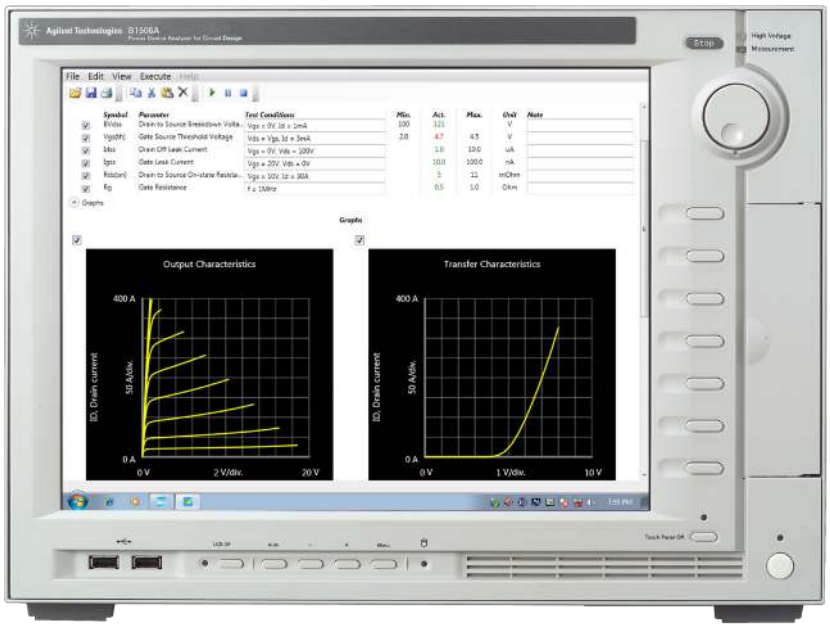
# Agilent B1506A
## Power Device Analyzer for Circuit Design

Data Sheet




*Evaluate all device parameters under a wide range of operating conditions to improve power electronics circuit design performance*

- Measures all IV parameters (Ron, BV, Leakage, Vth, Vsat, etc.)
- Measure transistor input, output and reverse transfer capacitances (Ciss, Coss, Crss, Cies, Coes, Cres, Rg) at high bias voltages
- Qg curve measurement
- Power loss (conduction, driving and switching) evaluation
- Easy to use and fully automated measurement
- Data sheet characterization mode supports quick and easy evaluations of data sheet parameters
- Wide operation I/V (1500A, 3kV)Thermal test ( -50°C to +250°C)
- Oscilloscope View provides visual verification of pulsed measurement waveforms

# Introduction

The B1506A Power Device Analyzer for Circuit Design is a complete solution that can help power electronic circuit designers maximize the value of their power electronics products by enabling them to select the correct power devices for their applications. It can evaluate all relevant device parameters under a wide range of operating conditions, including IV parameters such as breakdown voltage and on-resistance, as well as three terminal FET capacitances, gate charge and power loss.

The B1506A has a wide range of capabilities that help it identify substandard devices under actual circuit operating conditions, including a wide voltage and current range (3 kV and 1500 A), a wide temperature measurement range (-50°C to +250°C), fast pulsing capability, and sub-nA level current measurement capability. Its unique software interface presents the user with a familiar device data sheet format that makes it easy to characterize devices without going through any formal training. Integrated switching circuitry within the test fixture supports fully automated testing, with the ability to automatically change between both high voltage and high current testing as well as between IV and CV measurements. In addition, a unique plug-in style device test fixture socket adapter eliminates cable connection and other human-related errors. The B1506A also supports the complete automation of thermal characterization. This can be accomplished either through the integrated Thermostream control or via the Thermal Plate. Since the DUT is in close proximity to the B1506A's measurement resources, the large parasitics caused by cable extensions leading to a temperature chamber do not exist. For this reason, oscillation free ultra-high currents of up to 1500 A can be accurately evaluated at both low and high temperature.

The B1506A's capabilities revolutionize power electronics circuit design by both helping to maximize end product value and accelerating product development cycles.

## Specification conditions

The measurement and output accuracy are specified under the conditions listed below. Note: The SMU measurement and output accuracy are specified at the output terminals in the test fixture except for capacitance measurement that is specified at the output terminals of the MFCMU.

1. Temperature: 23 °C ± 5 °C
2. Humidity: 20% to 70%, No condensation
3. Self-calibration after a 40 minute warm-up is required.
4. Ambient temperature change less than ±1 °C after self-calibration execution. (Note: This does not apply to the MFCMU).
5. Measurement made within one hour after self-calibration execution. (Note: This does not apply to the MFCMU).
6. Calibration period: 1 year
7. SMU integration time setting: 10 PLC (1 nA to 1 A range, voltage range), 200 µs (20 A range) Averaging of high-speed ADC: 128 samples per 1 PLC
8. SMU filter: ON for MPSMU

## Operating conditions

The B1506A has to be used under the conditions listed below.
Temperature: +5°C to +40°C
Humidity: 20% to 70%, No condensation
When used with Thermostream and the air temperature is more than +20°C
Temperature: +20°C to +30°C
Humidity: 20% to 70%, No condensation
When used with Thermostream and the air temperature is less than +20°C
Temperature: +20°C to +30°C
Humidity: 20% to 50%, No condensation
When used with Thermal plate
Temperature: +5°C to +30°C
Humidity: 20% to 70%, No condensation

# Key Specifications of B1506A

| | | | | B1506A-H21 | B1506A-H51 | B1506A-H71 |
|---|---|---|---|---|---|---|
| Collector/Drain channel | Maximum output | Voltage | | ±3000 V | ±3000 V | ±3000 V |
| | | Current | DC | ±1 A | ±100 mA | ±100 mA |
| | | | Pulsed | ±20 A | ±500 A | ±1500 A |
| | Source | Minimum resolution | Voltage | 25 µV | 25 µV | 25 µV |
| | | | Current | 50 fA | 50 fA | 50 fA |
| | Measurement | Minimum resolution | Voltage | 0.5 µV | 0.5 µV | 0.5 µV |
| | | | Current | 10 fA | 10 fA | 10 fA |
| Gate channel | Maxium output | Voltage | | ±100 V | ±100 V | ±100 V |
| | | Current | DC | ±100 mA | ±100 mA | ±100 mA |
| | | | Pulsed | ±1 A | ±1 A | ±1 A |
| | Source | Minimum resolution | Voltage | 25 µV | 25 µV | 25 µV |
| | | | Current | 50 fA | 50 fA | 50 fA |
| | Measurement | Minimum resolution | Voltage | 0.5 µV | 0.5 µV | 0.5 µV |
| | | | Current | 10 fA | 10 fA | 10 fA |
| Capacitance measurement | Max bias | Gate | | ±100 V | ±100 V | ±100 V |
| | | Collector/Drain | | ±3000 V | ±3000 V | ±3000 V |
| | Frequency range | | | 1 kHz to 1 MHz | 1 kHz to 1 MHz | 1 kHz to 1 MHz |
| | Capacitance range | | | 100 fF to 1µF | 100 fF to 1µF | 100 fF to 1µF |

# Measurement parameters

| Characteristics | Category | Parameters |
|---|---|---|
| Static characteristics | Threshold voltage | Vgs(th),Vge(th) |
| | Transfer Characteristics | Id-Vgs, Ic-Vge, gfs |
| | On resistance | Rds-on. Vce(sat) |
| | Gate leakage current | Igss, Iges |
| | Output leakage current | Idss, Ices |
| | Output Characteristics | Id-Vds, Ic-Vce |
| | Breakdown voltage | BVds, BVces |
| Gate charge characteristics | Gate Charge | Qg, Qg(th), Qgs, Qgd, Qsw, Qsync,Qoss |
| Capacitance characteristics | Gate Resistance | Rg |
| | Device Capacitance | Ciss, Coss, Coss_eff, Crss, Cgs, Cgd, Cies, Coes, Cres |
| Switching characteristics | Switching parameter | Td(on),Td(off),Tr,Tf *1 |
| Power loss | | Driving loss/Switching loss *2<br>Conduction loss at specified duty cycle *3 |

**1. Switching parameters are calculated from measured Qg characteristics, Vth and Rg.*

**2. Driving loss and switching loss are calculated by measured Qg characteristics, Vth and Rg at specified frequency.*

**3. Conduction loss are calculated from measured Rds-on and peak current.*

## Operation range

| IV functionality | Operation range |
|---|---|
| Collector/Drain voltage | **±3000 V** |
| Collector/Drain current | **±1500 A (B1506A-H71)** |
| | **±500 A (B1506A-H51)** |
| | **±20 A (B1506A-H21)** |
| Gate | **±30 V/±1 A (pulse): MCSMU** |
| | **±100 V/±100 mA: MPSMU** |

| CV functionality | Operation range |
|---|---|
| Gate DC bias voltage | **±100 V** |
| Collector/Drain DC bias voltage | **±3000 V** |
| Frequency | **1 kHz to 1 MHz** |
| Capacitance | **100 fF to 100 nF** |

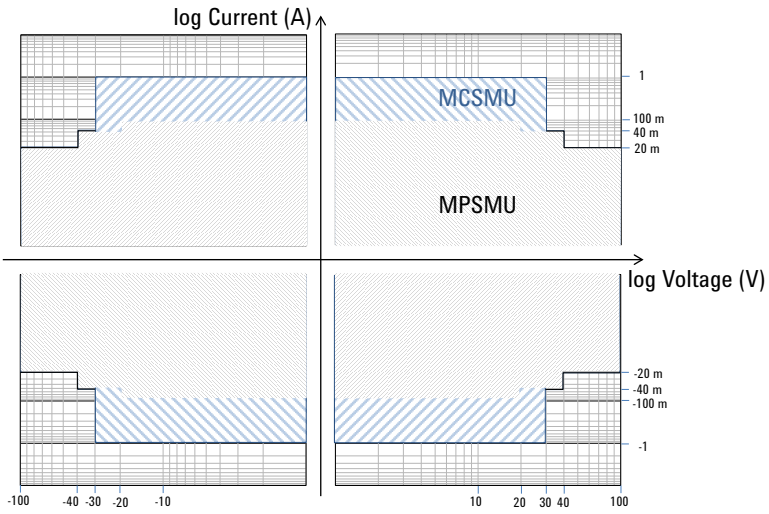
| Gate charge functionality | Operation range |
|---|---|
| Qg, Qgd, Qd | **1 nC to 100 µC** |
| VDD | **0 to +3000 V** |
| ID | **0 A to 1500 A** |
| Gate drive | **-30 V to 30 V** |

# Current/Voltage measurement specifications

## Gate/Base step generator specification

Gate/Base step generator IV Operating range is defined as the combination of MCSMU and MPSMU modules. The following graph shows entire IV operating range of gate/base step generator for B1506A (H21/H51/H71).

Refer to the section for each module later in this document for detailed specification of each module.



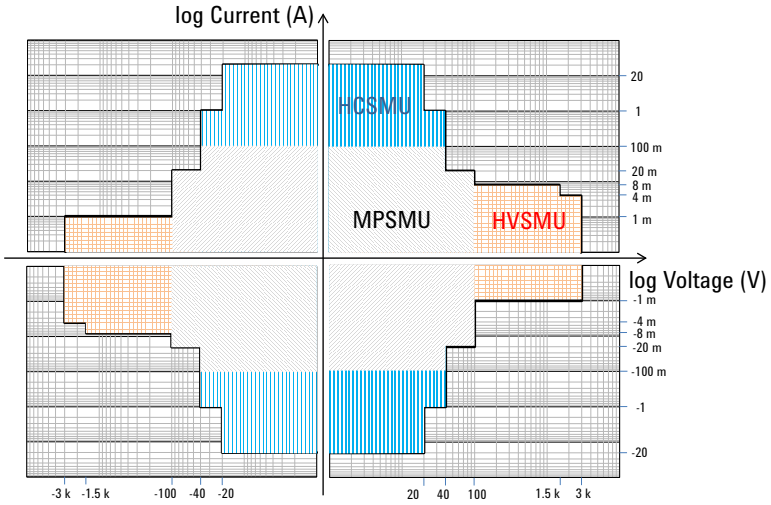

*Gate/Base step generator measurement and output range*

## Drain/Collector Supply Specification

### B1506A-H21

Drain/Collector Supply IV Operating range for B1506A-H21 is defined as the combination of HCSMU, MPSMU and HVSMU modules. The following graph shows entire IV operating range of drain/collector supply for B1506A-H21.

