

**2308**

# Portable Device Battery/Charger Simulator



The Model 2308 Portable Device Battery/Charger Simulator is optimized for use in testing mobile phones and other portable, battery-operated devices. When a device-under-test (DUT) transitions nearly instantaneously from a sleep or standby mode to the full power transmit state, the Model 2308's rapid response to load changes means there's little transient voltage drop from the programmed output voltage and the output recovers quickly. This fast response is particularly critical when testing portable devices with a pulsed mode of operation because it allows the device to perform properly while it's being tested. In contrast, the slow-responding source voltage typical of conventional power supplies causes the DUT to perform improperly, leading to production yield problems and costly retesting.

- **Specialized dual-channel power supply for design and testing of portable, battery-operated devices**
- **Ultra-fast response to pulsed load operation**
- **Speed-optimized command set reduces test times**
- **Variable output resistance for simulating an actual battery's output response**
- **Simulate a discharged battery and test charge control circuit performance with both a battery supply that can sink up to 3A and a charger supply**
- **Pulse peak, average, and baseline current measurements**
- **Integrating A/D converter for more precise measurements**
- **100nA current measurement sensitivity**
- **Analog output for complete load current waveform characterization**
- **Catch production wiring problems immediately with open sense-lead detection**
- **Built-in digital voltmeter**
- **Four built-in digital control lines**

The Model 2308 offers a complete solution for portable device sourcing and load current measurement. It has two independent power supply channels: one is optimized to simulate a battery; the second channel is optimized to perform like a charger for a rechargeable battery. The battery channel's variable output resistance can be used to simulate the internal resistance of a battery so design and test engineers can simulate a battery's output for testing devices under realistic operating conditions. This channel also sinks current to simulate a discharged battery. The charger channel can supply a voltage to test a portable device's battery charge control circuitry, with the battery channel acting as the discharged battery load.

In addition to maintaining output voltage levels under difficult load conditions, the Model 2308 can measure a wide dynamic range of load current levels and can measure narrow current pulses (or pulses as narrow as 50 $\mu$ s). That makes it ideal for characterizing device power consumption by making low-level sleep mode measurements as well as pulsed operating load currents.

## Maximize production yield with fast response to load changes

Mobile phones, other portable devices (such as Bluetooth headsets, MP3 players, etc.), and RF components such as power amplifiers, power transistors, and transmitter modules experience large instantaneous load changes when they transition from a standby state to full power operation. For a mobile phone, the load current can change from a 100mA standby current to a 1A transmission current or a 10 $\times$  (1000%) increase in the load current. The Model 2308 maintains a reliable, stable level of voltage output, even when the DUT produces large load current changes and/or has a pulsed operating mode.

The Model 2308's fast recovery from load changes helps prevent the causes of false failures and destroyed devices in production test as well as field failure quality problems due to compromised components. The Model 2308 assures you of a stable, constant voltage source to maximize production yield and minimize production retest and rework costs.

## APPLICATIONS

- **Design and test of a wide range of consumer electronics, including:**
  - **Mobile phones, mobile radios, cordless phones, and Bluetooth headsets**
  - **MP3 players, portable digital assistants (PDAs), digital cameras, GPS receivers, and notebook computers**
- **Design and test of electronic components such as RFIC power amplifiers, RF power transistors, and baseband and wireless chipsets for portable wireless devices**

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Fast transient response power supply

SPECIALIZED POWER SUPPLIES

# 2308

## Ordering Information

**2308 Portable Device Battery/Charger Simulator**

**Accessories Supplied**  
CD with documentation,  
output connectors mating  
terminal (part no. CS-846)

### ACCESSORIES AVAILABLE

- |  |  |
|--|--|
| 2306-DISP                                  | Remote Display   |
| SC-182                                     | Low Inductance Coaxial Cable   |
| <b>IEEE-488 INTERFACE CONTROLLER CARDS</b> |  |
| KPCI-488LPA                                | IEEE-488.2 Interface Board for the PCI bus   |
| KPXI-488                                   | IEEE-488 Interface Board for the PXI bus   |
| KUSB-488A                                  | IEEE-488.2 USB-to-GPIB Interface Adapter for USB Port with built-in 2m (6.6ft) cable |

### IEEE-488 INTERFACE CABLES

- |         |  |
|---------|--|
| 7007-05 | Double Shielded Premium IEEE-488 Cable, 0.5m (1.6ft) |
| 7007-1  | Double Shielded Premium IEEE-488 Cable, 1m (3.2ft)   |
| 7007-2  | Double Shielded Premium IEEE-488 Cable, 2m (6.5ft)   |
| 7007-3  | Double Shielded Premium IEEE-488 Cable, 3m (10ft)    |
| 7007-4  | Double Shielded Premium IEEE-488 Cable, 4m (13ft)    |

