU and RSU
16493R-002	2.4 m cable between WGFMU and RSU
16493R-003	3 m cable between WGFMU and RSU
16493R-004	5 m cable between WGFMU and RSU
16493R-005	4.4 m cable between WGFMU and RSU
16493R-006	1.5 m cable between WGFMU and RSU
16493R-101	SSMC-SSMC cable (50 mm) for current return path
16493R-102	SSMC-SSMC cable (70 mm) for current return path
16493R-202	SMA-SSMC cable (200 mm) between RSU and DC probe
16493R-302	SMA-SMA cable (200 mm) between RSU and RF probe
16493R-801	WGFMU connector adapter (female-female)
16493R-802	Magnet stand for RSU
16493R-803	Sync cable for WGFMU
Other accessories	
16442B	Test fixture
16493G	Digital I/O cable
16493J-001	Interlock cable (1.5 m)
16493J-002	Interlock cable (3 m)
16493L-001	GNDU cable (1.5 m)
16493L-002	GNDU cable (3 m)
Part numbers for adding additional modules	
B1510A	High power source/monitor unit module
B1511A	Medium power source/monitor unit module
B1517A	High resolution source/monitor unit module
E5288A	Atto-sense and switch unit
B1520A	Multi frequency capacitance measurement unit module
B1525A	High voltage semiconductor pulse generator unit module
B1530A	Waveform generator/fast measurement unit module

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Revised: October 1, 2008

Printed in USA, February 13, 2009
5989-2785EN

Agilent Technologies