Refer to the section for each module later in this document for detailed specification of each module.

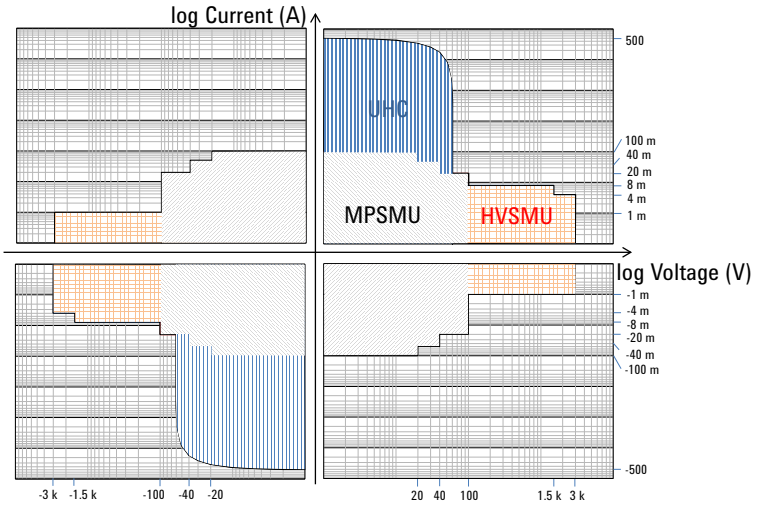



*IV operating range for B1506A-H21*

## B1506A-H51

Drain/Collector Supply IV Operating range for B1506A-H51 is defined as the combination of UHCU, MPSMU and HVSMU modules. The following graph shows entire IV operating range of drain/collector supply for B1506A-H51.

Refer to the section for each module later in this document for detailed specification of each module.

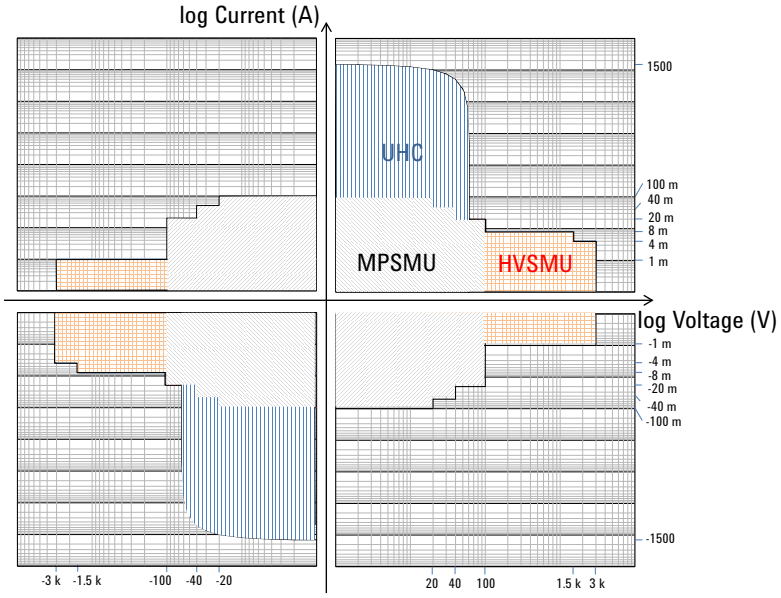



*IV operating range for B1506A-H51*

## B1506A-H71

Drain/Collector Supply IV Operating range for B1506A-H71 is defined as the combination of UHCU, MPSMU and HVSMU modules. The following graph shows entire IV operating range of drain/collector supply for B1506A-H51.

Refer to the section for each module later in this document for detailed specification of each module.




*IV operating range for B1506A-H71*

# Capacitance measurement specifications

Capacitance measurement of B1506A is provided with the combination of MFCMU module in the B1506A mainframe and built-in device capacitance selector in the B1506A test fixture.

## DC bias characteristics

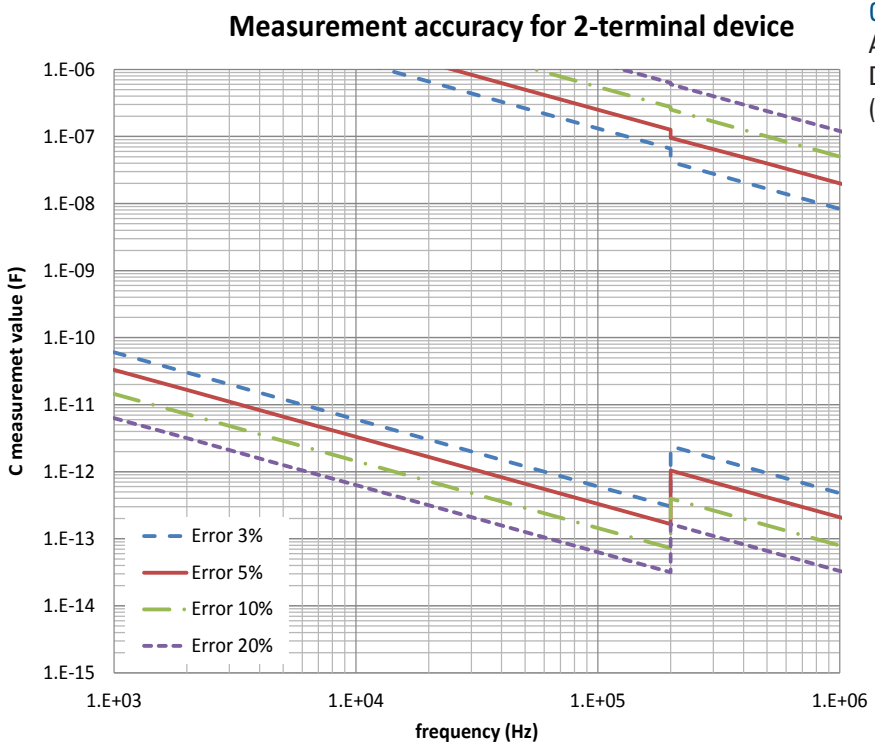
100 kΩ at SMU bias output resistance

Voltage drop compensation function is available.

## Bypass capacitance in the capacitance selector

| | Capacitance | Withstand voltage |
|---|---|---|
| Drain to Source Terminal | 1 µF | ±3000V |
| Gate to Source Terminal | 1 µF | ±100V |

## Measurement accuracy for 2-terminal device (Supplemental characteristics)




Condition
AC level: 30 mV rms
Dx < = 0.1
(Dx: Measurement value of D)

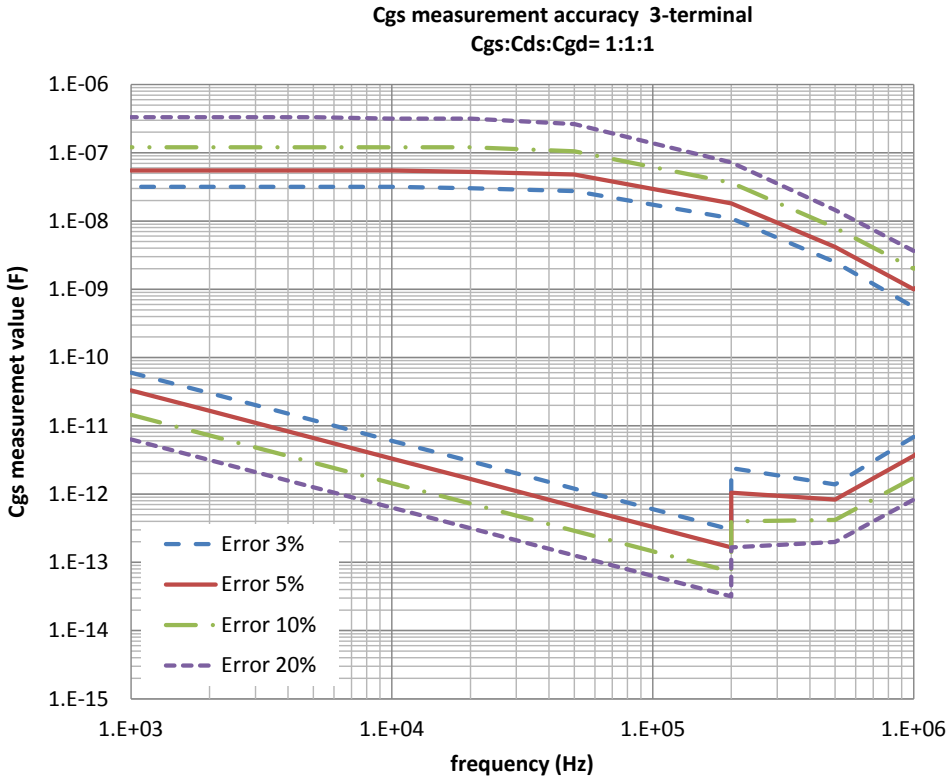
## Output terminals for 2-terminal device

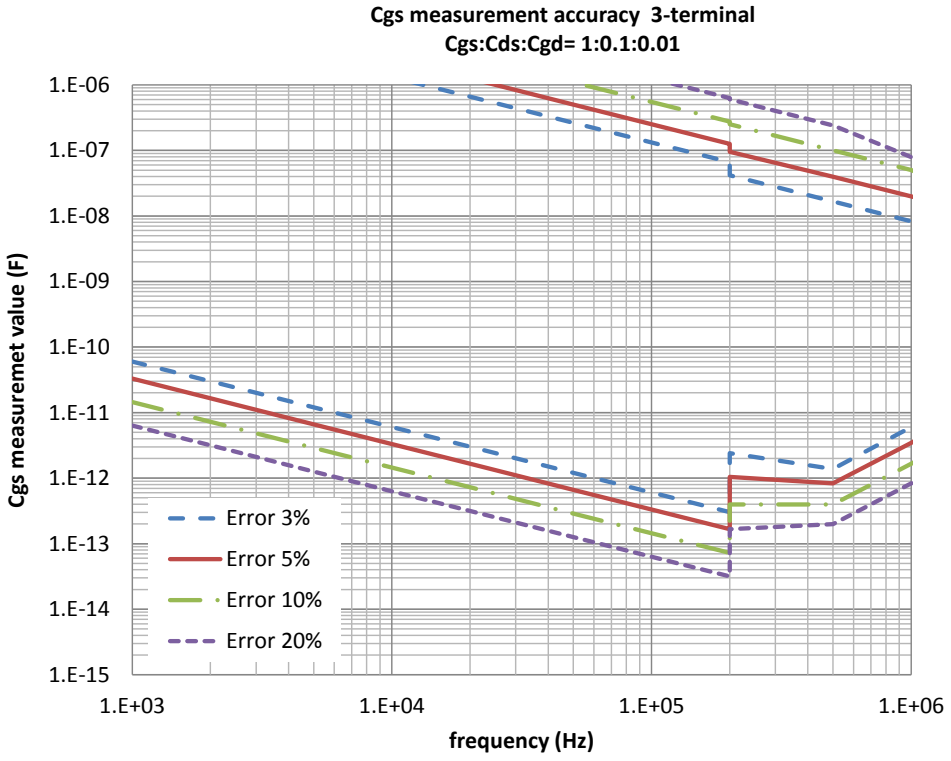
| | | | | |
|---|---|---|---|---|
| Collector/Drain | Force | Open | Open | Open |
| | Sense | High | High | Open |
| Emitter/Source | Force | Open | Open | Open |
| | Sense | Low | Open | Low |
| Base/Gate | High | Open | Low | High |
| | Low | Open | Open | Open |