### RACK MOUNT KITS

- |        |                             |
|--------|-----------------------------|
| 4288-1 | Single Fixed Rack Mount Kit |
| 4288-2 | Dual Fixed Rack Mount Kit   |

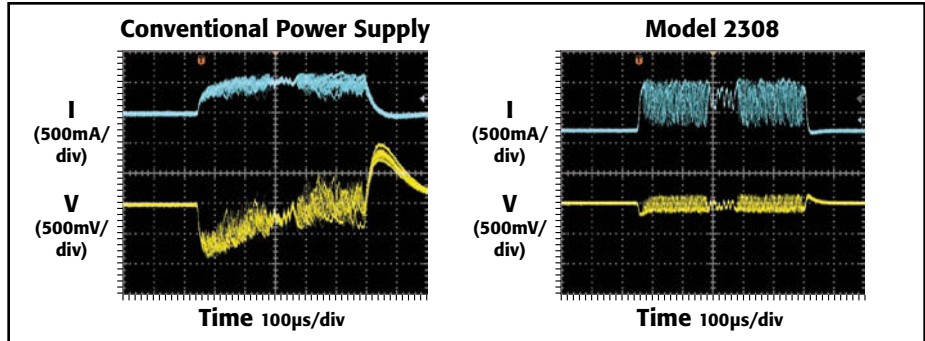
### SERVICES AVAILABLE

- |               |   |
|---------------|---|
| 2308-3Y-EW    | 1-Year Factory Warranty Extended to 3 Years for the Model 2308    |
| 2308-3Y-17025 | 3 (ISO-17025 Accredited) Calibrations within 3 Years of Purchase  |
| 2308-3Y-DATA  | 3 (ANSI-Z540-1 Compliant) Calibrations within 3 Years of Purchase |

### Model 2308 vs. Conventional Power Supplies

Large load changes will cause a large instantaneous drop in a conventional power supply's voltage output. If the supply's recovery time is long, the DUT will turn off when the supply voltage falls below the DUT's low battery turn-off threshold—**producing a false failure**. Even if the DUT does not turn off, the drop-off in input power prevents the output (RF or a power pulse) from meeting its specification—a **specification failure**. Furthermore, the conventional power supply may have an excessively large overshoot when the DUT's load current transitions from its operating load back to its standby load. The magnitude of the transient overshoot voltage could even be large enough to exceed the maximum safe input voltage, either rendering the device inoperable or damaging some components—a **device failure or a field failure**.

# Portable Device Battery/Charger Simulator



Compare the response of a conventional power supply (left) with the response of a Model 2308 (right) when both are powering a device operating on the EDGE mobile phone standard. Note how the conventional power supply distorts the load current and cannot maintain a stable source voltage, which in turn distorts the RF output signal.

### Reduce test costs and increase throughput with high speed command structure

To minimize production test times while still giving you all the information you need to characterize your devices fully, the Model 2308 is designed with a command structure optimized for speed, with voltage step times as short as 6ms and DC load current measurements in just 22ms. Commands that combine range changing and current measurement let you acquire the command, make the measurement, and transfer the data in as little as 30ms. In addition, special operating modes, such as the pulse current step

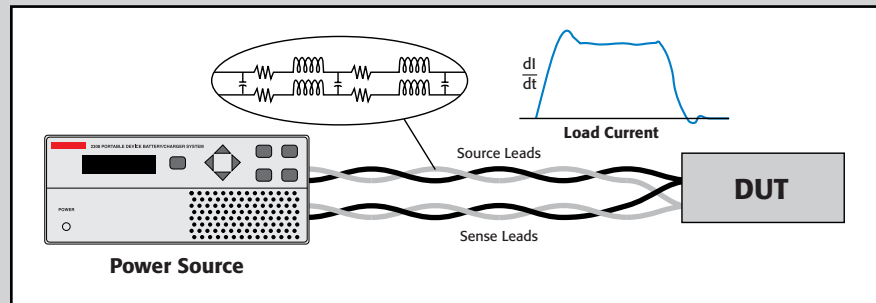
mode, allow taking a number of measurements on a complex load current waveform with a single command.

### Characterize load currents for power consumption verification

Characterizing the battery life of portable devices demands the ability to measure complex current waveforms over a wide dynamic range. The Model 2308 offers a far broader range of capabilities than conventional power supplies for measuring low current levels, peak pulse current levels, long-period load current waveforms, and multi-level current waveforms. A choice of four

### Your DC source leads are a transmission line when your portable device operates in a narrow pulsed mode.

Under pulsed operating conditions, your load circuit is an L-C-R network and that load impedance can cause problems for your power supply. Keithley's fast transient power supplies are designed to maintain a stable voltage under difficult, narrow pulse, loading conditions and to maintain the output voltage, even with long lengths of wire between the power supply and the DUT. The design of your DC sourcing test circuit requires just as much effort as your AC or RF test circuits. Using a fast transient response, battery simulating power supply needs to be a key part of your DC test circuit design.



