# Agilent B1500A
## Semiconductor Device Analyzer

### Technical Overview

**April 2006**

**Agilent B1500A Semiconductor Device Analyzer**

### Introduction

The Agilent B1500A Semiconductor Device Analyzer, with EasyEXPERT software, makes every user a parametric test expert. The MS Windows-based EasyEXPERT interface is familiar, even to new engineers who are inexperienced with parametric measurement instruments. Its unique task-based approach enables the user to focus on their real task-at-hand (device characterization), without having to become a specialist at using the instrument hardware. This new approach is enhanced via a touch screen interface, which makes the instrument as easy to use when racked as when on a benchtop.

The modular 10-slot configuration helps reduce the cost of test by ensuring that you purchase only what you need up-front, leaving room to grow as your needs change. This flexibility is advantageous for those needing capacitance measurement, as this function is available via a single-slot capacitance measurement unit (CMU). An innovative SMU CMU unify unit (SCUU) is available to eliminate cabling confusion when connecting the SMUs and CMU to your positioner-based wafer probing environment. This greatly improves efficiency and accuracy by resolving cable swapping and measurement compensation issues.

The B1500A also possesses impressive measurement performance, with available low-current measurement of 0.1 femtoamp and low-voltage measurement resolution of 0.5 microvolts.

**Basic Features**

- EasyEXPERT software resident on instrument
- Performs IV and CV measurements
- Ten module slots
- Multiple SMU types available: MPSMU, HPSMU, and HRSMU
- Multi-frequency capacitance measurement unit (1 kHz to 5 MHz) available
- High-resolution, analog-to-digital converter (ADC) available to all installed modules
- High-speed ADC present on each installed SMU
- 4.2-Amp ground unit
- SMU/AUX path switching available on the Atto Sense and Switch Unit (ASU)
- Supported CMU accessories include SMU CMU unify unit (SCUU) and guard switch unit (GSWU)
- Automatic identification of capacitance measurement accessories (MFCMU)
- GPIB port for instrument control
- Self-test, self-calibration, diagnostics

## Specification Conditions

The measurement and output accuracies are specified under the following conditions. And the SMU measurement and output accuracies are specified at the SMU connector terminals when referenced to the Zero Check terminal:

1. Temperature: 23°C ± 5°C
2. Humidity: 20% to 60%
3. After 40 minutes warm-up
4. Ambient temperature change less than ±1°C after self-calibration execution, not applicable for MFCMU
5. Measurement made within one hour after self-calibration execution, not applicable for MFCMU
6. Calibration period: 1 year
7. SMU integration time setting (high-resolution ADC must be used):
   1 PLC (1 nA to 1A range, voltage range)
   20 PLC (100 pA range)
   50 PLC (1 pA to 10 pA range)
8. SMU Filter: ON (for SMUs)
9. SMU measurement terminal connection: Kelvin connection

Note: 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 or 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.

Note: When you install or exchange modules into the B1500A mainframes, Agilent can guarantee that the modules will function and that the module performance is designed to meet its specifications. However, if you require that the modules be guaranteed to their specifications, then you must perform a calibration on the instrument.

# 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] |

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.

## Maximum Output Power

The total power consumption of all modules cannot exceed 82 W. Under this rule, 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. One single-slot MFCMU may take the place of a single-slot SMU in any of these configurations.

## Maximum Voltage between Common and Ground

≤ ± 42 V.

## 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

## Ground Unit (GNDU) Specification

The GNDU is furnished 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: innocent**

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) | |

1. ±(% of output/measured 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)<br>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)<br>2 fA (HRSMU) | ±(0.3 %+100 fA+100 aA x Vo) | ±(0.3 %+30 fA+100 aA x Vo) | 100 V |
| | ±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 |
| MPSMU | ±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 at lower range are affected strongly by vibrations and shocks. Do not place the environment of vibrations and shocks during measurements.
3. ±(% of output/measured 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:

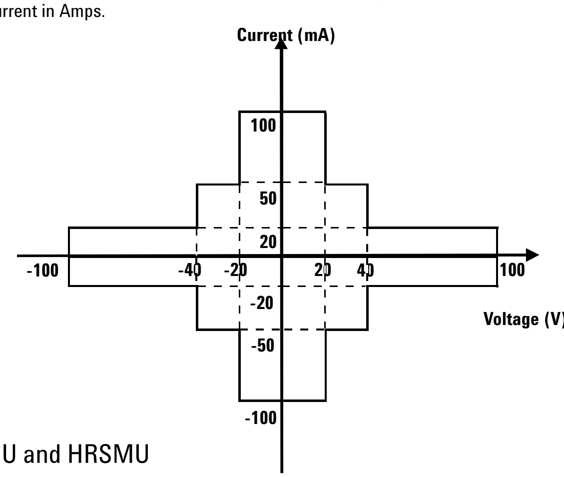
| Voltage Range | Power |
|---|---|
| 0.5 V | 20 x Ic (W) |
| 2 V | 20 x Ic (W) |
| 5 V | 20 x Ic (W) |
| 20 V | 20 x Ic (W) |
| 40 V | 40 x Ic (W) |
| 100 V | 100 x Ic (W) |

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) | ±(0.009 % + 900 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 output/measured 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 µA+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) | |

1. Specified measurement resolution is limited by fundamental noise limits.
2. ±(% of output/measured 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:

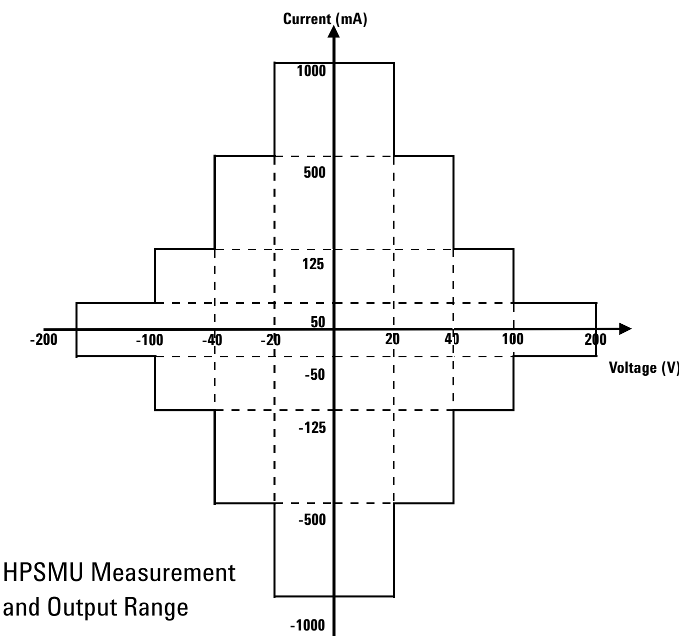
| Voltage Range | Power |
|---|---|
| 2 V | 20 x Ic (W) |
| 20 V | 20 x Ic (W) |
| 40 V | 40 x Ic (W) |
| 100 V | 100 x Ic (W) |
| 200 V | 200 x Ic (W) |

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:
Voltage and Current measurement accuracy of SMUs may be affected by RF electromagnetic field of strength over 3 V/m at frequencies from 80 MHz to 1 GHz. The frequency and degree of affection may vary with the installation condition of the instrument.
Conducted RF field noise and SMU measurement accuracy:
Voltage and Current measurement accuracy of SMUs may be affected by conducted RF field noise of strength over 3Vrms at frequencies from 150 kHz to 80 MHz. The frequency and degree of affection may vary with the installation condition of the instrument.

**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:
$\geq 10^{13}$ Ω
Current source output resistance:
$\geq 10^{13}$ Ω
Current compliance setting accuracy (for opposite polarity):
For 1 pA to 10 nA ranges:
V/I setting accuracy ±12% of range
For 100 nA to 1 A ranges:
V/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
SMU pulse setting accuracy (fixed measurement range):
Width: 0.5 % + 50 µs
Period: 0.5 % + 100 µs
Trigger out delay (pulsed measurements):
0 to 32.7 ms with 100 µs resolution (<pulse width)