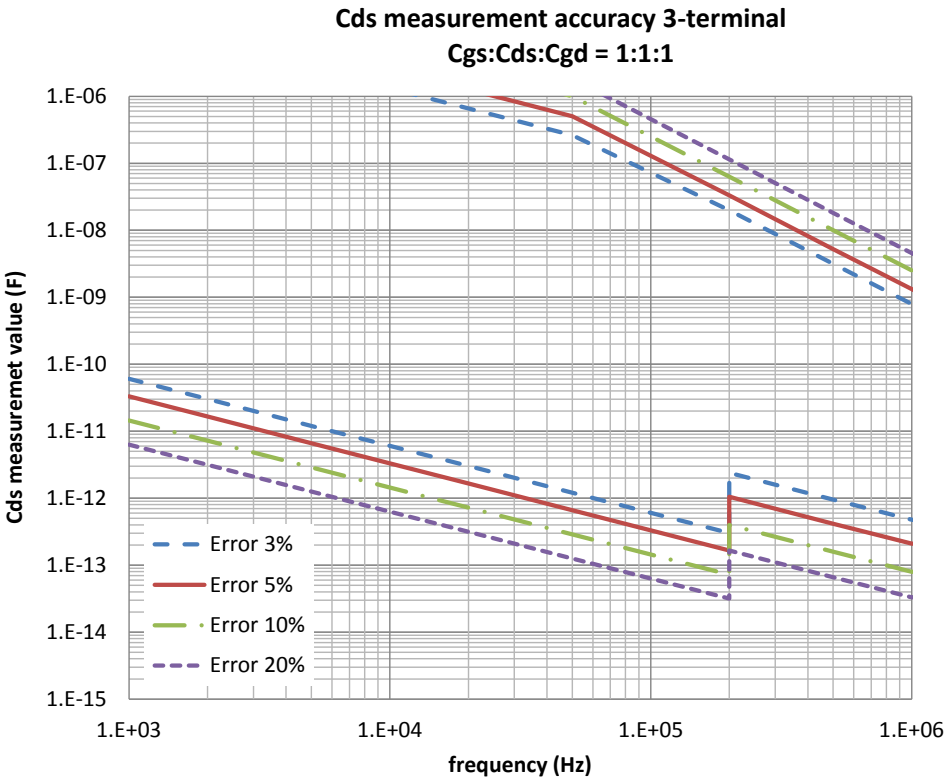
## Measurement accuracy for 3-terminal device (Supplemental characteristics)

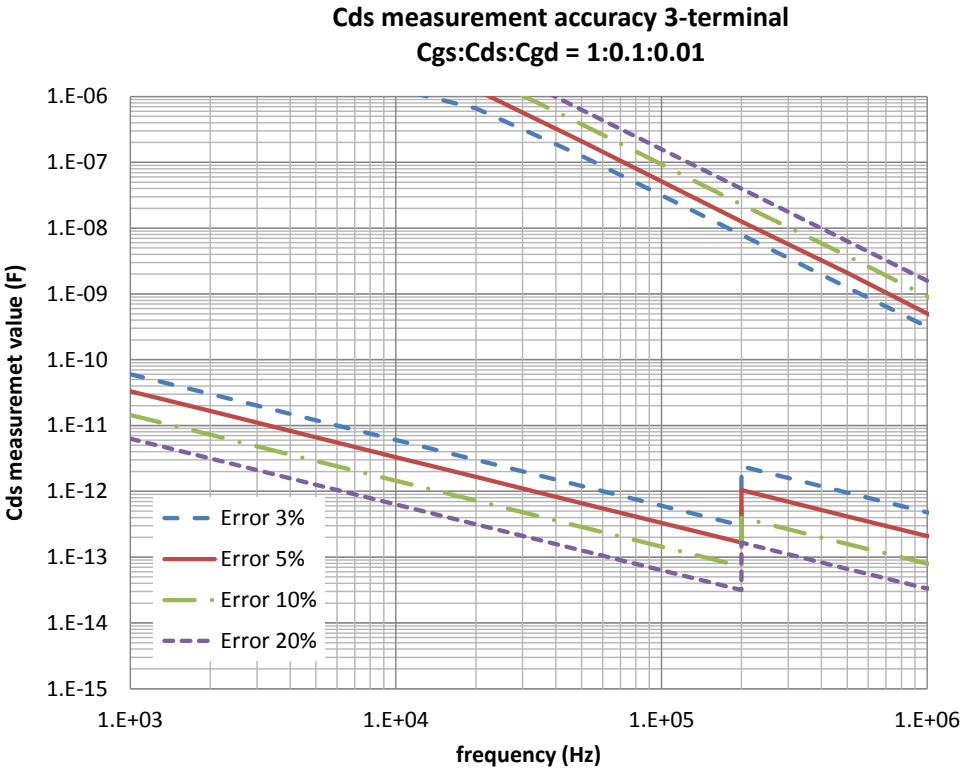
### Condition

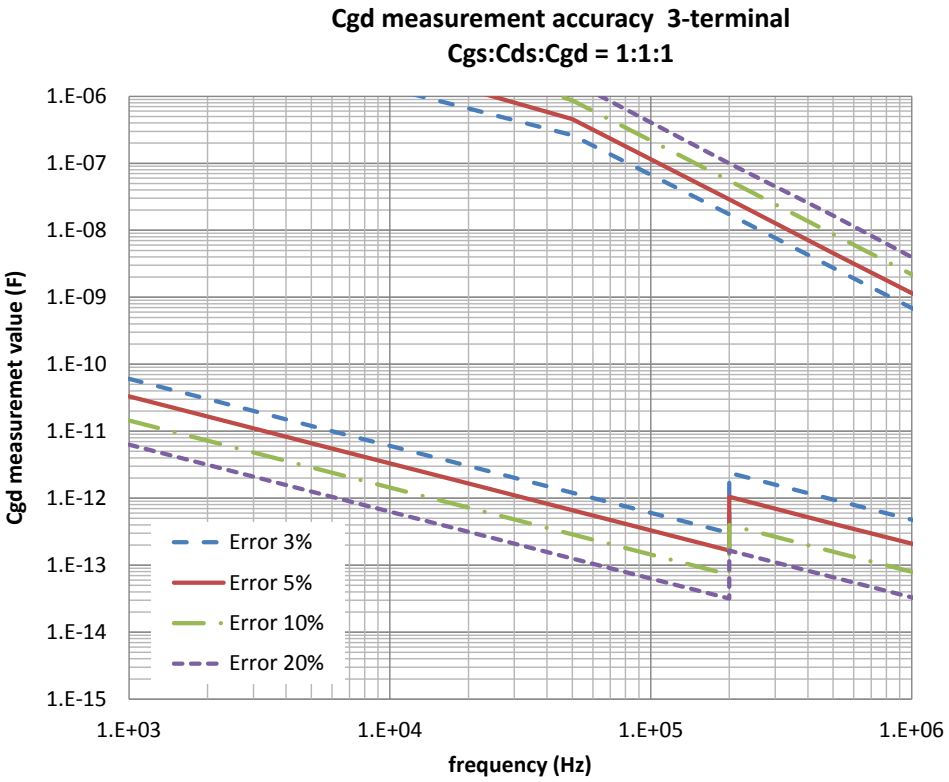
AC level: 30 mV rms, Dx < = 0.1 (Dx: Measurement value of D)