The DC source leads become a transmission line during dynamic load swings.

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ranges (5mA, 50mA, 500mA, and 5A) allows measuring load currents with exceptional resolution and accuracy.

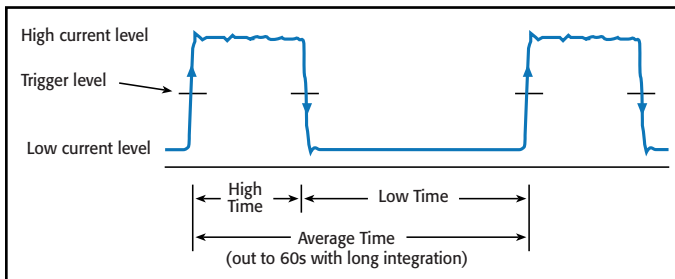
### Measure sleep and standby currents with the accuracy of integrating A/D technology

The Model 2308 is designed for fast and accurate measurements of devices in low power modes such as the sleep, hibernate, or standby state. It can resolve currents down to 100nA and measure them with 0.2% accuracy. The Model 2308 uses an integrating A/D converter that continuously acquires the signal rather than capturing discrete samples; this provides a more accurate measurement than other A/D techniques. In addition, the averaging effect built into integrating A/D converters reduces noise and delivers highly stable current readings. You can measure low and high currents at the same speed with no degradation in accuracy, so the Model 2308 is equally well-suited for the test line and the design lab.

### Measure load currents from pulsed-output devices

Devices like GSM-, EDGE-, WLAN-, and WiMAX-based mobile phones generate pulsed outputs. Determining their total power consumption requires measuring both the baseline current and the peak of the pulsed load current. The Model 2308 can capture peak currents of pulses as short as 50 $\mu$ s and as long as 833ms. Programmable trigger levels allow controlled capture of the pulse, then the Model 2308's programmable measurement delay and acquisition times make it easy to avoid rising edge transients so the pulse peak can be measured accurately. The instrument can also measure the pulse baseline current and the pulse average load current.

A long integration current mode supports measuring pulse trains with periods longer than 850ms. In this mode, the Model 2308 can measure average current on a load current waveform with a period from 850ms to 60 seconds.

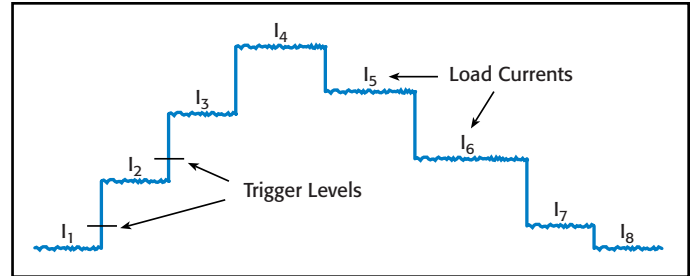


The Model 2308 can measure peak pulse currents, average currents, and baseline currents.

### Take multiple measurements on start-up sequences or on current levels at different voltage operating levels

Need to analyze a device's circuitry during the power-up phase as it transitions from a sleep mode or an off-state? The Model 2308's pulse step current function has the speed needed to measure the load current start-up levels in a single device start-up so that the measurements can be performed in production without an increase in test time.

The pulse step current function also offers a fast way to determine load currents of different operating states. For example, as source voltage levels are varied over a device's operating range, the corresponding operating current levels can be measured without executing multiple commands for



With a single command, the Model 2308's high speed pulse step current function can quickly capture varying load current levels to speed test throughput.

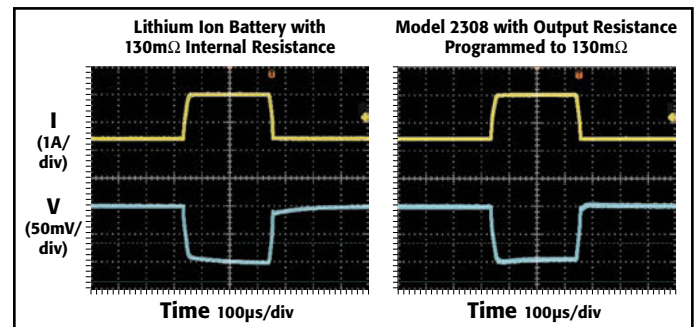
a significant time-savings when testing integrated circuits over their allowable range of Vcc levels.

### Capture the complete load current waveform

Two built-in analog outputs help designers of device's verify design performance and ensure its current draw conforms to design specifications without the need to connect any sensing circuitry in the power supply circuit. Once these outputs are connected to an oscilloscope or a data acquisition module, the load current waveform can be displayed or digitized and analyzed in a computer. When the Model 2308 is connected to a data acquisition module, the data acquisition module can sample the waveform at any sampling rate to create a record of any length desired.