**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 output/measured 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 at lower range are affected strongly by vibrations and shocks. Do not place the instrument in the environment of vibrations and shocks during measurements.
3. ±(% of output/measured 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-Rs, Cs-Rs, Cs-D, Cs-Q, Lp-G, Lp-D, Lp-Q, Lp-Rs, Ls-Rs, Ls-D, Ls-Q, R-X, G-B, Z-$\theta$, Y-$\theta$

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
Minimum resolution: 1 mHz
Accuracy: ±0.008 %

Signal output level:
Range: 10 mVrms to 250 mVrms
Resolution: 1 mVrms
Accuracy:
±(10.0 % + 1 mVrms) at four-terminal pair port of MFCMU
±(15.0 % + 1 mVrms) at measurement port of MFCMU cable (1.5 m or 3.0 m)

Output impedance: 50 Ω, typical

Signal level monitor:
Voltage range: Same as the voltage signal level setting range
Voltage monitor accuracy (open load):
±(10.0 % of reading + 1 mVrms) at four-terminal pair port of MFCMU
±(15.0 % of reading + 1 mVrms) at measurement port of MFCMU cable (1.5 m or 3 m)

**DC Bias Function**

DC voltage bias:
Range:
0 to ±25 V
Resolution:
1 mV
Accuracy:
±(0.5 % + 5.0 mV) at the High and Low terminals of the MFCMU measurement port or the MFCMU 1.5 m/3 m cable end

Maximum DC bias current (supplemental information):

| Impedance measurement 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: Same as the dc voltage bias setting range
Accuracy (open load):
±(0.2 % of reading + 10.0 mV) at the High and Low terminals of the MFCMU measurement port or the MFCMU 1.5 m/3 m cable end

**Sweep Characteristics**

Available sweep parameters:
Oscillator level, DC bias voltage, frequency (list sweep only)

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 four-terminal pair port of MFCMU and measurement port of MFCMU cable.

$Z_X$: 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 (%)

$\theta$ 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 $0.1 < D_X \leq 1$
$\pm E \times (1 + D_X)/100$

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 % | 31 µS | ± 192 nS |
| | 10 pF | ± 0.32 % | 314 µS | ± 990 nS |
| | 100 pF | ± 0.29 % | 3 mS | ± 9 µS |
| | 1 nF | ± 0.32 % | 31 mS | ± 99 µS |
| 1 MHz | 1 pF | ± 0.20 % | 6 µS | ± 13 nS |
| | 10 pF | ± 0.11 % | 63 µS | ± 68 nS |
| | 100 pF | ± 0.10 % | 628 µS | ± 620 nS |
| | 1 nF | ± 0.10 % | 6 mS | ± 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 switches either two SMUs or CMU to the output port. The MPSMU and HRSMU are supported as a module. The SCUU has dc bias adapter function by the SMU as dc bias source. Also error compensation function is supported. To connect the SCUU, the dedicated cable assembly is supplied. It can help to connect correctly and easily, and it eliminates cabling mistake.
The GSWU switches open when using SMUs and close when using CMU for the guard return path automatically depending on which the SCUU output is used for the capacitance measurement or not.

Supported SMU
- MPSMU and HRSMU

For SCUU
- Inputs:
  - Four triaxial ports: for Force1, Sense1, Force2, and Sense2
  - Four BNC ports: for MFCMU
  - One SCUU control port
- Outputs:
  - Four triaxial ports: for Force1/CMUH, Sense1, Force2/CMUL, and Sense2
  - One GSWU control port
  - Three LEDs, SMU/CMU output status indicator
- Docking Mode
  - Direct and indirect mode

For GSWU
- Input:
  - One control port from SCUU
  - Mini pin plug port: 2 ports (to Guard1, to Guard2
- Output:
  - One 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.

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

$Z_X$: Impedance measurement value (Ω)

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

$Z_S$:
- 500 + 500 x f (mΩ)

$Y_O$:
- 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

Measurement additional errors:

## Agilent EasyEXPERT Software

## Functions

Operation mode:

Application test mode, Classic test mode, Quick test mode

Key Functions:

- Categorized and predefined application library
- Device definition
- Measurement parameter settings
- Save/Recall My Favorite Setups
- Define/customize application library
- Execute measurement (Single/Repeat/Append)
- Quick test execution
- 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**

Category:

Sample test definitions for the following applications. They 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*
- Pulsed Sweep
- Staircase Sweep with Pulsed Bias
- IV Sampling
- High Speed IV Sampling
- CV Sweep
- Linear Search**
- Binary Search**

* EasyEXPERT supports VAR1 and VAR1'.
**They are supported by FLEX command only.