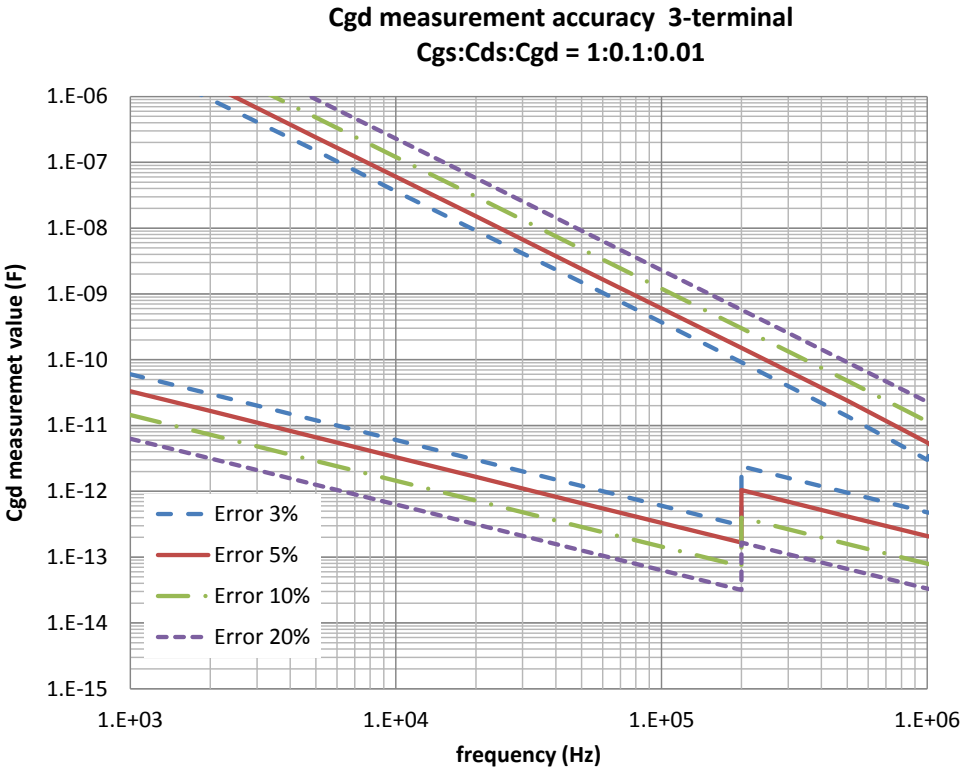


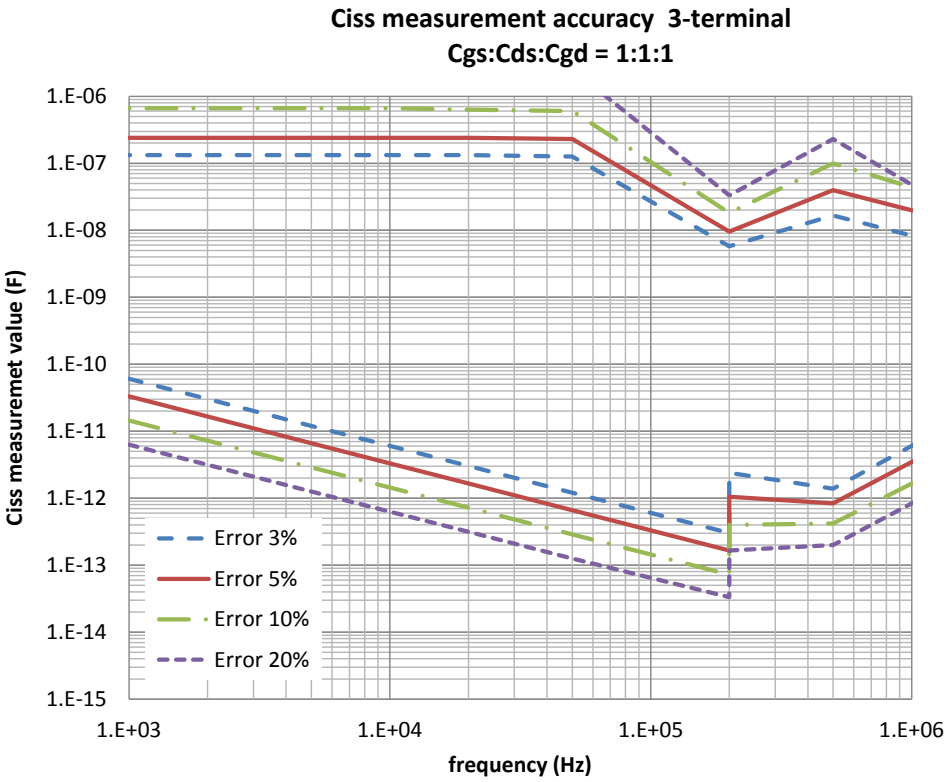



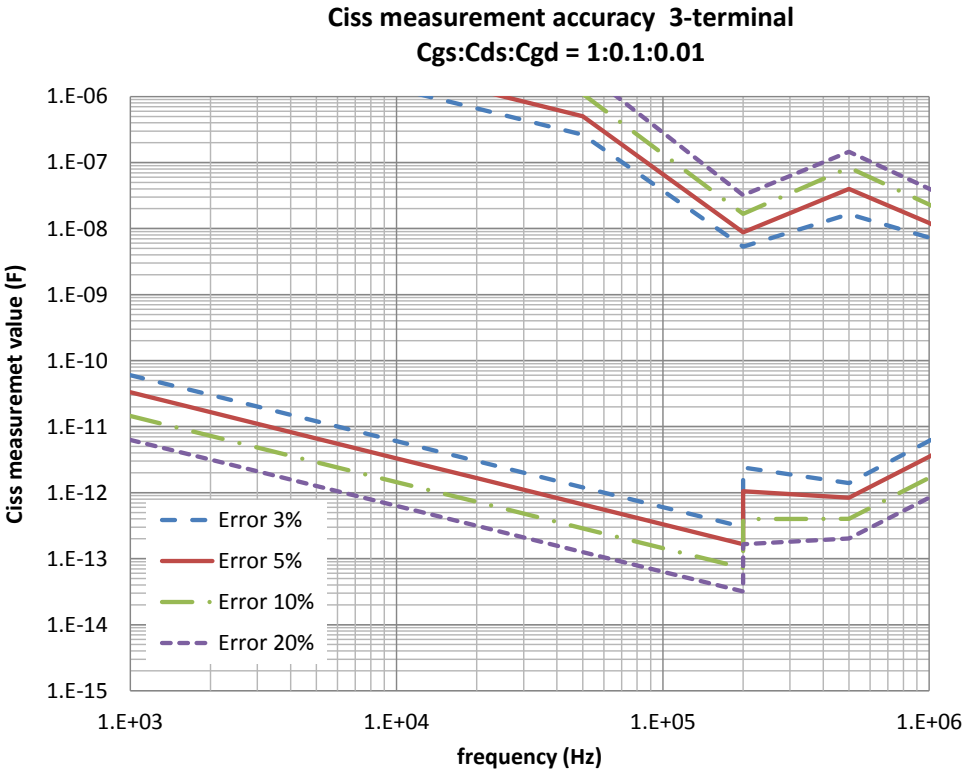

Cds measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:1:1
Cds measuremet value (F)
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)
Error 3%
Error 5%
Error 10%
Error 20%

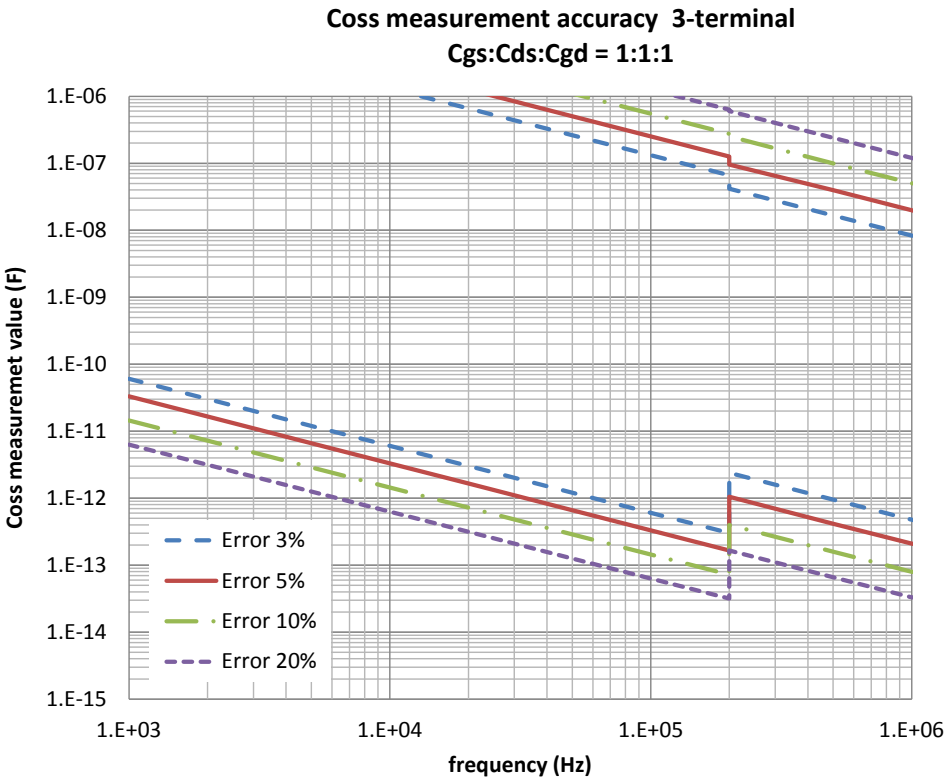

Cds measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:0.1:0.01
Cds measuremet value (F)
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)
Error 3%
Error 5%
Error 10%
Error 20%

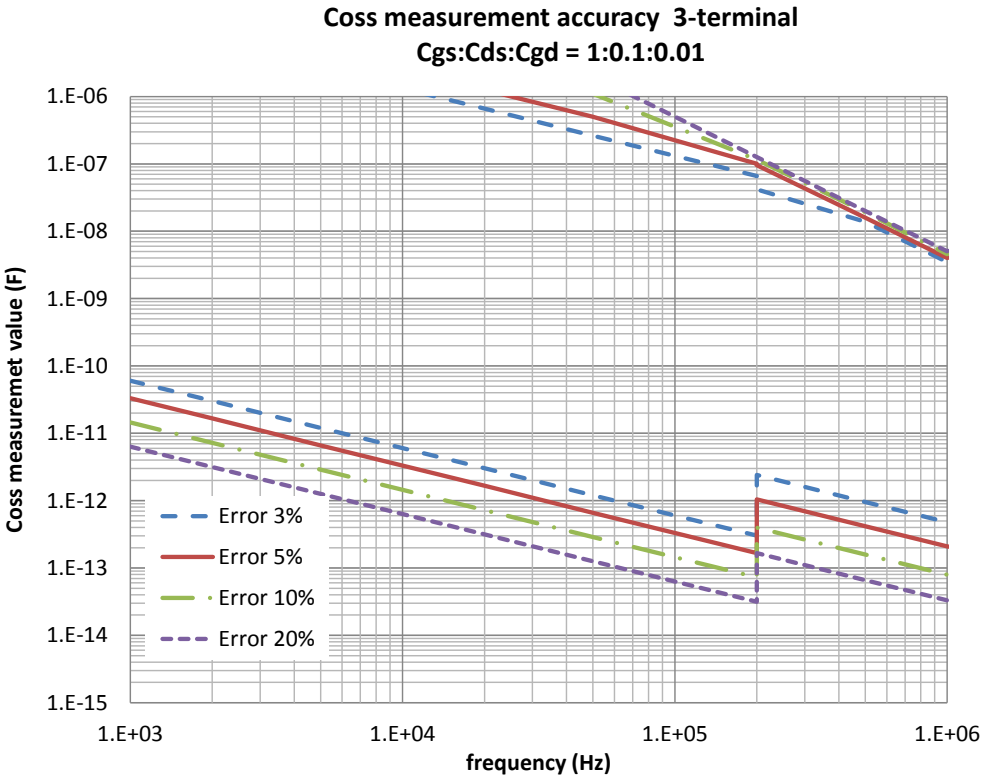

Cgd measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:1:1
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
Cgd measuremet value (F)
Error 3%
Error 5%
Error 10%
Error 20%
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)


Cgd measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:0.1:0.01
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
Cgd measuremet value (F)
Error 3%
Error 5%
Error 10%
Error 20%
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)


Ciss measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:1:1
Ciss measuremet value (F)
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)
Error 3%
Error 5%
Error 10%
Error 20%


Ciss measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:0.1:0.01
Ciss measuremet value (F)
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)
Error 3%
Error 5%
Error 10%
Error 20%


Coss measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:1:1
Coss measuremet value (F)
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)
Error 3%
Error 5%
Error 10%
Error 20%


Coss measurement accuracy 3-terminal
Cgs:Cds:Cgd = 1:0.1:0.01
Coss measuremet value (F)
1.E-06
1.E-07
1.E-08
1.E-09
1.E-10
1.E-11
1.E-12
1.E-13
1.E-14
1.E-15
1.E+03
1.E+04
1.E+05
1.E+06
frequency (Hz)
Error 3%
Error 5%
Error 10%
Error 20%

## Output terminals for 3-terminal device

| Parameter Name | | Coss | Cds | Crss | Cgs | Ciss /Rg |
|---|---|---|---|---|---|---|
| Collector/Drain | Force | Open | Open | Open | Open | Open |
| | Sense | High | High | High | ACG | Low |
| Emitter/Source | Force | Open | Open | Open | Open | Open |
| | Sense | Low | Low | ACG | Low | Low |
| Base/Gate | High | Low | ACG | Low | High | High |
| | Low | Open | Open | Open | Open | Open |

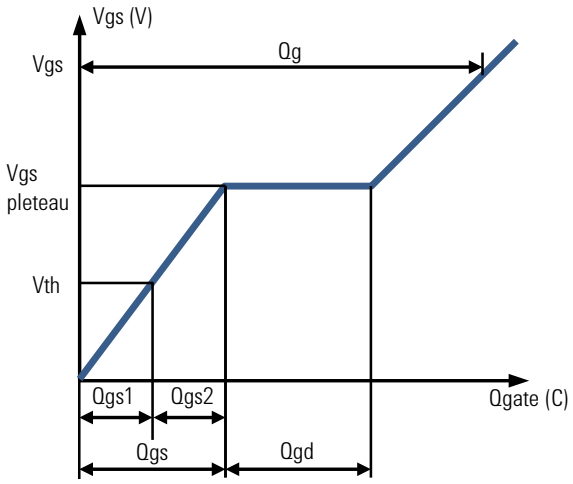
## Definition of 3-terminal device capacitances

| Symbol | Description |
|---|---|
| Cgs | Capacitace between Base/Gate terminal and Emitter/Source terminal |
| Cds | Capacitace between Collector/Drain terminal and Emitter/Source terminal |
| Cgd | Capacitace between Base/Gate terminal and Collector/Drain terminal |
| Crss | Capacitace between Base/Gate terminal and Collector/Drain terminal |
| Ciss | Capacitace between Base/Gate terminal and Emitter/Source terminal and capacitance between Base/Gate terminal and Collector/Drain terminal |
| Coss | Capacitace between Collector/Drain terminal and Emitter/Source terminal and capacitance between Base/Gate terminal and Emitter/Source terminal |

# Gate charge measurement specifications

B1506A can perform gate charge characterization by using gate charge socket adapter, that is included in B1506A as an accessory. Both resistor and transistor are supported as drain/collector current control device.