### Test under realistic conditions with true battery simulation

When a portable battery-operated device transitions from one load current level to another, the battery voltage supplying the current will drop by the product of the change in current and the battery's internal resistance. During the load current pulse, the device must operate with a voltage reduced by the battery's internal resistance. The Model 2308 allows simulating this resistance so its output is almost identical to a battery's output, allowing design or production test engineers to test devices or components under realistic conditions. This patented<sup>1</sup> technique permits the output resistance to be programmed between 0 $\Omega$  and 1 $\Omega$  with 10m $\Omega$  resolution. You can also decrease the voltage and increase the output resistance while the output is on to simulate the discharge of the battery.

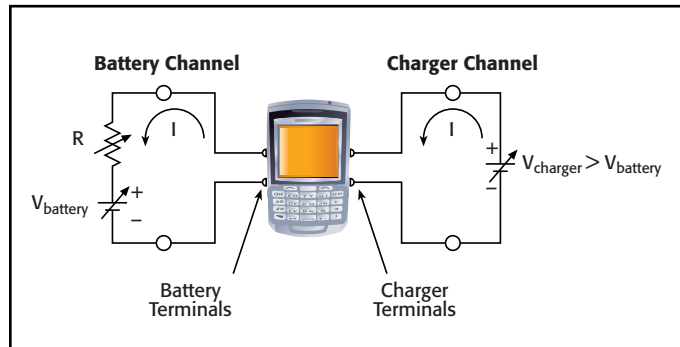


The Model 2308's programmable output resistance (right) allows it to simulate the output of a real battery (left), a capability conventional power supplies do not have. The 2308 output is identical to the battery's response.

1. U.S. Patent Number 6,204,647 B1

**Test a device's charge control circuitry**

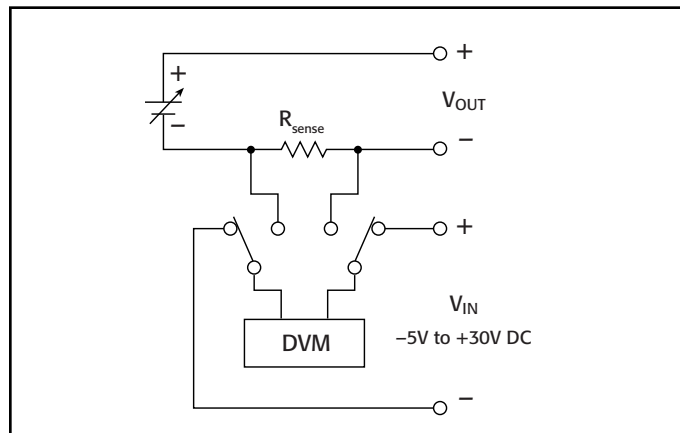
Both channels of the Model 2308 sink up to 3A of current continuously. Therefore, the battery channel can act like a discharged re-chargeable battery. The charger channel can supply a charging voltage for use in testing the operation of the DUT's charging circuitry. Because the charger channel can also act as an electronic load, the battery channel can operate the device and the charger channel can act as a load to test a battery capacity monitor or some other device function that requires a load.



For charger control circuit testing, the Model 2308's battery channel can sink current to simulate a discharged battery while the charger channel simulates a charger. One instrument provides high versatility for portable device testing.

**Reduce testing errors and retesting costs with remote sense lead monitoring**

Remote sensing capabilities let the Model 2308 ensure the voltage programmed is what is actually applied to the load. As DUTs are continuously inserted and removed from test fixtures, the instrument ensures this programmed voltage is maintained with an open sense lead detection monitor—any break in a sense lead connection is detected immediately. The open sense lead detection monitor eliminates the possibility that numerous devices could be tested or calibrated at an incorrect voltage.



The Model 2308's charger channel contains a built-in DVM, eliminating the need for a separate instrument in many test systems.

**Save with multiple instruments in one package – two power supplies, a DVM, digital controls, and a remote display**

The Model 2308 saves on both instrumentation costs and rack space by packing two independent power supply channels in one compact, 2U half-rack enclosure, along with additional capabilities power supplies rarely offer. For example, the built-in DC digital voltmeter can measure voltages in the DUT circuitry from -5VDC to +30VDC. The DVM and the battery channel voltage source can operate simultaneously. For many applications, the Model 2308 can eliminate the need for a separate DMM.

The digital outputs the Model 2308 provides can sink up to 100mA to control relays. External relays can be powered either by the internal 5V source or an external source with a maximum voltage of 24V. For applications that require only a few digital control lines, the Model 2308 eliminates the need for an additional control module.