Each SMU can sweep using VAR1 (primary sweep), VAR2 (secondary sweep), or VAR1' (synchronous sweep).

**VAR1**

Primary sweep controls the staircase (dc or pulsed) voltage or current sweep.

**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 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 type: linear or logarithmic

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 points:

For linear sampling:

1 to 100,001/(number of channels)

For log sampling:

1 to 1+(number of data for 11 decades)

Sampling mode: linear, log

Sampling interval range:

100 μs to 2 ms, 10 μs resolution

2 ms to 65.535 s, 1 ms resolution

For < 2 ms, the interval is

≥ 100 μs +20 μs x(num. of channels - 1)

Hold time, initial wait time:

-90 ms to -100 μs, 100 μs resolution

0 to 655.35 s, 10 ms resolution

Measurement time resolution:

100 μs

**Search Measurement Mode:**

Forces and measures voltage or current by using linear search method or binary search method.

**Bias Hold Function**

This function is used to keep source output after measurement. Source modules apply the specified bias between measurements in a quick test or application test that defines some classic test setups, or a repeat measurement. And the source modules change the output value and the unused modules are disconnected when the next measurement is started.

**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, 1.602177 E-19 C
- k: Boltzman's Constant, 1.380658 E-23
- $\varepsilon$ (e): Dielectric Constant of Vacuum, 8.854188 E-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 $\mu$ ($10^{-6}$), m ($10^{-3}$), k ($10^{3}$), M ($10^{6}$), G ($10^{9}$), T ($10^{12}$) , P ($10^{15}$)

## Analysis Capabilities

### Overlay Graph Comparison

A graphics plot 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 Modes

X-Y graph, list display, and parameter display

### X-Y Graph Display

X-axis and up to eight Y-axis
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 port for instrument control
Interlock port
USB port (USB 2.0, front 2, rear 2)
LAN interface
100BASE-TX/10BASE-T
Trigger in/out
Generic purpose digital I/O

### Trigger I/O

Only for GPIB remote mode.
Trigger in/out synchronization pulses before and after setting and measuring dc voltage and current.
Arbitrary trigger events can be masked or activated independently.

## Attached Software

Prober Control execution files
Desktop EasyEXPERT software (free version)
4155/56 setup file converter tool
Supported operating systems:
Microsoft Windows 2000 Professional and XP Home or Professional
A VXI *plug&play* driver for the B1500A is supplied.
Supported operating systems:
Microsoft Windows 2000 Professional and XP Professional

## 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

### Weight
B1500A (empty): 20 kg
B1510A: 2.0 kg
B1511A: 1.0 kg
B1517A: 1.2 kg
B1520A: 1.5 kg
E5288A: 0.5 kg

N1301A-100: 0.8 kg
N1301A-200: 0.1 kg

### Furnished Accessories
Power cable
Manual CD-ROM
Desktop EasyEXPERT CD-ROM
Software CD-ROM (including VXI*plug&play* driver and utility tools)

## Order Information

### Mainframe and Modules
B1500A
- Semiconductor device analyzer mainframe
- Configure the following modules:
  - High power SMU (HPSMU)
  - Medium power SMU (MPSMU)
  - High resolution SMU (HRSMU)
  - Atto-sense switch unit (ASU)
  - Multi frequency CMU (MFCMU)

B1500A-050
- 50 Hz line frequency

B1500A-060
- 60 Hz line frequency

B1500A-UK6
- Commercial calibration certificate with test data

B1500A-ABA
- English documentation

B1500A-ABJ
- Japanese documentation

### 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 triax. cable (1.5 m)
16493K-002 Kelvin triax. cable (3 m)

### B1500A 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)

### Other Accessories
16442A 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)

### 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

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go to **www.agilent.com**.

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Australia 1 800 629-485
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Luxembourg (0) 2 404-9340
Netherlands (0) 20 547-9999
Poland 20 547-9999
Russia 20 547-9999
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