Temperature dependency measurement using Thermostream or Thermal plate is not supported.




Qg: Gate charge
Qgs: Gate-source charge
Qgs1: Gate charge at threshold
Qgs2: Gate charge from threshold to onset of plateau
Qgd: Gate-drain charge

## Measurement parameters

| | B1506A-H21 | B1506A-H51 | B1506A-H71 |
|---|---|---|---|
| **Measurement Parameter** | **Measurable Range** | | |
| Qg | 1 nC to 100 µC | | |
| Min Resolution | 10 pC | | |
| Vds (Vce) @High Voltage | 0 V to +3000 V | | |
| Resolution | 3 mV / 6 µs | | |
| Vds(Vce) @ High Current | Not Support | -60 V to 60 V | |
| Resolution | | 100 µV / 2 µs | |
| Vgs (Vge) | -30V to +30V | | |
| V/T Resolution | 40 uV / 2 us | | |
| Id (Ic) | 0 to 20 A | 0 to 500 A | 0 to 1500 A |
| I/T Resolution | 2 mA / 2 µs | | |
| Ig | 10 nA to 1 A | | |
| I/T Resolution | 10 pA / 2 µs | | |

## Setting parameters

| | B1506A-H21 | B1506A-H51 | B1506A-H71 |
|---|---|---|---|
| **Setting Parameter** | **Setting Range** | | |
| Vds (Vce) @High Voltage | 0 V to +3000 V | | |
| Resolution | 3 mV / 6 us | | |
| Vds(Vce) @ High Current | -40 V to 40V | -60 V to 60 V | |
| Resolution | 40 µV / 2 µs | 100 µV / 2 µs | |
| Id max | 20 A | 450 A | 1100 A |
| Gate Drive Vgs(Vge) | -30 V to +30 V | | |
| Resolution | 40 µV | | |
| Gate Control Current Ig | 1 µA to 1 A | | |
| Resolution | 0.1 µA | | |
| Current Regulator Control Voltage | -30 V to +30 V | | |
| Resolution | 40 µV | | |
| On time | 50 µs to 950 µs | | 50 µs to 450 µs |
| Resolution | 2 µs | | |
| Target device | MOSFET, IGBT TO packeged device | | |
| | MOSFET, IGBT module device | | |

# UHC (Ultra High Current) Specifications

| Voltage range, resolution, and accuracy | | | | |
|---|---|---|---|---|
| **Voltage range** | **Setting resolution** | **Measure resolution** | **Setting accuracy[1,2,3] ±(% + mV)** | **Measure accuracy[1,3] ±(% + mV)** |
| ± 60 V | 200 µV | 100 µV | ±(0.2 + 10) | ±(0.2 + 10) |

*1. ±(% of reading value + fixed offset in mV)*
*2. Setting accuracy is defined at open load.*
*3. Accuracy is defined 1ms pulse width at 500A range and 500 µs pulse width at 1500A range.*

| Current range, resolution, and accuracy[1] | | | | |
|---|---|---|---|---|
| **Current range** | **Setting resolution** | **Measure resolution** | **Setting accuracy[2,3] ±(% + A + A)** | **Measure accuracy[2,3] ±(% + A + A)** |
| ± 500 A | 1 mA | 500 µA | ±(0.6 + 0.3 + 0.01*Vo) | ±(0.6 + 0.3 + 0.01*Vo) |
| ± 1500 A | 4 mA | 2 mA | ±(0.8 + 0.9 + 0.02*Vo) | ±(0.8 + 0.9 + 0.02*Vo) |

*1. Maximum voltage compliance in current pulse mode is 63 V. Over 400 A at 500 A range and over 1200 A at 1500 A range are supplemental characteristics.*
*2. Accuracy is defined with 1ms pulse width at 500 A range and with 500 µs pulse width at 1500 A range.*
*3. ±(% of reading value + fixed offset in A + proportional offset in A), Vo is the Output Voltage.*

| UHCU Pulse width and resolution | | | | |
|---|---|---|---|---|
| **Current range** | **Voltage pulse width** | **Current pulse width** | **Resolution** | **Pulse period[1]** |
| 500 A | 10 µsec – 1 msec | 10 µsec – 1 msec | 2 µsec | Duty ≤ 0.4% |
| 1500 A | 10 µsec – 500 µsec | 10 µsec – 500 µsec | 2 µsec | Duty ≤ 0.1% |

*1. At continuous maximum current output, the output current may be reduced due to insufficient charging time.*

| Output peak power | |
|---|---|
| **Current range** | **Peak power** |
| ± 500 A | 7.5 kW |
| ± 1500 A | 22.5 kW |

## Other functionality

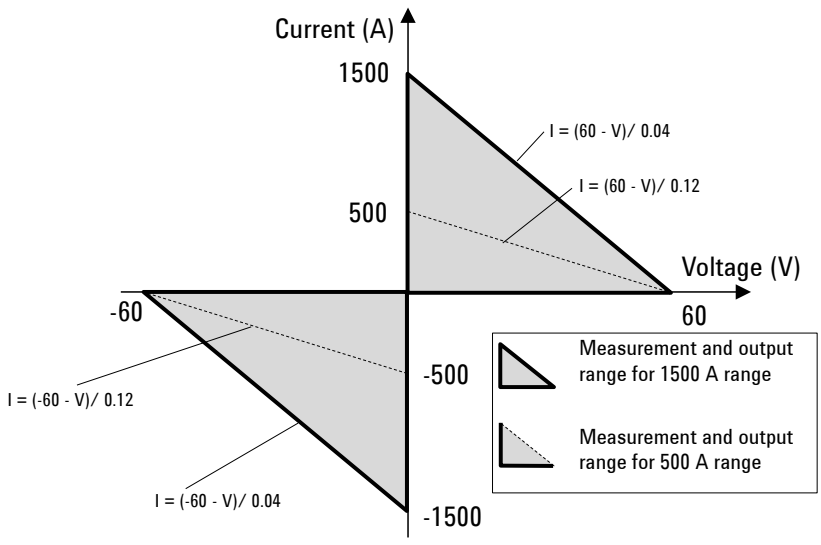
Fiilter

Filter can be used for UHC output in current mode at 500 A range.

## Supplemental characteristics

| UHCU Output resistance | |
|---|---|
| **Output range** | **Nominal value** |
| 500 A | 120 mΩ |
| 1500 A | 40 mΩ |

**UHC measurement and output range**




The UHCU output is only available in pulsed mode.

In the equations in the above diagram, 'I' stands for current, 'V' for Voltage and 'Rdut' stands for the impedance of the device under test.

# HCSMU Drain Output Specifications

**Voltage range, resolution, and accuracy**

| Voltage range | Force resolution | Measure resolution | Force accuracy [1] ±(% + mV + mV) | Measure accuracy [1] (% + mV + mV) | Maximum current |
|---|---|---|---|---|---|
| ±0.2 V | 200 nV | 200 nV | ±(0.06 + 0.6 + Io x 0.05) | ±(0.06 + 0.6 + Io x 0.05) | 20 A |
| ±2 V | 2 µV | 2 µV | ±(0.06 + 0.6 + Io x 0.5) | ±(0.06 + 0.6 + Io x 0.5) | 20 A |
| ±20 V | 20 µV | 20 µV | ±(0.06 + 3 + Io x 5) | ±(0.06 + 3 + Io x 5) | 20 A |
| ±40 V | 40 µV | 40 µV | ±(0.06 + 3 + Io x 10) | ±(0.06 + 3 + Io x 10) | 1 A |

*1. ±(% of reading value + fixed offset in mV + proportional offset in mV). Note: Io is the output current in A.*

**Current range, resolution, and accuracy**

| Current range | Force resolution | Measure resolution | Force accuracy [1] (% + A + A) | Measure accuracy [1] (% + A + A) | Maximum voltage |
|---|---|---|---|---|---|
| ±10 µA | 10 pA | 10 pA | ±(0.06 + 1E-8 + Vo x 5E-10) | ±(0.06 + 1E-8 + Vo x 1E-10) | 40 V |
| ±100 µA | 100 pA | 100 pA | ±(0.06 + 2E-8 + Vo x 1E-9) | ±(0.06 + 2E-8 + Vo x 1E-9) | 40 V |
| ±1 mA | 1 nA | 1 nA | ±(0.06 + 2E-7 + Vo x 1E-8) | ±(0.06 + 2E-7 + Vo x 1E-8) | 40 V |
| ±10 mA | 10 nA | 10 nA | ±(0.06 + 2E-6 + Vo x 1E-7) | ±(0.06 + 2E-6 + Vo x 1E-7) | 40 V |
| ±100 mA | 100 nA | 100 nA | ±(0.06 + 2E-5 + Vo x 1E-6) | ±(0.06 + 2E-5 + Vo x 1E-6) | 40 V |
| ±1 A | 1 µA | 1 µA | ±(0.4 + 2E-4 + Vo x 1E-5) | ±(0.4 + 2E-4 + Vo x 1E-5) | 40 V |
| ±20 A [2] | 20 µA | 20 µA | ±(0.4 + 2E-3 + Vo x 1E-4) | ±(0.4 + 2E-3 + Vo x 1E-4) | 20 V |

*1. ±(% of reading value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.*

*2. Pulse mode only. The maximum value of the base current during pulsing is ±100 mA.*

**Power consumption**

**Voltage source mode:**

| Voltage range | Power |
|---|---|
| 0.2 V | 40 x Ic (W) |
| 2 V | 40 x Ic (W) |
| 40 V | 40 x Ic (W) |

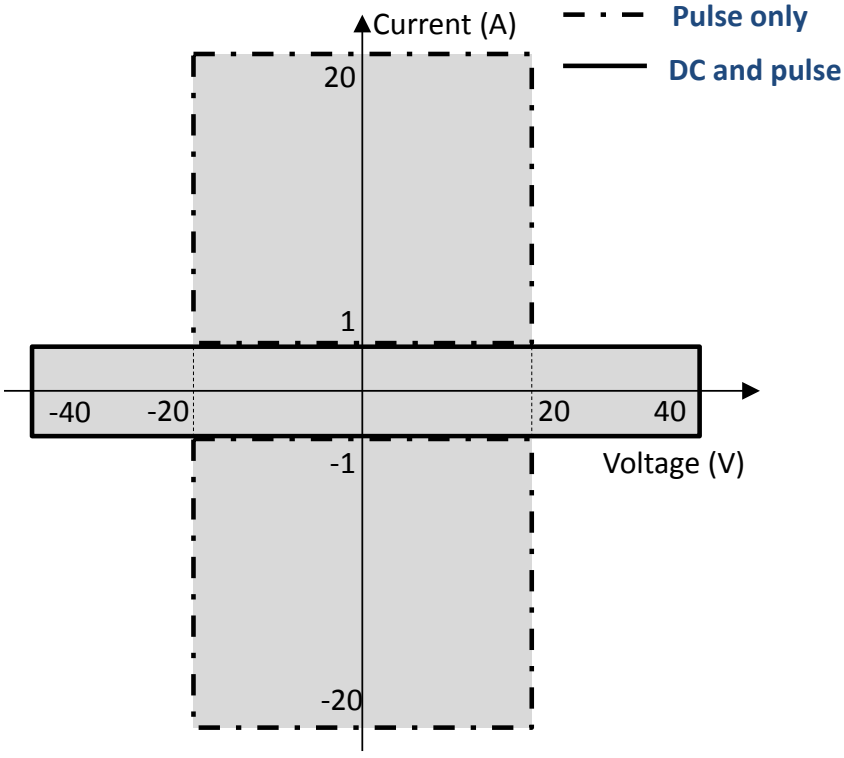
Where Ic is the current compliance setting.
For pulse current, Ic = (duty) x Ipulse