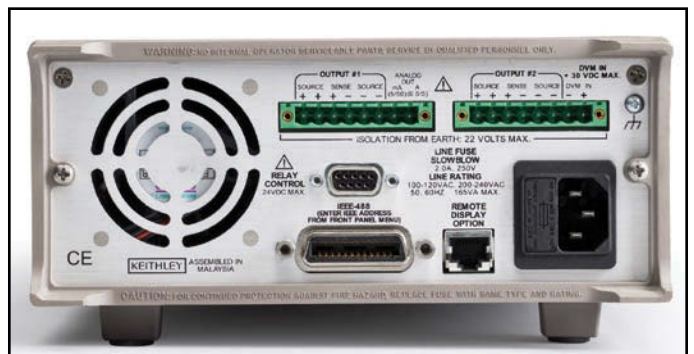
Need to reduce your test system size or want more system organization flexibility? Then mount the Model 2308 in the back of a test rack or near the test fixture—mounting the instrument in the test rack is unnecessary. The Model 2308's tiny (4.6 in. × 2.7 in.) remote display can be mounted anywhere for easy viewing of the outputs of both channels. If the Model 2308 is inaccessible, you can control it from the remote display because it has all the front panel pushbuttons that are on the instrument itself.



The Model 2306-DISP display can be mounted for easy viewing when the instrument itself must be mounted in an inaccessible location.

**Reduce test system problems with low impedance cable**

Keithley's SC-182 Low Inductance Coaxial Cable is designed to minimize the impedance and reduce the susceptibility to external EMI in your DC source-DUT circuit. This cable's characteristic impedance is nominally 15Ω with a low 42nH/ft of inductance and a low 182pF/ft of capacitance. In contrast, a typical coaxial cable has 50Ω or 75Ω characteristic impedance and twisted-wire pairs have at least 80Ω of characteristic impedance.



Model 2308 rear panel



**OUTPUT #1 (Battery Channel):****DC VOLTAGE OUTPUT (1 Year, 23°C ± 5°C)**

OUTPUT VOLTAGE: 0 to +15VDC.

OUTPUT ACCURACY: (0.05% + 3mV).

PROGRAMMING RESOLUTION: 1mV.

READBACK ACCURACY<sup>1</sup>: ±(0.05% + 3mV).

READBACK RESOLUTION: 1mV.

OUTPUT VOLTAGE SETTLING TIME: 5ms to within stated accuracy.

LOAD REGULATION: 0.01% + 2mV.

LINE REGULATION: 0.5mV.

STABILITY<sup>2</sup>: 0.01% + 0.5mV.MEASUREMENT TIME CHOICES: 0.002 to 10PLC<sup>3</sup>, in 0.002PLC steps.

AVERAGE READINGS: 1 to 10.

TRANSIENT RESPONSE: High Bandwidth Low Bandwidth

Transient Recovery Time<sup>4</sup> <35 μs<sup>5</sup> <50 μs<sup>5</sup>Transient Voltage Drop <90 mV<sup>5</sup> <180 mV<sup>5</sup>

REMOTE SENSE: 1V max. drop in each lead. Add 2mV to the voltage load regulation specification for each 1V change in the negative output lead due to load current change. Remote sense required. Integrity of connection continually monitored. If compromised, output will turn off automatically once settable window (±0 to ±8 volts) around normal voltage exceeded.

VARIABLE OUTPUT IMPEDANCE: Range: 0 to 1.00Ω in 0.01Ω steps. Value can be changed with output on.

- At PLC (Power Line Cycle) = 1.
- Following 15 minute warm-up, the change in output over 8 hours under ambient temperature, constant load, and line operating conditions.
- PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.
- Recovery to within 20mV of previous level.
- Remote sense, at terminals 1 and 6, with 4.5m (15 feet) 16 AWG (1.31mm<sup>2</sup>) twisted pair, with 1.5A load change, (0.15A to 1.65A) resistive load only, typical.

**DC CURRENT (1 Year, 23°C ± 5°C)****CONTINUOUS AVERAGE OUTPUT CURRENT**

CHANNEL #2 (CHARGER) OFF:

I = 50W/(V<sub>set</sub> channel 1 + 6V); 5A max.<sup>1</sup>

CHANNEL #2 (CHARGER) ON:

I = (50W – power consumed by channel #2)/(V<sub>set</sub> channel 1 + 6V); 5A max.<sup>1</sup>

The power consumed by channel #2 is calculated as:

Channel #2 Sourcing Current: Power consumed = (V<sub>set</sub> channel 2 + 6V) × (current supplied).

Channel #2 Sinking Current: Power consumed = 5V × (sink current).

**CONTINUOUS AVERAGE SINK CURRENT**

CHANNEL #2 (CHARGER) OFF:

0–5V: 3A max.

5–15V: Derate 0.2A per volt above 5V. Compliance setting controls sinking.