**Current source mode:**

| Voltage compliance | Power |
|---|---|
| Vc ≤ 0.2 | 40 x Io (W) |
| 0.2 < Vc ≤ 2 | 40 x Io (W) |
| 2 < Vc ≤ 40 | 40 x Io (W) |

Where Vc is the voltage compliance setting and Io is output current.
For pulse current, Io = (duty) x Ipulse

**HCSMU measurement and output range**



# HVSMU Drain Output Specifications

**Voltage range, resolution, and accuracy**

| Voltage range | Force resolution | Measure resolution | Force accuracy [1] ±(% + mV) | Measure accuracy [1] ±(% + mV) | Maximum current |
|---|---|---|---|---|---|
| ±200 V | 200 µV | 200 µV | ±(0.03 + 40) | ±(0.03 + 40) | 8 mA |
| ±500 V | 500 µV | 500 µV | ±(0.03 + 100) | ±(0.03 + 100) | 8 mA |
| ±1500 V | 1.5 mV | 1.5 mV | ±(0.03 + 300) | ±(0.03 + 300) | 8 mA |
| ±3000 V | 3 mV | 3 mV | ±(0.03 + 600) | ±(0.03 + 600) | 4 mA |

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

**Current range, resolution, and accuracy**

| Current range | Force resolution | Measure resolution | Force accuracy [1] ±(% + A + A) | Measure accuracy [1] ±(% + A + A) | Maximum voltage | Minimum set current [2] |
|---|---|---|---|---|---|---|
| ±10 nA [3] | 100 fA | 100 fA | ±(0.1 + 1E-9 + Vo x 8E-12) | ±(0.1 + 1E-9 + Vo x 8E-12) | 3000 V | 1pA |
| ±100 nA [3] | 100 fA | 100 fA | ±(0.05 + 1E-9 + Vo x 8E-12) | ±(0.05 + 1E-9 + Vo x 8E-12) | 3000 V | 100 pA |
| ±1 µA [3] | 1 pA | 1 pA | ±(0.05 + 1E-9 + Vo x 8E-12) | ±(0.05 + 1E-9 + Vo x 8E-12) | 3000 V | 100 pA |
| ±10 µA | 10 pA | 10 pA | ±(0.04 + 2E-9 + Vo x 1E-11) | ±(0.04 + 2E-9 + Vo x 1E-11) | 3000 V | 10 nA |
| ±100 µA | 100 pA | 100 pA | ±(0.03 + 3E-9 + Vo x 1E-11) | ±(0.03 + 3E-9 + Vo x 1E-11) | 3000 V | 10 nA |
| ±1 mA | 1 nA | 1 nA | ±(0.03 + 6E-8 + Vo x 1E-10) | ±(0.03 + 6E-8 + Vo x 1E-10) | 3000 V | 100 nA |
| ±10 mA | 10 nA | 10 nA | ±(0.03 + 2E-7 + Vo x 1E-9) | ±(0.03 + 2E-7 + Vo x 1E-9) | 1500 V | 1 µA |

*1. ±(%of reading value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.)*

*2. Output current needs to be set more than current shown in the table.*

*3. Supplemental characteristics*

**Power consumption**

**Voltage source mode:**

| Current compliance | Power |
|---|---|
| Ic ≤ 4m | 3000 x Ic (W) |
| 4m < Ic ≤ 8m | 1500 x Ic (W) |

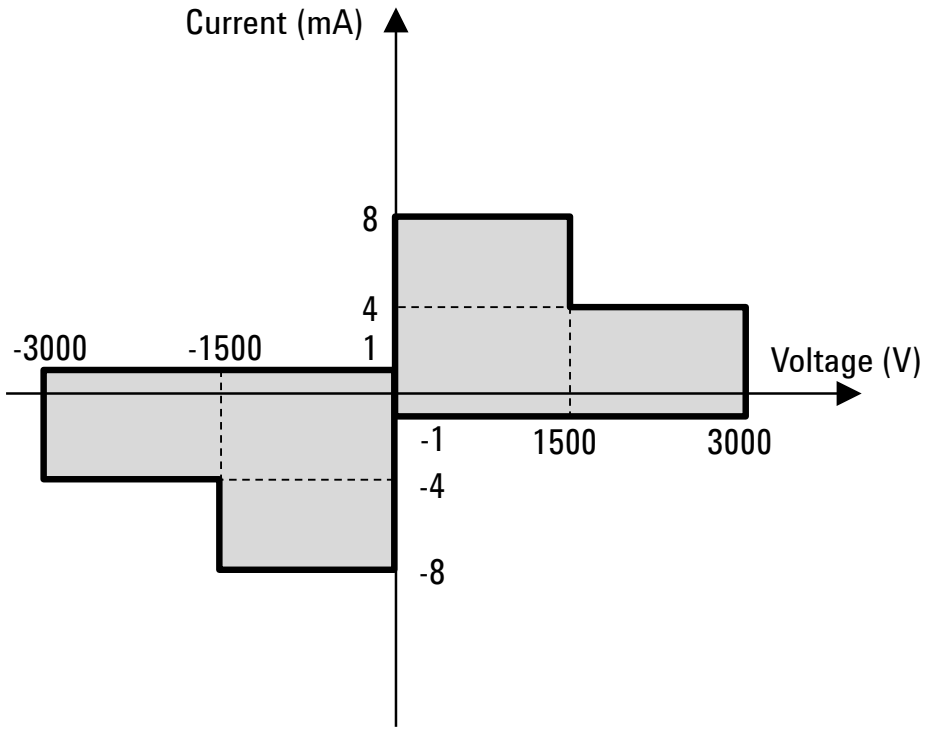
Where Ic is the current compliance setting.

**Current source mode:**

| Voltage compliance | Power |
|---|---|
| Vc ≤ 1500 | 1500 x Io (W) |
| 1500 < Vc ≤ 3000 | 3000 x Io (W) |

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

**HVSMU measurement and output range**



# MPSMU Drain Output / Gate Output Specifications

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

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

*1. ± (% of reading value + offset value in mV)*

*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)**

| Current range | Force resolution | Measure resolution | Force accuracy [1] ±(% + A + A) | Measure accuracy [1] ±(% + A + A) | Maximum voltage |
|---|---|---|---|---|---|
| ±10 nA [3] | 500 fA | 10 fA | ±(0.1 + 1E-9 + Vo x 4E-11) | ±(0.1 + 1E-9 + Vo x 4E-11) | 100 V |
| ±100 nA [3] | 5 pA | 100 fA | ±(0.05 + 1E-9 + Vo x 4E-11) | ±(0.05 + 1E-9 + Vo x 4E-11) | 100 V |
| ±1 µA [3] | 50 pA | 1 pA | ±(0.05 + 1E-9 + Vo x 4E-11) | ±(0.05 + 1E-9 + Vo x 4E-11) | 100 V |
| ±10 µA | 500 pA | 10 pA | ±(0.05 + 3E-9 + Vo x 4E-11) | ±(0.04 + 2E-9 + Vo x 4E-11) | 100 V |
| ±100 µA | 5 nA | 100 pA | ±(0.035 + 15E-9 + Vo x 1E-10) | ±(0.03 + 3E-9 + Vo x 1E-10) | 100 V |
| ±1 mA | 50 nA | 1 nA | ±(0.04 + 15E-8 + Vo x 1E-9) | ±(0.03 + 6E-8 + Vo x 1E-9) | 100 V |
| ±10 mA | 500 nA | 10 nA | ±(0.04 + 15E-7 + Vo x 1E-8) | ±(0.03 + 2E-7 + Vo x 1E-8) | 100 V |
| ±100 mA | 5 µA | 100 nA | ±(0.045 + 15E-6 + Vo x 1E-7) | ±(0.04 + 6E-6 + Vo x 1E-7) | [2] |

*1. ± (% of reading value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.)*

*2. 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.*

*3. Supplemental characteristics*

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

| Voltage range | Force resolution | Measure resolution | Force accuracy [1] ±(% + mV) | Measure accuracy [1] ±(% + mV) | Maximum current |
|---|---|---|---|---|---|
| ±0.5 V | 25 µV | 25 µV | ±(0.018 + 0.5) | ±(0.01 + 0.5) | 100 mA |
| ±2 V | 100 µV | 100 µV | ±(0.018 + 0.5) | ±(0.01 + 0.7) | 100 mA |
| ±5 V | 250 µV | 250 µV | ±(0.018 + 1) | ±(0.01 + 2) | 100 mA |
| ±20 V | 1 mV | 1 mV | ±(0.018 + 3) | ±(0.01 + 4) | 100 mA |
| ±40 V | 2 mV | 2 mV | ±(0.018 + 6) | ±(0.015 + 8) | [2] |
| ±100 V | 5 mV | 5 mV | ±(0.018 + 15) | ±(0.02 + 20) | [2] |

*1. ±(% of reading value + offset value in mV). Averaging is 128 samples in 1 PLC.*

*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)**

| Current range | Force resolution | Measure resolution | Force accuracy [1] ±(% + A + A) | Measure accuracy [1] ±(% + A + A) | Maximum voltage |
|---|---|---|---|---|---|
| ±10 nA [3] | 500 fA | 500 fA | ±(0.1 + 1E-9 + Vo x 4E-11) | ±(0.25 + 1E-9 + Vo x 4E-11) | 100 V |
| ±100 nA [3] | 5 pA | 5 pA | ±(0.05 + 1E-9 + Vo x 4E-11) | ±(0.1 + 1E-9 + Vo x 4E-11) | 100 V |
| ±1 µA [3] | 50 pA | 50 pA | ±(0.05 + 1E-9 + Vo x 4E-11) | ±(0.1 + 1E-9 + Vo x 4E-11) | 100 V |
| ±10 µA | 500 pA | 500 pA | ±(0.05 + 3E-9 + Vo x 4E-11) | ±(0.05 + 2E-9 + Vo x 4E-11) | 100 V |
| ±100 µA | 5 nA | 5 nA | ±(0.035 + 15E-9 + Vo x 1E-10) | ±(0.05 + 2E-8 + Vo x 1E-10) | 100 V |
| ±1 mA | 50 nA | 50 nA | ±(0.04 + 15E-8 + Vo x 1E-9) | ±(0.04 + 2E-7 + Vo x 1E-9) | 100 V |
| ±10 mA | 500 nA | 500 nA | ±(0.04 + 15E-7 + Vo x 1E-8) | ±(0.04 + 2E-6 + Vo x 1E-8) | 100 V |
| ±100 mA | 5 µA | 5 µA | ±(0.045 + 15E-6 + Vo x 1E-7) | ±(0.1 + 2E-5 + Vo x 1E-7) | [2] |

*1. ±(%of reading value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.)*

*2. 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.*

*3. Supplemental characteristics*

## 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) |

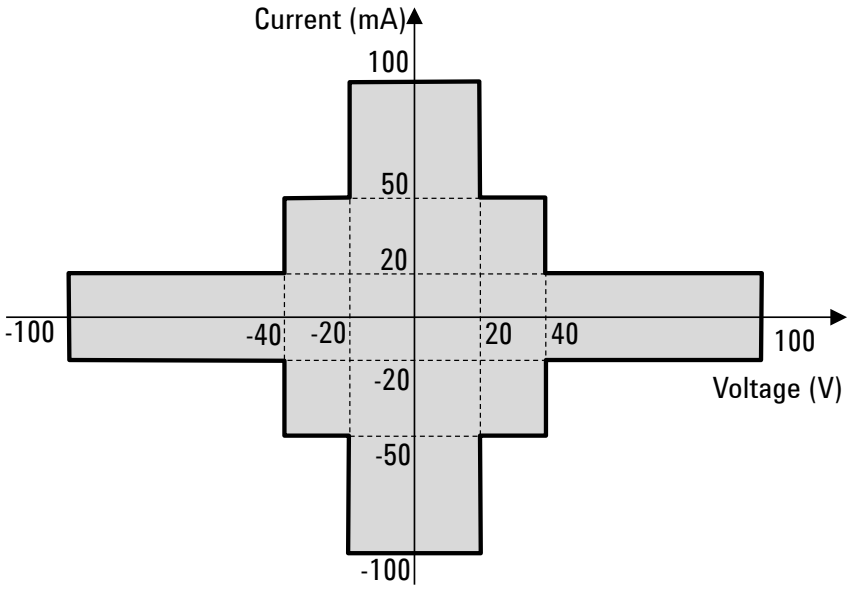
Where Ic is the current compliance setting.