CHANNEL #2 (CHARGER) ON:

Available Current = (50W – Power consumed by channel #2)/5V; 3A max. (0–5V).

Derate 0.2A per volt above 5V.

**DC CURRENT (1 Year, 23°C ± 5°C) (continued)**SOURCE COMPLIANCE ACCURACY: ±(0.16% + 5mA).<sup>2</sup>

PROGRAMMED SOURCE COMPLIANCE RESOLUTION: 1.25mA.

READBACK ACCURACY: 5A Range: ±(0.2% + 200μA).

500mA Range: ±(0.2% + 100μA).

50 mA Range: ±(0.2% + 5μA).

5mA Range: ±(0.2% + 2μA).

READBACK RESOLUTION: 5A Range: 100μA.

500mA Range: 10μA.

50 mA Range: 1μA.

5mA Range: 0.1μA.

LOAD REGULATION: 0.01% + 1mA.

LINE REGULATION: 0.5mA.

STABILITY: 0.01% + 50μA.

MEASUREMENT TIME CHOICES: 0.002 to 10 PLC<sup>3</sup>, in 0.002PLC steps.

AVERAGE READINGS: 1 to 10.

- Peak current can be a max. of 5A provided the average current is within the stated limits and terminals 1 and 6 are used.
- Minimum current in constant current mode is 6mA.
- PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.

**PULSE CURRENT MEASUREMENT OPERATION**

TRIGGER LEVEL: 5A Range: 0A to 5A, in 5mA steps.

500mA Range: 0mA to 500mA, in 0.5mA or 500μA steps.

50mA Range: 0mA to 50mA, in 0.05mA or 5μA steps.

5mA Range: 0mA to 5mA, in 0.005mA or 5μA steps.

TRIGGER DELAY: 0 to 100ms, in 10μs steps.

INTERNAL TRIGGER DELAY: 10μs.

HIGH/LOW/AVERAGE MODE:

Measurement Aperture Settings: 33.3μs to 833ms, in 33.3μs steps.

Average Readings: 1 to 100.

PULSE CURRENT MEASUREMENT ACCURACY<sup>1</sup> (1 Year, 23°C ± 5°C):

Accuracy ±(% reading + offset)

Aperture	5A Range	500mA Range	50mA Range	5mA Range
<100 μs	0.3% + 2 mA	0.3% + 1 mA	0.3% + 700 μA	0.3% + 200 μA
100 μs – 200 μs	0.3% + 2 mA	0.3% + 1 mA	0.3% + 700 μA	0.3% + 100 μA
200 μs – 500 μs	0.3% + 2 mA	0.3% + 1 mA	0.3% + 700 μA	0.3% + 100 μA
500 μs – <1 PLC	0.3% + 900 μA	0.3% + 900 μA	0.3% + 500 μA	0.3% + 90 μA
1 PLC <sup>2</sup>	0.3% + 900 μA	0.3% + 900 μA	0.3% + 200 μA	0.3% + 90 μA
>1 PLC	0.3% + 900 μA	0.3% + 900 μA	0.3% + 200 μA	0.3% + 90 μA

- Based on settled signal: 100μs pulse trigger delay.
- Also applies to other apertures that are integer multiples of 1PLC.

**BURST MODE CURRENT MEASUREMENT**

MEASUREMENT APERTURE: 33.3μs to 833ms, in 33.3μs steps.

CONVERSION RATE: 4100/second, typical.<sup>1</sup>

INTERNAL TRIGGER DELAY: 10μs.

NUMBER OF SAMPLES: 1 to 5000.

TRANSFER SAMPLES ACROSS IEEE BUS IN BINARY MODE<sup>2</sup>: 4400 readings/s, typical (4 bytes per reading).

- At 33.3μs aperture.
- Display off, Message Exchange Protocol (MEP) off, auto zero off.

**LONG INTEGRATION MODE CURRENT MEASUREMENT**

MEASUREMENT TIME, 60Hz (50Hz): 850ms (840ms) to 60 seconds in 1ms steps.

**ANALOG OUTPUT**

5A/500MA OUTPUT: 1V/A ± 25mA (typical).

50MA/5MA OUTPUT: 1V/10mA ± 0.25mA (typical).

INTERNAL IMPEDANCE: 1000Ω (nominal).

**OUTPUT #2 (Charger Channel)****DC VOLTAGE OUTPUT (1 Year, 23°C ± 5°C)**

OUTPUT VOLTAGE: 0 to +15VDC.  
 OUTPUT ACCURACY:  $\pm(0.05\% + 10\text{mV})$ .  
 PROGRAMMING RESOLUTION: 10mV.  
 READBACK ACCURACY<sup>1</sup>:  $\pm(0.05\% + 3\text{mV})$ .  
 READBACK RESOLUTION: 1mV.  
 OUTPUT VOLTAGE SETTLING TIME: 5ms to within stated accuracy.  
 LOAD REGULATION: 0.01% + 2mV.  
 LINE REGULATION: 0.5mV.  
 STABILITY<sup>2</sup>: 0.01% + 0.5mV.  
 MEASUREMENT TIME CHOICES: 0.002 to 10 PLC<sup>3</sup>, in 0.002 PLC steps.  
 AVERAGE READINGS: 1 to 10.