**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 measurement and output range**



# MCSMU Gate Output / AUX Output Specifications

**Voltage range, resolution, and accuracy**

| Voltage range | Force resolution | Measure resolution | Force accuracy[1] ±(% + mV) | Measure accuracy[1] (% + mV + mV) | Maximum current |
|---|---|---|---|---|---|
| ±0.2 V | 200 nV | 200 nV | ±(0.06 + 0.14) | ±(0.06 + 0.14 + Io x 0.05) | 1 A |
| ±2 V | 2 µV | 2 µV | ±(0.06 + 0.6) | ±(0.06 + 0.6 + Io x 0.5) | 1 A |
| ±20 V | 20 µV | 20 µV | ±(0.06 + 3) | ±(0.06 + 3 + Io x 5) | 1 A |
| ±40 V[2] | 40 µV | 40 µV | ±(0.06 + 3) | ±(0.06 + 3 + Io x 10) | 1 A |

*1. ±(% of reading value + fixed offset in mV + proportional offset in mV). Note:Io is the output current in A.*

*2. Maximum output voltage is 30 V.*

**Current range, resolution, and accuracy**

| Current range | Force resolution | Measure resolution | Force accuracy[1] (% + A + A) | Measure accuracy[1] (% + A + A) | Maximum voltage |
|---|---|---|---|---|---|
| ±10 µA | 10 pA | 10 pA | ±(0.06 + 1E-8 + Vo x 1E-10) | ±(0.06 + 1E-8 + Vo x 1E-10) | 30 V |
| ±100 µA | 100 pA | 100 pA | ±(0.06 + 2E-8 + Vo x 1E-9) | ±(0.06 + 2E-8 + Vo x 1E-9) | 30 V |
| ±1 mA | 1 nA | 1 nA | ±(0.06 + 2E-7 + Vo x 1E-8) | ±(0.06 + 2E-7 + Vo x 1E-8) | 30 V |
| ±10 mA | 10 nA | 10 nA | ±(0.06 + 2E-6 + Vo x 1E-7) | ±(0.06 + 2E-6 + Vo x 1E-7) | 30 V |
| ±100 mA | 100 nA | 100 nA | ±(0.06 + 2E-5 + Vo x 1E-6) | ±(0.06 + 2E-5 + Vo x 1E-6) | 30 V |
| ±1 A[2] | 1 µA | 1 µA | ±(0.4 + 2E-4 + Vo x 1E-5) | ±(0.4 + 2E-4 + Vo x 1E-5) | 30 V |

*1. ±(% of reading value + fixed offset in A + proportional offset in A), Vo is the output voltage in V.*

*2. Pulse mode only. The maximum value of the base current during pulsing is ±50 mA.*

**Power consumption**

**Voltage source mode:**

| Voltage range | Power |
|---|---|
| 0.2 V | 40 x Ic (W) |
| 2 V | 40 x Ic (W) |
| 40 V | 40 x Ic (W) |

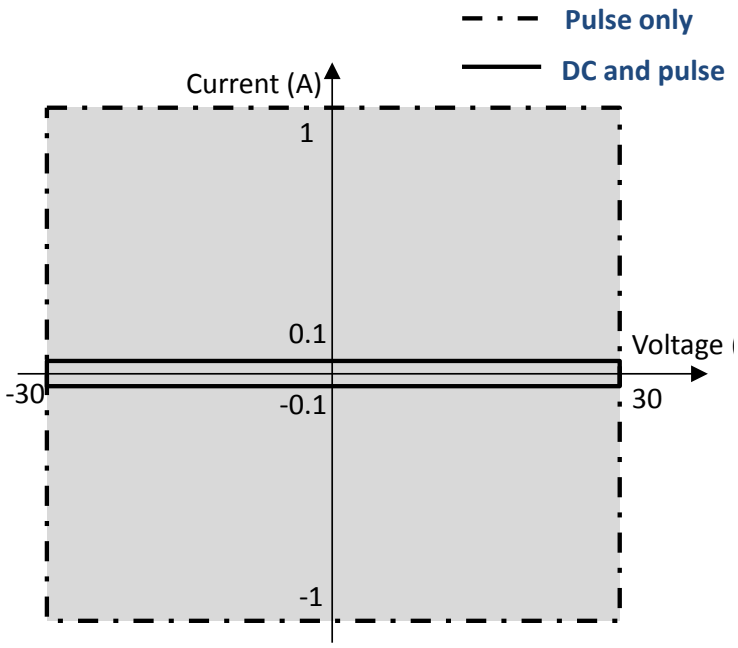
Where Ic is the current compliance setting.

**Current source mode:**

| Voltage compliance | Power |
|---|---|
| Vc ≤ 0.2 | 40 x Io (W) |
| 0.2 < Vc ≤ 2 | 40 x Io (W) |
| 2 < Vc ≤ 40 | 40 x Io (W) |

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

**MCSMU measurement and output range**



**SMU source measurement mode**

For MPSMU:
VFIM, IFVM

For HCSMU, MCSMU and HVSMU:
VFIM, VFVM, IFVM, IFIM

**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)
0 V to ±40 V (HCSMU)
0 V to ±30 V (MCSMU)
0 V to ±3000 V (HVSMU)

Current:
±10 pA to ±100 mA (MPSMU)
±10 nA to ±20 A (HCSMU)
±10 nA to ±1 A (MCSMU)
±10 pA to ±8 mA (HVSMU)

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

**Power compliance**

For MPSMU:
Power: 0.001 W to 2 W
Resolution: 0.001 W

For HCSMU:
Power: 0.001 W to 40 W (DC)
0.001 W to 400 W (Pulse)
Resolution: 0.001 W

For MCSMU:
Power: 0.001 W to 3 W (DC)
0.001 W to 30 W (Pulse)
Resolution: 0.001 W"

For HVSMU:
No power compliance

**SMU pulse measurement**

Pulse width, period, and delay:

For MPSMU:
Pulse width: 500 µs to 2 s
Pulse width resolution: 100 µs
Pulse period: 5 ms to 5 s
Period ≥ delay + width + 2 ms
(when delay + width ≤ 100 ms)
Period ≥ delay + width + 10 ms
(when delay + width > 100 ms)
Pulse period resolution: 100 µs
Pulse delay: 0 s

For HCSMU:
Pulse width:
50 µs to 1 ms (20 A range)
50 µs to 2 s (10 µA to 1 A range)
Pulse width resolution: 2 µs
Pulse period: 5 ms to 5 s
Pulse period resolution: 100 µs
Pulse duty:
For 20 A range: ≤ 1%
For 10 µA to 1 A range
Period ≥ delay + width + 2 ms
(when delay + width ≤ 100 ms)
Period ≥ delay + width + 10 ms
(when delay + width > 100 ms)
Pulse delay: 0 to (Period–width)

For MCSMU:
Pulse width:
10 µs to 100 ms (1 A range)
10 µs to 2 s (10 µA to 100 mA range)
Pulse width resolution: 2 µs
Pulse period: 5 ms to 5 s
Pulse period resolution: 100 µs
Pulse duty:
For 1 A range: ≤ 5%
For 10 µA to 100m A range
Period ≥ delay + width + 2 ms
(when delay + width ≤ 100 ms)
Period ≥ delay + width + 10 ms
(when delay + width > 100 ms)
Pulse delay: 0 to (Period–width)

For HVSMU:
Pulse width: 500 µs to 2 s
Pulse width resolution: 6 µs
Pulse period: 5 ms to 5 s
Period ≥ delay + width + 2 ms
(when delay + width ≤ 100 ms)
Period ≥ delay + width + 10 ms
(when delay + width > 100 ms)
Pulse period resolution: 100 µs
Pulse delay: 0 to (Period – width)
Pulse output limitation:
When the pulse voltage is more than 1500 volts, the peak and base of pulse should be same polarities.
Pulse measurement delay:
6 µs to (Period – pulse measurement time – 2 m) s,
6 µs resolution

# Supplemental Characteristics

**Current compliance setting accuracy**
(for opposite polarity):

For MPSMU:
- For 1 pA to 10 nA ranges:
  - V/I setting accuracy ±12% of range
- For 100 nA to 100 mA ranges:
  - V/I setting accuracy ±2.5% of range

For HCSMU and MCSMU:
- For 10 µA to 1 A ranges:
  - V/I setting accuracy ±2.5% of range
- For 20 A range (HCSMU):
  - V/I setting accuracy ±0.6% of range

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

**SMU pulse setting accuracy (fixed measurement range):**
For MPSMU:
- Width: ±0.5% ± 50 µs
- Period: ±0.5% ± 100 µs

For HCSMU and MCSMU:
- Width: ±0.1% ± 2 µs
- Period: ±0.1% ± 100 µs

For HVSMU:
- Width: ±0.1% ± 6 µs
- Period: ±0.5% ± 100 µs

**Minimum pulse measurement time:**
- 16 µs (MPSMU)
- 2 µs (HCSMU and MCSMU)
- 6 µs (HVSMU)

# 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

## 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 $mV_{rms}$)
Output impedance: 50 Ω, typical
Signal level monitor:
Range: 10 mVrms to 250 $mV_{rms}$
Accuracy:
±(10.0% of reading + 1 $mV_{rms}$) at the measurement port of the MFCMU
±(15.0% + 1 $mV_{rms}$)

## DC bias function

**DC bias:**
Range: 0 to ±25 V
Resolution: 1 mV
Accuracy: ±(0.5% + 5.0 mV)
at the measurement port

## Maximum DC bias current (Supplemental characteristics):

| 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

## 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.

$Z_X$: Impedance measurement value (Ω)
$D_X$: Measurement value of D
$E = E_P' + (Z_S'/|Z_X| + Y_0'|Z_X|) \times 100$ (%)
$E_P' = E_{PL} + E_{POSC} + E_P$ (%)
$Y_0' = Y_{0L} + Y_{OSC} + Y_0$ (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

| 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 $mV_{rms}$*
   *At four-terminal pair port of MFCMU*

# Test fixture specification

There are 3 types of test fixtures available for B1506A depending on the selected option.

### Functionality

Fixture capability

Current expander capability (H51/ H71)

Selector capability

This allows the user to switch the output between the HVSMU, MPSMU and UHCU or HCSMU.

Thermocouple input: 2ea
Two K-type thermocouple inputs
Temperature range: -50 °C to 300 °C.

| Thermocouple reading accuracy | |
|---|---|
| **Temperature range** | **Accuracy** |
| 0°C <= T < 100° C | +/-2°C |
| T>= 100° C | +/-5°C |
| T< 0° C | +/-5°C |

### Other Terminals/Indicators

Power indicator: 1ea.
High voltage indicator: 1ea.
Measurement mode indicator:
IV mode: 1ea.
CV mode: 1ea.
Interlock terminal: 1ea.
Earth terminal: 1ea.
Wrist strap terminal: 1ea.