TRANSIENT RESPONSE:	High Bandwidth	Low Bandwidth
Transient Recovery Time <sup>4</sup>	<50 $\mu\text{s}^5$	<60 $\mu\text{s}^5$
Transient Voltage Drop	<180 mV <sup>5</sup>	<500 mV <sup>5</sup>

REMOTE SENSE: 1V max. drop in each lead. Add 2mV to the voltage load regulation specification for each 1V change in the negative output lead due to load current change. Remote sense required. Integrity of connection continually monitored. If compromised, output will turn off automatically once settable window ( $\pm 0$  to  $\pm 8$  volts) around normal voltage exceeded.

- At 1PLC.
- Following 15 minute warm-up, the change in output over 8 hours under ambient temperature, constant load, and line operating conditions.
- PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.
- Recovery to within 20mV of previous level.
- Remote sense, with 4.5m (15 feet) of 16 AWG (1.31mm<sup>2</sup>) wire, 1.5A load change (0.15A to 1.65A), resistive load only.

**DC CURRENT (1 YEAR, 23°C ± 5°C)****CONTINUOUS AVERAGE OUTPUT CURRENT****CHANNEL #1 (BATTERY) OFF:**

$I = 50\text{W}/(V_{\text{set}} \text{ channel 2} + 6\text{V})$ ; 5A max.<sup>1</sup>

**CHANNEL #1 (BATTERY) ON:**

$I = (50\text{W} - \text{power consumed by channel \#1})/(V_{\text{set}} \text{ channel 2} + 6\text{V})$ ; 5A max.<sup>1</sup>

The power consumed by channel #1 is calculated as:

**Channel #1 Sourcing Current:** Power consumed =  $(V_{\text{set}} \text{ channel 1} + 6\text{V}) \times (\text{current supplied})$ .

**Channel #1 Sinking Current:** Power consumed =  $5\text{V} \times (\text{sink current})$ .

**CONTINUOUS AVERAGE SINK CURRENT****CHANNEL #1 (BATTERY) OFF:**

0–5V: 3A max.

5–15V: Derate 0.2A per volt above 5V. Compliance setting controls sinking.

**CHANNEL #1 (BATTERY) ON:**

Available Current =  $(50\text{W} - \text{Power consumed by channel \#1})/5\text{V}$ ; 3A max. (0–5V)<sup>1</sup>.

Derate 0.2A per volt above 5V.

**DC CURRENT (1 YEAR, 23°C ± 5°C) (continued)**

SOURCE COMPLIANCE ACCURACY:  $\pm(0.16\% + 5\text{mA})$ .<sup>2</sup>  
 PROGRAMMED SOURCE COMPLIANCE RESOLUTION: 1.25mA.  
 READBACK ACCURACY: 5A Range:  $\pm(0.2\% + 200\mu\text{A})$ .  
 5mA Range:  $\pm(0.2\% + 2\mu\text{A})$ .  
 READBACK RESOLUTION: 5A Range: 100 $\mu\text{A}$ .  
 5mA Range: 0.1 $\mu\text{A}$ .

LOAD REGULATION: 0.01% + 1mA.

LINE REGULATION: 0.5mA.

STABILITY: 0.01% + 50 $\mu\text{A}$ .

MEASUREMENT TIME CHOICES: 0.002 to 10 PLC<sup>3</sup>, in 0.002 PLC steps.

AVERAGE READINGS: 1 to 10.

- Peak current can be a max. of 5A provided the average current is within the stated limits.
- Minimum current in constant current mode is 6mA.
- PLC = Power Line Cycle. 1PLC = 16.7ms for 60Hz operation, 20ms for 50Hz operation.

**PULSE CURRENT MEASUREMENT OPERATION**

TRIGGER LEVEL: 5A Range: 5mA to 5A, in 5mA steps.

TRIGGER DELAY: 0 to 100ms, in 10 $\mu\text{s}$  steps.

INTERNAL TRIGGER DELAY: 10 $\mu\text{s}$ .

HIGH/LOW/AVERAGE MODE:

Measurement Aperture Settings: 33.3 $\mu\text{s}$  to 833ms, in 33.3 $\mu\text{s}$  steps.

Average Readings: 1 to 100.