# Software interfaces

The B1506A is equipped with a software suite for power device characterization (herafter referred to as the B1506A software suite). It supports various types of measurements and provides with easy-to-use and simple operation. The B1506A software GUI can be accessed via its front panel 15-inch touch screen, softkeys and rotary knob, as well as through an optional USB keyboard and mouse. Measurement setups and data can be stored on the B1506A's HDD, and they can be exported to external storage. The B1506A also supports Agilent EasyEXPERT software, a well-proven software interface for the B1500A and B1505A.

## B1506A software suite

### Key features:

- Dedicate software for;
  - Datasheet characterization
  - I/V characteristics measurement
  - Three-terminal device capacitance measurement
  - Gate charge measurement
  - Thermal monitor/control
  - Device power loss calculation
- Ready-to-use measurement templates for typical power device characteristics measurements
- ability to automatically accumulate measurement data on the HDD in exportable formats

### Software palette:

The Software Palette provides a complete list of the B1506A's measurement software and also allows this software to be launched. The Software Palette is displayed in full-screen mode after powering up the B1506A. The Software Palette can be minimized to access the Windows desktop.

### Datasheet characterization software:

The datasheet characterization software provides:

- A simple operating environment that can measure a range of device parameters and characteristics using a familiar datasheet-like format
  - The ability to input measurement conditions in a datasheet-like format
  - The ability to specify graphical limits on sweep measurements
  - Display measured parameters and characteristics in a datasheet-like format
  - The ability to compare measurement results with expected values
- Minimal software learning curve for device characterization using the pre-defined measurement templates
  - Furnished measurement templates are user-customizable
- The ability to effectively generate new datasheet specifications for operating conditions not covered on the manufacturer's datasheet

### IV measurement software:

I/V Measurement Software provides:

- Voltage/current sweep/spot measurements
- DC/pulse outputs
- Linear/log sweep with both single (one-way) and double (round-trip) capability for the primary sweep source (similar to the collector supply of a conventional curve tracer)
- Linear/list sweep capability for the secondary sweep source (corresponding to the step generator of a conventional curve tracer)
- The ability to assign the primary sweep source or the secondary sweep source to either the collector/drain terminal or to the base/gate terminal.
- Intuitive and interactive sweep/spot measurement operation using rotary knob.
- Pre-defined templates for typical MOSFET, IGBT and Diode I/V measurements.

### Oscilloscope View:

I/V Measurement Software supports the pulse mode Oscilloscope View function. Oscilloscope View provides:

- Both voltage and current waveform monitoring for the measurement channels of all supported modules

Oscilloscope View supports the following modules:

- MCSMU
- HVSMU
- HCSMU
- UHCU
- HVMCU
- UHVU

### Capacitance measurement software:

Capacitance measurement software provides:

- Automated measurement circuit configuration for three-terminal device capacitance measurement (e.g. Ciss, Coss and Crss), with no need to manually modify any device connections
  - With DC bias (sweep) control up to 3kV for Collector/Drain terminal
  - With DC bias (sweep) control up to 100V for Base/Collector terminal
- Automated correction for every measurement path
- Stable measurements even if the low-side load capacitance changes due to a bias change (load adaptive gain-phase compensation)
- Cancellation of the residual inductance measurement error on the AC guard path of three-terminal device capacitance measurements
- Pre-defined templates for typical capacitance measurements of both enhancement and depletion type MOSFETs, IGBTs and Diodes

### Gate charge measurement software:

Gate charge measurement Software provides;

- Support for both constant current load mode and resistive load mode
- Correction of for parasitic capacitance and residual resistance for in the gate path
- Monitoring of gate and drain/ collector voltage/ and current waveforms during the device turn-on periodphase
- JESD24-2 compliant Qg curve, line fitting and parameter extraction

### Thermal monitor/control software:

Thermal monitor/control software provides;

- Thermometer indication
- Thermal profile with measurement triggers
  - Optional control of Thermal Plate

### Power loss calculation software:

Power loss calculation software provides:

- Calculation of power loss at a switching device for:
  - Hard switching mode
  - Soft switching mode
- Device characteristics parameter input for:
  - Gate resistance
  - On resistance
  - Gate charge
  - Gate switching charge
  - Equivalent output capacitance energy related
  - Equivalent output capacitance time related
  - Parameter input assist from related measurement data with;
    - Display of source measurement data
- Switching condition parameter input
  - Support of parameter sweep for one parameter
- Power loss calculation results of;
  - Total power loss
  - Conductive power loss
  - Driving power loss
  - Switching power loss (inductive load)
  - Coss switching power loss (energy related)
  - Graph representation of loss components for optional parameter sweep
- Switching time (for resistive load) calculation results of;
  - Turn-on delay time
  - Turn-on rise time
  - Turn-off fall time
  - Turn-off delay time
  - Turn-on cross switching
  - Turn-off cross switching

## Agilent EasyEXPERT software

### Key features:

- Ready-to-use application test library
- Multiple measurement modes (application test, classic test, tracer test, oscilloscope view and quick test)
- Multiple measurement functions (spot, sweep, time sampling, C-V, C-f, C-t, etc.)
- Data display, analysis and arithmetic functions
- Workspace and data management
- External instrument control
- Multiple programming methods (EasyEXPERT remote control and FLEX GPIB control)
- Multiple interface (USB, LAN, GPIB and digital I/O)

### Key features:

EasyEXPERT comes with over 40 application tests conveniently organized by device type, application, and technology.

### Operation mode:

- Application test mode
- Classic test mode
- Tracer test mode
- Quick test mode

### Measurement mode:

•IV measurement
- Spot
- Staircase sweep
- Pulsed spot
- Pulsed sweep
- Staircase sweep with pulsed bias
- Sampling
- Multi-channel sweep
- Multi-channel pulsed sweep
- List sweep

- Linear search[1]
- Binary search[1]

• C measurement
- Spot C
- CV (DC bias) sweep
- Pulsed spot C
- Pulsed sweep CV
- C-t sampling
- C-f sweep
- CV (AC level) sweep
- Quasi-Static CV (QSCV)

*1. Supported only by FLEX commands.*

## Common specification for software interfaces

### Sweep measurement

Number of steps: 1 to 10001 (SMU), 1 to 1001 (CMU)
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 65.535 s, 100 µs resolution
0 to 655.35 s, 100 µs resolution
(CV (AC level) sweep, C-f sweep)
Step delay time:
0 to 1 s, 100 µs resolution
Step output trigger delay time:
0 to (delay time) s, 100 µs resolution
Step measurement trigger delay time:
0 to 65.535 s, 100 µs resolution

### Sampling (time domain) measurement [1]

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 to 2ms, 10µs resolution
2 ms to 65.535 s, 1 ms resolution
For < 2ms, 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

*1. Supported only by EasyEXPERT and FLEX commands.*

### 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

**Standby mode** [1]
SMUs in "Standby" remain programmed to their specified output value even as other units are reset for the next measurement.

**Bias hold function** [1]
This function allows you to keep a source active between measurements. The source module will apply the specified bias between measurements when running classic tests inside an application test, in quick test mode, or during a repeated measurement. The function ceases as soon as these conditions end or when a measurement that does not use this function 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** [1]
The B1506A supports a time stamp function utilizing an internal quartz clock.
Resolution: 100 µs

*1. Supported only by EasyEXPERT and FLEX commands.*

## Data display, analysis and arithmetic functions

### Data Display

**X-Y graph plot**
X-axis and up to eight Y-axes, linear and log scale, real time graph plotting. X-Y graph plot can be printed or stored as image data to clip board or mass storage device. (File type: bmp, gif, png, emf)
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
Overlay graph comparison:
Graphical plots can be overlaid.

**List display**
Measurement data and calculated user function data are listed in conjunction with sweep step number or time domain sampling step number. Up to 20 data sets can be displayed.

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

### 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.

**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.

## Arithmetic 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: Boltzmann'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 ($10^{15}$)

# General specifications

### 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)
B1506A mainframe: 900 VA
B1506A tesf fixture: 130VA (H21), 470 VA (H51/H71),

### Acoustic Noise Emission
Lpa < 55dB

Lwa:55dB (Operating mode)

Lwa:73dB (Worst Case mode)

### 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 Vrms in the frequency range of 150 kHz to 80 MHz. The extent of this effect depends upon how the instrument is positioned and shielded.

### Regulatory compliance
EMC:
- IEC 61326-1 / EN 61326-1
- Canada: ICES/NMB-001
- AS/NZS CISPR 11

Safety:
- IEC61010-1 / EN 61010-1
- CAN/CSA-C22.2 No. 61010-1

### Certification
CE, cCSAus, C-Tick, KC

### Dimensions
B1506A mainframe:
420 mm W x 330 mm H x 575 mm D
B1506A test fixture:
420 mm W x 360 mm H x 575 mm D

### Weight
B1506A mainframe
H21: 34.5 kg
H51/H71: 35 kg

B1506A test fixture
H21: 22 kg
H51/H71: 33.5 kg

### Furnished accessories
Measurement cables and adapter
System cable, 1 ea.
CMU cable, 1 ea
Digital I/O cable, 1 ea.
Blank Silicon Plate, 1 ea.
3-pin Inline Package Socket Module, 1 ea
Gate Charge Socket Adapter, 1 ea.
Thermocouple (high temperature resistant, 75 cm), 2 ea.
200 mm high current cable, 2 ea.
300 mm high current cable, 2 ea.
200 mm normal cable, 8 ea.
300 mm normal cable, 6 ea.
Banana pin adapter, 18 ea.
Mini alligator clip, 14 ea.
Large clip, 4 ea.

Keyboard, 1 ea.
Mouse, 1 ea.
Stylus pen, 1 ea.
Power cable, 2 ea.
Manual & Software CD-ROM, 1 ea.
Disk set for Agilent 4155B/4155C/4156B/4156C firmware update, 1 set

*1. In case of some supplemental characteristics, humidity range is defined as 20% to 50% RH*

# Ordering Information

| Model number | Option | Description |
|---|---|---|
| B1506A | | Power Device Analyzer for Circuit Design |
| | H21 | 20 A/3 kV/C-V/Gate Charge/Thermal Fixture Package |
| | H51 | 500 A/3 kV/C-V/Gate Charge/Thermal Fixture Package |
| | H71 | 1500 A/3 kV/C-V/Gate Charge/Thermal Fixture Package |
| | Thermal enclosure | |
| | T01 | Thermal Test Enclosure (Thermostream Compatible) |
| | Documentation | |
| | ABA | English User's Guide |
| | ABJ | Japanese User's Guide |
| | Calibration | |
| | UK6 | Commercial calibration certificate with test data |
| | A6J | ANSI Z540-1-1994 Calibration |
| | Drive option | |
| | DR1 | Replace A Built-in DVD-R Drive With A Read-only DVD Drive |
| B1506AU | | Upgrade kit for B1506A |
| | Current upgrade | |
| | 005 | 20 A to 500 A Current Upgrade Option |
| | 015 | 500 A to 1500 A Current Upgrade Option |
| | Accessories | |
| | T01 | Thermal Test Enclosure (Thermostream Compatible) |
| | F02 | Blank Silicon Plate |
| | F10 | 3-pin Inline Package Socket Module |
| | F14 | Gate Charge Socket Adapter |

*Note: Both Thermostream and Thermal plate (HP289) are sold and supported by inTEST corporation.*

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Published in USA,April 18, 2014
5991-4441EN

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