PULSE CURRENT MEASUREMENT ACCURACY<sup>1</sup> (1 Year, 23°C ± 5°C):

Aperture	Accuracy $\pm$ (% reading + offset)	
	5A Range	
<100 $\mu\text{s}$	0.3% +	2 mA
100 $\mu\text{s}$ – 200 $\mu\text{s}$	0.3% +	2 mA
200 $\mu\text{s}$ – 500 $\mu\text{s}$	0.3% +	2 mA
500 $\mu\text{s}$ – <1 PLC	0.3% +	900 $\mu\text{A}$
1 PLC <sup>2</sup>	0.3% +	900 $\mu\text{A}$
>1 PLC	0.3% +	900 $\mu\text{A}$

- Based on settled signal: 100 $\mu\text{s}$  pulse trigger delay.
- Also applies to other apertures that are integer multiples of 1PLC.

**BURST MODE CURRENT MEASUREMENT**

MEASUREMENT APERTURE: 33.3 $\mu\text{s}$  to 833ms, in 33.3 $\mu\text{s}$  steps.

CONVERSION RATE: 4100/second, typical.<sup>1</sup>

INTERNAL TRIGGER DELAY: 10 $\mu\text{s}$ .

NUMBER OF SAMPLES: 1 to 5000.

TRANSFER SAMPLES ACROSS IEEE BUS IN BINARY MODE<sup>2</sup>: 4400 readings/s, typical (4 bytes per reading).

- At 33.3 $\mu\text{s}$  aperture.
- Display off, Message Exchange Protocol (MEP) off, auto zero off.

**LONG INTEGRATION MODE CURRENT MEASUREMENT**

MEASUREMENT TIME, 60Hz (50Hz): 850ms (840ms) to 60 seconds in 1ms steps.

**DIGITAL VOLTMETER INPUT (1 Year, 23°C ± 5°C)**

INPUT VOLTAGE RANGE: –5 to +30VDC.

INPUT IMPEDANCE: 2M $\Omega$  typical.

MAX. VOLTAGE (either input terminal) WITH RESPECT TO OUTPUT LOW: –5V, +30V.

READING ACCURACY:  $\pm(0.05\% + 3\text{mV})$ .

READING RESOLUTION: 1mV.

CONNECTOR: HI and LO input pair part of Output #2's terminal block.

MEASUREMENT TIME CHOICES: 0.002 to 10 PLC<sup>1</sup>, in 0.002 PLC steps.

AVERAGE READINGS: 1 to 10.

- PLC = 1.00 Power Line Cycle.

### Operating Speeds (Typical)

	Channel 1	Channel 2
Voltage Step Time <sup>1</sup>	6 ms	7 ms
DC Current Reading Time <sup>1, 2, 3</sup>	22 ms	22 ms
DC Current Range Change and Read Time <sup>1, 2, 3</sup>	27 ms	
Digital Voltmeter <sup>1, 2, 3</sup>		22 ms

1. Display off, message exchange protocol (MEP) off, auto zero off.
2. PLC = 1 power line cycle.
3. Includes measurement and binary data transfer out of the GPIB port.

### GENERAL

**ISOLATION (LOW-EARTH):** 22VDC max. Do not exceed 60VDC between any two terminals of either connector.

**PROGRAMMING:** IEEE-488.2 (SCPI).

**USER-DEFINABLE POWER-UP STATES:** 4.

**REAR PANEL CONNECTORS:** Two 8-position quick disconnect terminal blocks.

**TEMPERATURE COEFFICIENT (outside 23°C ±5°C):** Derate accuracy specification by (0.1 × specification)/°C.

**OPERATING TEMPERATURE:** 0° to 50°C (derate to 70%), 0° to 35°C (Full power).

**STORAGE TEMPERATURE:** -20° to 70°C.

**HUMIDITY:** <80% @ 35°C non-condensing.

**DISPLAY TYPE:** 2-line × 16 character VFD.

**REMOTE DISPLAY/KEYPAD OPTION:** Disables standard front panel.

**DIMENSIONS:** 89mm high × 213mm wide × 411mm deep (3½ in × 8½ in × 16¼ in).

**NET WEIGHT:** 3.2kg (7.1 lbs).

**SHIPPING WEIGHT:** 5.4kg (12 lbs).

**INPUT POWER:** 100–120VAC/220–240VAC, 50 or 60Hz (auto detected at power-up).

**POWER CONSUMPTION:** 150VA max.

**EMC:** Conforms with European Union Directive 2004/108/EC.

**SAFETY:** Conforms with European Union Directive 2006/95/EC, EN 61010-1.

**AC LINE LEAKAGE CURRENT:** 450µA @ 110VAC, typ.; 600µA @ 220V, typical.

**RELAY CONTROL PORT:** 4-channel, each capable of 100mA sink, 24V max. Total port sink capacity (all 4 combined) is 250mA max. Accepts DB-9 male plug. A source of +5VDC referenced to output common is also provided on the port to power external 5V relays.